

POSTER SESSION ABSTRACTS

AIR QUALITY AND RELATED HEALTH RESEARCH

**IN-STATE/OUT-OF-STATE SOURCES OF SEMIVOLATILE
POLLUTANTS AND Hg IN NEW YORK STATE**

Philip K. Hopke, Ramya Sundar Raman, & Christopher Brancewicz
Department of Chemical Engineering, Clarkson University

Thomas M. Holsen & Soon-Onn Lai
Department of Civil and Environmental Engineering, Clarkson University

Michael S. Milligan
Department of Chemistry, SUNY Fredonia

The objectives of this project include the development of a database of ambient atmospheric measurements and the application of appropriate receptor models to these data to permit the determination of the contributions of electricity generation to observed concentrations of nitrate, sulfate, total gaseous mercury (TGM), reactive gaseous mercury (RGM), and fine airborne particulate matter. The contributions of in-state and out-of-state emissions are to be separated, and identification of transboundary sources is being emphasized. The project initially focused on data during the summer months of 2000 and 2001. Beginning in September 2001, the schedule was modified to sampling and sample analysis every third day throughout the year. During the entire program, concentrations of elements have been measured using X-Ray Fluorescence (XRF), anions and cations have been measured with ion chromatography, and black carbon was measured using light transmission. Initially, total gaseous mercury (TGM) was measured using manual methods. In 2002, reactive gaseous mercury (RGM) was added. We have now retrospectively analyzed samples collected since November 2002 for organic and elemental carbon using thermal optical methods. Recently, we have developed an ion chromatographic method to measure low-molecular-weight, water-soluble organic acids. Sampling concluded at the end of August 2005, and the samples are currently being analyzed. Once all of the data have been collected and validated, the detailed analyses of these data will be performed to explore the nature of the sources giving rise to the observed concentrations as well as their likely locations, so that we can ascertain the relative contributions of in- and out-of-state sources to the air quality of these rural areas of New York State.

ANALYSIS OF PM DATA IN NEW YORK USING ADVANCED SOURCE APPORTIONMENT METHODS

Philip. K. Hopke & Eugene Kim
Center for Air Resources Engineering and Science
Clarkson University

Carbonaceous particles are becoming a more significant fraction of fine particle mass as emissions of sulfate and nitrate precursors are being reduced. The recent promulgation of the Clear Air Interstate Rule will further reduce SO₂ and NO_x emissions. Accurate source identification and apportionment of the aerosol mass, including carbonaceous aerosols, will be important for developing effective control strategies for areas found to be out of attainment of the PM_{2.5} standard. In addition, there is increasing interest in epidemiological studies to relate adverse health effects to apportioned source contributions. Thus, the objective of this project is to apply advanced factor analysis models to data relevant to New York State. These data include results from the New York City Supersite; EMEP studies at Potsdam and Stockton, Hunter College and Tuxedo; the U.S. Environmental Protection Agency (EPA) Speciation Trends Network (STN) sites; and other data from New York State and nearby locations. The project team to date has completed the analyses of the STN site data around New York City including Elizabeth and Chester, NJ, and a site in Burlington, VT. These results will be presented.

**THE WORKSHOP ON THE SOURCE APPORTIONMENT OF PM HEALTH EFFECTS:
INTERCOMPARISON OF RESULTS AND IMPLICATIONS**

George D. Thurston¹, Kazuhiko Ito¹, Therese Mar², William F. Christensen³, Delbert J. Eatough⁴, Ronald C. Henry⁵, Eugene Kim⁶, Francine Laden⁷, Ramona Lall¹, Timothy V. Larson⁸, Hao Liu⁹, Lucas Neas¹⁰, Joseph Pinto¹¹, Matthias Stölzel¹², Helen Suh⁷, & Philip K. Hopke⁶

¹Nelson Institute of Environmental Medicine, New York University School of Medicine

²Department of Environmental Health, University of Washington

³Department of Statistics, Brigham Young University

⁴Department of Chemistry and Biochemistry, Brigham Young University

⁵Department of Civil and Environmental Engineering, Southern California University

⁶Center for Air Resources Engineering and Science, Clarkson University

⁷Department of Environmental Health, Harvard University School of Public Health

⁸Department of Civil and Environmental Engineering, University of Washington

⁹Department of Biostatistics, University of Washington

¹⁰National Health & Environmental Effects Research Laboratory, U.S. Environmental Protection Agency

¹¹National Center for Environmental Assessment, U.S. Environmental Protection Agency

¹²Institute of Epidemiology, Focus Network Aerosols and Health, GSF National Research Center for Environment and Health, Neuherberg, Germany

While the association between exposure to ambient fine particulate matter (PM_{2.5}) mass and human mortality is well established, the particle types/sources most responsible for these effects are as yet uncertain. In May 2003, the U.S. Environmental Protection Agency's Particulate Matter Centers Program sponsored the "Workshop on the Source Apportionment of PM Health Effects." The goal was to evaluate the consistency of the various source apportionment methods in assessing source contributions to daily PM_{2.5} mass-mortality associations. Seven research institutions, using varying methods, participated in the estimation of source apportionments of PM_{2.5} mass samples collected in Washington, DC and Phoenix, AZ. Apportionments were evaluated for their respective associations with mortality using Poisson regressions, allowing a comparative assessment of the extent to which variations in the apportionments contributed to variability in the source-specific mortality results. The various research groups generally identified the same major source types, each with similar elemental make-ups. Intergroup correlation analyses indicated that soil, sulfate, residual oil, and salt-associated mass were most unambiguously identified by various methods, while vegetative burning and traffic were less consistent. Aggregate source-specific mortality relative risk (RR) estimate confidence intervals overlapped each other, but the sulfate-related PM_{2.5} component was most consistently significant across analyses in these cities. Analyses found source types to be a significant predictor of RR, while apportionment group differences were not. Variations in the source apportionments added only some 15% to the mortality regression uncertainties. These results provide supportive evidence that existing PM_{2.5} source apportionment methods can be used to derive reliable insights into the source components that contribute to PM_{2.5} health effects.

**PENETRATION OF THE AMBIENT ULTRAFINE AEROSOL INTO A
CARDIAC REHABILITATION FACILITY IN ROCHESTER, NY**

David Ogulei & Philip K. Hopke
Clarkson University

David Chalupa, Laurie Kopin, & Mark Utell
University of Rochester Medical Center

Epidemiological studies have suggested a link between increases in ambient particulate matter (PM), essentially particle numbers, and an accelerated onset of excess cardiorespiratory mortality and morbidity. Such studies suggest that research be conducted to establish relationships between PM concentrations measured in the indoor environment and those measured outdoors. The indoor environment plays an important role in the exposure of an individual to air pollutants, since people spend the vast majority of their time indoors. In this study, the relationship between indoor and outdoor levels of ultrafine particles (UFPs) was examined for a functional cardiac rehabilitation facility located in a commercial building in Rochester, NY. The facility offers both preventive and rehabilitative care for individuals recovering from or at risk for heart disease and is located approximately two miles from the University of Rochester Medical Center (URMC). Continuous size-fractionated PM samples were simultaneously measured from indoor and outdoor air of the facility using an MSP Wide-range Particle Spectrometer (WPSTM). The initial sampling period was July 2004, and a second set of measurements were made in November–December 2004. The rehabilitation facility data were compared with concurrently measured SMPS data from the New York State (NYS) Department of Environmental Conservation (DEC) site located a few miles from the facility site. For comparison purposes, clean air measurements were also made from early January 2005 to mid-August 2005 in an environmental chamber located in the URMC using the same WPSTM system. This chamber was designed for human clinical exposure studies and was therefore expected to provide the relatively much-cleaner indoor air necessary for comparative studies. The simultaneously measured outdoor concentrations at this site were compared with measurements made at the DEC site. A quantitative comparison was made between the measured number concentrations at the cardiac center and DEC locations by computing the spatial correlation index (ρ_s) for the time-size plots for each of the days of the study. All of the calculated ρ_s -values were very large compared to the cutoff value of 1.6, meaning that there were highly significant correlations among these data. The relationship was observed to be stronger between the indoor and outdoor values at the rehabilitation center ($\rho_s \geq 200$) than between the outdoor and DEC ($\rho_s \geq 130$), or between the indoor and DEC values ($\rho_s \geq 65$). The results also showed a high level of penetration for this building, especially for particles in the size bins 0.01–0.05 μm and 0.1–0.5 μm , for which the penetration fractions (I/O) were approximately 0.8 and 0.7, respectively. Outdoor number concentrations measured at the URMC and DEC sites were found to be correlated both on temporal and spatial scales, indicating that the WPSTM system generally reproduced the temporal and spatial variability of UFPs measured at the central site, even if the actual particle numbers were different at both locations. Spearman rank correlation coefficients ranged from 0.5 (for 0.01–0.05 μm particles) to 0.9 (for 0.1–0.47 μm particles). The peaks for UFPs in the size range 0.01–0.1 μm were highly related to traffic rush hours in both sites. By relating the outdoor number concentrations measured at URMC and DEC sites to wind speed and direction, particles in the compounded size range 0.01–0.47 μm appeared to have common sources, highly influenced by busy downtown Rochester.

ASSESSMENT OF CARBONACEOUS FINE PARTICLE (PM_{2.5}) FOR NEW YORK AND THE REGION

Phil Johnson

Northeast States for Coordinated Air Use Management

This project aims to produce a policy-relevant, comprehensive assessment of carbonaceous fine particulate matter (PM_{2.5}) in New York and the region. 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. In order to integrate scientific knowledge and policy efforts toward reducing carbonaceous PM_{2.5} levels in New York and the region, available and emerging information in three key areas will be synthesized: atmospheric emissions sources and chemistry, health effects, and control strategies. Better knowledge of carbonaceous PM_{2.5} is an important component of an integrated plan to reduce PM emissions in New York and the region. The synthesized information will significantly benefit policymaking efforts to improve air quality, in particular by assisting the NYS Department of Environmental Conservation in its development of New York's PM_{2.5} State Implementation Plan for meeting national ambient air standards.

SOURCE APPORTIONMENT OF FINE PARTICLES IN NEW YORK CITY

Ramona Lall & George D. Thurston
New York University School of Medicine

New York City is presently in violation of the nation's $PM_{2.5}$ annual mass standard and will have to take actions to control the sources contributing to these violations. This study seeks to differentiate the impact of long-range transported aerosols on the air quality of downtown New York City (NYC), so that the roles of local sources can more clearly be evaluated. A rural site located in Sterling Forest, NY (SF) that is near to the NYC area but unaffected by local NYC sources is used as a reference to separate the portion of the aerosol that is transported to the Manhattan, NYC site. Sterling Forest is confirmed as a background site via elemental comparisons with NYC during regional transport episodes of Asian and Sahara sandstorm dusts, as well as by comparisons with a second background site in Chester, NJ. Two different approaches toward including these SF data in the NYC source-apportionment analysis have been applied in this work. Six source categories are identified for NYC: regional transported sulfate and transcontinental desert dust, traffic, residual oil, Fe-Mn dust and World Trade Center fires. Of these, the transported sulfates and transcontinental desert dust account for nearly one-half of the total $PM_{2.5}$ mass in Manhattan during 2001, with nearly two-thirds of $PM_{2.5}$ coming from transported sources during the summer months. Differing percentages of the various elements were transported (vs. local), with almost 90% of the Manhattan elemental carbon being of local origin, while up to 90% of sulfate mass was transported into the city. These results indicate that meeting the ambient $PM_{2.5}$ mass standards will likely require that upwind sources outside of the state be controlled if the city is to comply reliably.

RECENT CLOUD CHEMISTRY MEASUREMENTS AT WHITEFACE MOUNTAIN, NY

Nenad Aleksic, Karen Roy, & Gopal Sistla
NYS Department of Environmental Conservation

James Dukett, Nathan Houck, & Paul Casson
Adirondack Lakes Survey Corporation

In recent years, many studies have been undertaken to study cloud water deposition, which is thought to be one of the principal causes of the forest decline at elevations between 800 m and tree line. A routine cloud water chemistry measurement program, operational during the summer season, was established in 1994 under the auspices of the Mountain Acid Deposition Program (MADPro) at the summit of Whiteface Mountain, NY, which is at an elevation of 1483 m. Even though the MADPro monitoring program was terminated in 2000, the cloud chemistry program was continued, utilizing the same equipment and measurement procedures as those of the Adirondacks Lakes Survey Corporation (ALSC). In this presentation, we summarize the recent measurements of cloud water chemistry, cloud liquid water content, and cloud frequency and changes over the entire monitoring period.

Cloud-water ion concentrations are dominated by sulfate (SO_4^{2-}) and nitrate (NO_3^-) in the anion category, while hydrogen (H^+) and ammonium (NH_4^+) are the dominant cations. Concentrations are found to be considerably higher in the cloud samples than in rain. While analysis of individual cloud events shows considerable variability between events, on an overall basis the cloud chemistry data show a decrease in the concentration levels of the measured ions with time.

**NEAR-REALTIME CMAQ AIR QUALITY SIMULATIONS OVER NEW YORK STATE SINCE
SUMMER 2004: PROJECT OVERVIEW, MODEL PERFORMANCE, AND FUTURE DIRECTIONS**

C. Hogrefe

NYS Department of Environmental Conservation
SUNY Atmospheric Sciences Research Center

W. Hao, K. Civerolo, J.-Y. Ku, & G. Sistla

NYS Department of Environmental Conservation

Daily photochemical model simulations of O₃ and PM_{2.5} have been performed on a near-realtime basis for two summer seasons (2004 and 2005) and one winter season (2004) over New York State employing the Community Multiscale Air Quality (CMAQ) model. In this poster, we present an overview of this pilot study partnering the New York State (NYS) Department of Environmental Conservation (DEC) with the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Environmental Protection Agency (EPA).

To assess CMAQ's ability to capture ambient levels of O₃ and PM_{2.5} and their temporal fluctuations, model predictions are compared to hourly O₃ measurements and hourly total PM_{2.5} mass measurements from TEOM[®] monitors and daily average PM_{2.5} speciation data. Results of this analysis indicate that the performance of the photochemical modeling system is within the range of current regulatory air-quality modeling studies employing meteorological data assimilation. There is no pronounced seasonality in model performance for total PM_{2.5} over New York State, but model performance for individual species shows seasonal behavior. The model evaluation results also reveal a significant overestimation of the inert PM_{2.5} species in New York State. In addition, a comparison was performed between the CMAQ simulations of O₃ and PM_{2.5} for New York State and non-model-based routine air-quality forecasts issued by NYS DEC. The metric for this comparison is the air quality index (AQI), a quantity used to relate ambient observed or predicted pollutant concentrations to levels of health concern. Results indicate a tendency for CMAQ to overpredict the AQI in some regions. Finally, an outlook for future project activities is presented.

**ASSOCIATIONS BETWEEN AIR POLLUTANTS AND ASTHMA
EXACERBATIONS IN NEW YORK CITY**

Daniel Luttinger & Gregg Recer
Center for Environmental Health, NYS Department of Health

Patrick Kinney
School of Public Health, Columbia University

Syni-An Hwang
Center for Environmental Health, NYS Department of Health

This study evaluates temporal associations between a panel of air contaminants and emergency room (ER) visits in communities in the Bronx and Manhattan in New York City (NYC). Time-series analysis was used to determine whether and to what extent various air contaminants, or mixtures of air contaminants, contribute to emergency-room visits for asthma and whether the magnitude of the air pollution effect differs in the two communities.

Daily average ambient air concentrations of aldehydes, metals, hydrogen ion, sulfate, pollens and mold spores were collected between January 1999 and November 2000 at two sites (one in each community). In addition, hourly concentrations for ozone, sulfur dioxide, nitrogen oxides, particulate matter = 2.5 micrometers ($PM_{2.5}$), particulate matter = 10 micrometers (PM_{10}), and three-hour concentrations for elemental and organic carbon were measured. The hourly data were also used to calculate daily averages, daily maximums, and for ozone, eight-hour moving averages. Meteorological data (temperature, wind speed and direction, humidity) were also collected. Residents living within ~1.5 miles of the air measurement sites with an ER visit resulting in a primary diagnosis of asthma were considered as cases. ER visits for several other health conditions not thought to be related to ambient air contaminants (e.g., noninfectious gastrointestinal disorders) were selected as control outcomes.

The analytical plan includes a time-series approach (GLM model) to test for associations of 14 key pollutants with daily ER visits, after controlling for temporal cycles, temperature, and day-of-week effects. The core analysis combines outcomes for 0–4 day lags. Sensitivity analyses were performed to examine individual lag effects. Multiple pollutant models were developed to investigate the robustness of the associations. Development of the analytical plan and selection of the key pollutants will be discussed.

Mean daily crude rates of asthma ER visits were more than eight-fold higher in the Bronx study area (16.9 per 100,000 persons) than in the Manhattan area (2.02 per 100,000 persons). The potential for greater statistical power in the Bronx, high correlation among pollutants, and uncertainty about how representative the central monitors are for estimating personnel exposures for certain pollutants will be discussed.

The study is being conducted by the New York State (NYS) Department of Health, NYS Department of Environmental Conservation (DEC) and Columbia University, with partial unding from the Agency for Toxic Substances and Disease Registry (ATSDR) as part of Cooperative Agreement (V50/ATV200002-11) and the New York State Energy and Research Development Authority (NYSERDA).

CHEMICAL COMPOSITION OF FINE PARTICULATE MATTER FROM URBAN AND REGIONAL BACKGROUND LOCATIONS IN NEW YORK STATE

Monica A. Mazurek

Civil and Environmental Engineering Department
Rutgers, the State University of New Jersey

The primary scientific objective of this proposed research is to develop improved understanding of the atmospheric abundances and sources of fine carbonaceous particulate matter in urban and regional locations in New York State (NYS). This information is critical to controlling fine particle concentrations in community-based monitoring sites and for addressing control strategies for reducing regional haze. The research addresses NYSERDA Program Interest Area 4: to improve the understanding of the role of primary and secondary organics in particulate matter (PM) in New York State.

The research tasks involve partnership with the NYS Department of Environmental Conservation (DEC) Bureaus of Mobile Sources and Technology Development and Air Quality Surveillance, and with the State University of New York at Albany. This project also is connected to a one-year field sampling program (Speciation of Organics for Apportionment of PM_{2.5} in the New York City Metropolitan Area [SOAP]) supported by the Northeast States for Coordinated Air Use Management (NESCAUM).

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. This NYSERDA project extends the measurement and identification of organic molecular markers present in the neutral organic fraction of fine ambient particles to include two years of ambient fine-particle measurements at the Bronx, NYC and Pinnacle State Park, NY NYS DEC air-quality monitoring sites (SOAP-NY). Molecular markers and elemental, organic, and total carbon (EC, OC, and TC, respectively) will be measured for the two-year field program. Critical EC, OC, and TC will be measured on subsamples from SOAP archived fine-particle filters to verify and compare ambient carbon mass-balance relationships, now using only Speciation Trends Network (STN) EC and OC data. A third project objective is to identify and measure molecular markers from diesel- and gas-powered sources' particle emissions in collaboration with the NYS DEC vehicle emission testing program and from unregulated primary sources such as commercial and domestic cooking operations. These additional molecular marker measurements from primary emission sources of fine particles will improve quantitative estimates of major primary sources in the NYS regional airshed.

**ENHANCED MEASUREMENTS OF OXIDANTS, FINE PARTICLES, AND THEIR PRECURSORS :
SELECTED RESULTS FROM THE PINNACLE STATE PARK RESEARCH STATION**

James J. Schwab, Min-Suk Bae, Olga Hogrefe, Yongquan Li, & Kenneth L. Demerjian
SUNY Atmospheric Sciences Research Center

Air-quality research measurements have been ongoing at the Pinnacle State Park research station in Addison, New York for 10 years. Measurements of ozone and $PM_{2.5}$ and their precursors are performed year round using continuous measurement methods whenever possible. These measurements are used to explore ozone and fine aerosol production, to apportion pollution sources, to test and evaluate models, and for other purposes. The site has also been used to test a number of continuous measurement methods for trace gases and fine particulate matter, and hosted a four-week-long intensive field campaign in the summer of 2004 as part of ICARTT, in which advanced instrumentation was deployed, including an Aerosol Mass Spectrometer (AMS) and Tunable Diode Laser Absorption Spectrometer (TDLAS). The poster presents selected measurement results, including highlights from the summer 2004 field-intensive campaign, an evaluation of a continuous sulfate aerosol instrument, and an investigation of the organic matter-to-organic carbon ratio in the carbonaceous $PM_{2.5}$ measured at the site.

**ENHANCED MEASUREMENTS OF OXIDANTS, FINE PARTICLES, AND THEIR PRECURSORS :
RELATIONSHIP BETWEEN NO_y, PM_NITRATE, AND PM_{2.5} AT A MOUNTAIN
SITE IN UPSTATE NEW YORK**

U. K. Roychowdhury & R. A. Lamica
SUNY Atmospheric Sciences Research Center

O. Rattigan & H.D. Felton
NYS Department of Environmental Conservation

J. Schwab & K. L. Demerjian
SUNY Atmospheric Sciences Research Center

NO_y, PM_{2.5}, and particulate matter nitrate (PM_nitrate) measurements performed at Whiteface Lodge as part of the joint NYSERDA and U.S. Environmental Protection Agency PM_{2.5} Technology Assessment and Characterization Study (PMTACS-NY) “Supersite” program are presented and discussed for the period 2002–2004. The findings show that PM_nitrate contributes less than 5% toward the NO_y inventory at Whiteface Mountain, with monthly averaged PM_nitrates ranging from 3.3% to 8.6% of NO_y, with an overall mean of 4.8%. PM_nitrate is generally well correlated with NO_y in winter months, with (r^2 NO₃, NO_y) ranging between 0.5 and 0.9. Mean monthly ratios of NO_z and NO_y show clear seasonal dependence, in contrast to the corresponding ratios of PM_nitrate and NO_y. The lack of seasonal variation suggests the production of PM_nitrate in the sampled aged air masses, which is further evidenced by the fact that a significant fraction of the air masses sampled for the measurement of PM_nitrate and NO_y arrive at the sampling locations from the same sectors, irrespective of whether the data are parsed for summer, winter, or the entire year. The percent of data above minimum detection limits show that the most significant contributions toward the data originate from the air masses arriving from the southwestern sector. The PM_nitrate and relative-humidity data show poor correlation throughout the year with no seasonal dependence. However, every year, several short-duration events with significantly higher (r^2 NO₃, RH) are observed during the winter months.

**ENHANCED MEASUREMENTS OF OXIDANTS, FINE PARTICLES, AND THEIR PRECURSORS :
PERSPECTIVES ON AMBIENT AEROSOL COMPOSITION IN NEW YORK CITY**

Kenneth L. Demerjian & James J. Schwab
SUNY Atmospheric Sciences Research Center

H. Dirk Felton
NYS Department of Environmental Conservation

O. Hogrefe & Y. Li
SUNY Atmospheric Sciences Research Center

O. Rattigan
NYS Department of Environmental Conservation

Silke Weimer & Frank Drewnick
SUNY Atmospheric Sciences Research Center

A summary of the composition and size distribution of particulate matter (PM) in Queens, NY based on routine and advance measurement technologies deployed during field-intensive campaigns in 2001 and 2004 as part of the NYSERDA and U.S. Environmental Protection Agency PM_{2.5} Technology Assessment and Characterization Study (PMTACS-NY) "Supersite" program is presented. Data analysis focuses on seasonal differences in PM composition and size distribution, on regional and urban contributions in terms of primary and secondary PM production, and on local versus regional contributions of key PM chemical constituents. Wintertime mean mode mass size distributions are significantly smaller on average than in the summer. The fractional compositional mass contribution of organic PM remains relatively constant throughout the year, but there is evidence for a substantial shift in the contribution of primary and secondary organics from winter to summer. The PM sulfate mass fraction is somewhat higher in summer than in winter, but the likely heterogeneous conversion source of wintertime sulfate is not well understood. The high PM nitrate mass fraction observed in winter is driven by the equilibrium temperature dependence of NH₄NO₃. But the details of the wintertime sources of its precursor gases remain somewhat uncertain.

**PHYSICAL AND CHEMICAL CHARACTERIZATION OF LABORATORY-GENERATED
ORGANIC PARTICULATE MATTER**

Olga Hogrefe

SUNY Atmospheric Sciences Research Center

Brian P. Frank

NYS Department of Environmental Conservation

G. Garland Lala, James J. Schwab, Mingyu Tang, & Kenneth L. Demerjian

SUNY Atmospheric Sciences Research Center

Three previously conducted intensive urban and rural field campaigns (PMTACS-NY; 2001–2004) showed that 45%–50% of particulate matter (PM) mass can be attributed to carbon-containing species. Secondary organic production under summertime conditions at urban and rural sites is an important contributor to the organic fraction of the PM mass. The objectives of the project include, but are not limited to, studying physical and chemical properties of primary and secondary organic laboratory-generated aerosols (POA and SOA) and developing characteristic mass spectra for compound-specific primary and secondary PM products.

PM organic characterization experiments are performed at the Atmospheric Sciences Research Center (ASRC) Aerosol Generation and Research Facility. Analytical instrumentation to study the organic aerosols generated include an Aerodyne Aerosol Mass Spectrometer (AMS), Sunset Labs OC/EC monitor, TSI particle counters, and scanning mobility particle sizers. Modifications to several components of the aerosol facility, including the slow-flow chamber, are underway to expand the secondary-aerosol generation capabilities of the facility. The performance of the OC/EC monitor and scanning mobility particle sizers in measuring generated primary organic aerosols has been evaluated. Distinctive AMS spectra of several primary organic compounds have also been obtained. Preliminary results indicate that primary organic aerosols are characterized by unique fragmentation patterns that are dependent on the operational parameters (e.g., the heater temperature) of the AMS.

FORMATION AND TRANSFORMATION OF PARTICLES IN MOTOR ENGINE EXHAUST

Fangqun Yu & Hua Du
SUNY Atmospheric Sciences Research Center

Brian Frank & Thomas Lanni
NYS Department of Environmental Conservation

Engine-generated particles are known to contribute substantially to particulate pollution, especially in urban regions or areas near heavily traveled roads. In addition to the primary soot particles, the secondary volatile ultrafine particles formed in engine exhaust may also be relevant to $PM_{2.5}$ and health-effects issues. On the one hand, these ultrafine particles may directly lead to adverse health effects owing to their high number concentration, high deposition efficiency in the pulmonary regions, and high propensity to penetrate the epithelium. On the other hand, ultrafine particles may pick up enough precursor gases in the atmosphere and contribute to ambient $PM_{2.5}$. It is important to understand the key parameters and processes controlling the formation and properties of engine-generated ultrafine particles on and near highways. Such an understanding is necessary to develop aerosol emission inventories and to help establish criteria for engine design, operation, after-treatment, and fuel and lubricating-oil compositional modifications that would effectively reduce engine ultrafine particle emissions.

Under this project, we have investigated key processes and parameters controlling the formation and transformation of volatile ultrafine particles formed in motor-vehicle exhaust. We have carried out extensive case studies and sensitivity studies using a kinetic aerosol microphysics model that is suitable for studying the complex aerosol dynamics in a rapidly diluting engine exhaust. We have explored the possible contributions of different nucleation mechanisms to ultrafine particle formation under different conditions. We find that nucleation on chemi-ions (produced in the combustor) is always favored, but the number of particles formed on ions is limited by the concentration of ions in the exhaust. Experiments have been designed and carried out to measure the ion concentrations in engine exhaust. The binary homogeneous nucleation (BHN) of H_2SO_4 - H_2O may significantly contribute to new particle formation for engines running on fuel with a fuel sulfur content (FSC) of ~ 330 ppm. Our simulations show that the BHN rate is very sensitive to FSC and sulfur-to-sulfuric acid conversion efficiency (e_s). For e_s value of 1%, BHN is negligible under typical conditions when FSC is less than ~ 100 ppm. The sensitivities of particle formation via BHN to key factors (including ambient temperature and relative humidity, FSC, e_s , and the soot number concentration) are investigated. In addition to chemi-ion theory and BHN theory, we have also explored the possible role of ammonia in nucleation. The contribution of low volatile organic species associated with lubricating oil and unburned fuel to the growth of nucleated particles are also investigated.

INNOVATION IN AIR MONITORING OF PARTICULATE MATTER (PM)

Michael B. Meyer & Jeffrey L. Ambs
Thermo Electron Corporation

Evolving particulate matter (PM) air pollution regulations and health-related science initiatives have paved the way for innovations in automated continuous PM and PM chemical speciation monitors. What are required are methods that provide a better measure of particles in the form that humans breathe. We present an overview of PM measurement methods that focus on the quantification of nonvolatile and volatile particles, as well as specific chemical species (particulate carbon, sulfate, and nitrate). These are commercially available tools that address timely PM measurement concerns.

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

**M. J. Utell, W. Beckett, L. Kopin, W. Zareba,
M. W. Frampton, J. Bisognano, & D. Chalupa**
University of Rochester Medical Center

D. Ogulei & P. K. Hopke
Clarkson University

Epidemiological studies demonstrate that ambient particulate (PM) pollution increases cardiac morbidity and mortality. A current research gap is the role that different PM components (organics, metals, ultrafines) play in cardiovascular health effects. The objectives of this study are to assess the effects of ambient ultrafine particle (UFP) exposure on cardiovascular morbidity in a panel of patients with coronary artery disease. Since we have previously characterized year-round UFP temporal variation in Rochester, NY, we have designed a study to examine the cardiovascular responses to UFPs in community-dwelling patients undergoing medically monitored exercise rehabilitation after acute coronary events. In this study, UFP number and particle mass will be measured continuously in the cardiac rehabilitation center and at a central measuring site in downtown Rochester. Other U.S. Environmental Protection Agency Criteria Pollutants are also measured in downtown Rochester. Patients from an active cardiac rehabilitation program within the University of Rochester Medical Center will be offered enrollment in the health-effects study as they enter the cardiac rehabilitation program. These are patients who have had a recent coronary event, such as myocardial infarction or unstable angina leading to coronary stenting. The program involves supervised, graded, twice-weekly exercise sessions for a total of 12 weeks. The project will assess the following specific hypotheses, that in vulnerable subjects with ischemic heart disease, elevated levels of ambient ultrafine and fine particles are associated with

1. Slower and compromised rehabilitation;
2. Changes in autonomic nervous system function, measured by heart-rate variability parameters, as well as in myocardial substrate and myocardial vulnerability, measured by QRS duration, QT interval, ST segment changes, and T wave abnormalities; and
3. Changes in biomarkers of enhanced cardiovascular risk, including systemic inflammation (C-reactive protein) and hypercoagulability (fibrinogen).

Levels of ambient ultrafine and fine particles will then be associated with health data from the cardiac rehabilitation panel study. This will be the first study with such highly susceptible cardiac patients in which ultrafine PM level variation is well characterized. The results of this study will address policy questions about the risks of UFPs versus larger particles and the potential health effects of specific types of emission sources.

**CROSS-CUTTING RESEARCH ON AIR QUALITY, HEALTH, AND
ECOSYSTEM RESPONSE**

**QUANTIFYING THE ECONOMIC AND ENVIRONMENTAL BENEFITS OF COMBINED
HEAT AND POWER TECHNOLOGIES IN NEW YORK STATE**

James Carter
Navigant Consulting

This project analyzes the economic and environmental impacts of Combined Heat and Power (CHP) projects in New York State. Various CHP market and regulatory scenarios are postulated, and characteristics of several technologies are established. Market penetration levels of the CHP technologies under the different scenarios are then developed. A simulation model is used to (1) determine changes in the overall power-grid generating mix resulting from varying CHP penetrations and (2) estimate the impact on power-plant emissions and the cost of electricity.

**ANALYSIS OF NEW POLLUTION CONTROL STRATEGY UTILIZING EMISSION REDUCTION
CREDITS AND SMALL-SCALE COMBINED HEAT AND POWER UNITS**

Andrew Greene
Navigant Consulting

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 (SO₂) emission allowance set-aside programs now in effect. Information emerging from these findings will be presented in a NO_x and SO₂ 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.

**REDUCING EMISSIONS FROM THE ELECTRICITY SECTOR:
THE COSTS AND BENEFITS NATIONWIDE AND IN THE EMPIRE STATE**

Karen Palmer, Dallas Burtraw, & Jhih-Shyang Shih
Resources for the Future

Recent federal policy proposals to reduce emissions of SO₂, NO_x, and mercury from the U.S. electricity sector promise important improvements in air quality and reductions in acid deposition in New York State and across the nation. The costs of achieving these reductions depend on the form and stringency of regulations. This research analyzed the economic benefits and costs of the U.S. Environmental Protection Agency (EPA) Clean Air Interstate Rule (CAIR), as characterized in the supplemental rule proposed in June 2004 and the Clean Air Mercury Rule (CAMR) proposed in February 2004. The assessment integrated a model of the electricity sector, two models of atmospheric transport of air pollutants, and a model of environmental and public health endpoints affected by pollution. The project team explicitly modeled SO₂, NO_x, mercury, and CO₂ emissions and the effects of changes in SO₂ and NO_x emissions on environmental and public health. The ways in which mercury emissions are regulated will have important implications not only for the cost of the regulation, but also for emission levels and source locations of SO₂ and NO_x. This research shows that the economic benefits of CAIR and CAMR are far greater than the costs. Recent estimates of benefits of reductions in mercury and acidification indicate that this model captures the lion's share of quantifiable benefits. With tighter mercury targets (beyond EPA's CAMR), a maximum achievable control technology (MACT) approach would preserve the role of coal in electricity generation.

**PRELIMINARY RESULTS FROM A LABORATORY INTERCOMPARISON OF GASEOUS
AMMONIA MEASUREMENT METHODS**

James J. Schwab, Min-Suk Bae, Yongquan Li, & Kenneth L. Demerjian
SUNY Atmospheric Sciences Research Center

Sara Pryor
Atmospheric Science Program
Department of Geography, Indiana University

Bjarne Jensen
Department of Atmospheric Environment
National Environmental Research Institute, Roskilde, Denmark

Jin Hou & Xinaglian Zhou
Wadsworth Laboratories, NYS Department of Health

Ammonia gas, while not routinely monitored in the atmosphere, plays a number of important roles in atmospheric chemistry, aquatic chemistry, acid deposition, and air pollution. Ammonia is the most abundant basic gas in the atmosphere, and it is a reduced species: properties that assure it important roles in an oxidizing atmosphere that transforms emissions of sulfur and nitrogen oxides into acidic species. Ammonia is important in the formation of inorganic aerosols such as ammonium sulfate and nitrate (and probably organic aerosols). It is crucial to the acid balance of cloud water, rainwater, and fog water, as well as aerosol particulate matter. Ammonia is also a key agricultural byproduct, and large localized emissions from animal husbandry can produce eutrophication of streams, rivers, and ponds.

The promise of routine low-level measurement of gaseous ammonia has attracted much attention in the past few years, but the difficulty of the task has precluded the realization of this goal. This project attempts to identify and deploy an ammonia gas measurement system suitable for routine deployment at continuously operating atmospheric chemistry and air-quality research stations. One of the major tasks of this project involved the laboratory intercomparison of continuous measurement systems for gaseous ammonia. This activity took place in September 2005 at the Atmospheric Sciences Research Center on the University at Albany campus. Six different measurement methods were represented. Three of the methods used custom-built research instruments, and three methods used commercially built analyzers. Details of the research protocols and a selection of preliminary findings will be presented at the meeting.

**ELUCIDATING SOURCES AND FACTORS AFFECTING DELIVERY OF NITROGEN TO SURFACE
WATERS OF NEW YORK STATE**

Elizabeth W. Boyer
University of California, Berkeley

Heather E. Golden
SUNY College of Environmental Science and Forestry

Richard B. Alexander, Douglas A. Burns, Emily Elliott, & Carol A. Kendall
U.S. Geological Survey

Rapid changes in power generation, transportation, and agriculture have appreciably altered nitrogen (N) cycling at regional scales, increasing N inputs to landscapes and surface waters. Numerous studies have linked this surplus N to a host of concerns, including eutrophication and violations in drinking water standards. Inputs of N nationwide have increased during recent decades, primarily from the production and use of fertilizers, the planting of N-fixing crops, and the combustion of fossil fuels. The role of atmospheric N sources is of particular concern in New York, as rates of atmospheric N deposition in the Northeast are among the highest in the nation. We utilize multiple modeling and spatial analysis approaches to understand the sources and fate of N in landscapes throughout New York and characterize factors controlling the retention and release of N to surface waters. We quantify nitrogen inputs through both measurement data (e.g., wet and dry atmospheric deposition, precipitation, streamflow, and water quality) and synoptic spatial databases (e.g., terrain, land use, and fertilizer inputs). We present preliminary results from large catchments in contrasting spatial settings across the state (different land-use configurations and atmospheric deposition gradients), illustrating the contribution of N sources to each region and factors affecting delivery to surface waters. Our work provides information that is necessary to develop sound strategies for understanding and managing nutrients at regional scales.

**TRACING ATMOSPHERIC SOURCES OF NITROGEN TO WATERSHEDS: NITRATE ISOTOPES IN
PRECIPITATION IN THE NORTHEASTERN AND CONTINENTAL UNITED STATES**

Emily M. Elliott & Carol Kendall
U.S. Geological Survey

Karen Harlin
National Atmospheric Deposition Program

Scott D. Wankel
U.S. Geological Survey

Elizabeth W. Boyer
University of California at Berkeley

Douglas A. Burns
U.S. Geological Survey

Thomas J. Butler
Cornell University
Institute of Ecosystem Studies

Rick Carlton
Electric Power Research Institute

Atmospheric deposition of nitrogen (N), particularly wet deposition of nitrate, is an important input of fixed, bioavailable N to ecosystems worldwide. In order to effectively mediate the impacts of nitrate deposition, it is critical to understand the dynamics of NO_x sources, atmospheric chemical transformations and transport, and the characteristics of the nitrate that is ultimately deposited. To address this research need, we have conducted a national survey of nitrate isotopes in wet deposition collected as part of the National Atmospheric Deposition Program (NADP). Archived samples (2000) from 156 NADP sites across the United States were pooled into bimonthly, concentration-weighted composites and analyzed for $\delta^{15}\text{N}$, $\delta^{18}\text{O}$, and a subset for $\delta^{17}\text{O}$ using the microbial denitrifier method. We determined that nitrate concentrations in the archived samples were stable over several years, indicating that the probability of isotopic fractionation associated with sample storage is very low.

We investigate the critical question of whether variations in $\delta^{15}\text{N}$ of nitrate wet deposition are a function of atmospheric processes (e.g., seasonal variations in reaction pathways) or NO_x source contributions (e.g., power plant emissions, vehicle exhaust). Correlations between isotopic values and major NO_x sources are explored using datasets for monthly county-level emissions from two major NO_x sources: electric generating units and on-road vehicles.

Results from the Northeast and Mid-Atlantic regions suggest that $\delta^{15}\text{N}$ is a powerful tracer of stationary-source NO_x emissions. The $\delta^{15}\text{N}$ values are significantly correlated with NO_x emissions within various radial distances of NADP sites in the Northeast and Mid-Atlantic. Along the northeastern N deposition gradient that spans western New York to Maine, $\delta^{15}\text{N}$ values are significantly correlated with nitrate deposition, sulfate deposition, and mean annual pH. We observed that $\delta^{18}\text{O}$ values are not correlated with stationary or mobile-source NO_x emissions, nitrate deposition, sulfate deposition, or pH. These results suggest that $\delta^{18}\text{O}$ of atmospheric NO₃⁻ reflects the relative contributions of OH and O₃ oxidation pathways to NO₃⁻ formation. Despite the fact that vehicle emissions are the largest NO_x source in the eastern United States, we found no correlations between $\delta^{15}\text{N}$ and vehicle NO_x emissions in this region. This raises some interesting questions about the fate of ground-level vehicle NO_x emissions. Similar metrics will be applied to data across the U.S., and the applicability of using these techniques to trace NO_x sources at this scale will be discussed.

TRACING SOURCES OF NITROGEN TO NEW YORK WATERSHEDS USING NITRATE ISOTOPES

Carol Kendall & Emily M. Elliott
U.S. Geological Survey

Elizabeth W. Boyer
University of California at Berkeley

Douglas A. Burns
U.S. Geological Survey

Heather E. Golden
SUNY-Syracuse

Scott D. Wankel
U.S. Geological Survey

Thomas J. Butler
Cornell University

Increasing inputs of reactive nitrogen (N) to ecosystems in the northeastern United States 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 policymakers, 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.

Recent advances in isotopic techniques allow researchers to quantify sources of N at finer spatial and temporal scales than have been possible with isotopic and mass-balance budget approaches employed to date. Recent research suggests that different anthropogenic sources of N often have characteristic $\delta^{15}\text{N}$, $\delta^{18}\text{O}$, and/or $\delta^{17}\text{O}$ values, thus potentially allowing researchers to use the isotopic composition of nitrate in streams to estimate how much of the nitrate was derived from power plants, automobiles, row crops, and animal sources.

The overall goal of the joint NYSERDA, Electric Power Research Institute (EPRI), and U.S. Geological Survey (USGS) project, "Quantifying Atmospheric Nitrogen Sources with New Stable Isotope Techniques," is to use novel isotopic methods for measuring $\delta^{17}\text{O}$, $\delta^{18}\text{O}$, and $\delta^{15}\text{N}$ in nitrate to address two related research questions: (1) Can the isotopic composition of nitrate be used to quantify the relative contributions of different sources of atmospheric N to precipitation (e.g., distinguishing between stationary, automotive, and agricultural sources)? (2) Can the isotopic composition of nitrate be used to quantify the relative contributions of different sources of anthropogenic N to land and surface waters in New York's watersheds (e.g., distinguishing between atmospheric, fertilizer, and wastewater N)? Our approach involves the analysis of the isotopic composition and water chemistry of wet and dry precipitation and surface water samples from a variety of environmental settings within New York's watersheds. Work to date suggests that the answer to the first question is YES: Stationary sources appear to have distinctive $\delta^{15}\text{N}$ values relative to background sources (Elliott et al., 2005). This poster is aimed at showing our progress with answering the second question.

**ATMOSPHERIC DEPOSITION OF SULFUR, NITROGEN, AND
MERCURY AND ECOSYSTEM RESPONSE**

LONG-TERM MONITORING AND ASSESSMENT OF MERCURY BASED ON INTEGRATED SAMPLING EFFORTS USING THE COMMON LOON, PREY FISH, WATER, AND SEDIMENT

Nina Schoch

Adirondack Cooperative Loon Program
Wildlife Conservation Society

David Evers & Melissa Duron
BioDiversity Research Institute

Michale Glennon
Wildlife Conservation Society

Howard Simonin

Bureau of Habitat, NYS Department of Environmental Conservation

Charles Driscoll

Department of Civil and Environmental Engineering, Syracuse University

John Ozard

Bureau of Wildlife, NYS Department of Environmental Conservation

The Adirondack Cooperative Loon Program, a partnership of the Wildlife Conservation Society, Natural History Museum of the Adirondacks, New York State (NYS) Department of Environmental Conservation, BioDiversity Research Institute, and the Audubon Society of New York, is using the common loon (*Gavia immer*) as an indicator species to assess the mercury exposure and risk in aquatic ecosystems in New York's Adirondack Park. As part of a long-term study examining loon survival and reproductive success in relation to mercury, abiotic (water and sediment) and biotic (loon, prey fish, crayfish, and zooplankton) samples were collected from 44 lakes in the Park from 2003 to 2004. Mercury analysis of these samples is used to develop a mercury exposure profile to evaluate the ecological risk that mercury deposition poses to Adirondack waterbodies. Ecological risk will be quantitatively assessed using a formula for a wildlife criterion value to determine if the water column mercury value is protective of wildlife at the population level in the Adirondack Park. The differences in reproductive success and survival in common loons in relation to their mercury exposure is used to develop a mercury hazard profile. A population model will also be developed to determine if mercury contamination is affecting the population growth rate of loons in the Adirondacks. Results of this project will enable researchers, regulatory agencies, and policymakers in New York State to make informed decisions regarding regulation of airborne pollutants and management of wildlife species and freshwater ecosystems.

**LONG-TERM MONITORING PROGRAM FOR EVALUATING CHANGES IN WATER
QUALITY IN ADIRONDACK LAKES 1982–2004**

Karen Roy & Kevin Civerolo
NYS Department of Environmental Conservation

Charles Driscoll & Kimberley Driscoll
Department of Civil and Environmental Engineering, Syracuse University

James Dukett, Nathan Houck, Phil Snyder, & Sue Capone
Adirondack Lakes Survey Corporation

The Adirondack Long-Term Monitoring (ALTM) Program was established in 1982 to assess seasonal and long-term patterns in the chemistry of lakes in the Adirondack region of New York. The monthly sampling program, initiated with 17 lakes, was expanded in 1992 by an additional 35 lakes that were considered as being representative of lake classes across the Adirondacks. In this study, we report on time-series analyses on the acid-base status of ALTM lakes relative to changes in acidic deposition as a function of different sampling periods. Time-series analyses were performed for 16 nonlimed lakes covering the sampling periods of 1982–2000 and 1992–2000 (Driscoll et al. 2003) and 48 nonlimed lakes over 1992–2000 and 1992–2004 (Driscoll et al. 2005). Results indicate decreasing concentration trends in sulfates and increasing trends in pH and acid neutralizing capacity (ANC), which are not necessarily uniform over the monitoring periods. Lake nitrate changes have varied along with pH and ANC, but are not explained by nitrate deposition changes. Dissolved organic carbon (DOC) increases have also been detected in a number of lakes. Low levels of pH and ANC with corresponding high levels of toxic inorganic monomeric aluminum (Al_m) continue to occur, particularly during springmelt. Year-round levels of Al_m remain high in several ALTM lakes. Preliminary results from lakes sampled more intensively during springmelt indicate that weekly sampling is more efficient at capturing spring depressions in pH and ANC.

Regional comparisons with other sensitive lakes and streams for 1990–2000 found that lakes in the Adirondacks responded similarly to those in New England and the Northern Appalachian Plateau, with substantial declines in sulfate and base cations and small increases in pH, ANC, and DOC (Kahl et al. 2004).

**POTENTIAL NEGATIVE EFFECTS OF AIR POLLUTANTS ON THRUSHES AND OTHER
SONGBIRDS IN THE APPALACHIAN MOUNTAINS**

D. Evers

BioDiversity Research Institute

T. Tear

The Nature Conservancy

R. Hames

Cornell Lab of Ornithology

J. Loukmas

New York State Department of
Environmental Conservation

M. Duron

BioDiversity Research Institute

A. White

The Nature Conservancy

G. Lovett

Institute of Ecosystem Studies

C. Driscoll

Department of Civil and Environmental
Engineering, Syracuse University

C. Rimmer

Vermont Institute of Natural Sciences

K. McFarland

Vermont Institute of Natural Sciences

K. Schmidt

Texas Tech University

R. Taylor

Texas A&M University

Multiple anthropogenic stressors cause population effects on birds that are qualitatively different from the documented effects of single, or even multiple, additive stressors of organisms in the wild. Such stressors may act at spatial extents or scales ranging from the habitat patch to the landscape level. Because synergies, or interactions between stressors, can include not only additive, but also multiplicative effects, responses to multiple stressors may be both unexpected and unexpectedly large. There are few opportunities to test this overarching hypothesis across large geographic extents, however, and much ecological research is therefore based on the simplifying assumption that populations respond to average conditions across their range. Most research focuses on single drivers of population dynamics, for reasons of tractability, logistics, or cost, although the negative effects of stressors in combination have been shown to often exceed those expected from simple additive effects. The capability to elucidate the effects of multiple stressors on organisms in the wild, occurring at a range of spatial extents, has the potential to radically change our understanding of how human-caused change influences natural systems, and is thus of both theoretical and conservational interest. Recent developments suggest that this assessment of broad-scale environmental risk to natural organisms from multiple stressors is not only necessary, but is also made possible by combining intensive studies at a few sites with extensive studies covering large geographic areas.

The atmospheric deposition of Hg has the potential to have negative landscape-level impacts on bird populations. Further, Hg methylation by sulfate-reducing anaerobic bacteria that convert non-toxic inorganic mercury (Hg) into toxic organic methylmercury (MeHg) is enhanced in acidic environments. Acidic environments are also typically poor in calcium (Ca) and Ca-rich prey needed by many birds to successfully reproduce. Further, both the uptake and the effects of Hg

are increased by low dietary Ca. Insectivorous birds in acidified areas also receiving Hg deposition are thus particularly susceptible to Hg toxicity because they occur at high trophic levels (e.g., susceptible to biomagnification), are long-lived (e.g., susceptible to bioaccumulation), are dependent on Ca-rich supplemental prey items for breeding, and are vulnerable to neurological and reproductive impacts from elevated Hg levels.

Because eastern U.S. breeding bird populations may be suffering the negative effects of multiple stressors such as fragmentation, acidic and Hg deposition, as well as other human-caused environmental changes, the effects of air pollutants on thrushes breeding in northeastern forests are examined. Focal species are the Wood Thrush (*Hylocichla mustelina*) and the Veery (*Catharus fuscescens*) with range-wide decreasing population trends, and sharp declines over much of the Northeast. Because the Bicknell's Thrush's (*C. bicknelli*) habitat is restricted to mountain tops where cloud and fog acidic and Hg deposition occur, in addition to increased precipitation due to orographic effects, this species serves as an illustration of the effects of high levels of both acidic and Hg deposition.

**ASSESSMENT OF EXTENT TO WHICH INTENSIVELY STUDIED LAKES ARE
REPRESENTATIVE OF THE ADIRONDACK MOUNTAIN REGION**

Timothy J. Sullivan
E&S Environmental Chemistry

This initiative represents a multi-disciplinary and multi-institutional effort to extrapolate research, monitoring, and modeling results, including physical, chemical, and biological findings, from intensively studied lakes to the regional population of acid-sensitive Adirondack lakes. Extrapolation is based on the statistical framework of the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP). Intensively studied sites were drawn from the Rensselaer Polytechnic Institute Adirondack Effects Assessment Program (AEAP) and the New York State (NYS) Department of Environmental Conservation's Adirondack Long-term Monitoring (ALTM) project. A total of 70 watersheds are included in this effort, which has involved field sampling during summer 2003 to develop a statistically representative soils database and subsequent model projections using the MAGIC and PnET-BGC models to classify lakes according to their sensitivity to changes in sulfur and/or nitrogen deposition. The results of this research will allow fuller utilization of data from ongoing chemical and biological monitoring and process-level studies by providing a mechanism to extrapolate findings regionally and to develop/refine relationships among watershed characteristics, chemical change, and biological responses to changing levels of acid deposition. This project is important for the management of New York ecosystems that are most sensitive to changes in acid deposition, because it will define the acidified lakes that are likely to recover and the extent of the expected recovery in response to varying future deposition scenarios. It will also identify types of watersheds in which recovery is unlikely and will provide critical information for determining which areas require the most intensive research or remediation efforts.

EFFECTS OF NITROGEN ADDITION ON FINE ROOTS IN AN OAK FOREST

Gary Lovett & Julie Hart
Institute of Ecosystem Studies

Bruce Machona
Wiley College

Burning fossil fuels causes emission of nitrogen oxides, which can be deposited to ecosystems downwind of emission sources. Excess nitrogen (N) deposition to forests can result in changes in carbon allocation by the trees and increased nitrate leaching, causing depletion of base cations such as calcium (Ca). Depletion of base cations may cause soil acidification and increased aluminum (Al) concentration and mobility. Aluminum competes with base cations and inhibits their uptake by tree roots.

The experimental addition of nitrogen to an upland oak-hickory forest near Millbrook, New York resulted in increased tree mortality, especially after two years of summer drought. We investigated two hypotheses: (1) increases in nitrogen might cause trees to produce fewer fine roots, causing increased water stress; and (2) nitrogen can cause soil acidification, possibly resulting in Al toxicity. Nitrogen fertilization increased the extractable Al in soils, and decreased extractable Ca and the Ca/Al ratio. We found that the Ca concentration and Ca/Al ratio in roots were significantly lower in N-fertilized plots, compared to unfertilized controls, but there was no significant difference in Al concentrations. There was no significant difference in the biomass of live or dead roots. There was also no significant difference in the Ca/Al ratio in green foliage from the plots in 1996, but the ratio was significantly lower in fertilized plots than in unfertilized plots in 2002. Thus, this study did not support the hypothesis that increased nitrogen causes changes in fine root biomass, but it did support the hypothesis that increased nitrogen leads to potential Al toxicity, as evidenced by lower Ca/Al ratios in roots and foliage, and perhaps to a lesser Ca supply, as evidenced by lower Ca concentrations in roots. In these ridgetop oak forests, excessive N deposition may lead to soil acidification and result in the death of trees.

STRATEGIC MONITORING OF MERCURY IN NEW YORK STATE FISH

Howard Simonin, Jeff Loukmas, & Larry Skinner
Bureau of Habitat, NYS Department of Environmental Conservation

Large predatory fish are known to bioaccumulate mercury to high levels in certain waters. However, most waters have not been monitored to determine mercury concentrations in fish. In a four-year cooperative project funded by the New York State Energy Research and Development Authority and the New York State Department of Environmental Conservation, 131 inland lakes, ponds, and reservoirs from across the state were selected for an assessment of mercury in fish and surface water chemistry samples. Largemouth bass, smallmouth bass, walleye, and yellow perch were identified as the target fish, since these species are known to accumulate mercury, are popular sportfish, and are generally widespread in distribution. Data reported for the first two years of this study, which included 1758 fish samples from 94 waters, have resulted in 37 new fish consumption advisories from the New York State Department of Health. In 2005, obvious geographic patterns in fish mercury concentrations prompted a region-based consumption advisory for the Adirondack and Catskill parks. Preliminary trend analysis of our data showed that mercury concentrations in yellow perch have either decreased or remained the same when compared with fish monitored 15 years ago in a number of Adirondack lakes. Additional data analysis will include multivariate analysis to determine relationships among fish mercury concentrations, various water chemistry parameters, and watershed characteristics. Initial analyses indicate a significant relationship between methylmercury levels in water and the color of the water. The relationship between water and fish mercury concentrations is not as strong.

**ASSESSMENT OF NITROGEN AND ACIDIC DEPOSITION IMPACTS ON TERRESTRIAL AND
AQUATIC ECOSYSTEMS OF THE TUG HILL**

Gregory G. McGee & Myron J. Mitchell
SUNY College of Environmental Science and Forestry

Patrick Crast
The Nature Conservancy

The Tug Hill region of New York consistently receives among the highest levels of acidic and nitrogen (N) deposition in the eastern United States. Compared to other regions of New York that are impacted by atmospheric deposition, the Tug Hill has the highest long-term (1980–2002) average annual deposition rates for NH_4^+ , NO_3^- , total inorganic N, SO_4^{2-} , and H^+ . Therefore, great potential exists for the Tug Hill to display symptoms of N saturation and acidification. Even still, there have been no regional assessments of atmospheric deposition effects on this region, which contains 6400 km of streams, supports world-class fisheries, serves as a drinking water supply for several municipalities, and sustains an \$80 million wood products and paper manufacturing industry. We have initiated a two-year survey of surface water quality, soil chemistry, and tissue chemistry across ~50 sites in the Tug Hill. At each site (defined by random segment of a randomly selected first-order stream) surface water samples will be collected during snowmelt and baseflow over two years and analyzed for pH, alkalinity, total N, organic N, NO_3^- , NH_4^+ , and base and acid cations. Adjacent to each water sampling location, we are collecting, from upper and lower slope positions, forest floor and upper mineral horizon soils and foliar tissue of canopy-dominant tree species. Soils are being analyzed for pH, C:N ratio, and extractable N. Foliage is being analyzed for C:N ratios, base cation content, cation:Al ratios, and lignin content. Data will be synthesized to make site-level assessments of base-cation nutrient depletion and N saturation potentials. These site-level evaluations will, in turn, facilitate a regional determination of potential acidic and N deposition impacts to the Tug Hill and produce an assessment of variation among sites in response to acidification and N status that may be attributed to site conditions, forest species composition, and stand development stage.

**LONG-TERM MONITORING: AN INTEGRATION OF THE EFFECTS OF ATMOSPHERIC
DEPOSITION AND CLIMATIC EFFECTS ON THE ARBUTUS
WATERSHED IN THE ADIRONDACK MOUNTAINS**

Myron J. Mitchell & Dudley J. Raynal
SUNY College of Environmental Science and Forestry

Charles T. Driscoll
Department of Civil and Environmental Engineering, Syracuse University

The Arbutus Lake Watershed has been gauged at the lake outlet since October 1991 with a V-notch weir. The data logger at the weir is connected to a telephone line, permitting realtime monitoring of water discharge from Arbutus Lake. The 130 ha Archer Creek Catchment drains into Arbutus Lake. This catchment has been monitored since 1994 using an H-flume equipped with automated discharge logging and sample collection system. Water chemistry samples are taken weekly, except during storm events when more frequent sampling is done. In addition, transects of piezometers, water table wells, soil tension lysimeters, snow lysimeters, and throughfall collectors have been installed for characterizing solute chemistry. Various plots and subcatchments, including both upland and wetland sites, have been intensively instrumented since 1994. In addition, a detailed Geographical Information System (GIS) has been developed for the site that includes a Digital Elevation Model (DEM) with 3 m resolution and other GIS information. Detailed stream and wetland maps have been produced and sampling points located, all of which are part of the GIS.

Over the past five years, biogeochemical studies at the Huntington Forest have evaluated a broad range of biogeochemical constituents including DOC, S, and N. Research has also focused on the interactions between geology, soils, vegetation, and biogeochemical responses. Also, recent efforts have focused on evaluating interactions between hydrology and biogeochemistry, including analyses of the influences of snowmelt and storms on the hydrology and biogeochemistry of this catchment. These studies have particular importance for evaluating the effects of both atmospheric deposition and climate change on the Adirondack landscape.

APATITE AS A CALCIUM SOURCE TO FORESTS

Ruth D. Yanai & Byung B. Park
SUNY College of Environmental Science and Forestry

Carmen A. Nezat & Joel D. Blum
University of Michigan

The degree to which acid rain threatens forest health and productivity depends in part on the ability of soils to supply calcium (Ca) and other base cations for forest growth. Apatite ($\text{Ca}_5\text{PO}_3(\text{OH}, \text{F}, \text{Cl})$) is a readily weathered trace mineral in rocks that is known to be important in supplying phosphorus to soils but that has been overlooked in studies of Ca supply. Our previous work demonstrated the importance of apatite as a Ca source to northern hardwoods in New Hampshire. For example, at the Hubbard Brook Experimental Forest, 12%–22% of the Ca in the vegetation was supplied from apatite weathering.

The objective of our current study is to determine the importance of apatite to Ca supply in other parent materials and forest types, specifically those important in New York State. Our initial results suggest that apatite is important in granitoid parent materials but not in sedimentary rocks. Readily weathered minerals such as apatite tend not to persist to form sediments and thereby 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.

Clearly, an 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.

**ECOSYSTEM INTEGRITY IN ADIRONDACK UPLAND HEADWATER CATCHMENTS: A
COMPARISON OF REFERENCE AND LOGGED CATCHMENTS**

Timothy Mihuc, Thomas Woodcock, Edwin Romanowicz, Janet Mihuc¹, Eileen Allen, Chris Cirno², Robert Fuller, David Franzi, Celia Evans¹, & James Allen¹
Lake Champlain Research Institute & Center for Earth and Environmental Science,
SUNY Plattsburgh

¹Paul Smith's College

²SUNY Cortland

Catchment-scale characteristics and land-use practices were used to define and assess ecosystem integrity in Adirondack upland headwater catchments to compare systems managed for timber harvest and reference sites located in the New York State Forest Preserve. A suite of variables describing catchment geomorphology (area, circularity, slope, elevation, aspect, soil depth, surficial geology), water chemistry, surface water hydrology (drainage density, baseflow discharge, 'flashiness', groundwater influx, water velocity), and channel habitat (slope, width, depth, substrate particle size, stored and transported organic matter, transported sediment) were determined. These data were compared to biotic data (stream biota and upland plant communities). Watershed geomorphology was similar between land-use types. However, Forest Preserve streams tended to have deeper and wider channels (despite steeper channel slopes), while streams in logged watersheds had more stored organic matter and finer substrate. Over 175 macroinvertebrate taxa sites were recorded in the streams, and taxa richness was significantly reduced in managed watersheds ($p = 0.006$). Twenty-seven taxa showed a bias toward Preserve sites, and nine were more common in managed streams (chi-square, $p < 0.10$). Distributions of these taxa were related to channel geomorphology and particle size at the patch scale, and to watershed circularity, ground and surface water drainage patterns, and inorganic sediment load at the watershed scale. Invertebrate distributions were affected both by land-use patterns and watershed-scale geomorphologic variables. Fish (brook trout) had higher biomass and density in managed sites. Surface water chemistry, selected hydrology variables, forest community composition, and riparian plant communities also showed differences between managed and Preserve catchments. Multivariate comparison of these variable sets has allowed us to develop a preliminary definition of ecosystem integrity in these systems.

**ATMOSPHERIC DEPOSITION, TRANSFORMATIONS, AND FATE OF MERCURY ACROSS A
NORTHERN FOREST LANDSCAPE**

Joseph T. Bushey & Pranesh Selvendiran

Department of Civil and Environmental Engineering, Syracuse University

Hyun-Deok Choi

Department of Civil and Environmental Engineering, Clarkson University

Linghui Huang & Alexei Nallana

Department of Civil and Environmental Engineering, Syracuse University

Thomas M. Holsen, Tim Sharac, & Soon-Onn Lai

Department of Civil and Environmental Engineering, Clarkson University

Michael McHale

U.S. Geological Survey

Ron Munson

Tetra Tech, Inc

Charles T. Driscoll

Department of Civil and Environmental Engineering, Syracuse University

Mercury (Hg) is a toxic trace metal, linked to human illness and degradation of ecosystems. Atmospheric emissions have caused widespread Hg contamination in aquatic environments, including dangerously high concentrations in Adirondack lake biota. However, the linkage between atmospheric deposition and contamination of aquatic biota is not well established. Additional research is necessary to determine the ultimate fate of Hg within remote ecosystems. A quantitative understanding of atmospheric Hg deposition and the factors regulating the fate, transformation, and bioavailability of such Hg within terrestrial environments and downstream aquatic ecosystems are critical research needs.

The current research examines Hg deposition and cycling within the Arbutus Lake watershed (Newcomb, NY) in order to clarify the atmospheric, geochemical, and biological mechanisms regulating Hg concentrations in soft-water lakes of the northeastern United States. The effects of deposition pathway, soil retention, and landscape characteristics are being examined. Precipitation and throughfall are being collected to quantify atmospheric inputs. The interaction and fate of this atmospheric Hg with respect to plants is being monitored through plant tissue and litterfall collection, centered upon two upland soil plots from which soil and soil water samples have also been collected. The effect of landscape characteristics on methylmercury (MeHg) production and bioavailability is being investigated via streamwater and piezometer sampling within the Archer Creek wetland system. Data obtained within the Arbutus watershed will provide information on Hg contamination and bioavailability in Adirondack ecosystems. The data may be extrapolated regionally via modeling to predict the effect of Hg deposition within similar watersheds of the Adirondacks.

MERCURY IN ADIRONDACK WETLANDS, LAKES, AND TERRESTRIAL SYSTEMS

R. K. Munson
Tetra Tech, Inc.

C. T. Driscoll,
Department of Civil and Environmental Engineering, Syracuse University

R. M. Newton
Smith College

The Mercury in Adirondack Wetlands, Lakes, and Terrestrial Systems (MAWLTS) project has involved field research and modeling of the Sunday Lake–watershed system in the western Adirondack mountains of New York. The overall objective of the project was to develop an understanding of the behavior of mercury in drainage lake–watershed systems through a mass-balance analysis and to produce an integrated mathematical model with the capability of simulating the terrestrial, wetland, and in-lake processes that influence the levels of mercury in fish tissue. This has involved hydrological characterization of the Sunday Lake–watershed system to determine volumetric inputs and outputs and to establish flowpaths of water; chemical characterization of the atmospheric deposition, surface waters, and groundwater to track mercury movement and transformations; determination of mercury concentrations in fish and zooplankton; and development and application of the Mercury Cycling Model for Headwater Drainage Lakes (MCM-HD). Project results include the following:

- ◆ Wet deposition of Hg_T and CH_3Hg^+ are similar to other values reported for eastern North America.
- ◆ Fluxes of Hg_T draining the forest floor are high compared to wet deposition inputs. This discrepancy may reflect unmeasured inputs of Hg via dry deposition.
- ◆ The watershed is a sink for atmospheric Hg_T deposition (77%).
- ◆ The watershed is a source for CH_3Hg^+ , probably owing to production largely in riparian wetlands.
- ◆ The lake is a sink for Hg_T and a source for CH_3Hg^+ .
- ◆ Model results show decreases in aqueous Hg concentrations in response to decreasing deposition.

**LONG-TERM MONITORING OF WATER QUALITY IN MASSACHUSETTS :
ASSESSMENT OF ACID DEPOSITION IMPACT CHANGES**

Paul Jos. Godfrey

Water Resources Research Center, National Institutes for Water Resources
University of Massachusetts

The Massachusetts Acid Rain Monitoring Program has monitored nearly every surface water in Massachusetts for two years and a randomly selected group of 800 lakes and streams for eight additional years (1983–1993). In 2001 the effort was restarted with sampling for 22 "signature" sites that might be expected to reveal changes quickly because of their low alkalinity. Additionally, another 100 randomly chosen sites have been sampled for pH and acid neutralizing capacity (ANC). This presentation will focus on the changes in the signature sites. Briefly stated, these changes are mixed for pH and ANC (14 of 22 declining), with 16 sites declining in calcium levels, 15 declining in magnesium, and 20 declining in sulfate. Sodium has increased at 20 sites, and chloride has increased at 18 sites. There is a general increase in base cations, principally as a result of sodium increases. Aluminum has declined at 12 sites. Color, a surrogate for organic carbon, has increased at 18 sites. General slope data for changes in all chemical parameters and the statistical significance of the difference between the first and second sampling periods will be presented.

**CLIMATE VARIABILITY AND CHANGE IN THE NORTHEASTERN UNITED STATES AND
EASTERN CANADA: CONSEQUENCES FOR NORTHERN FOREST ECOSYSTEMS**

Lindsey Rustad

U.S. Department of Agriculture Forest Service

A new program on "Climate Variability and Change in the Northeastern United States and Eastern Canada: Consequences for Northern Forest Ecosystems" was initiated in July 2005. The goals of this two-year program are (1) to summarize the accumulating climate variability and change research on northern forest ecosystems in the region and (2) to make this summary available to policymakers, land and resource managers, stakeholders, and the interested public. The program goals will be accomplished in a three-phase process. Phase 1 will involve a survey of end-users (including state and provincial agencies and governments, NGOs, land managers, education organizations, and industry) to assess what type of information would be most useful and relevant and what format(s) would be most accessible. Phase 2 will involve a scientific synthesis of climate variability and change research in the region, resulting in a peer-reviewed paper suitable for a journal such as *BioScience* or *PNAS*. This document will include (1) a review of the historical record of climate within the region, (2) environmental indicators of this past climate change, (3) updated climate projections for the region, (4) current research on these issues within the region, (5) ecological implications of this change for the northern forest, and (6) future scientific research needs. Phase 3 will involve the translation of this document for the nonscientific community. Results from Phase 3 will be disseminated to the appropriate stakeholders as a Forest Service General Technical Report (GTR), a website, and fact sheets. This project is unique in that it will (1) update the work done for the New England Regional Assessment, (2) include the northern forest regions of Eastern Canada as well as the northeastern United States, and (3) focus primarily on the northern forest ecosystem.

**POTENTIAL RECOVERY OF WATER CHEMISTRY AND STREAM BIOTA FROM REDUCED
ACID DEPOSITION AT A SENSITIVE WATERSHED IN THE CATSKILLS**

Douglas A. Burns & Karen R. Murray
U.S. Geological Survey

Robert W. Bode
NYS Department of Environmental Conservation

Atmospheric acid deposition has decreased in the northeastern United States during the past two decades, primarily owing to decreases in sulfur emissions from power plants in source areas to the southwest of the region in the Ohio River Valley. The decreased acidity of precipitation has resulted in modest increases in pH, acid neutralizing capacity (ANC), and decreases in inorganic monomeric aluminum (Al_{im}) since the 1980s in the acid-sensitive Neversink River watershed in the Catskill Mountains of New York. In the summer of 2003, we sampled 12 stream sites within the Neversink River watershed for water chemistry, periphytic diatoms, macroinvertebrates, and fish. These sites were sampled (1) to establish a baseline of chemical and biological data against which future changes caused by changing rates of atmospheric acid deposition could be evaluated and (2) to compare data to previously collected stream chemical and biological data from 1987, as well as to smaller data collections in 1992, 1999, and 2002. Metrics and indices that reflect sensitivity to stream acidity were developed with these biological data to determine whether modest chemical recovery observed in this watershed has been sufficient to promote biological recovery over the intervening 16 year period. Cluster analysis of acid-sensitive macroinvertebrate species indicates that some of the differences between the 1987 and 2003 data are due to seasonal variation, because the 1987 samples were collected in July and August, whereas the 2003 samples were collected in September. Additionally, the summer of 2003 was much wetter than 1987, with higher precipitation and streamflow, which likely affected the chemical and physical characteristics of the habitat. Nonetheless, the most upstream and acidic sites show changes over the 16 year interval that are consistent with modest recovery from reduced levels of acid deposition, whereas downstream sites with circumneutral pH, higher ANC, and lower Al_{im} concentrations show little change in the presence/absence of acid-sensitive macroinvertebrate taxa. Examination of biological metrics from all sites and years in relation to Al_{im} concentrations and ANC revealed apparent thresholds of change in water chemistry at which significant changes in acid-intolerant species of fish, aquatic macroinvertebrates, and diatoms occur. These thresholds varied among the three groups of aquatic organisms we examined, with diatom indices showing the greatest sensitivity. These results indicate that biological recovery will not be uniform across taxonomic groups and suggest that efforts to monitor acid impact and recovery should not be limited to one group of organisms.

**ASSESSMENT OF ACIDIC DEPOSITION EFFECTS ON STREAM CHEMISTRY IN THE WESTERN
ADIRONDACK REGION OF NEW YORK**

Karen M. Roy

NYS Department of Environmental Conservation

Gregory B. Lawrence & Barry P. Baldigo

U.S. Geological Survey

Howard A. Simonin

NYS Department of Environmental Conservation

Susan B. Capone

Adirondack Lakes Survey Cooperation

James S. Sutherland

NYS Department of Environmental Conservation, Darrin Freshwater Institute

Sandra A. Nierzwicki-Bauer

Rensselaer Polytechnic Institute

Assessments and monitoring have provided detailed information on the chemical condition of Adirondack lakes and have served as the primary measure of acid deposition effects on this region, one of the most affected in North America. However, this focus on lake chemistry has resulted in an incomplete picture of effects on Adirondack surface waters. Relatively little information is available on streams in this region, although they are more prone to acidification, particularly during high flows. Stream assessments are lacking, in part, because early studies that identified the episodic nature of stream acidification suggested that synoptic surveys would be highly uncertain if flows varied during sampling.

To obtain current information on Adirondack streams, a synoptic survey was designed to characterize stream chemistry in the Oswegatchie and Black River drainages: 400,000 ha in the western Adirondack ecoregion with acidic deposition levels that are among the highest in the U.S. To minimize the time required for collection, only streams accessible within a one-hour hike from the nearest road were identified for possible sampling. This enabled all samples to be collected in three consecutive days, which helped to minimize variations in flows. Streams with upstream lakes or ponds that affected more than 25% of the drainage area were excluded. Of the 565 streams that met these criteria, 200 were randomly selected for sampling. Samples were collected during a high-flow period, on 27–29 October 2003 and during snowmelt, on 29–31 March 2004. Three streams were sampled on each of the three days during both samplings to evaluate daily variations in chemistry. One gaged stream was available within the study area, which provided an index of flow.

During the October 2003 sampling, flow of the index stream ranged from 4.8 to 23 mm a day, and the coefficients of variation of acid neutralizing capacity (ANC) for the reference streams were 7.3%, 12.3%, and 59%. Effects were evaluated by comparing measured values with biologically relevant thresholds listed in Driscoll et al. (2001). Concentrations of inorganic monomeric Al in 54% of the streams exceeded $2 \mu\text{mol L}^{-1}$, the threshold above which biota are negatively affected. Values of ANC in 66% of the streams were below $50 \mu\text{eq L}^{-1}$, and values of

pH in 64% of the streams were below 6.0, the threshold values below which ecosystems are considered at risk.

Stream flows were lower during the March sampling than the October sampling and varied over a smaller range (5.6–7.9 mm per day). Coefficients of variation of ANC measurements for the three reference streams were 5.8%, 6.6%, and 15%. Although flows in March were generally lower, the percentages of streams that were negatively affected were similar to those in October. Inorganic Al concentrations exceeded $2 \mu\text{mol L}^{-1}$ in 45% of the streams, ANC values fell below $50 \mu\text{eq L}^{-1}$ in 70% of the streams, and pH values fell below 6.0 in 64% of the streams.

**ASSESSMENT OF REGIONAL FOREST HEALTH AND STREAM AND SOIL CHEMISTRY USING A
MULTI-SCALE APPROACH AND NEW METHODS OF REMOTE-SENSING INTERPRETATION IN
THE CATSKILL MOUNTAINS OF NEW YORK**

Peter S. Murdoch
U.S. Geological Survey

Collaboration between the U.S. Geological Survey and the U.S. Forest Service will link field and remote-sensing data to produce the most detailed maps to date of forest, soil, and surface-water conditions. The resulting GIS database will highlight forest stands and watersheds sensitive to changes in atmospheric deposition and logging in the Catskill Mountain region. During this collaboration, we will further develop existing remote-sensing methods for forest condition mapping that will make it possible to assess regional changes in forest health (foliar calcium and nitrogen; tree decline) at a fine scale across the landscape. The result will be an integrated picture of landscape sensitivity to disturbance, as well as of the spatial variability in potential forest and surface water response to decreased or increased levels of acidic deposition. Data products derived from state-of-the-art hyperspectral imagery will be validated by regional surveys of foliar, soil, and stream chemistry. The combined datasets will be used to map areas most susceptible to calcium depletion due to nitrogen (N) and sulfur (S) deposition and harvesting in the watersheds of the New York City water supply. The methods proposed follow the Federal Collaborative Environmental Monitoring and Research Initiative (CEMRI), in which data from intensive research areas, regional surveys, regional gradient studies, and remote-sensing instruments are systematically integrated to generate a comprehensive research and monitoring strategy.

**INTEGRATED ASSESSMENT OF THE RECOVERY OF SURFACE WATERS FROM REDUCED
LEVELS OF ACID DEPOSITION IN THE CATSKILLS AND ADIRONDACKS**

Douglas A. Burns & Michael R. McHale
U.S. Geological Survey

Charles T. Driscoll
Department of Civil and Environmental Engineering, Syracuse University

Karen M. Roy
Adirondack Lakes Survey Corporation

Gary M. Lovett & Kathleen C. Weathers
Institute of Ecosystem Studies

Myron J. Mitchell
SUNY College of Environmental Science and Forestry

In light of recent reductions in sulfur (S) and nitrogen (N) emissions mandated by Title IV of the Clean Air Act Amendments of 1990, temporal trends and trend coherence in precipitation (1984–2001 and 1992–01) and surface-water chemistry (1992–2001) were determined in two of the most acid-sensitive regions of North America, the Catskill and Adirondack mountains of New York. Precipitation chemistry data from six sites located near these regions showed decreasing sulfate (SO_4^{2-}), nitrate (NO_3^-), and base cation (C_B) concentrations and increasing pH during 1984–2001, but few significant trends during 1992–2001. Data from five Catskill streams and 12 Adirondack lakes showed decreasing trends in SO_4^{2-} concentrations at all sites, and decreasing trends in NO_3^- , C_B , and H^+ concentrations and increasing trends in dissolved organic carbon (DOC) at most sites. In contrast, acid neutralizing capacity (ANC) increased significantly at only about one-half of the Adirondack lakes and one of the Catskill streams. Flow correction prior to trend analysis did not change any trend directions, had little effect on SO_4^{2-} trends, but caused several significant non-flow-corrected trends in NO_3^- and ANC to become nonsignificant, suggesting that trend results for flow-sensitive constituents are affected by flow-related climate variation. Sulfate concentrations showed high temporal coherence in precipitation, surface waters, and in precipitation–surface water comparisons, reflecting a strong link between S emissions, precipitation SO_4^{2-} concentrations, and the processes that affect S cycling within these regions. Nitrate and H^+ concentrations and ANC generally showed weak coherence, especially in surface waters and in precipitation–surface water comparisons, indicating that variation in local-scale processes driven by factors such as climate are affecting trends in acid-base chemistry in these two regions.

OTHER ENVIRONMENTAL RESEARCH

**EFFICIENCY AND EMISSIONS BENEFITS OF LOW-SULFUR HEATING OIL AND
CONDENSING APPLIANCES**

Wai-Lin Litzke, Roger McDonald, & Thomas Butcher
Brookhaven National Laboratory

High levels of fine particulate matter ($PM_{2.5}$) in New York City and surrounding metropolitan areas have been attributed mostly to diesel engines with contributions from oil used for heating during the wintertime. Number 2 heating oil consumption, typically high-sulfur, is concentrated in the Northeast region, with about 3.4 billion gallons (1997 data) used annually in the Mid-Atlantic states (NJ, NY, and PA). Improved energy efficiency of furnaces and boilers with significant reductions in sulfur oxides and total particulate matter can be achieved through the use of low-sulfur fuels. Reducing sulfur levels even further to ultralow levels, which is now available as transportation diesel, allows for continued advances in condensing oil-fired systems. These advances allow for up to 10% improvements in energy efficiency or 94%-efficient systems. Brookhaven National Laboratory is developing these technologies with the objectives of quantifying the efficiency benefits in addition to characterization of emissions. This poster will present specific data on the correlation between sulfur levels and $PM_{2.5}$ using a new, portable dilution-tunnel sampling system for condensing boilers and furnaces in residential systems.

A NEW, COMPACT INSTRUMENT FOR REALTIME AEROSOL SIZING

Suresh Dhaniyala & Manish Ranjan

Department of Mechanical and Aeronautical Engineering
Clarkson University

Accurate characterization of particles in micro-environments and large-scale deployment of instruments for ambient and indoor monitoring require compact, inexpensive instruments that can provide *in situ* real-time measurements. In particular, temporal and spatial variations in ultrafine and nanoparticle populations complicate exposure analysis and assessments of their impact on human health and environment based on time-averaged measurements at single locations. The popular technique for nanoparticle characterization involves electrical mobility measurements, typically made using a differential mobility analyzer (DMA; Knutson & Whitby 1972). While, the DMA provides high-resolution measurements, it is expensive, requires multiple flow measurements, and is large in size. We will present a design of a compact instrument (Miniature Electrical Aerosol Spectrometer [MEAS]) for particle sizing using the principle of electrical mobility. The MEAS has rectangular flow geometry and is divided into two major components: an electrostatic precipitator (ESP) section and a classification section. The classification section has a parallel plate precipitator design with high voltage on one plate and grounded potential on the other. The grounded section is split into several thin strips of collection plates, which are separated by small insulating sections where collected charged particles are sized by detection using electrometer circuits. The introduction of charged particles into the classification section is through the ESP section, where several thin parallel plates are used to divide the height of the flow region into smaller channels (~2 mm in width). These plates are maintained at user-controlled potentials and are operated so that selected channels between the plates can either trap or pass all the charged particles. Thus, by trapping charged particles through all channels but one, charged particles can be injected into the classification section at a desired distance from the collection plates in the classification section. Variation of particle injection location permits characterization over a wide particle size range with a relatively compact instrument. The use of the ESP section enables operation of the instrument with a single flow measurement. The current development efforts will be highlighted, and preliminary comparisons with other particle sizing instruments will be presented.

**MITIGATING NEW YORK CITY'S HEAT ISLAND WITH URBAN FORESTRY, LIVING ROOFS,
AND LIGHT SURFACES: NEW YORK CITY REGIONAL HEAT ISLAND INITIATIVE**

Cynthia Rosenzweig

NASA Goddard Institute for Space Studies

William D. Solecki

Hunter College, CUNY

Lily Parshall

NASA Goddard Institute for Space Studies

Jennifer Cox & Sara Hodges

Hunter College, CUNY

Richard Goldberg, Barry Lynn, & Stuart Gaffin

NASA Goddard Institute for Space Studies

New York City, like other large cities, is warmer than surrounding areas because of the urban heat island effect caused by absorption of heat by building materials and lack of vegetation. Heat island mitigation strategies, such as urban forestry, living/green roofs, and light surfaces, could be implemented at the community level within New York City. This study evaluates whether these strategies can reduce surface and near-surface air temperatures enough to have a measurable impact on energy demand, especially at peak times on hot summer days. The objectives were to analyze and model the summer heat island effect in New York City and test potential mitigation strategies. Methods included analysis of observed meteorological data; Landsat, ASTER and MODIS satellite data; and environmental characteristics, including albedo, normalized difference vegetation index (NDVI), building height, and road network density. The MM5 mesoscale model and an energy-balance model were used to characterize surface and near-surface temperatures associated with impervious surfaces, grass, and trees in six case-study areas and for New York City as a whole. Mitigation scenarios tested included open-space planting, curbside planting, living roofs, and light surfaces separately and in combination and at different intensities of adoption. Three heat waves during the summer of 2002 were used to test the mitigation scenarios. Results show that curbside planting is an individual strategy with effective cooling potential. In areas with greater available space for rooftop redevelopment, living roofs are also effective. Owing to the large areas of impervious surfaces, light surfaces also have potential cooling effects.

CONTINUOUS AIR MONITORING OF MERCURY IN ROCHESTER, NY

Kevin Civerolo

Bureau of Air Quality Analysis & Research, Division of Air Resources
NYS Department of Environmental Conservation

H. Dirk Felton & Oliver Rattigan

Bureau of Air Quality Surveillance, Division of Air Resources
NYS Department of Environmental Conservation

There is currently little information about baseline air concentrations of mercury in New York State, particularly in urban areas. Efforts to monitor speciated mercury in ambient air, its elemental (Hg_0), reactive gaseous (Hg_2), and particle-bound (Hg_p) forms, are necessary to evaluate the effects of proposed emissions regulations such as the Clean Air Mercury Rule. To this end, the New York State (NYS) Department of Environmental Conservation has operated a continuous Tekran instrument in Rochester, NY since August 2004. The reactive gaseous form of mercury is of particular interest, since high concentrations may be indicative of nearby waste incineration and coal burning. Preliminary results, including diurnal and monthly variation and comparisons with other copollutants, such as SO_2 , are presented here.

REALTIME PM_{2.5} BLACK CARBON MEASUREMENTS AT ROCHESTER, NY AND THE SOUTH BRONX, NY

O. V. Rattigan, H. D. Felton, & K. Civerolo

Division of Air Resources, NYS Department of Environmental Conservation

Particulate carbon constitutes a major fraction of ambient air PM_{2.5} concentrations in New York. While organic carbon can be emitted directly or produced by photochemical reactions in the atmosphere, PM_{2.5} black carbon is emitted directly from the combustion of carbonaceous materials. Black carbon concentrations are usually dominated by local sources, although transport can also be a significant factor. Black carbon is typically present in the submicron particle size range and therefore has been associated with adverse health effects. Realtime measurements are important in tracking concentration variations, as mobile source emissions can vary throughout the day. This project presents five-minute PM_{2.5} black carbon data for a period of two years at the South Bronx and one year at Rochester. The South Bronx data show a clear diurnal pattern, with an early morning peak at ~6–10 am. The data are correlated with NO_x and PM_{2.5} nitrate concentrations, which is consistent with mobile emission sources. There is also a clear weekday versus weekend trend and a seasonal trend. The Rochester data show lower black carbon concentrations, but the same day-of-week and seasonal patterns. The data were compared to 24 hr filter measurements of elemental carbon from collocated Speciation Trends Network (STN) samplers at both sites. Black carbon data at the South Bronx site were also compared to hourly elemental carbon measurements from a recently installed SUNSET labs carbon analyzer.

**NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION'S AMBIENT AIR
MONITORING WEBSITE**

Paul Sierzenga

NYS Department of Environmental Conservation

The New York State Department of Environmental Conservation's Bureau of Air Quality Surveillance operates a network to measure the ambient air quality throughout the state. Near-realtime data for gaseous compounds, particulate matter, and meteorological parameters are available with updates posted hourly. Data from manual methods including filter-based particulate matter and acid deposition analysis are also available. A live link to the website will be provided for registrants to explore the site and view reports.

NEW YORK STATE CLEAN AIR SCHOOL BUS PROGRAM

Patrick Bolton
NYSERDA

New York State has approximately 46,000 large school buses operating on its roads, which is more than any other state. School buses are primarily diesel fueled, and much attention has been focused recently on the harmful effects that emissions related to this fuel can have on school children. Recent studies such as the “Children’s Exposure to Diesel Exhaust on School Buses” report by Environment and Human Health, Inc. have reported that the fine particulate matter (PM_{2.5}) concentrations may be 5–10 times higher inside a school bus than at the fixed monitoring stations in nearby locations. The air quality issue is highlighted in New York City, where the U.S. Environmental Protection Agency has listed the City as severely out of air quality attainment for ozone and Manhattan also out of attainment for PM₁₀ standards. To help alleviate this, the New York City Department of Education is being awarded \$1.25 million to retrofit 209 school buses with Diesel Particulate Filters. Funded through Governor Pataki's Clean Air/Water Bond Act and administered by the New York State Energy Research and Development Authority (NYSERDA), the New York State Clean Air School Bus Program is providing \$5 million to retrofit 2,200 school buses across the State with advanced emission-reducing equipment. The funding is being awarded to 74 school districts, and the districts receiving the highest amounts of funding are the urban-area districts with the worst air quality. The awards will cover 100% of the cost, including installation of emission-reducing technology such as particulate traps or filters and diesel oxidation catalysts.

An oxidation catalyst used with standard diesel reduces particulate emissions (PM) by 20%–25% on average. Used with ultra-low sulfur diesel (ULSD), a bus equipped with an oxidation catalyst can achieve 40%–50% reduction in PM. A particulate trap and filter, which is only effective when used with ULSD, can result in 90% reduction in PM. Reductions of 40% of carbon monoxide (CO) and 50% in hydrocarbon (HC) emissions are also achievable. The Donaldson Spiracle reduces up to 100% of the crankcase emissions.

IMPROVING THE NYC FERRY BOAT TRANSPORTATION SYSTEM

Frank Ralbovsky
NYSERDA

Green Ferry Alternatives Program

Passenger ferry service has grown rapidly in New York (NYC), and government and private organizations are looking for ways to expand ferry service to mitigate highway congestion and to achieve other objectives. Recent projects include efforts to improve service to Battery Park and other areas in lower Manhattan to alleviate problems created by the 9/11 terrorist attacks. New York Waterway, an advisor to the proposed project, operates over 40 ferries in and around New York harbor and has an additional five ferries on order. Unfortunately, these vessels are powered by diesel engines and raise significant environmental and fuel-diversity issues. Interested parties have suggested using new technology to address these issues. The project team includes organizations with strong backgrounds in marine design and other pertinent areas, including electric propulsion, advanced batteries, and fuel cells.

The objective of this project is to identify and determine the feasibility of one or more appropriate technologies to implement a "green ferry" initiative in New York State (NYS). Green ferry alternatives will comprise technologies that show significant potential in any or all of the following areas: increased energy efficiency, reduced environmental emissions, and reduced dependence on nonrenewable petroleum fuels.

The initial study will investigate the needs of the ferry industry relative to environmentally friendly (i.e., "green") technology that could be incorporated into future vessels. The project will bring together a large advisory group to identify specific objectives and proposed solutions. Besides the proposers, proposed advisors include the NYC Department of Transportation, NY Power Authority, Port Authority of New York and New Jersey, Empire State Development, NY Waterway, and NYS manufacturers of relevant technologies. The work will include a survey of market requirements and technical analysis of potential combinations of hull designs, propulsion systems, alternate fuels, and emission controls. If a workable vessel configuration can be identified, recommendations will be made for next-phase prototype construction and demonstration.

A fleet of "green" ferries has the potential to substantially reduce air emissions and petroleum consumption in New York, specifically in New York City. Involvement of NYS stakeholders will yield the potential of NYS-based manufacturing content for producing propulsion system components and complete vessels.

New York Harbor Private Ferry Emissions Reduction Program

Diesel engine emissions from the private ferry fleets operating in the New York Harbor are responsible for emissions of significant amounts of nitrogen oxides (NO_x), particulates, and other pollutants. As the emission sources from existing ferry fleets/engines are mostly unregulated, it has become apparent that an incentive program would be needed to produce the desired reduction in emissions from the ferry operators. The priority and urgency of addressing these emissions is underscored by the reported doubling of private ferry services since the events of 9/11, juxtaposed with a transportation-sensitive, highly populated area already in ozone nonattainment before 9/11.

To begin addressing the problem, New York City (NYC) Department of Transportation (DOT) has secured a grant from the Federal Highway Administration for an initial evaluation and demonstration program and a small pilot deployment program. The Federal Transit Administration, with the assistance of the U.S. Environmental Protection Agency, recently agreed to provide additional federal funding of \$4.8 million, for a combined initiative of \$6.8 million dedicated to improving emissions from private ferries.

The objectives of the program are to evaluate, demonstrate, and deploy the optimum emissions reduction technologies applicable to retrofitting the existing fleet of privately run ferry vessels operating in the New York Harbor, and thus to achieve the maximum degree of emissions reduction of NO_x, particulates, and other emissions.

This program is managed by the New York State Energy Research and Development Authority (NYSERDA) in conjunction with the NYCDOT. Seaworthy Systems Inc., with Environment Canada, ESI International, and the Northeast States for Coordinated Air Use Management (NESCAUM), will be conducting the field demonstration with the private ferry fleets.

The multiyear program will provide

1. Credible information on the costs, benefits, and feasibility of a wide range of possible emissions control options for private ferry fleets and the subsequent identification of a group of “best choices”;
2. Real-world experience with the use of the identified “best-choice” emissions control technologies in private ferry fleets operating in New York’s Harbor through a field demonstration initiative; and
3. Ultimate widespread deployment of successful technologies within the NYC private ferry fleets to achieve maximum reduction of NO_x, particulates, and additional emissions.

Currently, private ferries in the New York Harbor emit approximately 1,000 tons per year of NO_x and 145 tons per year of particulates. Achieving a reasonable target level across the majority of the private fleet can result in NO_x reductions of 150–300 tons per year—the rough equivalent of a new 500 MW combined cycle generating station—and reductions of particulates on the order of 30–90 tons per year. The project establishes the New York/New Jersey ferry operations as a model of environmental stewardship and city, state, federal, and private sector cooperation.

Strong Arm Ferry Docker Program

Passenger ferry service has grown rapidly in New York, with large, mostly older diesel engines being the dominant type of prime mover. Various initiatives are in the planning or early implementation stages of addressing the emissions problems (mainly particulates and NO_x) with these engine types. In addition to engine, fuel, and propulsion system modification, emissions reductions might also be achieved by boat operational changes.

Initial research indicates that most passenger ferries use engine power to hold their boats to the dock, remaining at full or substantial throttle during loading and unloading operations. The use of an alternate means of docking, e.g., a mechanical docking mechanism, may hold the potential of up to 20%–50% fuel use reduction by allowing the engines to be throttled back when loading and unloading. This potential reduction in fuel usage can not only lessen New York City and the state's use of petroleum, but can also result in less particulate and NO_x emissions in the City's environmentally sensitive harbor area.

The objective of this project is to analyze, design, fabricate, and test a prototype device, comprising a mechanical docking arm mechanism, to secure passenger ferries during passenger loading and unloading. Following the establishment of a detailed set of functional requirements for a docking mechanism, detailed analysis will be done on motions, loads, and stability parameters for ferry docking operations. Subsequently, a prototype docking mechanism will be designed and fabricated. A prototype test program will be structured and carried out, with ultimate testing being done on a ferry vessel in the New York City harbor area. The field tests will verify the anticipated functional performance and utility of the device for displacing the current process of using engine power to hold ferry boats against the dock during loading and unloading.

NYSERDA'S CLEAN DIESEL INITIATIVE: OFF-ROAD FIELD TESTING PROGRAM

Tim Hansen
Southern Research Institute

NYSERDA has recently initiated the Clean Diesel Technology: Non-Road Field-Testing Program in collaboration with the New York State (NYS) Department of Environmental Conservation (DEC). The goal of the NYSERDA program is to provide quality data and information to potential technology end-users, regulators, and others, such that implementation of diesel emission control strategies can be encouraged and widely adopted. This will ultimately provide significant reductions in the impacts of diesel emissions in New York State. This project is part of a broader NYSERDA Clean Diesel Program that was designed to support the development and implementation of new clean diesel technologies in the non-road sector in New York State. As part of its overall clean diesel program, NYSERDA has also sponsored a statewide Clean Air school bus retrofit program and ferry retrofit program focused on New York Harbor.

The Non-Road Field Testing Program will assess the performance of retrofit emission control technologies through in-use testing in select non-road diesel-powered equipment applications. Non-road emissions inventories will be developed for the state and the 10-county New York City Metropolitan Area (NYCMA) and refined via surveys of equipment owners focusing on the construction/mining equipment (NYCMA) and locomotive (statewide) sectors. Commercially available control technologies, primarily focusing on the control of particulate matter (PM) and oxides of nitrogen (NO_x), will be screened from technical, economic, and operational perspectives. Certification of these technologies by the U.S. Environmental Protection Agency (EPA) or California Air Resources Board (ARB) Control will also be a factor in the screening process. Based on the inventory and control-technology evaluations, the field testing program will be designed. Prior to implementation of the field testing program, an in-use test protocol will be developed that will be used to provide real-world performance data to complement the U.S. EPA and ARB engine/control system certification programs. Emission control technologies will be evaluated for emission control (NO_x, PM, CO, CO₂, THC), fuel consumption, operation (engine power, etc.), maintenance, and economic impacts. Testing will be completed while equipment is in use, using portable emissions measurement systems (PEMS) and portable dilution sampling systems.

**IMPROVING EMISSION INVENTORIES FOR EFFECTIVE AIR-QUALITY MANAGEMENT ACROSS
NORTH AMERICA: A NARSTO ASSESSMENT**

J. David Mobley

U.S. Environmental Protection Agency

Marc Deslauriers

Environment Canada

Leonora Rohas-Bracho

Mexico National Institute of Ecology

George Hidy

Envair/Aerochem Associates

NARSTO has recently completed an assessment of the current state of emission inventories for Canada, the United States, and Mexico, and offers suggestions for improvement. The assessment, entitled *Improving Emission Inventories for Effective Air-Quality Management across North America: A NARSTO Assessment*, addresses the needs of a broad user base composed of decisionmakers as well as developers and users of emission inventories. The Assessment begins with a vision statement: The ultimate emission inventory is one that includes all significant emissions, from all sources, for all time periods, in all areas, with quantified uncertainties, and is accessible in a timely manner. The Assessment

1. Identifies many national, state, provincial, and regional, local, and specialty inventories and provides information for accessing them;
2. Describes the methods used to generate emission inventories and discusses the strengths and weaknesses of these methods as well as of the resulting inventories;
3. Directs considerable attention to methods for determining uncertainties in emission estimates and provides comparisons between emission estimates and independent measurements for key sectors; and
4. Suggests ways to improve future inventories, characterize their uncertainty, and improve the delivery of emission data to users.

The Assessment concludes with recommendations and an action plan for improving emission inventories in the future to meet the expectations of timeliness, quality, and affordability. This presentation will summarize the main points of the assessment and the recommendations for improving current emission inventories. The assessment argues that significantly more resources need to be invested in the development and analysis of emission inventories if we are going to achieve effective management of ozone, particulate matter, and air toxics in the future.

**AN ON-LINE ANALYZER FOR LOW-SULFUR-CONTENT
MEASUREMENTS IN PETROLEUM PRODUCTS**

Jay Burdett, David Gibson, Stuart Shakshober, Berry Beumer, & Thomasin Miller
X-Ray Optical Systems, Inc.

Sulfur in transportation fuels is emitted as SO₂ or SO₃, which typically forms sulfuric acid in the atmosphere and sometimes forms ammonium sulfate or ammonium bisulfate. These sulfur compounds are major contributors to acid rain and formation of particulate matter less than 2.5 microns in aerodynamic diameter (PM_{2.5}) in the atmosphere, which is associated with adverse health effects. Although there are other human-based sources of sulfur, transportation fuels have been a major contributor. In New York City, for example, more than one-half of the sulfur in air comes from transportation sources. Sulfur in fuels poisons catalytic converters, so reduction in sulfur levels in fuels also allows for reductions of other pollutants from transportation sources.

To address these sources, the U.S. Environmental Protection Agency (EPA) has mandated a reduction of sulfur in on-road diesel fuel from the current level of 500 ppm to 15 ppm by 2006. Although the petroleum industry has demonstrated the ability to remove sulfur from fuel, controlling ultra-low sulfur (ULS) fuel production and distribution are problematic, as currently there are no practical methods for on-line measurement of the low-sulfur level in fuels.

An on-line sulfur analyzer for low-sulfur-content measurements, based on monochromatic wavelength dispersive X-ray fluorescence (WDXRF) using monochromatic excitation, has been developed by X-Ray Optical Systems, Inc. The analyzer sample delivery system allows continuous flow of the fuel for direct sulfur-content measurements. The innovative optic technologies employed allow for the intake pressure of the fuel stream to be as high as 100 psi, with excellent linearity ranging from 5 to 500 ppm sulfur levels in the petroleum product.