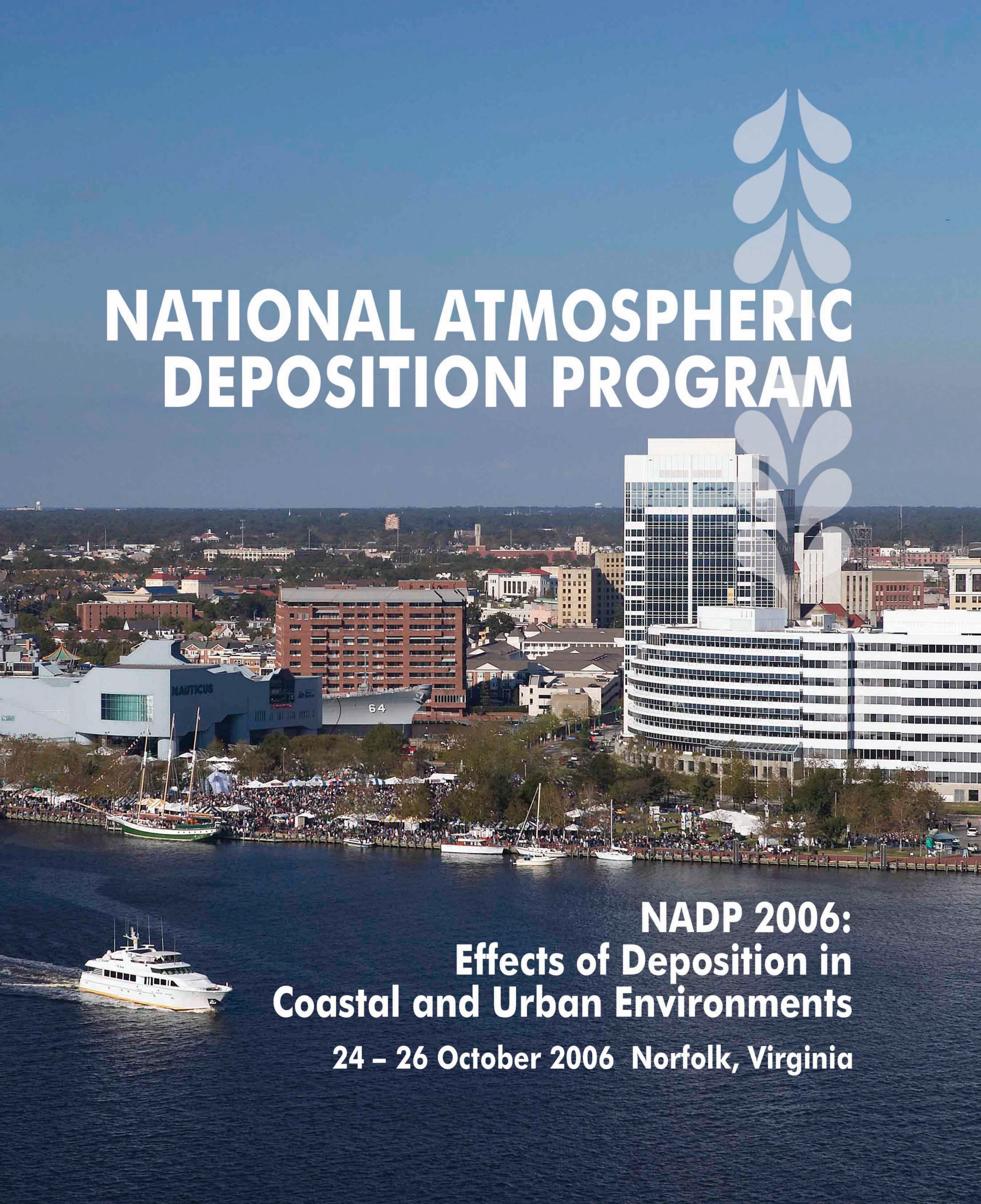

NATIONAL ATMOSPHERIC DEPOSITION PROGRAM

NADP 2006: Effects of Deposition in Coastal and Urban Environments

24 – 26 October 2006 Norfolk, Virginia

In 2005, scientists, students, educators, and others interested in the National Atmospheric Deposition Program (NADP) logged more than 310,000 sessions and viewed nearly 93,000 maps on the NADP Web site. Users downloaded 18,564 data files from this site, which now annually receives more than 1.2 million hits. These data are used to address important questions about the impact of the wet deposition of nutrients on eutrophication in coastal estuarine environments; the relationship between wet deposition, the health of unmanaged forests, and the depletion of base cations from forest soils; the impact of pollutant emissions changes on precipitation chemistry; and the rate at which precipitation delivers mercury to remote lakes and streams.

The NADP was organized in 1977 under State Agricultural Experiment Station (SAES) leadership to address the problem of atmospheric deposition and its effects on agricultural crops, forests, rangelands, surface waters, and other natural and cultural resources. In 1978, sites in the NADP precipitation chemistry network first began collecting one-week, wet-only deposition samples analyzed by the Central Analytical Laboratory (CAL) at the Illinois State Water Survey. The network was established to provide data on amounts, temporal trends, and geographic distributions of the atmospheric deposition of acids, nutrients, and base cations by precipitation. The NADP initially was organized as SAES North Central Regional Project NC-141, which all four SAES regions endorsed as Interregional Project IR-7 in 1982. A decade later, IR-7 was reclassified as National Research Support Project NRSP-3, which it remains.

In October 1981, the federally supported National Acid Precipitation Assessment Program (NAPAP) was established to increase understanding of the causes and effects of acidic precipitation. This program sought to establish a long-term precipitation chemistry network of sampling sites distant from point source influences. Because of its experience in organizing and operating a national-scale network, the NADP agreed to coordinate operation of NAPAP's National Trends Network (NTN). To benefit from identical siting criteria and operating procedures and a shared analytical laboratory, NADP and NTN merged with the designation NADP/NTN. Many NADP/NTN sites were supported by the U.S. Geological Survey, NAPAP's lead federal agency for deposition monitoring. Under Title IX of the federal Clean Air Act Amendments of 1990, NAPAP continues. Today there are more than 250 sites in the network, and the network designation has been shortened to NTN.

In October 1992, the Atmospheric Integrated Research Monitoring Network (AIRMoN), currently with seven sites, joined the NADP. AIRMoN sites collect samples daily when precipitation occurs. Samples are refrigerated until analysis at the CAL for the same constituents measured in NTN samples. The AIRMoN seeks to investigate pollutant source/receptor relationships and the effect of emissions changes on precipitation chemistry, combining measurements with atmospheric models. The AIRMoN also evaluates sample collection and preservation methods.

In January 1996, the Mercury Deposition Network (MDN), currently with more than 90 sites, joined the NADP. MDN sites collect wet-only deposition samples that are sent to the MDN analytical laboratory at Frontier Geosciences, Inc. The MDN was formed to provide data on the wet deposition of mercury to surface waters, forested watersheds, and other receptors. Forty-five states and eight Canadian provinces have advisories against consuming fish from lakes with high mercury concentrations in fish tissues. MDN data enable researchers to investigate the link between mercury in precipitation and this problem.

The NADP receives support from the U.S. Geological Survey; Environmental Protection Agency; National Park Service; National Oceanic and Atmospheric Administration; U.S. Department of Agriculture - Forest Service; U.S. Fish & Wildlife Service; Tennessee Valley Authority; Bureau of Land Management; and U.S. Department of Agriculture - Cooperative State Research, Education, and Extension Service under agreement 2002-39138-11964. Additional support is provided by other federal, state, local, and tribal agencies, State Agricultural Experiment Stations, universities, and nongovernmental organizations. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the U.S. Department of Agriculture or any other sponsor.

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The Illinois State Water Survey is an Affiliated Agency of the University of Illinois and a Division of the Illinois Department of Natural Resources

NADP 2006
Technical Committee Meeting

October 24 – 26, 2006
Norfolk, Virginia

Technical Program Chair
Maggie Kerchner
National Oceanic & Atmospheric Administration
Office of Oceanic and Atmospheric Research
Air Resources Laboratory

PROCEEDINGS

Prepared by

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October 2006

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NADP TECHNICAL COMMITTEE MEETING AGENDA

NADP Technical Committee Meeting
Norfolk, Virginia
October 24 – 26, 2006

TUESDAY, October 24, 2006		**Room Location**
	Registration Desk Open All Day	
8:00 a.m. to 10:00.a.m.	Joint Committee Meetings NOS, DMAS, EROS	Monticello Room
10:00 a.m. to 10:20 a.m.	Break	
10:20 a.m. to 12:00 p.m.	Subcommittee Meetings	
	NOS	Monticello Room
	DMAS	Montpelier Room
	EROS	Riverview Room
12:00 p.m. to 1:30 p.m.	Lunch (on your own)	
1:30 p.m. to 2:45 p.m.	Subcommittee Meetings	
2:45 p.m. to 3:00 p.m.	Break	
3:00 p.m. to 5:00 p.m.	Executive Committee Meeting	Monticello Room

WEDNESDAY, October 25, 2006		**Room Location**
7:30 a.m.	Registration Open	
8:00 a.m. to 9:45 a.m.	Annual Technical Committee Business Meeting	Monticello Room
9:45 a.m. to 10:00 a.m.	Break	
Technical Session:	**IMPORTANCE OF QUANTIFYING DEPOSITION IN COASTAL AND URBAN ENVIRONMENTS** Session Chair: Greg Wetherbee U.S. Geological Survey	Monticello Room
10:00–10:20	**Importance of Atmospheric Deposition as a New Nitrogen Source Supporting Coastal Eutrophication** Hans Paerl, University of North Carolina	
10:20-10:40	**Coastal and Urban Settings: Are These Areas of Increased Concern for Mercury Deposition?** Dave Krabbenhoft, U.S. Geological Survey	

WEDNESDAY, October 25, 2006 — Room Location

Technical Session: **IMPORTANCE OF QUANTIFYING DEPOSITION IN COASTAL AND URBAN ENVIRONMENTS (CONTINUED)** — Monticello Room
Session Chair: Greg Wetherbee
U.S. Geological Survey

10:40-11:00 **How Important is Near-Source Deposition of Nitrogen from Vehicle Emissions in the Northeastern US?**

Robert Howarth, Cornell University/Ecosystems Center, Marine Biological Laboratory

11:00-11:20 **Contribution of Trace Metals from Atmospheric Deposition to Stormwater in a Small Impervious Urban Catchment**

Kenneth Schiff, Southern California Coastal Water Research Project

11:20-11:50 **Baltimore Long Term Ecological Research (LTER) Urban Biogeochemical Cycles**

Rich Pouyat and Jon Hom, USDA Forest Service

11:50-12:00 **Announcement**

12:00 p.m. to 1:30 p.m. Lunch (on your own)

1:30-1:50 **Dry Deposition in Urban Areas**

Tom Holsen, Clarkson University

1:50-2:10 **A Comparison of Ambient Atmospheric Chemistry at Three Coastal Sites Across a Region of Varying Density in Animal Production Facilities**

Wayne Robarge, North Carolina State University

Technical Session: **UTILITY OF NADP DATA** — Monticello Room
Session Chair: Cari Furiness
North Carolina State University

2:10-2:30 **Daily Ammonium and Nitrate Wet-fall Deposition Models for the Chesapeake Bay Watershed: Current Status and Proposed Refinements**

Jim Lynch, Pennsylvania State University

WEDNESDAY, October 25, 2006		**Room Location**
Technical Session:	UTILITY OF NADP DATA (CONTINUED) Session Chair: Cari Furiness North Carolina State University	Monticello Room
2:30-2:50	**Estimating Atmospheric Deposition Loads in the Chesapeake Watershed: Two Decades of Progress** Lewis Linker, EPA Chesapeake Bay Program	
2:50-3:10	**Air Pollution is a Major Source of Water Pollution** Cathy Richardson, Maine Department of Environmental Protection/Casco Bay Estuary Partnership	
3:10 p.m. to 3:30 p.m.	Break	
3:30-3:50	**An Application of NADP Precipitation Monitoring: Diagnostics for Local Source Contributions to Wet Deposition of Gaseous and Particulate Nitrogen** Noreen Poor, University of South Florida College of Public Health	
3:50-4:10	**Adequacy of NTN Site Coverage for Monitoring Trends in Ammonium, Sulfate and Nitrate Species** Chris Lehmann, Illinois State Water Survey	
4:10-4:30	**An Analysis of Kriging Interpolation Uncertainties in North American Wet Deposition Mapping** Chul-Un Ro, Environment Canada	
4:30-4:50	**Modification of NADP Collector Data Algorithms and Collector Designs for High Altitude Monitoring** Greg Wetherbee, USGS	
5:30 p.m. to 8:00 p.m.	POSTER SESSION –SOCIAL MIXER	Riverwalk

THURSDAY, October 26, 2006 — Room Location

7:30 a.m. Registration Open — Monticello Room

Technical Session: LINKING WITH THE NADP
Session Chair: Ray Knighton
USDA CSREES

8:30-8:50 **Integrating Atmospheric Deposition into the National Water Quality Monitoring Network**

Dave Whitall, NOAA

8:50-9:10 **Nitrate Isotopes in Precipitation across the United States: An Assessment of Sources and Oxidation Chemistry**

Emily Elliott, USGS and University of Pittsburgh

9:10-9:30 **Acid Rain Chemistry in the College Classroom**

Cathy Middlecamp, University of Wisconsin-Madison

Technical Session: MERCURY DEPOSITION — Monticello Room
Session Chair: David Gay
Illinois State Water Survey

9:30-9:50 **Evaluating Mercury Deposition in Urban and Undeveloped Watersheds**

Lia Chaser, USGS

9:50-10:10 **Sources of Mercury Wet Deposition in Steubenville, Ohio**

Matthew Landis, U.S. EPA

10:10-10:30 **Long-range Transport and Deposition of Atmospheric Mercury in the Lake Champlain Basin**

Eric Miller, Ecosystems Research Group

10:30 a.m. to 10:50 a.m. Break

10:50-11:10 **How Does Atmospheric Mercury Deposition Affect Fish Mercury Concentrations: Results from the METAALICUS and MESOSIM Studies in Ontario**

Cindy Gilmour, Smithsonian Environmental Research Center

11:10-11:30 **Trends in Mercury Deposition from the MDN**

Curt Pollman, Frontier GeoSciences

THURSDAY, October 26, 2006 — Room Location

Technical Session: **MERCURY DEPOSITION (CONTINUED)** — Monticello Room
Session Chair: David Gay
Illinois State Water Survey

11:30-11:50 **Developing an Open, Coordinated and Collaborative Atmospheric Mercury Monitoring Network in North America**

Eric Prestbo, Frontier GeoSciences

11:50-12:15 **Mercury Wet Deposition Patterns in Pennsylvania**

Arnout ter Schure, Electric Power Research Institute

12:15 p.m. to 1:50 p.m. Lunch (on your own)

1:50-2:10 **Mercury Deposition in Urban Areas: Observations and Importance**

Jerry Keeler, University of Michigan

2:10-2:30 **Modeling of Atmospheric Deposition of Mercury, Sulfate, Ammonium and Nitrate and Comparison with NADP Measurements**

Krish Vijayaraghavan, Atmospheric & Environmental Research, Inc. (AER)

Technical Session: **CRITICAL LOADS** — Monticello Room
Session Chair: Pam Padgett
USDA Forest Service

2:30-2:50 **Critical Loads Strategic Efforts within the Multi-Agency Community**

Tamara Blett, NPS

2:50-3:10 **The Use of Critical Loads to Guide the Assessment and Management of Air Pollution Effects on Natural Resources**

Charlie Driscoll, Syracuse University

3:10-3:30 **Calculation of Critical Loads of Acidic Deposition for the Protection of Acid-Sensitive Surface Waters**

Tim Sullivan, E&S Environmental Consulting

3:30 p.m. to 3:50 p.m. Break

THURSDAY, October 26, 2006 — Room Location

Technical Session:	**CRITICAL LOADS (CONTINUED)** Session Chair: Pam Padgett USDA Forest Service	Monticello Room
3:50-4:10	**Redefining Critical Load Limits in United States Ecosystems to Include Multiple Environmental Stresses: Implications and Solutions** Erika Cohen, Southern Global Change Program	
4:10-4:30	**Atmospheric Nitrogen Deposition and Aquatic Ecosystems of the Western United States: Paleolimnological Approaches to Determing Critical Loads** Jim Sickman, University of Florida	
4:30-4:50	**Translating Science into Management: The Development and Implementation of a Critical Load in Rocky Mountain National Park** Ellen Porter, National Park Service	
5:30 p.m. to 6:30 p.m.	***SCIENCE-ON-A-SPHERE***	NAUTICUS

2006 NADP SITE OPERATOR AWARDS

NATIONAL TRENDS NETWORK OPERATOR AWARDS

5 Year Awards

Site	Operator Name	Site Name	Wet Start	Agency
AZ03	Hernan Abreu	Grand Canyon National Park-Hopi Point	11-Aug-81	National Park Service-ARD
CAN5	Serge D’Amour	Frelighsburg	02-Oct-01	U.S. Geological Survey
CT15	George Askew	Abington	26-Jan-99	U.S. EPA-Clean Air Markets
FL05	Robert Quarles	Chassahowitzka National Wildlife Refuge	27-Aug-96	U.S. FWS-Air Quality Branch
GA09	Ronald Phernetton	Okefenokee National Wildlife Refuge	03-Jun-97	U.S. FWS-Air Quality Branch
NY22	Angela Benedict-Dunn	Akwesasne Mohawk-Fort Covington	18-Aug-99	U.S. EPA-Clean Air Markets
SC07	Amy Dukes	ACE Basin National Estuarine Research Reserve	31-Dec-01	NOAA – Air Resources Lab South Carolina-DNR
TX21	Edmond Johnson	Longview	29-Jun-82	Texas Commission on Environmental Quality

10 Year Awards

Site	Operator Name	Site Name	Wet Start	Agency
CA99	Katy Warner	Yosemite National Park-Hodgdon Meadow	08-Dec-81	National Park Service-ARD
KS32	Curt Sauer	Lake Scott State Park	27-Mar-84	U.S. Geological Survey
KY35	Jeff Stamper	Clark State Fish Hatchery	30-Aug-83	U.S. Geological Survey
NM12	Abbie Reaves	Capulin Volcano National Monument	15-Nov-84	NM Environment Dept-AQB U.S. EPA
TX10	Terry Rossignol	Attwater Prairie Chicken National Wildlife Refuge	03-Jul-84	U.S. Geological Survey
WA24	Robert Barry	Palouse Conservation Farm	20-Aug-85	U.S. Geological Survey
WI37	Mark Sundeen	Spooner	03-Jun-80	Wisconsin DNR

15 Year Awards

Site	Operator Name	Site Name	Wet Start	Agency
C022	Mark Lindquist	Pawnee	22-May-79	National Science Foundation Shortgrass Steppe LTER
CO91	Todd Pitcher	Wolf Creek Pass	26-May-92	U.S. Forest Service
IA08	Robert Zach	Big Springs Fish Hatchery	14-Aug-84	U.S. Geological Survey
ND11	Gayle Cook	Woodworth	29-Nov-83	U.S. Geological Survey
NY98	Douglas Wolfe	Whiteface Mountain	03-Jul-84	U.S. Geological Survey
OH49	Mike Franko	Caldwell	26-Sep-78	U.S. Geological Survey
PA29	Don Dorn	Kane Experimental Forest	18-Jul-78	U.S. Forest Service
WI28	Barry Benson	Lake Dubay	29-Jun-82	Wisconsin DNR
WI98	Karen Teed	Wildcat Mountain	01-Aug-89	Wisconsin DNR

NATIONAL TRENDS NETWORK OPERATOR AWARDS

Site	Operator Name	Site Name	Wet Start	Agency
20 Year Awards				
KS07	Dan Mosier	Farlington Fish Hatchery	27-Mar-84	U.S. Geological Survey
MI99	David Toczydlowski	Chassell	15-Feb-83	National Park Service-ARD
MS30	Hilliard Griffin	Coffeeville	17-Jul-84	Tennessee Valley Authority
NE99	Jim Goeke	North Platte Agricultural Experiment Stn	24-Sep-85	U.S. Geological Survey
TX03	Domingo Martinez	Beeville	07-Feb-84	NOAA – Air Resources Lab
VT01	Dan Taylor	Bennington	28-Apr-81	U.S. Geological Survey
WI09	Cathy McLain	Popple River	30-Dec-86	Wisconsin DNR
WV18	John Pearce	Parsons	05-Jul-78	U.S. Forest Service
25 Year Awards				
CA45	Charles Vaughn	Hopland	03-Oct-79	U.S. Geological Survey
MI09	Robert Vande Kopple	Douglas Lake	03-Jul-79	SAES-Michigan State Univ

MERCURY TRENDS NETWORK OPERATOR AWARDS

Site	Operator Name	Site Name	Wet Start	Agency
10 Year Awards				
MN18	Christine Barton	Fernberg	05-Mar-96	U.S. Forest Service – Superior National Forest
MN23	Mary McGuire	Camp Ripley	02-Jul-96	Minnesota Pollution Control Agency
MN27	Lee Klossner	Lamberton	02-Jul-96	Minnesota Pollution Control Agency
WI08	Ron Perala	Brule River	05-Mar-96	Wisconsin DNR
WI09	Cathy McLain	Popple River	05-Mar-96	Wisconsin DNR

TECHNICAL SESSION: IMPORTANCE OF QUANTIFYING DEPOSITION IN COASTAL AND URBAN ENVIRONMENTS

Session Chair:
Greg Wetherbee, U. S. Geological Survey

Importance of Atmospheric Deposition as a New Nitrogen Source Supporting Coastal Eutrophication

Hans W. Paerl*, David R. Whitall[1], Robin L. Dennis[3]

At least three decades of monitoring and research have shown that atmospheric deposition of nitrogen (AD-N) is a major contributor of externally-supplied or “new” nitrogen (N) to N-sensitive estuarine and coastal waters. Watershed N export estimates indicate that AD-N can be a significant source of N input to these waters (indirect AD-N). Direct deposition to these waters is an additionally important new N source that can bypass the terrestrial and in-stream filters that process N entering via the watershed. In European and North American coastal waters downwind of anthropogenic emission sources, AD-N contributes from 10 to over 40 percent of new N loading, and can be the single largest source of new N impacting these waters. In developing regions of the world, AD-N is one of the most rapidly expanding sources of new N. In North Carolina, USA, AD-N deposition has at least doubled since the 1970's as a result of urbanization (chiefly NO_x) and more recently agricultural growth (NH_X and organic N). Recent growth and intensification of animal operations in the Midwest and coastal regions (e.g., Mid-Atlantic coastal plain) have been linked to increasing amounts of NH_X deposition, according to a 3 decadal analysis of the National Atmospheric Deposition Program (NADP) deposition network. Ammonia emitted from these operations accounts for approximately half the AD-N in nearby estuarine and Atlantic coastal waters. The ecological ramifications of this growing N source in N-sensitive estuarine and coastal waters include eutrophication, manifested as algal blooms, hypoxia and food web alterations. In regions where AD-N is among the largest new N sources, its contribution as a new N source may allow certain systems to exceed the critical load needed to promote and sustain algal blooms. The role of AD-N in eutrophication dynamics depends on sources, chemical forms and amounts of N and interactions with other atmospheric nutrient sources (Fe). Trophic and biogeochemical effects of AD-N are dependent on physical conditions, including stratification, residence time, and optical properties of receiving waters. Quantitative and qualitative aspects of AD-N and other atmospheric nutrient sources may promote major biotic changes now apparent in these waters, including the proliferation of harmful algal blooms, declines in water quality and loss of fisheries habitat. Because of its relatively large contribution to total new N loading and potential biogeochemical and ecological importance in N sensitive waters, AD-N requires attention from local and regional air/watershed nutrient budgeting and management perspectives.

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Coastal and Urban Settings: Are These Areas of Increased Concern for Mercury Deposition?

Dave Krabbenhoft, U.S. Geological Survey

Abstract Unavailable

How Important is Near-Source Deposition of Nitrogen from Vehicle Emissions in the Northeastern US?

Robert Howarth*[1, 2], Roxanne Marino[1, 2], Neil Bettez[1, 2],
Eric Davidson[3], and Thomas Butler[1, 4]

Several lines of evidence suggest that total nitrogen deposition can sometimes be substantially higher than is estimated by traditional approaches that rely on NADP wet data and extrapolation of CASTNet and AIRMON data for dry deposition. Here, we will briefly review this evidence and some of the suggested explanations for the discrepancies. For the northeastern US as a whole, NOy deposition estimated from global emission-based models (GCTM, TM3) is ~ 80% higher than is estimated from these traditional approaches based on monitoring data. Among the possible explanations, we have hypothesized that there might be a substantial deposition of nitrogen from vehicle emissions in relatively close proximity to roads; this deposition would not be measured in most monitoring networks. We have been funded for the past 2 years by Woods Hole SeaGrant to test this hypothesis by examining patterns of nitrogen pollution and deposition away from heavily traveled roads in Falmouth, MA. This portion of Cape Cod has many coastal marine ecosystems that are highly impacted from nitrogen pollution.

We have measured nitrogen deposition in bulk collectors, nitrogen throughfall under oak-tree canopies, and concentrations of NO_2, NOx, and NH_3 in passive samplers along gradients at distances from 5 to 150m away from 2 heavily traveled roads. The bulk-deposition collectors show no pattern in space for either dissolved inorganic nitrogen or total nitrogen, whereas both dissolved inorganic nitrogen and total nitrogen are much higher in throughfall near the roads and decreases with distance away from the road. The throughfall rates are higher than are the bulk deposition rates throughout our gradients. We believe that the throughfall data provide the best estimate of total nitrogen deposition. We have also measured throughfall along a gradient away from a non-road edge (powerline right of way) to test for edge effects. Finally, the concentrations of NO_2, NOx, and NH_3 are all higher near the roads and decrease with distance from roads. Our goal is to estimate deposition from these gas-concentration data, to compare these estimates with the throughfall estimates, and to compare both with estimates of nitrogen emissions from vehicles traveling on the roads at the same time.

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Contribution of Trace Metals from Atmospheric Deposition to Stormwater in a Small Impervious Urban Catchment

Kenneth C. Schiff*[1], Lisa D. Sabin[1], Jeong Hee Lim[2], Keith D. Stolzenbach[2]

The contribution of atmospheric deposition to trace metals emissions in stormwater runoff was investigated by quantifying wet and dry deposition fluxes and stormwater discharges within a small, highly impervious urban catchment in Los Angeles. At the beginning of the dry season in spring 2003, dry deposition measurements of chromium, copper, lead, nickel, and zinc were made monthly for one year. Stormwater runoff and wet deposition samples also were collected, and loading estimates of total deposition (wet + dry) were compared with loadings in stormwater runoff. Wet deposition contributed 1 to 10% of the total deposition inside the catchment, indicating the dominance of dry deposition in semi-arid regions such as Los Angeles. Based on the ratio of total deposition to stormwater, atmospheric deposition potentially accounted for as much as 57% to 100% of the total trace metal loads in stormwater within the study area. Despite potential bias attributable to processes that were not quantified in this study (e.g., resuspension out of the catchment or sequestration within the catchment), these results demonstrate atmospheric deposition represents an important source of trace metal contribution in stormwater to waterbodies near urban centers.

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Baltimore Long Term Ecological Research (LTER): Urban Biogeochemical Cycles

Richard Pouyat[1,] John Hom[*],

Urban land-use change can affect biogeochemical cycles through altered disturbance regimes, landscape management practices (e.g., irrigation and fertilization), built structures, and changes in environment (heat island effect, atmospheric pollution, introduction of non-native species). These changes have created novel ecosystems, which have the potential to significantly affect biogeochemical cycles at local, regional, and global scales. The Baltimore Ecosystem Study (BES) was the first of two Long Term Ecological Research Sites funded by the National Science Foundation to the effects of these changes in urban and urbanizing ecosystems. BES is guided by three overarching questions; however, we will focus on one question: What are the fluxes of energy and matter in urban ecosystems, and how do they change over the long term? To address this question, we have continuously monitored a nested network of watersheds varying from entirely forested to "ultra" urban and a long-term network of biogeochemical study plots. As part of one of the suburban watersheds, a permanent micrometeorological flux tower has been continuously measuring atmospheric variables since 2001. These include a ten level profile system for CO_2 and H_2O concentration and an eddy correlation system for carbon, water, and energy flux measurements.

Thus far our results have shown that urban and suburban watersheds had much higher N and P losses than the completely forested watershed. Our forested and agricultural watersheds appear very similar to others in our region and in the LTER network. The urban and suburban watersheds have concentrations and loads intermediate between forest and agriculture, with much higher variation. Retention of N in the suburban watershed was surprisingly high, 75% of inputs, which were dominated by home lawn fertilizer (14.4 kg N ha^{-1} y^{-1}) and an estimated atmospheric deposition of 11.2 kg N ha^{-1} y^{-1}), though we have no direct measurements of atmospheric deposition in these urban areas.

The urban conditions of elevated carbon dioxide, ozone, nitrogen deposition and elevated heat island effects represent future scenarios which forests will face. The global average concentration of carbon dioxide is currently 375 parts per million (ppm). The average concentration in the Baltimore suburban environment is slightly higher, 390 ppm at the top of the Cub Hill flux tower, with peaks of more than 475 ppm. Monitoring stations in Baltimore city center, where there is less tree cover and more automobile traffic averages 511 ppm. There were lower overall CO_2 emissions for the weekends than that of the weekday possibly due to higher energy use for the workweek. The energy use within the residential area surrounding the tower apparently makes this area a net source of CO_2. The patches of forests and vegetation cover at Cub Hill have a beneficial impact by sequestering some of the carbon dioxide but the amount of vegetation cover does not offset the emissions from residential energy use.

Increased nitrogen deposition has been associated with increased fossil fuel use in urban areas and along roadways. Estimates of forest productivity and N leaching loss are presented with the use of ecosystem modeling under future scenarios of N deposition, CO_2 and ozone.

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Dry Deposition in Urban Areas

Thomas M. Holsen
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Clarkson University
Potsdam, NY 13699

Quantifying dry deposition is difficult because it is often highly dependent on local atmospheric and surface conditions and the measurement technique being used. In this talk an overview of the techniques used to measure dry deposition and the importance of dry deposition in urban areas will be presented using measurements made in two recent studies: The Lake Michigan Mass Balance Project and The Detroit Atmospheric Deposition Study. Results from these studies show that dry deposition of mass, metals and semi-volatile pollutants in urban areas is significantly greater than in non-urban areas. For example Chicago fluxes were on average 5 to 30 times higher than the non-urban fluxes and 2 to 10 times higher than the fluxes measured over Lake Michigan. Comparisons between measured airborne particle sizes and measured fluxes suggest that large particles (> 10 μm) are responsible for the majority of the dry deposition. In the Detroit study it was found the dry deposition was responsible for a significant fraction of the pollutants found in run-off.

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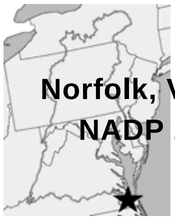

A Comparison of Ambient Atmospheric Chemistry at Three Coastal Sites Across a Region of Varying Density in Animal Production Facilities

Wayne Robarge[*1], John Walker[2], Arun Shendrikar[3], Hoke Kimball[3]

We present approximately one year (June/July 2004 to June 2005) of ambient ammonia (NH_3), ammonium (NH_4^+), hydrochloric acid (HCl), chloride (Cl^-), nitric acid (HNO_3), nitrate (NO_3^-), nitrous acid (HONO), sulfur dioxide (SO_2), and sulfate ($SO_4^{=}$) concentrations at three sites in eastern North Carolina. One site is located at the Peanut Belt Research Station (latitude 36˚ 07'40.34"N, longitude 77˚ 10'32.13"W; Lewiston, NC) in Bertie Co., NC. The total NH_3 emission density of Bertie Co. ranges from 500 to 750 kg NH_3-N km^{-2} yr^{-1}, and the county itself is approximately 80 km northeast of the second site (latitude 34˚ 57' 43.97"N, longitude 77˚ 57' 44.96"W) located near Kenansville, NC, which is in Duplin Co. and has the highest density of ammonia emissions (> 5000 kg NH_3-N km^{-2} y^{-1}) in the state. The third site (an urban site; latitude 35˚ 53'31.50"N, longitude 78˚ 37'53.64"W) was located in the center of Raleigh, NC in Wake Co. Annular denuder technology with computerized mass flow controllers was deployed at each location and concurrent day (06:00 to 18:00 h) and night (18:00 to 06:00 h) samples collected starting 18:00 h Wednesday to 18:00 h Sunday each week continuously for one year. Acid gases were collected using sodium carbonate coated denuder tubes, ammonia using phosphorous acid, and Teflon and Nylon filters in the filter pack. A Teflon-coated cyclone (2.5 micron cutoff) was used at the inlet (flow rates = 10Lpm). Calculated yearly averages (combining day and night measurements) for HNO_3, NH_3, SO_2 and ammonium-based aerosols are presented in the following table (Units = μg m^{-3}):

Loc. (County)	NH_3 Emission Density	Gases			Aerosols			
		HNO_3	NH_3	SO_2	NH_4^+	Cl^-	NO_3^-	SO_4^{2-}
Bertie	Low	0.56	0.73	3.78	1.13	0.16	0.99	3.30
Duplin	High	0.42	6.34	2.06	1.04	0.12	1.25	2.95
Wake	Urban	0.89	1.21	4.60	1.00	0.27	1.19	3.24

Cumulative frequency distributions of the data confirm that the differences in the calculated yearly average ambient concentrations of NH_3, HNO_3 and SO_2 in the above table are in fact real and consistent between the three locations. The cumulative frequency distributions also reinforce the conclusion that there are no significant differences in aerosol NH_4^+, NO_3^- and SO_4^{2-} across the three locations. When compared to the long-term trend recorded by the CASTNet site at Beaufort, NC (e.g. Period 1999-2004; NH_4^+ = 0.90+/-0.07 μg m^{-3}; NO_3^- = 1.26+/-0.12 μg m^{-3}; SO_4^{2-} = 3.91+/-0.22 μg m^{-3}) the data suggest that ambient ammonium-based aerosol concentrations are remarkably consistent across the region.

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TECHNICAL SESSION: UTILITY OF NADP DATA

Session Chair:
Cari Furiness, North Carolina State University

Daily Ammonium and Nitrate Wet-fall Deposition Models for the Chesapeake Bay Watershed: Current Status and Proposed Refinements

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Daily precipitation nitrate and ammonium concentration models were developed for the Chesapeake Bay Watershed (CBW) using a linear least-squares regression approach and single-event precipitation chemistry data from 29 NADP/NTN sites. The most significant variables in both models included: precipitation volume, the number of days since the last event, seasonality, latitude, and the proportion of land within 8 km covered by forests or devoted to transportation and industry. Local and regional ammonia and nitrogen oxides emissions were not as well correlated as land cover. The abilities of these variables to predict wet deposition arise primarily from their relationship to either (1) the spatial and temporal distribution of emissions of ammonium and nitrate precursors from sources within or upwind of the CBW and (2) the chronology and characteristics of precipitation events. Modeled concentrations compared very well with event chemistry data collected at 6 NADP/AirMoN sites within the CBW. Wet deposition estimates were also consistent with observed deposition at selected sites. Despite these favorable comparisons, considerable variation between estimates and observed values remain, particularly for ammonium. Furthermore, some of the relationships between broadly defined categories of land cover and patterns of wet deposition of both nitrate and ammonium were ambiguous. To reduce this ambiguity and further improve the accuracy of modeled estimates, improvements in the sampling and representation of spatial and temporal patterns of land use activities and intensities and of emissions levels will be incorporated into the daily ammonium and nitrate deposition models. Also detailed meteorological data will be assimilated into the models to identify contributing emission source areas and to estimate the impact of these contributions on daily deposition rates on a per-event basis.

The first phase of this two-phased effort involves incorporating data from nine additional NADP/NTN sites (DE99, MD07, MD08, MD15, MD99, PA47, VA10, VA27, VA98, and VA99) that were placed in operation in and around the CBW since 2001. These sites will provide a more complete representation of agricultural influences in the CBW than the set of stations used in earlier analyses. Phase 1 also involves the development of a more accurate and comprehensive representation of the spatial and temporal distribution and intensity of livestock production and other agricultural activities across the CBW. An improved accounting of livestock production activities will be achieved by combining county- and watershed unit-specific livestock production statistics with high resolution (30 meters) land use data from the USGS's National Land Cover Database (NLCD). Estimates of local ammonia emissions from fertilizers and manure applications to croplands will also be assimilated into the revised models using EPA inventories and high resolution NLCD to identify likely cropland areas. Lastly localized estimates NH_3 and NO_x emissions for the CBW region and surrounding states will be developed by combining facility and county-specific emissions reports from the EPA's National Emissions Inventory (NEI) database with the NLCD classifications.

Volume, duration, and frequency of precipitation events have obvious roles in determining wet deposition rates. However, these parameters alone do not completely describe all of the characteristics of a precipitation event and its history that determine the flux of nitrogen that it deposits. Of particular interest are interactions between storm trajectories and emission sources. Using metrological data from The National Center for Environmental Prediction's North American Regional Reanalysis (NARR), we propose to add components to our daily ammonium and nitrate wet deposition models that predict the rate at which emissions from area and point sources are emitted, dispersed and transported to specific deposition locations. Surface and upper-level vertical and horizontal air movement data from the NARR will allow us to estimate the extent to which emissions are transported and mixed into surface and upper-level atmospheric layers; and, thereby, enable us to construct more realistic multi-level air mass trajectories with which to predict the movement of emissions from multiple source locations to deposition points of interest.

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Estimating Atmospheric Deposition Loads in the Chesapeake Watershed: Two Decades of Progress

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Since the late-1980's the Chesapeake Bay Program has been estimating the atmospheric deposition load of nitrogen and it's delivery to the Chesapeake Bay. Initial estimates were done using Thiessen polygons to spatially distribute the NADP derived annual average wet deposition. Dry deposition was provided by literature estimates of the time, which indicated a 1:1 wet to dry deposition ratio (Fisher and Oppenheimer, 1991; Hinga et al., 1991; Tyler, 1988). The estimated atmospheric deposition loads were input as a constant daily load to the watershed, and delivery of these loads to the Chesapeake were included in the estimates of the first Chesapeake nutrient reduction allocation in 1992. Atmospheric deposition loads were included in the potion of loads considered to be "uncontrollable" at the time because of the uncertainty associated with this newly estimated load source.

Chesapeake Bay Program data and models have advanced greatly over the years. Both the Community Multi-scale Air Quality (CMAQ) model and the Chesapeake Bay Program's Watershed Model are being upgraded for the next round of decision-making in the Program planned for 2008-2010 to develop plans ensuring attainment of dissolved oxygen, chlorophyll, and clarity water quality standards under future 2030 conditions despite changes brought about by the challenges of growth and climate change. The Watershed Model will be upgraded to the Phase 5 version using inputs from a refined, more detailed regression of wet deposition (Lynch and Grimm, 2003). The CMAQ will provide dry fall estimates and the estimated changes in deposition due to emissions management actions. The "one atmosphere" model approach of CMAQ will improve coordination between water and air management programs of nitrogen, acidity, and mercury controls.

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Air Pollution is a Major Source of Water Pollution

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The Casco Bay watershed consists of 41 of the fastest-growing communities in Maine and is home to 25% of Maine's population. The Casco Bay Estuary Partnership is devoted to protecting and restoring the water quality, and fish and wildlife habitat of the Casco Bay ecosystem, while ensuring compatible human uses. The strength of the Casco Bay Estuary Project is in its collaborative nature. Partners include Federal and State government agencies, municipalities, non-governmental environmental organizations (including land trusts), businesses and the regional public sector, educational institutions, and countless citizens.

The Casco Bay Estuary Partnership has actively supported maintaining NTN and MDN monitoring within the watershed. Data, collected since 1998 at our NTN/MDN site in Freeport, Maine, has allowed us to evaluate the extent of mercury deposition to the estuary and bay. We know that atmospheric deposition is the major source of mercury to Casco Bay and a significant source of inorganic nitrogen pollution to the bay: Air pollution is a major source of water pollution. As part of an extensive air monitoring program in Maine, data from the NTN/MDN network provides support for regulatory decisions at local, state and federal levels. The data highlights regional transport of pollutants across state borders and the direct relationship between fossil fuel energy choices and air/water pollution.

In a continuing effort to educate communities and support local estuarine management activities, The Casco Bay Estuary Partnership partners have disseminated NTN/ MDN data through conferences (2005 State of the Bay), educational activities (The Children’s Water Festival – held annually at many locations throughout Maine), publications (“2005 State of the Bay Report”, “Estimating Estuarine Pollutant Loading from Atmospheric Deposition Using Casco Bay, Maine as a Case Study”).

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An Application of NADP Precipitation Monitoring: Diagnostics for Local Source Contributions to Wet Deposition of Gaseous and Particulate Nitrogen

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Rainfall delivers on the average ~25 % of the total annual nitrogen load to Tampa Bay, directly to the surface and indirectly via the watershed. Of this, we estimated that local sources contributed about ~25% of the nitrogen wet-deposited to the bay and its watershed. Estimates were based on rainfall chemistry from precipitation monitoring at a National Atmospheric Deposition Program (NADP) Atmospheric Integrated Research Monitoring Network (AIRMoN) site located adjacent to Tampa Bay in urban Tampa, FL, and a National Trends Network (NTN) site located 70 km distant at a rural site near Sarasota, FL, coupled with air mass trajectories obtained from the National Oceanic and Atmospheric Administration (NOAA) HYbrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model. Parameters from a power law model fitted to rainfall concentration data amplified patterns diagnostic of source direction and strength. Correlations between parameters gave important clues to gas and particle phase nitrogen scavenging from the atmosphere.

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Adequacy of NTN Site Coverage for Monitoring Trends in Ammonium, Sulfate, and Nitrate Species

Christopher M.B. Lehmann[*], Van C. Bowersox[1], Susan M. Larson[2]

The last evaluation of the National Trends Network (NTN) design was performed in 1985; since that time, almost 150 sites have been added to the NTN. Significant changes in precipitation chemistry have also occurred since 1985, with statistically-significant trends in concentrations of ammonium, sulfate, and nitrate in precipitation observed in almost the entire continental United States.

This presentation addresses the adequacy of NTN site coverage by evaluating whether currently active NTN sites are well distributed across regions with 1) similar ecology, 2) high concentrations of ammonium, sulfate, and nitrate measured in precipitation, 3) predictions of high wet deposition loadings of these pollutants, and 4) high magnitude trends. This evaluation is intended to provide guidance to NTN site sponsors as to priority regions for the location of new sites. The evaluation is based on an “equal area representation,” i.e., it is assumed that the number of sites in a region should be proportional to the region’s geographic area.

The principal findings of this study are:

- The NTN has equal-area site representation of all but seven of the 35 ecoregion provinces in the continental U.S.
- Regions given the highest priority for locating new sites include western Nebraska, northern Utah, and northern Texas. Other priority areas include central and western states.
- Areas in the northeast, Pacific Northwest, and Louisiana and Alabama gulf coasts appear to have equal area representation with respect to the current number of active NTN sites, within the limits of the parameters evaluated in this study. This does not preclude the addition of sites in these regions to address other concerns, not considered here, such as the deposition of pollutants to sensitive ecosystems.
- There are regions in the United States where data from some sites cluster statistically. It is suggested that new sites not be located in the vicinity of these sites.

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An Analysis of Kriging Interpolation Uncertainties In North American Wet Deposition Mapping

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Acid rain has been monitored in North America (US and Canada) since the late 1970s. Since the onset of monitoring, annual deposition maps have been reported in various publications. Concerns have been raised about the accuracy of the interpolated spatial deposition patterns because of year-to-year variability in the number, spatial distribution and density of monitoring sites, especially between the eastern and western parts of North America. Concerns have also been raised about the most appropriate type of interpolation technique to use, the most common of which are the Inverse Distance Weighting and Kriging techniques. The Kriging technique has an advantage over other methods in that it provides estimates of the interpolation uncertainty through the calculation of the Kriging standard error. This paper presents an interpolation uncertainty analysis for wet deposition mapping using the Kriging technique.

A North American non-sea-salt sulphate wet deposition map for the year 2004 was generated using the Kriging interpolation technique. Also produced was a spatial pattern of the uncertainty at the interpolated 10 km grid points. It was found that there are significant differences in the estimated interpolation uncertainties between eastern North America (<3kg/ha/yr or <30%) and western North America (<3kg/ha/yr, >100%). The higher percentage uncertainties in western North America appear to be due mainly to that area's lower site density and larger percent variability in wet deposition values related to topographical and climatological variations. It was found that interpolating the data for eastern and western North America separately led to significantly reduced uncertainties compared to interpolating the entire area at once. It is therefore recommended that separate eastern and western deposition maps be produced and then merged to produce a full North American map. An acceptable uncertainty level (i.e., kriging standard error/deposition value) for proceeding with Kriging interpolation over North American is recommended at 30%, which is suitable for most parts of eastern North America but not most areas of western North America.

Modification of NADP Collector Data Algorithms and Collector Designs for High Altitude Monitoring

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National Trends Network (NTN) sites of the National Atmospheric Deposition Program (NADP) that receive most of their annual precipitation as snow typically do not meet all NADP data-completeness criteria, which specify a minimum collection efficiency for the precipitation collector. Collection efficiency typically is insufficient for snow-dominated sites because the NADP precipitation collectors have limited sensitivity for detecting light snowfall and limited volume capacity for heavy snowfall. Consequently, data from snow-dominated sites typically have been excluded from annual NADP summary brochures and deposition isopleth maps.

Data from high altitude sites are valuable for research in sensitive alpine and sub-alpine environments. Many snow-dominated sites are located at altitudes greater than 2,000 meters (m) throughout the Rocky Mountains. Efforts to improve wet deposition collection in snow dominated areas include modifying sample-collection and data-analysis protocols for high altitude (>2,000 m) sites. The NTN collector was redesigned to use a modified motorbox, a linearly-actuated lid, and deeper collector buckets with a higher depth to width aspect ratio. These modifications will be field-tested beginning in fall 2006 at five NTN sites: AZ03, CO02, CO97, CO98, and VT99. Wind shielding of rain gages and collectors and improvements of the standard NADP resistance-triggered moisture sensor are under investigation.

Data algorithms to improve estimates of wet deposition at high elevations are being evaluated. Exploratory illustration of the influence of elevation on wet deposition using data from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) is also being studied.

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TECHNICAL SESSION: LINKING WITH THE NADP

Session Chair:
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Integrating Atmospheric Deposition into the National Water Quality Monitoring Network

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In 2004, the U.S. Commission on Ocean Policy (COP) recommended a national monitoring network to improve management of ocean resources. In response to this report, the Advisory Committee on Water Information (ACWI) was charged with the task of designing a national water quality monitoring network. The National Water Quality Monitoring Council, acting on the request of ACWI, convened about 80 individuals who represent 40 different organizations, including federal and state agencies, academia, interstate organizations, and the private sector, to design the Network. The proposed Network shares many attributes with ongoing monitoring efforts but is unique in that it uses a multidisciplinary approach and addresses a broad range of resource components, from upland watersheds to offshore waters and does so using an integrated approach. The network design includes multi-resource and multidisciplinary approach that integrates water resource components from uplands to the coast and that integrates physical, chemical, and biological characteristics of water resources. In addition to an assessment of resources, the network will also include measurements of fluxes of contaminants to coastal systems, including atmospheric deposition. The focus of the atmospheric deposition component of the Network is the deposition that falls directly on estuaries and coastal waters and the loads of substances that are present in wet and dry deposition. This monitoring of direct deposition is distinguished from the water and associated constituents that enter coastal waters through storm water runoff. The Network will address the atmospheric deposition by monitoring wet and dry atmospheric deposition near the mouths of coastal HUC 6 outflows. Actual site locations will be selected by resource management agencies and other technical experts. This will provide data for estimates of direct atmospheric deposition to coastal waters. Although these sites are likely to be land based, if they are located near the coast, they will capture dry deposition that is representative of the area to be monitored and wet deposition from widespread storms. These sites will not capture the effects of localized events but this is consistent with the overall Network design which is focused on a larger spatial scale. The constituents in atmospheric deposition that need special attention include nutrients, synthetic organic chemicals, and mercury. At present, the primary atmospheric deposition monitoring program is the National Atmospheric Deposition Program (NADP) and the Network anticipates a strong collaborative relationship with NADP.

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Nitrate Isotopes in Precipitation across the United States: An Assessment of Sources and Oxidation Chemistry

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Atmospheric deposition is a major source of nitrate exported to coastal waters and a key contributor to eutrophication of surface waters worldwide. In order to reduce N loads to surface waters, it is important to understand the relative contributions of major NO_x sources to wet and dry deposition to watersheds. In the United States, the two largest NO_x sources are vehicular emissions (54 percent) and stationary fuel combustion (40 percent). Reducing emissions from these sources is critical to improving air and surface water quality. However, using nitrate concentration data alone, it is difficult to establish relationships between individual NO_x sources and wet deposition of nitrate. Previous research has shown that different NO_x sources can have different isotopic compositions and can be used to identify NO_x sources to wet deposition.

To address this research need, we have completed the first national survey of nitrate isotopes in wet deposition using samples collected by the National Atmospheric Deposition Program (NADP). Archived samples (2000) from 156 NADP sites across the United States were pooled into bimonthly, volume-weighted composites and analyzed for $\delta^{15}N$, $\delta^{18}O$, and a subset for mass-independent $\Delta^{17}O$ of nitrate using the microbial denitrifier method. 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 present spatial and temporal variations in both N and O isotopes, and investigate the critical question of whether these variations are a function of atmospheric processes or NO_x source contributions. In our analyses (n=883), we determined that $\delta^{15}N$ values ranged from -11 to +3 permil, whereas $\delta^{18}O$ values ranged from +63 to +94 permil. On average, both $\delta^{15}N$ and $\delta^{18}O$ values are higher in the winter than in the summer (approximately 2 and 10 permil higher, respectively).

In the Northeastern and Mid-Atlantic US, we observed strong correlations between $\delta^{15}N$ and NO_x emissions from nearby electric generating units. Along a regional N deposition gradient from Ohio to Maine, $\delta^{15}N$ values are strongly correlated with nitrate deposition, sulfate deposition, and mean annual pH. These results suggest that in this region, $\delta^{15}N$ is a powerful tracer of stationary source NO_x emissions. Despite the fact that vehicle emissions are the largest NO_x source in the eastern US, we found no correlations between $\delta^{15}N$ 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 US and the applicability of using these techniques to trace NO_x sources at this scale will be discussed.

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Acid Rain Chemistry in the College Classroom

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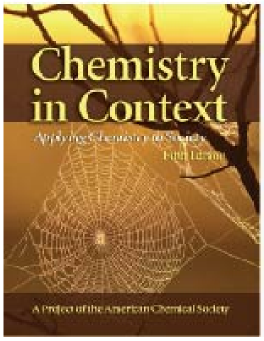

Chemistry in Context, an undergraduate textbook for liberal arts students, is a project of the American Chemical Society. This textbook teaches through complex, real-world issues to the underlying chemical principles needed to understand these issues. Since its first edition in 1994, the spider web motif has appeared on the cover. The introduction to the text points out "The word *context* derives from the Latin word meaning 'to weave.' …the spiderweb reminds you that this text emphasizes the strong and complex connections that exist among chemistry, societal and personal concerns."

Since its first edition in 1994, Chemistry in Context has contained a chapter on acidic deposition entitled "Neutralizing the Threat of Acid Rain." In the current fifth edition, the acid rain chapter opens with this quote:

> "In the beginning, there was acid rain, millions of year ago. Then it got better. Then it got worse as people came along. Then it got better, especially in 1990 for the U.S. with the Clean Air Act amendments. Now we see it is getting somewhat worse, as we increased our understanding of the effects of acid rain and, most of all, the linkages of acid rain with other issues." *Professor James Galloway*, *Conference in 2001, Acid Rain: Are the Problems Solved?*

Now in preparation, the sixth edition starts this way:

> **"STOP five people on the street and chances are they will be able to tell you that carbon dioxide emissions cause global warming. Stop another five and ask them about nitrogen emissions, and they will probably stare at you blankly."** ***The New Scientist, January 21, 2006.***

As these quotes show, the emphasis in this chapter is shifting. This presentation, given by the lead author on four chapters (including the acid rain chapter) describe the Chemistry in Context project and track through the changes in the topic of acid rain over the six editions of the textbook. One thing has not changed, however. In all editions, data from the NADP/NTN and information about the Central Analytical Laboratory has been used to tell the story of acidic deposition in the U.S., and this presentation will describe how this has been accomplished.

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TECHNICAL SESSION: MERCURY DEPOSITION

Session Chair:
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Evaluating Mercury Deposition in Urban and Undeveloped Watersheds

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The U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program is conducting a series of process-oriented studies in streams across the United States to help understand the relative influences of mercury (Hg) source strength, methylation efficiency, and food-web complexity on bioaccumulation of methylmercury (MeHg) in aquatic biota. Urban environments present specific challenges, such as point sources, hydrologic short-circuiting, increased erosion, and locally impacted air and water chemistries, that can significantly affect traditional pathways for formation, transport, and bioavailability of Hg; thus one of the primary objectives of the NAWQA studies is to compare urban and undeveloped settings. The NAWQA Program recently (2002-2004) completed its first round of studies in Oregon, Wisconsin, and Florida. Individual study areas in each state typically consisted of two undeveloped basins (low and high percent wetland) and one urban basin; Oregon had only one undeveloped basin (low percent wetland). Studies were located in basins with existing USGS gaging stations and established NADP/MDN stations. Urban areas were not well-represented within the NADP/MDN at the beginning of the study, so it was necessary to establish new stations for all three of the urban areas (Portland, OR; Milwaukee, WI; and Orlando, FL).

NAWQA collected weekly total mercury (THg) and monthly composites of MeHg in wet deposition from all MDN stations. Volume-weighted Hg concentrations and stream outflows were compared across gradients of precipitation volume and Hg deposition. Fluvial Hg yields were calculated as percent of deposition across study areas to illustrate differences in the retention, transformation, and export of deposited Hg. To improve our understanding of the relative contributions of wet vs. dry deposition in urban settings, stormwater runoff from a 2-acre impervious surface and ambient speciated atmospheric Hg (elemental Hg, reactive gaseous Hg, and particulate Hg) were sampled in Orlando during the spring and summer of 2005 in parallel with the MDN wet deposition collection.

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Sources of Mercury Wet Deposition in Steubenville, Ohio

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In the fall of 2002, an enhanced air monitoring site was established in Steubenville, Ohio as part of a multi-year comprehensive mercury monitoring and source apportionment study to investigate the impact of local and regional coal combustion sources on atmospheric mercury deposition in the Ohio River Valley. This study deployed advanced monitoring instrumentation, utilized innovative analytical techniques, and applied state-of-the-art statistical receptor models. This paper will present wet deposition data and source apportionment modeling results from daily event precipitation samples collected during the calendar years 2003-2004. The volume-weighted mean mercury concentrations for 2003 and 2004 were 14.0 and 13.5 ng L^{-1}, and total annual mercury wet deposition was 13.5 and 19.7 μg m^{-2}, respectively. Two new EPA implemented multivariate statistical models, Positive Matrix Factorization (PMF) and Unmix, were applied to the data set and six sources were identified. The dominant contributor to the mercury wet deposition was found by both models to be coal combustion (~70%).

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Long-Range Transport and Deposition of Atmospheric Mercury in the Lake Champlain Basin

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Recent emission-transport modeling conducted by USEPA in support of the Clean Air Mercury Rule (CAMR) depicted rapid deposition of divalent mercury (Hg^{2+}) – also known as reactive gaseous mercury (RGM) – after its release into the atmosphere from major emission sources such as electrical generating units (EGUs). Rapid Hg^{2+} deposition is thought to produce deposition hot-spots immediately downwind of EGUs but to limit the ecological impact on areas like the Lake Champlain Basin which are distant from major emissions sources. Current emission-transport models depict gaseous elemental mercury (GEM) emitted from EGUs as transported long distances and not readily deposited. Model simulations of low deposition rates for GEM and low rates of GEM to RGM conversion in the continental atmosphere have been used to suggest that GEM emissions are environmentally benign and have little impact on ecosystems either local or distant from sources. Model simulations of the behavior of emitted mercury have had an important influence on recent federal rulemaking. However, few observations have been available to evaluate the validity of the model parameterizations and assumptions.

New observations of RGM in air and Hg^{2+} in precipitation at Underhill, Vermont (distant from major sources) suggest that significant long-range transport of divalent mercury occurs frequently in both summer and winter. Air-mass back-trajectories suggest that source regions for elevated RGM and precipitation Hg in northern Vermont are western NY, OH, PA, and NJ where older EGUs are located. The new observations also suggest that conversion of GEM to RGM via ozone oxidation can be significant.

The emission-transport modeling conducted in support of CAMR underestimated the observed wet and dry deposition of Hg^{2+} in northern Vermont. The CAMR modeling also did not quantify GEM deposition to plant foliage, omitting ~1/3 of total mercury deposition and an important pathway for transfer of atmospheric mercury to terrestrial food webs.

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How does Atmospheric Mercury Deposition Affect Fish Mercury Concentrations: Results from the METAALICUS and MESOSIM Studies in Ontario

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and M. Tate[12]

The timing and magnitude of the relationship between mercury (Hg) loading to ecosystems and fish methylmercury (MeHg) concentrations is a critical consideration for science-based assessments of potential controls on Hg releases to the environment. Stable Hg isotope addition studies to experimental systems are a valuable approach to addressing these problems, because Hg added as enriched isotopes can be traced separately in time and space.

METAALICUS and MESOSIM are two stable Hg isotope addition studies that have been carried out in boreal ecosystems at the Experimental Lakes Area in northwest Ontario. METAALICUS is a long-term, whole-ecosystem Hg addition experiment. Beginning in 2001, and continuing through 2006, Hg additions with three different isotopic signatures were applied each year to the surface of first order Lake 658, to its upland watershed, and to a wetland in the basin, at a rate 6-7 fold greater than ambient wet deposition. Average annual Hg additions to the lake surface, upland and wetland were 22 µg/m2/yr for the 2001-2004 period. MESOSIM was a two year dose-response experiment conducted in large (10m diameter) *in-situ* mesocosms in Lake 240. Mercury was added at 11 different loading levels to simulate a broad range of atmospheric deposition rates (7 – 107 µg Hg $m^{-2} y^{-1}$).

In both studies, the experimentally-added Hg began to be converted *in situ* to methylmercury (MeHg) and incorporated into the aquatic food web within weeks. Further, the newly added Hg was more available for methylation than ambient Hg pools in sediment and soils. By 2004, Hg added directly to Lake 658 resulted in 30-40% more methyl mercury in biota, including small fish, than would otherwise have occurred. In contrast, the wetland and upland delayed the delivery of Hg to the lake. Reasons for this were related to the pool sizes of ambient inorganic Hg in different parts of the ecosystem, mobility of new Hg to methylation sites, and differences in rates of transport of MeHg to biota. In MESOSIM, the dose-response relationship between Hg loading and concentrations of the experimentally-added Hg in fish, and in the lower food web, were linear and proportional. Importantly, the loading rate of Hg had no effect on its relative distribution in the aquatic environment, or the fraction converted to MeHg.

These studies demonstrate that Hg concentrations in biota will respond to changes in atmospheric deposition. The rate of response will vary from lake to lake, and will depend partly on the ratio of watershed area to lake surface area.

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Trends in Mercury Deposition from the MDN

Curtis D. Pollman[*1], Eric M. Prestbo[1], and Michael Ungs[2]

Using primarily the MDN data set, we are conducting an assessment to determine the spatial and recent temporal trends of mercury (Hg) in wet deposition and whether the trends (or absence of trends) can be related to changes in atmospheric emissions of Hg during the same period. Trend analysis has been conducted using the seasonal Mann-Kendall test in conjunction with the Sen's median slope test for all MDN sites with weekly data greater than $n = 104$ weeks (a total of 72 sites). Because trends in deposition flux can be driven solely by changes in precipitation, our trends analysis includes examining trends in precipitation flux and Hg concentration as well as the Hg deposition flux. This allows us to more confidently assess whether an identified trend in Hg deposition truly represents a change in the atmospheric Hg signal.

Four long-term sites in New England and Canada (ME02, NB02, NH00, and NS18) show significant ($p<0.05$) declines in Hg deposition that are reinforced by concomitant and significant declines in wet deposition Hg concentrations. Similar self-consistent declines in Hg deposition and concentration also were observed for sites in coastal North Carolina (NC08) and Seattle, Washington (WA18). In addition, a significant decline was observed for site WI32 located in northeastern Wisconsin, but was not matched by other sites in Wisconsin with longer periods of record, and presumably reflects short-term dynamics that may not translate to a long-term trend. Analysis of variance models also have been constructed to elucidate trends at both WA18 and site FL11 in the Florida Everglades where a longer term period of record from late 1993 through 2005 has been compiled. The ANOVA analysis for WA18 confirms the non-parametric results showing a significant decline, and inspection of the time series indicates that the decline occurred due to an essential step function decline in Hg concentrations in late 1997 and may be related to the closure of several Seattle area medical waste incinerators in 1998. The ANOVA analysis for FL11 suggests that there has been an overall decline in the Hg signal that has been obscured by an anomalous increase in deposition to peninsular Florida between March and August 2003. This increase is anomalous in part because it does not appear in other sites with the MDN network, and is coupled to increases in both precipitation and the concentration of Hg in rain during that period.

We have also used the non-parametric Kolmogorov-Smirnov test of the cumulative frequency distribution of rainfall and wet deposition Hg concentrations to identify differences in the atmospheric Hg signal between sites. This analysis is focused on selected subsets of sites (e.g., Pennsylvania sites, Wisconsin and Florida) that can be used to help test the hypothesis that local sources can influence local deposition fluxes. Results from these analyses also will be presented.

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Developing an Open, Coordinated and Collaborative Atmospheric Mercury Monitoring Network in North America

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The protection of the environment has often been deemed successful when there is a regulatory driver and complimentary monitoring component. Starting in the next 2 to 4 years and continuing until 2018, the mercury emissions from the remaining single largest source category in the United States, coal-fired power plants, will be decreasing due to USEPA and state regulations. Fortunately, the science and technology is available for monitoring the efficacy and impact of these regulations on the environment. In addition, the conceptual groundwork for mercury monitoring has been previously devised through two similar but separate efforts (EPA PBT Strategy and SETAC Workshop). However, there remains a significant challenge to take what are currently research based atmospheric mercury methods and undergo an open, collaborative and inclusive process to devise an effective air monitoring network. The purpose of developing a monitoring network is multifaceted and will serve modelers, especially those estimating dry deposition, researchers, policy makers and also public outreach. Since the NADP has a long history of being an open and collaborative structure, it is logical to develop the framework for an ambient air mercury monitoring and total deposition network within this organization. Over the past 18 months a team of scientists have lead the effort to facilitate the process to inform and obtain input toward a new ambient air mercury monitoring network. The results to date will be presented and include: 1) A Draft Mercury Trends Network 12-Point Plan, 2) Guiding Scientific Principles for Atmospheric Mercury Monitoring in North America, 3) Draft Survey Questionnaire on Best Practices for Atmospheric Mercury Monitoring and 4) Draft list of current atmospheric mercury research and monitoring sites in North America. In 2007, a transitional ambient air mercury monitoring network will start and provide additional information and details to optimize the network, especially in the areas of standard operating procedures, quality assurance measurements, data base development and the cost structure.

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Mercury Wet Deposition Patterns in Pennsylvania

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Data from Pennsylvania's 8 National Atmospheric Deposition Program Mercury Deposition Network (NADP/MDN) monitoring stations (1997-2005) were evaluated for spatial and temporal trends. Source-receptor relationships with regard to proximity to Coal-Fired Power Plants (CFPPs) were initiated. Hg concentrations in event precipitation samples were significantly correlated, and statistically different among some sites, indicating similar and dominant source (s). At all stations, strong seasonal patterns were evident, whereas Hg concentrations were not related to elevation, latitude, or longitude.

At four stations, the measured Hg levels in wet deposition decreased significantly and similarly over time, whereas the Hg wet deposition rates remained constant over the sampling time. Rainfall intensities increased however significantly at two of these stations. In addition, Hg wet deposition, Hg concentrations and rain volumes were positively and negatively correlated, respectively, with identical slopes indicating similar depositional mechanisms.

Wind roses indicated that westerly wind directions (SW to NW) prevail at all eight stations. In addition, 384 HYSPLIT back trajectories for two stations usually showed identical air mass origins. However, modeled 1996 SO_4 annual deposition did not correlate with the measured median annual Hg deposition. Hence, with the current data Hg levels in wet deposition in Pennsylvania are subject to similar depositional mechanisms and not related to proximity to coal combustion sources, e.g. CFPPs.

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Mercury Deposition in Urban Areas: Observations and Importance

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Mercury (Hg) is a pollutant that once released into the environment can be converted to an extremely persistent, bioaccumulative organic form, methylmercury. Methylmercury can then build up in organisms high within the food chain, such as fish, posing a risk to wildlife and humans that consume these fish. Mercury continues to be targeted as a pollutant of concern for source identification, reduction and/or elimination through a variety of state, federal, and international efforts. The atmosphere has been determined to be the most significant source of Hg to most inland lakes and many sensitive ecosystems. While early measurements pointed to the importance of urban areas on downwind water bodies, quantification of the levels of reactive gaseous mercury (RGM), the most important form of Hg for deposition, has only been accomplished recently in any systematic manner in a few urban areas. In addition, measurements of the size distribution of particulate bound Hg have revealed the importance of large particle Hg on the dry deposition of Hg in urban areas to adjacent water bodies

The importance of urban mercury cycling to the global atmospheric mercury budget has not been well characterized to date. Areas in which mercury emissions densities are high, such as most urban areas in the Great Lakes Basin and along the east coast of the US, have very distinct differences in deposition patterns when compared to the rural areas where the majority of the ambient mercury monitoring has been done in previous studies. Specific differences that had not been well quantified include the relative importance of mercury dry and wet deposition flux and the relationship between deposition and the mercury concentrations in surface runoff. This paper will focus on the differences between urban and rural Hg atmospheric chemistry and deposition, and it's importance to the regional and global cycle of mercury. Measurements of both event wet deposition, dry deposition, and urban runoff will be discussed and the relative importance of these different pathways will be discussed.

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Modeling of Atmospheric Deposition of Mercury, Sulfate, Ammonium, and Nitrate and Comparison with NADP Measurements

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A 3-D Eulerian air quality model was used to simulate the atmospheric deposition of mercury, sulfate, ammonium, nitrate, and other chemical species over the United States. This model, CMAQ-MADRID (the Community Multiscale Air Quality model coupled with a new particulate matter (PM) and mercury module, the Model of Aerosol Dynamics, Reaction, Ionization and Dissolution) is a state-of-the-science multi-pollutant model which offers an advanced treatment of ozone, PM and mercury processes. We present the application of CMAQ-MADRID for 2001 over a modeling domain that encompasses the United States and parts of Canada and Mexico and has a horizontal spatial resolution of 36 km. Meteorology was driven by the Mesoscale Model version 5, (MM5). Emissions of mercury and criteria pollutants and their precursors over North America were obtained from the U.S. EPA. CMAQ-MADRID was used to simulate the wet and dry deposition of elemental, gaseous divalent and particulate-bound divalent mercury, and of sulfate, ammonium, and nitrate. Model performance is evaluated by comparison of simulated wet deposition of these four species with 2001 wet deposition data from the Mercury Deposition Network (MDN) and National Trends Network (NTN) in the National Atmospheric Deposition Program (NADP). Annual NADP precipitation measurements are further used to determine the model sensitivity to input precipitation fields. Differences in the spatial and seasonal deposition patterns of mercury and the other three species are analyzed.

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TECHNICAL SESSION: CRITICAL LOADS

Session Chair:
Pam Padgett, USDA Forest Service

Critical Loads Strategic Efforts within the Multi-Agency Community

Tamara Blett[1], Rick Haeuber[2]

"Critical Load" is a term used to help understand policy and management questions such as: Has air pollution reached a tipping point or threshold for effects on plants, animals, soils, or water? If so, what amount of N or S deposition causes that tipping point? Once critical loads are established they can be used in policy and management contexts to determine whether current policies and programs are protecting ecosystems from reaching a threshold or, if the point has been reached, to assist in developing goals and strategies for recovery. Critical loads could potentially be used most effectively in the U.S. through coordination between critical loads research, development, modeling, monitoring, and policy efforts. However, currently, development of critical loads is being conducted in an uncoordinated fashion through multiple efforts affiliated with many different agencies and universities. This results in a variety of different methods, some overlap and duplication of effort, and an insufficient linkage between research and policy needs. A multi-agency U.S. workshop on critical loads was held in May 2006 in Charlottesville, Virginia to facilitate improved coordination of applied research projects, as well as continued dialogue on policy and management issues. Strategy developed during this workshop to begin a coordinated, effective, multi-agency critical loads effort in the U.S. will be presented. In addition, a progress report from the first meeting of the multi-agency "Critical Loads Ad Hoc Committee" (CLAD) within NADP, will also be discussed.

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The Use of Critical Loads to Guide the Assessment and Management of Air Pollution Effects on Natural Resources

Charles T. Driscoll*, and Jack Cosby[1]

In this presentation we will define critical loads, outline how they are determined, discuss how science, policy and society interact concerning the determination of critical loads for natural resources, and make suggestions for the research necessary to advance the use of critical loads in the US. The steps to determine critical loads include: 1) identification of ecosystem disturbance resulting from atmospheric deposition of air pollutants; 2) identification of receptors subject to the disturbance; 3) selection of biological indicators to be protected within each receptor and determine the critical indicator responses that define biological damage; 4) identification of chemical variables that affect the responses of biological indicators and determine the critical chemical limits at which damage to the biological indicator occurs; and 5) identification of the atmospheric pollutants that affect the pertinent chemical variables and determine the critical pollutant loads at which the chemical variables reach their critical limits. Additional considerations that we will address include: 1) effects of spatial variability within a receptor; 2) the response time scales and lags of the biological indicators and chemical variables; and 3) the interactions of multiple pollutants producing the same disturbance in a receptor.

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Calculation of Critical Loads of Acidic Deposition for the Protection of Acid-Sensitive Surface Waters

T.J. Sullivan[1], B.J. Cosby[2], C.T. Driscoll[3]

Dynamic models of watershed acid-base chemistry have been applied to calculate critical loads of sulfur and nitrogen deposition for the protection of lake and stream resources at many locations throughout the United States. Critical load calculations have been based on multiple surface water acid neutralizing capacity (ANC) endpoint criteria values and evaluation years, yielding a matrix of calculated critical loads for each aquatic system. These critical load values vary in association with current water chemistry, extent of sulfur adsorption on soils, and extent of past acidification. Such differences are examined, using example model applications, in the Appalachian Mountains and the mountainous West. Relationships are explored between simulated critical loads, selection of endpoint criteria, and policy judgments based on target loads. Implications for critical loads analysis in the Adirondack Mountains of New York are discussed.

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Redefining Critical Load Limits in United States Ecosystems to Include Multiple Environmental Stresses: Implications and Solutions

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The federal agencies of the United States (US) are currently developing guidelines for critical nitrogen load limits for US forest ecosystems. These guidelines will be used to develop regulations designed to maintain pollutant inputs below the level shown to damage specified ecosystems. By traditional definition, an ecosystem is considered to be at risk when nitrogen loads exceed a critical level. The excess over the critical load is termed the accidence, and a larger exceedance is often considered to pose a greater risk of damage to an ecosystem. This definition of critical loads applies to acute or chronic individual stress impacts, but does not work well when an ecosystem is subjected to multiple environmental stresses. For example, the mountains of western North Carolina received some of the highest rates of nitrogen deposition in the eastern US, but these nitrogen deposition levels are still considered to be below the critical load rate. The area experienced a moderate three year drought from 1999-2002. In 2001, white pine and spruce trees began to die in large numbers in the area. The initial evidence confirmed that the affected trees were killed by the southern pine beetle (SPB). This insect species is not normally successful at colonizing these tree species because heavy oleoresin production exudes the boring beetles from impacted trees. Subsequent investigations revealed that the relative ratio of above ground to below ground biomass was high compared to ratios of same species from lower nitrogen deposition areas. I believe that elevated nitrogen deposition reduced the root biomass, reduced the tree water uptake potential, reduced oleoresin production, and caused the trees to become more to susceptible to insect colonization during the drought period. If multiple stress (i.e., drought, and insects) impacts are included, then the forests in this area were in exceedance of their critical nitrogen threshold. Recent advances in ecosystem modeling of multiple stress impacts on forest ecosystems allow for more complex analysis of multiple stress scenarios. This paper explores how multiple environmental stress impacts can be assessed using computer models to determine variable critical load limits. The implications for improved forest management and pollutant regulation will also be presented.

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Atmospheric Nitrogen Deposition and Aquatic Ecosystems of the Western United States: Paleolimnological Approaches to Determining Critical Loads

James Sickman[1], Thomas Whitmore[2], Mark Brenner[3],
Leland Tarnay[4] and Annie Esperanza[4]

In the western United States large areas of land are exposed to low levels of atmospheric N deposition with interspersed hotspots of elevated N deposition downwind of metropolitan centers and large agricultural operations. Mountain ranges downwind of N source areas have elevated N deposition rates owing to orographically enhanced deposition. In this presentation we will examine current knowledge of rates of N deposition and its effect on aquatic ecosystems in the western United States. Mountain lakes in the West are sensitive indicators of climatic and depositional changes. We will review recent paleolimnological studies in mountain lakes that are yielding important insights into how aquatic ecosystems are responding to external drivers. These studies suggest that diatom taxa are potentially a tool for assessing the impacts of elevated N deposition on aquatic ecosystems. To conclude the presentation we will discuss a planned investigation in Yosemite and Sequoia-Kings Canyon National Parks which will use paleo-studies of lake sediments in conjunction with a regional deposition model to estimate critical loads for N in the Sierra Nevada.

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Translating Science into Management: The Development and Implementation of a Critical Load in Rocky Mountain National Park

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Over 20 years of ecosystem research has documented significant effects from nitrogen deposition to sensitive aquatic and terrestrial ecosystems at Rocky Mountain National Park. Total wet inorganic nitrogen deposition, as measured by an NADP sampler at the Loch Vale site in the park, is relatively low at 3.1 kilograms per hectare per year (annual average for 1999-2003). Over the last two decades, nitrogen deposition has increased about two percent per year. Ammonium and nitrate contribute approximately equally to wet deposition. The park's high elevation ecosystems are very sensitive to nitrogen deposition because of thin soils, sparse vegetation, and short growing seasons. Nitrogen effects include changes in spruce forest soil and foliar chemistry, increased soil nitrogen mineralization rates, nitrogen saturation of alpine soils, elevated nitrate in streams and lakes, and shifts in phytoplankton communities from species typical of oligotrophic lakes to species typical of disturbed, more eutrophic lakes. Manipulation experiments suggest that alpine tundra vegetation communities may currently be at the threshold of change; additions of nitrogen in similar areas have been found to result in increased abundance and cover of grasses and sedges that could eventually replace forbs (e.g., wildflowers). And if nitrogen continues to increase, episodic or chronic acidification of high elevation streams could occur.

The National Park Service (NPS) has entered into a Memorandum of Understanding (MOU) with the Colorado Department of Public Health and Environment (CDPHE) and U.S. Environmental Protection Agency to develop air quality management policies and programs to address harmful impacts to air quality and other natural resources occurring in Rocky Mountain National Park and to reverse the trend of increasing nitrogen deposition. The MOU requires NPS to develop a resource management goal, e.g., a nitrogen critical load, to protect park resources and requires CDPHE to develop an enforceable standard or air management goal that will be protective of park resource management goals. In response, the NPS has established a critical load for wet nitrogen deposition of 1.5 kilograms per hectare per year for high elevation aquatic ecosystems in the park, a value that is about half of current deposition.

Parties to the MOU are now working on strategies to determine what sources contribute to nitrogen deposition at the park and which should be reduced, and when the reductions should occur. A "glidepath" model is being considered, in which an interim target load for deposition would be used to achieve initial quick reductions, with further reductions over time to bring deposition down to the critical load, or slightly below to provide a margin of safety. Continued monitoring of wet deposition will help track progress towards the interim target load and critical load.

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POSTER SESSION
(IN ALPHABETICAL ORDER BY CORRESPONDING AUTHOR)

Indications of Nitrogen Saturation in Forests Adjacent to Roadways Due to Near Source Deposition of Mobile Source Emissions

Neil D. Bettez[*1], Robert W. Howarth[1], Roxanne Marino[1, 2], Eric A. Davidson[3]

As we continue to add evermore additional nitrogen (N) to ecosystems, it is important to estimate their ability to retain these inputs. Over the last decade, determining an ecosystems critical load, or the point at which it is N saturated, has been the focus of a great deal of work using both regional gradients and whole ecosystems N additions. While both offer unique insight into forests ability to retain N inputs, each has drawbacks as well. Deposition gradients that span long distances covary with respect to elevation and climate, and study areas across these deposition gradients have different geology and land use history. Fertilization experiments are expensive and tend to be "sledgehammer" in nature with N applied at 5-10 times the ambient deposition rate. We attempt to overcome these issues and investigate the effects of low level chronic N inputs by using the short (<300 m) deposition gradients adjacent to roadways due to near source deposition of mobile source emissions. Plots were set up at 10, 50, 100, 150 and 300 meters away from a moderately traveled roadway (~ 18,000 vehicles day^{-1}) and throughfall, foliar N, forest floor C:N, and N leaching were measured. Samples for NO_3^-, NH_4^+, TDN, cations, and anions were collected immediately following each rain event during June, July, and August from 2003 - 2006. Leaves and forest floor samples were collected during the growing season. The amount of N in the throughfall decreased with distance from the roadway, while the amount of N in the nearby bulk collectors showed no changes with distance from roadway. The N content of the foliage and litter was higher in sites closer to the road. Forest floor C:N increases with distance from the roadway. Preliminary data collected from plots along our transects indicate that the forests are beginning to show symptoms of N saturation consistent with those found in forest N addition experiments.

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Field Intercomparison of Existing and Prototype Mercury Wet Deposition Collectors

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The Mercury Deposition Network (MDN) is part of the National Atmospheric Deposition Program (NADP) and has been measuring Hg in wet deposition across North America for greater than 10 years. Currently, the MDN has 93 MDN sites utilizing a standardized collector that has been in operation since the inception of the program. Standardized collection equipment is an essential part of the NADP network design and critical in order to preserve the ability to examine long-term, spatial and temporal trends. Recent interest in a more modern, improved collector that utilizes an optical sensor has been posed as a potential replacement of the current MDN collector. Further, some scientists have expressed interest in comparing and potentially integrating Hg wet deposition data from a small regional network that utilizes a highly sensitive dual grid rain sensor collector. In order to examine the possible integration of data generated by these collectors to that of the MDN, a field intercomparison to measure potential differences in capture efficiency and chemistry for both total and methyl mercury in precipitation was initiated. The intercomparision examines four, collocated mercury deposition collection instruments (1) the existing MDN wet-only collector (2) The Meteorological Instrument Centre (MIC) Type B-1, utilized in a small regional Hg network in the North East United States (3) The NCONN-ADS wet-only collector recently built as an improved, potential replacement for the MDN and (4) a Bulk precipitation collector. Each collection instruments' specifications and are detailed along with the study location and design. Capture efficiency was compared to a National Weather Service standard rain gauge and more importantly, the time the collector opened and closed in relation to each rain event was recorded to examine potential collection of dry deposition. Initial observations indicate that the MIC B-1 and Bulk collector trend significantly higher in precipitation mercury concentrations than the NCON-ADS and MDN, likely due to longer exposure times to dry deposition. The NCON-ADS and the MDN collectors show good agreement for both capture efficiency and Hg concentration, although each use two very different rain sensors (optic v.s. 11-grid). One year of total and methyl mercury measurements from each of the four collectors are presented along with precision measurements from 3 MDN collocated instruments.

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Observations and Measurement of Methyl Mercury in Precipitation: 1996-2004 Seasonal, Spatial and Yearly Trends at Selected MDN Sites in North America

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Bloom and Watras were the first to report reliable observations of monomethyl mercury (MMHg) in precipitation (1989). Since then, there have been some possible explanations for the source of this species of mercury in rain, but no clear consensus. Even though MMHg is nominally a small fraction (0.1 to 5%) of the total Hg in rain, the measurement of MMHg is important because of its greater toxicity and potential importance as an indicator of atmospheric Hg chemistry. The NADP Mercury Deposition Network (MDN) has been contributing to the understanding of atmospheric organic mercury by monitoring the spatial and temporal concentrations and deposition of MMHg in rainwater. Currently, there are 24 MDN sites that have made measurements of MMHg in rain. At eight MDN sites, monthly composite rain samples have been analyzed for MMHg for over 8 years. Most other participating sites measure MMHg in each weekly-integrated rainwater sample. The Upper Mid-West and Gulf Coast States are the most well represented regions. The overall seasonal pattern for the upper Midwest sites is higher MMHg concentration and deposition during the spring and summer months, when aquatic biological uptake is greatest.

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Wet Deposition of Trace Metals at Selected MDN Sites

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Ryan Nelson[*], Clyde Sweet[1]

The National Atmospheric Deposition Program (NADP)-Mercury Deposition Network (MDN) has been operating since 1994 and is well established with almost 100 sites collecting wet deposition for Total Mercury. Trace Metals measurements in wet-deposition are critical in order to examine the potential transport and input of trace metals to aquatic and terrestrial ecosystems. The importance and need to measure trace metals in wet deposition was recognized long ago by the National Atmospheric Program (NADP) as stated in their original planning document (USDA, 1977). More recently, in 1991, (USDA, 1992) NADP hosted a symposium on the deposition and fate of trace metals in the environment to facilitate a discussion about adding trace metals to the NADP network. With the original NAPD charge in mind and increased MDN sponsor interest, the Mercury Deposition Network (MDN) - Hg Analytical Lab (HAL) and NADP MDN Program Office began a new initiative in 1998 to develop a trace metals wet deposition capability. The focus of this initiative was to identify and develop the necessary tools needed to accurately measure a series of priority trace metals including but not limited to Ag, As, Be, Cd, Cr, Cu, Pb, Ni, Se, Zn in addition to Hg. Since this time, trace metals wet deposition studies have been performed at 17 MDN sites. Long-term monitoring of trace metals continues at a series 5 sites with over a 5 year collection record. Advances to support this initiative for the MDN are presented and include: (1) Modified MDN collector for Trace Metals Collection (2) Designed and implemented a Trace Metals sample train to work in conjunction with the MDN collector (3) Developed routine trace metals sample train cleaning protocols (4) Developed standard operating procedures for trace metals Field Sampling and (5) Designed and validated the proper digestion and ICP-MS based trace metals analysis techniques that enable the cost affective and routine analytical detection of low-level (sub ppb) concentrations of trace metals expected in wet deposition. The HAL Trace Metals Initiatives are presented along with results from several selected MDN sponsor trace metals studies performed at MDN sites. Overall, annual deposition and volume weighted average precipitation concentrations for As, Cr, Cu, Mn, Ni, Pb, Se and Zn fall into a deposition range many times that measured for Hg and Cd. Trends and Annual volume Weighted means are examined.

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The Direct Contribution of Atmospheric Nitrate Deposition to Stream Nitrate in a Suburban Watershed as Determined through Dual Isotope Analysis

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Atmospheric nitrogen (N) deposition is the dominant source of N to many upland forested ecosystems in eastern North America, and has been linked to elevated nitrate (NO_3^-) concentrations and acidification of surface waters. Isotope studies in which δ^{15}N and δ^{18}O of NO_3^- were measured in surface waters in these upland forested ecosystems, have generally shown that the majority of the NO_3^- carries the signature of soil nitrate, except during high flow conditions. These results have been attributed to the rapid cycling of N through immobilization in microbial biomass followed by nitrification, which alters the initial δ^{18}O values of NO_3^-. Atmospheric deposition of N is still recognized as the principal source of N in these upland forested ecosystems. Less is known about the transport and fate of N in urban and suburban landscapes where potential N sources may include human waste, animal waste, and fertilizer as well as atmospheric N deposition. Here, we report results from a study in which dual isotope NO_3^- data were used to compare the sources and fate of atmospheric N deposition in a suburban watershed with that of two upland forested watersheds in New York. Nitrate in stream water from the dominantly forested watersheds had δ^{18}O values that ranged from +5 to +15, indicating the dominant immediate source was nitrification in soils; however, a tendency towards higher direct contributions of atmospheric nitrate during high flow was noted. Nitrate in the watershed dominated by suburban land use had δ^{18}O values as high as +30‰, indicating a large direct contribution of atmospheric NO_3^- transported over impervious surfaces and discharged to the stream via storm drains. These data show an inverse relation between δ^{18}O and δ^{15}N values suggesting a mixture of human waste and direct atmospheric sources of NO_3^-. The human-engineered network of storm sewers that delivers storm runoff directly to streams via impermeable surfaces in urban and suburban landscapes tends to magnify the direct impact of atmospheric N deposition on NO_3^- concentrations in surface waters, particularly at high flow when other sources that dominate at baseflow such as human waste may be at a minimum.

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Mercury at MDN Sites, 1998-2005: Declines in the Northeast, No Change in the Southeast

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An examination of 32 long-term MDN sites located in the eastern USA showed significantly different patterns for northern and southern regions. This was true for both annual and warm season volume-weighted concentration and wet deposition trends for the period 1998 to 2005. Using random coefficient models, the 20 northern sites showed a highly significant ($P<0.0001$) decline of 2.53% (± 0.49 s.e.) per year in annual concentrations of mercury. When mercury wet deposition is the dependent variable for the northern sites, a similar significant ($P<0.0001$) decline of 2.14% (± 0.43) occurs.

Mercury concentrations at all sites are higher in the warmer months. When the dependent variable is the volume-weighted concentration for the period May through September, we see a greater seasonal decline of 3.56% (±0.58) per year ($P<0.0001$). When warm month deposition is the dependent variable, the decline is 2.91% (± 0.53, $P<0.0001$).

The 12 long-term southern sites in this study do not show any significant positive or negative temporal linear trends for either concentration or wet deposition. There are a couple of plausible explanations that may account for this. There has probably been a greater decline in local and regional mercury emissions in the northeastern quarter of the country, which would suggest a local/regional impact on mercury wet deposition.

Another possibility is a greater long range global influence in the southern states. Guentzel et al. 2001 proposed that high altitude long range transport of RGM and particulate Hg are a significant source of mercury deposition in Florida due to summertime large convective storms that scavenge globally derived RGM and particulate mercury from the middle and upper troposphere. These storms also occur in other southeastern areas where intense summer heating leads to major convective activity. Global mercury emissions from Asia have significantly increased during this time period and may offset any local/regional declines in USA emissions impacting the southeastern US.

We have also examined back trajectories for both high and low deposition and concentration storms at three MDN sites (PA13, PA37 and WI99) to see if any patterns emerge. For all three sites, 33% to 50% of the high deposition storms are derived from relatively stagnant air masses. WI99 also has >40% of its high deposition storms originating from the south to southwest. West to southwest air masses account for a significant amount of high deposition storms for PA37, and to a lesser extent PA13 .

Low deposition storms commonly originate from coastal air masses for PA13 and PA37, whereas for WI99 west to northwest air masses are important.

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Mercury Dynamics in the Piney Creek Reservoir-Watershed System

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The Piney Creek reservoir is a relatively remote manmade water impoundment in western Maryland, which has some of the highest mercury concentrations (up to 1 ug g^{-1}) in freshwater game fish in Maryland. To better understand mercury dynamics in this reservoir we started an intensive measurement program in 2000. Over the past six years, we measured weekly wet deposition inputs of total mercury, monthly total mercury concentrations (and other water quality parameters plus water discharge) in five small streams that drain into this reservoir, monthly to quarterly total and methylmercury concentrations at various depths in the reservoir and in bottom sediments, and monthly total mercury concentrations in the outlet of the reservoir. In the summer of 2005, we started making measurements of elemental, reactive gaseous (RGM) and particulate mercury (Hgp) in ambient air. To date, annual wet deposition of total mercury ranged from 6 to 15 ug m^{-2} yr^{-1}. Total mercury concentrations in streams ranged from 2.5 to 30 ng L^{1}, with the highest concentrations associated with major runoff events, elevated particulate carbon and suspended solids, but does not appear to be related to watershed land-uses. Under low flow conditions, most of the mercury in all streams was in the dissolved form, up to 90% of the total mercury. Under high flow conditions, however, most of the mercury was in particulate form, sometimes accounting for up to 90% of the total mercury. Total and methylmercury concentrations in the reservoir ranged from 1 to 3 ng L^{-1} and 0.02 to 0.3 ng L^{-1}, respectively, with highest concentrations in late summer and early fall, and these concentrations were not related to sampling depth. Total mercury concentrations in the upper 2 cm of sediment ranged from 32 to 135 ng g^{-1}, with an average of 68 ng g^{-1}. Methylmercury concentrations in these sediments ranged from 0.04 to 1.1 ng g^{-1}, with an average of 0.5 ng g^{-1}. Ambient air concentrations of elemental mercury averaged 1.5 ng/m^{-3}, 10.5 pg/m^{-3} for RGM and 5.2 pg/m^{-3} for Hgp. Highest concentrations of RGM coincided with elevated concentrations of SO_2 and winds from the northwest. Over the next few months, our six-year data set will be used to estimate annual mercury budgets for each watershed, net retention or export of mercury by this reservoir, and to calibrate a lake mercury cycling model to estimate the impacts of changing atmospheric and watershed mercury inputs on mercury concentrations in the fish community.

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Acidic Deposition in Urban and Rural Locations in New York: Results from the New York State Atmospheric Deposition Monitoring Program

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The New York State Atmospheric Deposition Monitoring (ADM) Program was established in the mid-1980s to monitor acidic deposition in rural, suburban, and urban locations across the state to track the effectiveness of reductions in precursor emissions. Currently there are 20 ADM sites that provide information on spatial patterns and temporal trends in wet deposition over the past two decades, and that complement the efforts of the NADP in the state. Here we describe the network and estimate temporal trends with a particular focus on 11 sites with continuous data records through 2005. Changes in sulfate and nitrate concentrations at both urban and rural sites are presented, and are compared with the corresponding changes in ambient SO_2 and NO_2 levels at collocated sites.

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The Watershed Deposition Tool: A Means to Link Atmospheric Deposition to Watersheds

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A software tool is being developed by NOAA/EPA's Atmospheric Sciences Modeling Division to aid the linkage of air and water for TMDL (Total Maximum Daily Load) and related nonpoint-source watershed analyses. The objective of this software tool is to take gridded atmospheric deposition (wet and dry) estimates from NOAA/EPA's regional, multi-pollutant air quality model, CMAQ, and allocate them to 8-digit HUC's (hydrologic cataloging units of rivers and streams) within a watershed or State or Region. The WDT can also export GIS Shape files of the CMAQ gridded outputs for experienced GIS users. CMAQ estimates can help fill in for emissions hot spots that are not resolved by the monitoring networks and fill in dry deposition to provide an estimate of total atmospheric deposition. The WDT will calculate the average wet, dry or wet + dry atmospheric deposition across a HUC or a set of HUC's for a given emissions (or scenario) year as estimated by CMAQ. The WDT will also calculate the average change in air deposition across a HUC due to Clean Air Act regulations, given base simulation year air deposition and deposition for a future year that incorporates estimated reductions in air emissions due to the Clean Air Act regulations. Currently the capability is designed for wet and dry deposition of oxidized- and reduced-nitrogen, total-nitrogen and total-sulfur over the continental U.S. domain at the 36-km grid resolution. Extensions to mercury are planned. Several capabilities of the WDT will be illustrated in the poster and demonstrated on a laptop computer during the poster session.

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Determination of Background Levels of Metals in National Atmospheric Deposition Program/National Trends Network Field Blank Samples and the Central Analytical Laboratory In-House Blank Samples by Inductively Coupled Plasma-Optical Emission Spectroscopy

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The NADP/National Trends Network (NTN) collects weekly precipitation samples for the measurement of major ions (SO4, NO3, Cl, NH4, Na, K, Mg, Ca, and ortho-P) and pH. Samples are collected in HDPE buckets without preservative and kept at ambient temperature until analysis is performed. An investigation was made to determine the background levels of trace metals in samples collected via the NTN protocol to evaluate the use of NTN samples for semi-quantitative monitoring for soluble fractions of selected metals. An ICP-OES was used to measure cadmium, cobalt, chromium, copper, iron, manganese, nickel, strontium, vanadium and zinc. The ICP was optimized for the analysis of the softer elements (Na, K, Mg, and Ca), however, low ppb detection limits for selected metals could be obtained under these conditions. A NIST 1643e trace elements in water standard reference solution was used to validate this approach. In addition, the CAL participated in three NWRI trace metal round robin studies using this method. Twenty weeks of CAL internal bucket, sample bottle, and lid blank samples and 118 pairs of USGS external field blank samples were analyzed to identify background concentration levels for the selected metals. Concentrations well above the detection limits were found for copper and zinc in USGS field blank control solutions. Higher levels of copper and zinc were found in the bucket portion of the USGS field blank compared to bottle portion. This finding indicates that copper and zinc are being leached from the bucket. The average concentration for copper in the bucket field blank was 76 ppb compared to 2 ppb for the bottle field blank sample pair. The average concentration for zinc in the bucket field blank was 16 ppb compared to a value <DL for the bottle field blank sample pair. The deionized water matrix USGS bucket/bottle pair resulted in 5 ppb for copper, < 1 ppb for iron, and 2 ppb for zinc. This strongly suggests that these metals are being leached from the buckets when acidic matrices are used. Copper and zinc levels near the DL were found in internal CAL blank samples (buckets, Nalgene 1-liter sample bottles, and bucket lid blank samples). All other metals were <DL for the samples evaluated.

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Summary of Mercury and Trace Metal Results from the Culpeper, Virginia (VA-08) Mercury Deposition Network Site, 2002-2005

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The VA-08 Mercury Deposition Network (MDN) site, southwest of Culpeper, Virginia, was established in autumn of 2002. This site along with nearby VA-28 (~31 km west) in Shenandoah National Park fill a spatial gap in the Mid-Atlantic region of the MDN network and provide Hg deposition data immediately west of the Washington, D.C., metropolitan area. Results from autumn of 2002 to the end of 2005 for the VA-08 site suggest that the highest mercury (Hg) deposition (up to 5 $\mu g/m^2$ per quarter of the 7.8-12.6 $\mu g/m^2$ annual Hg deposition) is measured during the second and third quarters of the year (April-August). This is a result of both elevated Hg precipitation concentrations (up to 27 ng/L) and greater precipitation during these months. The data also exhibit a general statistically significant ($p<0.05$) negative correlation between weekly total precipitation and average Hg concentrations, suggesting a dilution effect during larger precipitation events. Comparison of results between the VA-08 and VA-28 sites indicates that although quarterly Hg deposition was not significantly different ($p<0.05$) between sites, quarterly volume-averaged Hg precipitation concentrations were statistically larger ($p<0.05$) and precipitation was significantly lower ($p<0.05$) at VA-08. Lower Hg concentrations at the VA-28 site relative to VA-08 are likely a result of greater total precipitation and thus additional dilution of Hg in precipitation.

Starting in November of 2004, samples for trace elements analysis in precipitation at the VA-08 site were collected. Principal component analysis of the Hg and trace metal data for 2004 and 2005 indicates that 3 source categories account for roughly 80% of the variability in the trace metal data. The first principal component is dominated by strong factor loadings (>0.6) of Ni, Mo, Cd, Zn, Co, and Pb and is likely a mixture of anthropogenic sources. Strong factor loadings of Ca, Mg, Hg, Al, and Sr in the second principal component likely represent a crustal source for trace metals. A strong positive loading of Na with negative loadings of Mn, Ba, and Pb in the third principal component suggest an input from other anthropogenic sources.

HYSPLIT air mass trajectory modeling suggests that the Washington, D.C.-Richmond, Virginia corridor is the likely source region for trace elements that dominate the first principal component. Source areas for trace metals which dominate the other two source categories are more varied indicating input from multiple sites or one or more distal sources which may be affecting the entire region.

Findings from this study suggest that Hg and other trace metals measured in precipitation at the VA-08 site are derived from multiple sources on both local and regional scales. Similar total Hg deposition between the VA-28 and VA-08 sites and the strong relationship between Hg and crustally-derived trace elements indicate that a large fraction of the Hg measured at the VA-08 site is derived from the global Hg pool rather than local, anthropogenic sources. Additional data collected during continued sampling will be used to monitor multi-year trends in deposition at the site.

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Wet Deposition of Mercury in the U.S. and Canada, 1996-2004: Results, Trends and Future Directions of the Nadp-Mercury Deposition Network (MDN)

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The Mercury Deposition Network (MDN) is part of the National Atmospheric Deposition Program (NADP), and operates sites in North America to monitor total mercury in wet deposition. The primary goal of MDN is to provide both spatial and temporal trends in mercury wet-deposition fluxes for North America to be used by scientists, educators, NGOs and public policy makers. As such, the benefits of this monitoring program are only now coming to fruition due to the number of sites and the length of time they have been in operation. MDN now has 93 sites in operation and 48 have been operating for 5 years or more. With the advent of new mercury air emission regulations in Canada and the USA, the MDN is poised to provide an important means to measure the efficacy of the regulations in years to come. This will be especially true with the recent addition of MDN sites in predicted source-influenced locations, including several with event-based sampling. Annual summaries from weekly data collected at 88 locations are reported for the years 1996-2004. Volume-weighted total mercury concentrations are lowest at remote sites in Northern California/Oregon and the Canadian Maritime Provinces (4 to 6 ng/L) and highest in Florida and Minnesota (10 to 16 ng/L). Wet deposition of mercury ranges from over 25 μg/m^2/yr in South Florida to less than 3 μg/m^2/yr in Northern California. Mercury deposition is strongly seasonal in Eastern North America. In the summer, the average mercury concentration in rain is about double that found in the winter. The average wet deposition of mercury is more than 3 times higher in summer than in winter. Thirty eight sites with datasets of 5 years or more were tested for trends using the non-parametric seasonal Kendall trend test with the Sen's slope estimator. Significant decreasing concentration trends were noted at about half of sites, particularly across Pennsylvania through the Northeast. Seven primarily Atlantic coast sites had depositional decreases, with several sites showing increases. Many increasing and decreasing seasonal trends for individual sites will be presented along with possible explanations focused on mercury emission source strength changes.

Plans are currently being made to add atmospheric measurements of speciated mercury to the network. Coupled with wet deposition, these measurements will provide the data for validation and calibration of models and calculation of wet, dry and total deposition of atmospheric mercury.

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The Rocky Mountain Atmospheric Nitrogen and Sulfur (RoMANS) Study Sampling Network and Initial Results

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Recent ecological studies have shown a number of deleterious effects due to elevated deposition of nitrogen and sulfur compounds to Rocky Mountain National Park (RMNP). Elevated levels of these atmospheric pollutants also negatively impact regional haze and human health. In past years measured oxidized and reduced nitrogen and oxidized sulfur deposition from NADP and CASTNET show that the total wet and dry deposition flux of these species to RMNP are ~3.1 and ~1.1 kg/ha/yr, respectively. The Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) Study was initiated to improve our understanding of oxidized sulfur as well as oxidized and reduced nitrogen in the context of 1) their sources, 2) their forms in the atmosphere, and transformations during transport, and 3) their deposition rates. Meeting these study objectives required an extensive study domain operated during important spring and summer deposition periods. A spring campaign was conducted over five weeks in March and April 2006, and the summer campaign occurred over five weeks during July and August 2006. Due to RMNP's complex terrain, deposition rates vary widely within the park. In order to assess this spatial variability, several sampling sites were located within the park boundaries. Additional measurement sites were located on the east and west sides of the park, with more sites situated in the plains of Colorado and near the eastern, western, and southeastern boundaries of Colorado to assess the transport of sulfur and nitrogen species into Colorado. Measurements include 24-hour integrated ammonia, nitric acid, sulfur dioxide, the ionic composition of particulate matter less than 2.5 μm in diameter ($PM_{2.5}$), and the ionic composition of wet deposition. A core measurement site included more detailed and higher time resolution chemical, optical, and size distribution measurements. Measurements here included 15 min measurements of $PM_{2.5}$ inorganic composition using a Particle Into Liquid Sampler (PILS) coupled to two ion chromatographs, a Micro Orifice Uniform Deposition Impactor (MOUDI), a suite of 5 minute gaseous measurements, a nephelometer, and detection of particle size distribution over the range of 40 nm to 15 micrometers in diameter. To assist with subsequent transport modeling several sites also included 5 minute meteorological measurements collected at a height of 10m. The chemical composition of collected PM2.5 filters, wet deposition, and PM size fractions were later analyzed by two Ion Chromatographs configured to detect either anions or cations typical in the atmosphere. Initial study findings will be presented including the inorganic composition of collected $PM_{2.5}$, concentrations of key trace gas species, and wet deposition composition and fluxes. We will also examine variability in composition between sites and show preliminary observations of relationships between transport patterns and pollutant concentrations in the park.

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Examining Biological Transport of Mercury from the Ocean to the Watershed: A Case of Pacific Salmon Life History

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Even though quite limited and fragmented in nature, currently available data on mercury in the United States Arctic show very low concentrations in seawater (order of 50 pg/L), atmosphere (order of 5 ng/m^3), and sediment (order of 20 ng/g). Low background levels are also reflected in mercury residues in tissues of several marine mammals that are hunted for subsistence, for example, different species of seals, bowhead whale, gray whale and beluga whale. Except for beluga whale whose diet include a variety of fish, reported average mercury levels in the muscle tissues of these species are less than 100 ng/g (wet weight); in the case of beluga whale, the average value exceeded 1,000 ng/g. Neither do the data suggest the presence of particular point sources of mercury, except for major rivers that could be transporting substantial amounts of atmospherically-deposited mercury from their vast watersheds. Locally in the vicinity of mercury mines in western Alaska – Kuskokwim River drainage – stream sediments have been reported to contain mercury in excess of 5,000 ppm.

Local concentration of mercury is determined by its sources and greatly influenced by processes of transport between environmental matrices, transformation and sequestration that vary among its different chemical forms. Presently, there is little understanding of the biological transport of mercury that in some cases may be quite significant. One such mechanism is spawning migration of anadromous fish, particularly of Pacific salmon in the Pacific Northwest and Alaska. Due to the enormous numbers of returning salmon and their large body size, the salmon nutrient subsidy has been equated ecologically to the migration of the wildebeest on the Serengeti plains with estimated input of 20 to 72 percent of total nitrogen to different aquatic ecosystems in the region, which for the most part are oligotrophic and pristine.

The study of sockeye salmon *Oncorhyncus nerka* may be more appropriate in this regard since it is a highly abundant and widely distributed species, and nearly all of them return to lakes for spawning. The mean concentration of total mercury in the muscle tissue of the sockeye salmon varied between 51 and 61 ng/g (wet weight) in three sampling areas; for methylmercury, it varied between 33 and 46 ng/g, amounting to about 75 percent of total mercury. Given these data and a general escapement value of 12 million sockeye salmon in the Bristol Bay region, an annual import of about 2 kg of mercury would be a significant source for the lakes and lake-related aquatic habitats in the region.

Variations in N-15 and presence of diatoms in sediment cores have been used to reconstruct patterns of salmon abundance in relation to overall biological productivity in different lakes over decadal to millennial scales and to estimate salmon runs in different lakes prior to the start of commercial fishing. There may also be mercury-related signatures of regime shifts in biological productivity through mercury evasion and redeposition.

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National Air Toxics Deposition Monitoring Meta-database

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There are no national networks for monitoring the deposition of toxic air pollutants, with the exception of the Mercury Deposition Network. Nevertheless, deposition monitoring of toxic pollutants is being done through regional networks and research studies. To provide environmental professionals and interested citizens with easy access to basic information about these networks and studies, the U.S. EPA's Office of Air Quality Planning and Standards, with technical support from Alpha-Gamma Technologies, Inc., is developing the national air toxics deposition monitoring meta-database.

The meta-data includes the pollutants monitored; deposition type monitored (wet, dry or both); geographic location; the dates that a site has been active; who runs the site; with which network the site is associated; and where to find additional information, including links to the monitoring data itself, if available. Pollutants include mercury, lead, cadmium, polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and a group of pesticides.

A web interface to the database will provide users the capability to search by several criteria, such as pollutant, monitoring network, State/Region, deposition type, and start/end date of the monitoring. Search results can be mapped. In addition, users will be able to select meta-data that they want to download in either text or comma-delimited format.

Parties responsible for the monitoring sites will have rights to comment on and verify the information in the database about their sites through a password-protected web interface.

The database will be available before January 2007. It will be linked to EPA's site for the Great Waters Program at http://www.epa.gov/oar/oaqps/gr8water/.

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The Role of Custom Computer Programs and Databases in NADP/CAL Shipping and Receiving, Data Entry, and Laboratory Analysis

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The NADP Central Analytical Laboratory uses several specially designed computer applications in its operations. Primary among these are a custom programmed Laboratory Information Management System (LIMS) and a Supply and Parts tracking program (SAP). The SAP program assists the Site Liaison to monitor the flow of samples, supplies and parts to and from NTN and AIRMoN sites. The LIMS program provides for initial sample processing including field data entry, and accumulation of chemistry data pending transfer to the CAL's data group. This poster presents an overview of the functions of these programs and how they assist the CAL's operations.

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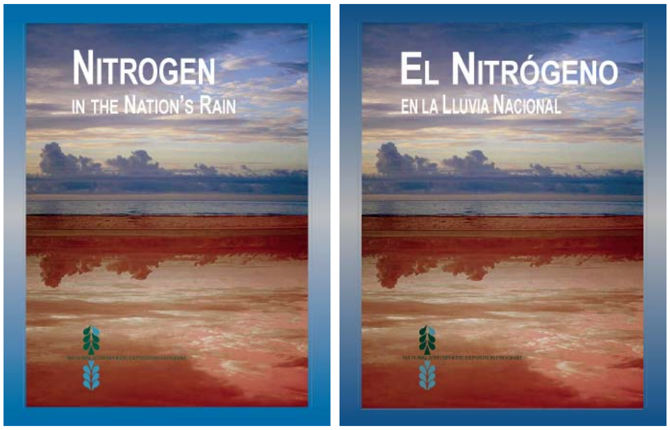
Atmospheric Chemistry in the Undergraduate Classroom: NADP and the International Center for Undergraduate Chemistry Education (ICUC)

Christopher Lehmann*, Cathy Middlecamp[1], Paul Kelter[2]

The National Atmospheric Deposition Program (NADP) has formed a partnership with the International Center for First-Year Undergraduate Chemistry Education (ICUC) to facilitate our shared mission of providing information on chemistry issues to the educational community. The ICUC has recently provided the NADP with a Spanish translation of the NADP's informational brochure, "Nitrogen in the Nation's Rain" *(El Nitrógeno en la Lluvia Nacional)*. This publication will broaden the audience for NADP outreach materials and raise international awareness of the adverse environmental impacts of atmospheric deposition.

The ICUC connects educators world-wide to share information and expertise on entry-level chemistry education, and currently has 150 members from 14 countries across 5 continents. This presentation introduces the ICUC to the NADP audience and highlights future collaborative activities.



NITROGEN
IN THE NATION'S RAIN

EL NITRÓGENO
EN LA LLUVIA NACIONAL

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Data-Quality Objectives for the National Atmospheric Deposition Program/Mercury Deposition Network

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The National Atmospheric Deposition Program/Mercury Deposition Network (NADP/MDN) provides quality assured monitoring data and information in support of environmental management and research pertaining to atmospheric wet-deposition of mercury in North America. The objective of the MDN is to develop a national database of total and methyl mercury concentrations in precipitation and the seasonal and annual flux of mercury in wet deposition. These data are used to develop information on spatial and seasonal trends in mercury deposited to surface waters, forested watersheds, and other sensitive receptors. The NADP requires a comprehensive quality assurance (QA) program with quality control (QC) procedures that ensure pre-defined standards of accuracy, completeness, and representativeness. The NADP's Quality Assurance Advisory Group (QAAG) has developed data-quality objectives (DQOs) to ensure that data collected by or for the NADP continue to meet the needs of the research community. For the purposes of the NADP, DQOs are qualitative and quantitative statements that specify the technical characteristics of NADP data that are required to support the intended purposes and uses of the data. The QAAG has evaluated the performance of the NADP using data from its established QA programs. Targets have been defined for the principal data-quality indicators (DQIs) of completeness, sensitivity, variability, bias, comparability, and representativeness. This presentation provides an overview of NADP/MDN QA programs, and discusses the development of DQOs specific to the NADP/MDN in support of long-term mercury trends research.

[This poster was originally presented at the Eighth International Conference on Mercury as a Global Pollutant, August 6-11, 2006, Madison, WI.]

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Comparison of the MDN Standard Aerochem, Proposed MDN NCON, and University of Michigan Air Quality Lab Modified MICB Precipitation Collectors for Mercury Deposition

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We conducted a 1-year study (August 2005 – July 2006) of the event-based relative collection performance of the MDN modified Aerochem (ACM) sampler, the University of Michigan modified MICB sampler, and the NCON Systems mercury deposition sampler. The samplers were deployed at the Underhill, VT Air Quality Research Facility (VT99). The study was designed to assess the effects of differential rain sensor performance, sampling trains, and collector geometry on sampled mercury concentrations and deposition. Extensive data on collector lid status and meteorological conditions including rainfall rate, surface wetness, and humidity were collected. National Weather Service standard 8-inch precipitation gages were monitored as the reference for precipitation amount. Samples from the MICB were analyzed at the University of Michigan Air Quality Laboratory. Samples from the ACM and NCON were analyzed at the MDN HAL.

All three collectors experienced mechanical and other failures during the study. Drive systems failures compromised the results from each of the samplers at one time or another. The MICB collector overflowed during 3 rain events. Heater problems and collector geometry resulted in poor snow collection performance for the ACM and NCON collectors. Approximately 20% of precipitation events and ~24% of precipitation volume were either disqualified or classified as questionable results for each of the samplers. All 3 collectors simultaneously functioned satisfactorily (according to respective laboratory QA standards) during 69% of events and 68% of the precipitation measured by the NWS gage during the study period. Because failures occurred more frequently during the colder months, lower fractions of observed snow (33%) and mixed precipitation (62%) were represented in the valid comparison data set than rain (74%).

Compared to the NWS gage, all three collectors under collected snow (NCON < ACM < MICB). The ACM and NCON collectors under collected mixed precipitation (ACM < NCON). The MICB was within 1% of the NWS gage catch for mixed events. All three samplers collected +/- 2.7% of the NWS gage catch for rain events. Part of the observed difference in collection efficiency can be attributed to the precipitation sensing logic of each collector. The MICB lid cycled 3302 times, the NCON 3186 times, and the ACM only 1190 times during the valid comparison period. The NCON lid was open for 1248 hours, the MICB for 789.6 hours, and the ACM for 617 hours during the valid comparison period. The NCON opened immediately in response any rain shower activity. The MICB was slightly less responsive and did not open for all minor shower events detected by the NCON and an independent wetness sensor. The ACM was often delayed in opening relative to the NCON and MICB for light precipitation and did not stay open as long. The NCON and ACM collectors frequently failed to melt snow rapidly enough to prevent “blow-out” or “knock-off” (when lid closing displaced snow accumulated on the funnel). The MICB and the NCON collected more Hg than the ACM during the comparison period. There are multiple hypotheses we are exploring to explain differing collection efficiency for Hg.

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A Survey of the Mercury in Brook Trout and Waters of the Shenandoah National Park, Virginia, USA

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Mercury was found in brook trout sampled in 14 streams in the Shenandoah National Park (SHEN) in the summer of 2004 (Snyder et al 2006). The mercury concentration in fish tissue was below advisory levels of 0.3 ppm everywhere but exhibited interesting patterns of spatial distribution within the park. To determine the sources of mercury to brook trout, this project collected samples of water from seven streams across the landscape of the SHEN, six streams within a single catchment, and two streams during high flow events. The mercury concentration in brook trout tissue was determined in all of these streams in 2004. The water samples were taken seasonally for one year (2005) and analyzed for total mercury (THg). Stream water THg concentration was positively correlated with pH and alkalinity across the landscape, but was found not to vary within the single catchment, or by season. Stream water THg concentration also was found to be highest in streams on basaltic bedrock (mean 0.648 ng/L), lowest in streams on siliciclastic bedrock (mean 0.301 ng/L), and intermediate on granitic bedrock (mean 0.522 ng/L) (the three types of bedrock encountered in the park). This is the opposite of the relationship found for brook trout THg content in the SHEN. Brook trout total mercury concentration was the highest in siliciclastic streams, lowest in basaltic streams, and intermediate in granitic streams. These findings show that mercury concentrations in the fish and streams of the SHEN are highly dependent on the predominant bedrock type of the stream. However, the inverse relationship between stream water THg and brook trout THg indicates that the brook trout are probably accumulating mercury through processes other than direct exposure to THg in the water.

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Real-time Rain Conductivity as a Surrogate for pH: Prototype Development

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The “daily” protocol of AIRMoN, compared with the “weekly” sampling of NTN, has improved the temporal resolution of wet-deposition data, but it nevertheless yields only a single set of precipitation-quality measures. For instance, the single measurement of pH that AIRMoN currently provides on a given day represents only the broadest average of rain acidity; all the natural variability of the weather system is masked by the blending of rain collected from one moment to the next. The fine temporal signature of individual storms at a given location, which might well reveal mechanistic information about cloud processes, is not available with the current monitoring strategy. In order to address the need for higher-resolution data, yet avoid the high costs associated with more frequent sampling and complete chemical analyses, we have started developing a real-time, single-parameter monitor of precipitation quality. Electrical conductivity, unlike pH, is relatively easy to measure, and its variations can be monitored continually in time to give data representative of rain pH over the entire duration of a storm. A commercially available conductivity probe has been mounted beneath a collection funnel and its electrical output interfaced to a data logger. Early tests reveal response times of a few seconds and evidence that convective storms yield rain with highly variable conductivity (hence acidity). Routine measurements of conductivity may help unravel the temporal signature of rain pH and yield a wealth of new data that are certain to stimulate hypotheses about the chemical evolution of acidic storms.

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Impact of Federally-Mandated Emission Controls on Rainfall Hydronium, Sulfate, and Nitrate Concentrations in Tampa, FL, USA

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The Acid Rain Provisions (Title IV) of the Clean Air Act Amendments of 1990 mandated that within a decade nationwide SO_2 emissions would be reduced by 9 million metric tons over 1980 levels and using rate-based limits, NOx emissions would be reduced by 2 million tons below the 8 million tons forecast for 2000. Enforcement of these provisions by the USEPA and the State of Florida lead to a landmark agreement with the Tampa Electric Company (TEC). The TEC agreement featured substantial reductions in SO_2, NOx, and PM emissions from two coal-fired power plants in Tampa, Hillsborough County, FL. The TEC committed to re-powering the FJ Gannon power plant from coal to natural gas, re-naming the plant to the Bayside power plant; to adding SO_2 scrubbers on two older boiler units at their Big Bend power plant; and to the installation of NOx controls on the Big Bend power plant. Between 1997 and 2005, TEC power plants reduced SO_2 emissions from 170,000 tons to 11,000 tons, and NOx emissions from 57,000 tons to 16,000 tons. From mid-1996 through mid-2006, the Environmental Protection Commission of Hillsborough County operated an AIRMoN site adjacent to Tampa Bay. The site has been funded by the Tampa Bay Estuary Program and the Florida Department of Environmental Protection. The purpose of this site was to estimate the annual load of wet-deposited nitrogen to Tampa Bay. Rainfall sulfate concentrations tracked well the emissions reductions, but NOx emissions less so, as transportation and industrial sources of NOx contributed almost 50% of the total NOx emissions inventory. We explore the trends in daily power plant SO_2 and NOx emissions versus rainfall concentrations of hydronium, nitrate, and sulfate and from this analysis estimate the reduction in nitrogen loading to Tampa Bay as a consequence of the emission controls.

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Abrupt Decrease in Mercury Wet-Deposition Concentration and Annual Flux in Seattle, Washington Due to Emission Point-Source Changes

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Frontier Geosciences

The primary goal of the North American Mercury Deposition Network (MDN) is to characterize the long-term spatial and temporal trends in mercury wet-deposition. However, certain MDN sample sites are likely to be influenced by nearby point sources, providing the means to evaluate source-receptor relationships as a secondary goal. The ability to use MDN data to determine source-receptor impacts will be enhanced by the addition of new sites in urban and strongly source-influenced (hotspot) locations (e.g. Milwaukee, S. Indiana) and due to impending regulations of mercury emissions from coal-fired power plants in Canada and the USA. The MDN site, WA18, located in northeast Seattle was one of the first sites in the MDN, beginning in March of 1996. The volume weighted average concentration and annual deposition rate for 1996 to 1997 was 18.6 ng/l and 16.6 µg/m^2/yr. For the subsequent years, 1998 to 2004 the volume weighted average concentration and annual deposition rate are 7.86 ng/l and 6.27 µg/m^2/yr. This precipitous drop in wet deposition concentration and annual flux is statistically significant ($p<0.001$) when comparing the residuals between predicted and observed Hg concentrations for 1996-1997 using a model based on the years 1998-2004. Evidence to date attributes this drop to the closure of medical waste incinerators at Seattle area hospitals by 1998 due to the implementation of EPA MACT regulations for these sources. Uncontrolled medical waste incinerators are known to have high fractions of water-soluble oxidized gaseous mercury in their emissions, which is readily washed out of the atmosphere close to the source. However, the observed decrease in mercury wet-deposition at WA18 may also be the result of fuel changes for other source categories. A complete history of past and current Seattle area emission point source locations and trends will be compared to the mercury wet-deposition trend at MDN Site WA18.

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Calculating a Simple Estimate of Nitrogen Deposition across a Region of Variable Ammonia Emission Density in Eastern North Carolina

Wayne Robarge*, John Walker[1]

Animal production in eastern North Carolina, particularly for swine and poultry, is centered primarily in six counties. Ammonia emission densities arising from animal production in these six counties ranges from > 5000 to 2000-3000 NH_3-N km^{-2} yr^{-1}. The ammonia emission density for the remainder of eastern North Carolina declines steadily moving away from these six counties. The fate and transport of this emitted ammonia and its potential impacts on air quality and nutrient sensitive ecosystems within the state and along the coast is of major concern. We have followed a three-step approach in deriving a simple estimate of ammonia-N deposition across this region of variable ammonia emissions density. First, over 5 years of monitoring ambient ammonia chemistry in eastern North Carolina using annular denuder technology has yielded insight into the distribution of gaseous ammonia and fine particulate ammonium (PM2.5) throughout the region. Yearly mean gaseous ammonia varies by a factor of 5 going from high to low regions of ammonia emissions. Fine particulate ammonium concentrations vary by a factor of 2 to 3. Both gaseous ammonia and fine particulate ammonium demonstrate seasonal differences in concentration, as does the association of fine particulate ammonium with chloride, nitrate and sulfate. Second, our knowledge of the atmospheric ammonia chemistry across the region, combined with micrometeorological studies of ammonia-N deposition to various vegetative canopies, is used to estimate dry deposition of ammonia-N. These estimates are combined with N wet deposition measurements from several National Atmospheric Deposition Program collectors located in eastern North Carolina. Together, these data yield an estimate of ammonia-N deposition across this region of variable ammonia emission density. This number is compared to the estimate of total ammonia-N emissions from animal production. Third, the estimate of ammonia-N deposition is contrasted to projections of N deposition in this region using multi-media computer models. This comparison is used to assess the need for further monitoring of ambient atmospheric ammonia chemistry in the region, and to determine the presence of possible error in the databases, such as the NADP data sets. It is acknowledged that these calculations are only approximate and cannot differentiate from other agricultural sources of ammonia in eastern NC. However, emission inventories in the state indicate that swine production is the dominant source of ammonia emissions in this area, and that changes in swine density of production are the most consistent with observed changes in wet deposition chemistry. These calculations also reflect actual field observations that have been made in eastern NC during the past five years, as well as general rules of thumb that have been derived from deposition studies on various ecosystems. As such, the attempted simple mass balance calculation can only account for ~ 40 to 50% of the estimates NH_3 emissions from swine. The remaining emissions, if real, must be transported outside of the Coastal Plain, either West into central NC, along the East Coast, and/or East out to the Atlantic Ocean.

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Using Throughfall to Estimate Atmospheric Nitrogen Deposition in the Vicinity of Large Scale Swine Production Facilities in Eastern North Carolina

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For the past 7+ years, most attention regarding the large-scale swine production facilities in eastern North Carolina has focused on measuring emissions of N (as ammonia) and deriving emission factors. Less attention has been focused on the fate of volatilized N (primarily as NH_3) exported from lagoons and the animal production houses. Ammonia in the atmosphere deposits to the earth's surface as wet deposition and dry deposition. Historical records are available (National Acid Deposition Program) to discern trends in wet deposition of N (NH_4-N) in rainfall. No such records exist for dry deposition of N compounds. In this survey, bulk deposition and throughfall collectors in forest canopies were used to: (1) To measure atmospheric N deposition in the immediate vicinity of a large scale swine production facility (Eastern Farm site); and (2) To monitor atmospheric nitrogen deposition in the immediate vicinity (5 km) of large scale swine production facilities located in eastern North Carolina.

At the Eastern Farm site, NH_4-N dry deposition was approximately 2x (10.2 kg N/ha) that from wet deposition during the collection period of August 6, 1997 to April 16, 1998, and total NH_4-N deposition to the forest floor (from both wet and dry deposition) was 14.5 kg N/ha. The dry deposition of NH_4-N observed at the Eastern Farm site also enhanced the apparent dry deposition of Cl (9.2 kg Cl/ha) and SO_4 (17.1 kg SO4/ha), and perhaps NO_3-N (2.7 kg N/ha), either through the formation of ammonium aerosols formed in the atmosphere and deposited as NH_4NO_3, NH_4Cl or NH_4HSO_4, or after dry deposition of NH_3 to the forest canopy which in turn enhances the dry deposition of HNO_3, HCl and SO_2. These results suggest that enhanced dry deposition of NH_4-N to forest canopies in the vicinity of production facilities should be accompanied by enhanced dry deposition of Cl and SO_4, and possibly NO_3-N.

Measurable amounts of dry deposition of NH_4-N were recorded for deciduous forest canopies within 3 kms of production facilities along a NE-SW transect extending from Goldsboro, NC to the Bladen State Forest. Enhanced dry deposition of Cl and SO_4 were also recorded for these canopies, as compared to deciduous forest canopies > 5 km away from production facilities. Total N loading to the forest floor (wet and dry; NH_4-N plus NO_3-N) ranged between 7.2 and 13.1 kg N/ha for deciduous forest canopies < 3 kms of production facilities versus values of 3.8 to 5.2 kg N/ha for deciduous forest canopies > 5 kms from such facilities.

This limited survey demonstrated that use of bulk deposition and throughfall collectors provides one means to assess the enhanced dry deposition of NH_4-N in eastern North Carolina due to the presence of a high density of animal production facilities. However, this approach cannot address direct incorporation of NH_3 into the forest canopy and surrounding vegetation. Such estimates are now possible given the extensive monitoring of ambient atmospheric ammonia chemistry within the region (see e.g. Robarge et al., 2002, *Atmospheric Environment* 36:1661-1674). Although labor intensive, collection of throughfall does support attempts to model dry deposition of N in regions with a relatively high density of emission sources.

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Wisconsin Mercury Deposition Network (MDN) & Trends

Bruce Rodger*, David Gay, Eric Prestbo

The Mercury Deposition Network (MDN) is part of the National Atmospheric Deposition Program (NADP), and operates sites in the United States, Canada, and Mexico to monitor total mercury in wet deposition. The State of Wisconsin (including several Tribal Organizations) has been a longtime active member of this network, with 8 operating sites within its borders.

Volume weighted mean concentrations for total mercury in precipitation across Wisconsin for the period of 1998 – 2004 range from 9.2 – 16.7 ng/L while mean deposition rates in Wisconsin for the same period range from 4.9 – 14.5 ng/m2. Some of the highest concentrations have been measured at Wisconsin's urban MDN station in Milwaukee. Spatial trends across Wisconsin typically indicate an increase in concentration and deposition of mercury in a gradient from northwest to southeastern Wisconsin. The summer season is highest for concentration and deposition of mercury while the winter season is lowest.

Four Wisconsin sites were tested for trends (WI08, WI09, WI36, WI99) using the non-parametric seasonal Kendall trend test with the Sen's Slope Estimator. No annual concentration trends were found, but deposition decreased at WI09 (with increasing precipitation). No other annual WI trends were found, with the 4 stations generally acting as a similar, homogeneous group. Similarly, few trends were shown for the entire upper Midwest grouping (MN, WI). The group of homogeneous in deposition and precipitation, but individual site concentration changes are present (decreasing at MN18 and MN23).

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Intercomparison of CASTNET NO_3^- and HNO_3 Measurements with Data from Other Monitoring Programs

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The EPA Clean Air Status and Trends Network (CASTNET) utilizes a filter pack system to measure concentrations of atmospheric sulfur and nitrogen species. Previous studies have suggested that typically a fraction of the ammonium nitrate (NH_4NO_3) collected on the Teflon® filter dissociates into HNO_3 and ammonia. Also, NH_4NO_3 can react with acid sulfate particles on the Teflon® filter to produce HNO_3. These reactions could result in an overestimate of HNO_3 and an underestimate of particulate NO_3^- and NH_4^+. Data from CASTNET are being compared with other measurement systems used to estimate uncertainties in CASTNET filter pack measurements of HNO_3, NO_3^-, and NH_4^+ on a seasonal, annual, and geographic basis.

Measurements of nitrogen species from the Maryland Aerosol Research and Characterization (MARCH) monitoring site at Ford Meade, MD were compared with CASTNET nitrogen species measurements from the sites at Beltsville, MD; Blackwater, MD; and Arendtsville, PA. Results indicate that CASTNET measures higher particulate NO_3^- and lower gaseous HNO_3 concentrations than the MARCH measurements. However, CASTNET total nitrogen (HNO_3, NO_3^-, plus NH_4^+) measurements are comparable to MARCH total nitrogen data. An explanation is that the CASTNET filter pack collects larger NO_3^- particles because the instrument does not include a size selection inlet (e.g., cyclone) and may not collect HNO_3 as efficiently as other measurement systems. Current work is investigating the effect of size selection inlets on the collection of nitrate particles by measuring weekly nitrate and nitric acid concentrations with and without cyclones. Measurements are being collected at the same three CASTNET sites. Preliminary results indicate the size section cyclones have a significant effect on both NO_3^- and HNO_3 concentrations.

Filter pack concentrations were also compared with results from the Monitoring Instrument for Aerosols and Gases (MARGA) instruments currently deployed at the Beltsville, MD site. In general, MARGA concentrations are lower for both analytes. For HNO_3, MARGA values are approximately 80% of filter pack concentrations. Particulate NO_3^- values measured by the MARGA instrument are approximately 60% of filter pack concentrations.

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Mercury in the Environment
What Do You Monitor & Where Do You Do it?

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EPA's Office of Air and Radiation is developing capacity to assess the effectiveness of air regulations designed to control mercury emissions from coal-fired power plants. A significant part of this effort entails coordinating with many partners who monitor, assess, and report on different aspects of the mercury cycle – from sources to fish to people – over time and space. The purpose of this poster is to encourage scientists collecting mercury data to share information about their work by identifying on the map what they are collecting and the places they are doing it. Mercury monitoring metadata collected through this effort will be compiled into a database and used to forge partnerships with the mercury scientific community. Through this effort, we will be able to explore the extent of existing mercury monitoring capabilities, gaps in coverage, and raise awareness of the need for future integrated long-term monitoring programs.

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Is Atmospheric Deposition a Significant Source of Phosphorus to Coastal Plain Estuaries?

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We have examined the atmospheric loading of phosphorus in the context of a nutrient budget for the Delaware Inland Bays. Both soluble reactive phosphorus (SRP, orthophosphate) and total dissolved phosphorus (TDP) were measured in precipitation collected on an event basis at the Lewes NADP/AIRMoN site. Several lines of evidence suggest that atmospheric P in this region is primarily of terriginous or biogenic origin. Preliminary data indicate that most of the P in precipitation is in inorganic form (TDP:SRP ≈ 1.25), and exhibits little regional geographic variation. Dry deposition of P was estimated based on size-segregated aerosol concentrations and representative deposition velocities. Both wet (125 – 185 kg/yr) and dry deposition (~325 kg/yr) to surface waters is highest in the spring and early summer, when potential primary production in the Bays is at its maximum; however, it is uncertain what fraction of the dry deposited P is bioavailable. Based on these estimates, the total atmospheric input to the Inland Bays (450 - 500 kg/yr) is comparable to the annual watershed load, but is an order of magnitude smaller than the P input from the Rehoboth wastewater treatment plant (which is slated for removal under the state-mandated TMDL). Overall, atmospheric P deposition currently represents ≤ 4% of the total annual P load, but may influence primary production at times of the year and in regions of the bays that are P limited.

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Applications of a Regional-Scale Mercury Deposition Model to Watershed Loading Estimates

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The Power Plant Research Program in the Maryland Department of Natural Resources has developed a mercury deposition modeling capability to assess the impact of regional emission sources on the State and the Chesapeake Bay watershed. All freshwater impoundments in Maryland are subject to fish consumption advisories for mercury and the source of the mercury causing the impairments is deposition from the atmosphere. While the emissions domain is regional, it does encompass approximately 50% of the total US inventory and over 60% of the electricity generating unit [EGU] emissions. The Lagrangian formulation of the model allows source – receptor relationships to be established between sources in the emissions domain and specified receptor locations. As with other atmospheric mercury models, there is a lack of observational data for performance verification: Comparisons of predicted and monitored ambient speciated mercury from a site in western Maryland are presented. Also, predictions of wet deposition are compared to observations from the NADP-MDN network. The role of global background mercury and its contribution to deposition loading in the US has been controversial. This modeling shows that background contributes between 25 and 50 % of wet deposition loading at the MDN sites investigated. This value depends upon the separation of the monitoring site from local and regional sources that are affecting it. The more distant a source is, the larger is the contribution from background. The results from the current applications of the model to assess total deposition loading at TMDL-affected sites within Maryland and for the Chesapeake Bay generally are presented. A source by source ranking is presented as well as the predicted effect of emission reductions required under the EPA's Clean Air Mercury Rule and the Maryland Healthy Air Act. In addition, a program to improve the model validation data set is discussed.

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Observations of Nutrient Deposition in the Maryland Coastal Bays

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Atmospheric deposition has been identified as a significant source of excess nutrient nitrogen to the Coastal Bays ecosystem. To assess this nutrient source, the monitoring station in the National Atmospheric Deposition Program [NADP] National Trends Network [NTN] designated MD18 has operated at the Assateague Island National Seashore since 2000. MD18 is fairly unique in the NTN in that it is a coastal site and hence impacted by ocean input. Data from MD18 are compared to those from MD13, a site on the eastern shore of the Chesapeake Bay with a more than 20-year period of record and NJ00 also a coastal site associated with the New Jersey Coastal Bays. Data from the CASTnet site BWR139 are included in the MD18 analysis to provide estimates of total deposition. The dry deposition site, BWR139, is located at the Blackwater Wildlife Refuge about 50 miles due east of MD18 and located on the eastern shore of the Chesapeake Bay. The landscape settings at the two monitoring sites are similar [coastal plain, cleared of forest] and temporal patterns in wet deposition are similar hence dry deposition at BWR139 was taken as a surrogate for dry deposition at MD18 without the local sea salt effect. Deposition of reduced nitrogen [ammonia and ammonium] is a particular concern due to the intensive confined animal [chicken] feeding operations on the Delmarva Peninsular. Ammonium in wet deposition appears to dominate this form and shows a generally increasing trend over time with the seasonal maximum occurring in the spring and summer at all three sites. While the last 5-year period of record at all three sites does not provide a statistically significant trend in wet nitrate deposition there is a downward trend at MD13 and NJ00, but an upward trend at MD18. The latter site has been shown from source-receptor modeling to be significantly impacted by local mobile and area sources of NOx, while the other two sites may be more impacted by fossil-fueled electricity generating facilities that in the east and mid-west have generally been regulated beginning in 2000. Hence apparent reductions in nitrate at MD13 and NJ00 may reflect the reductions in this source type. The NADP sites on the mid Atlantic coastal plain are beginning to provide important information for planners dealing with nutrient enrichment in the Coastal Bays, and as the period of record is extended they will become a vital data source in the recovery of these Bays.

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Dissolved Oxygen Improvements in Long Island Sound from Nitrogen Management

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Connecticut and New York began managing nitrogen sources in the early 1990's to address a seasonal offshore hypoxia problem in shared waters of Long Island Sound. State dissolved oxygen criteria were violated in bottom waters over extensive areas, often affecting more than half of the Sound. In 2000, a formal Total Maximum Daily Load (TMDL) analysis was completed by the two states and approved by EPA in April 2001. The TMDL called for about a 60% reduction in nitrogen loads from the two states, and recommended aggressive reductions in contributions from out of state sources, including atmospheric deposition.

CT and NY have made substantial progress in controlling point sources of nitrogen, primarily from sewage treatment plants. Monitoring has also shown weather-driven variation in nitrogen loads from other watershed sources that provide an opportunity to correlate loading change with oxygen response in Long Island Sound. Fourteen years of monthly monitoring data were analyzed that demonstrate the relationships among nitrogen load, nitrogen cycling in the Sound's waters, chlorophyll-a concentration, and dissolved oxygen levels.

The data support model predictions that reductions in nitrogen loads will improve oxygen condition and demonstrate a positive trend related to management actions. These empirical relationships between nitrogen loads and oxygen response are used in this presentation to estimate dissolved oxygen improvements from projected changes in atmospheric nitrogen deposition from CAIR and other nitrogen emission control initiatives. The analysis reaffirms the importance of managing nitrogen deposition if water quality goals for Long Island Sound are to be attained.

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Multivariate Linear Regression Analysis to Assess Atmospheric Ion Deposition at PA47

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Over the past century acid rain and other conditions that are the result of ion fluctuations in rain water have been shown to deleteriously affect lives and ecosystems. Air contaminants originating from countless point sources and extended sources become entrained in air parcels and are advected away from the source to be later removed from the atmosphere by either dry or wet deposition processes. The NADP network is interested in the concentrations of ions that rain-out (wet deposition).

A precipitation collection field site (PA47) has been established about 1.8 km west of Millersville through long-term funding from the Pennsylvania Department of Environmental Protection (PA-DEP) to continuously monitor liquid water equivalent (rain or melted snow). Students have been dutifully collecting samples every Tuesday in accordance with NADP collection and quality assurance protocols since the site was established in November 2002. Once the samples are collected, and after preliminary analysis at Millersville University, they are sent to national labs for detailed analysis of the following ions: Ca^{+2}, Mg^{+2}, K^+, Na^+, NH_4^+, NO_3^-, Cl^-, SO_4^{-2}, and H^+.

This study will focus on the PA47 (Millersville) NADP/NTN database. Many factors affect the concentrations of ions measured at a particular site. Arguably, the most important of these factors is the meteorology of the region and its affect on the amount of precipitation deposited from passing weather systems. Consequently, average monthly and annual concentrations can be very different from one period to the next.

The following research will attempt to quantify the effects of various meteorological variables on ion concentration fluctuations through the use of multivariate linear regression modeling. By converting Millersville University Weather Center data (temperature, vector wind, dew point/humidity, precipitation amount, station pressure, total solar insolation) into weekly averages and performing multi-linear regression analysis on the NADP site PA47 database should allow us to estimate regression coefficients for each relevant weather variable. Once the slopes and correlation coefficients are computed, we will test the ability to predict future fluctuations based on measured meteorological variables.

It is anticipated that this model will help to differentiate between the impacts of passing weather systems and other external factors affecting the concentration of ions in precipitation. Our research goal is to create and test preliminary model output statistics relating weather variables to ion concentration before expanding the research to include other factors that can affect ion concentration in precipitation such as industrialization, agriculture, and geographical influences that could increase pollutant concentrations in the region. Qualitative inferences will be made regarding these factors by comparing the regional database with local measurements.

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The OTT Pluvio Precipitation Gage from Hach Environmental Is Approved for Use at NADP Sites

Kevin Sweeney
Hach Environmental

The NADP commissioned testing of modern precipitation gages beginning in 1998. After full participation in all three phases of the formal test program, and continued design refinement through 2006, the OTT Pluvio from Hach Environmental is now approved and available for use at NADP sites.

The OTT Pluvio is already in use in critical precipitation networks throughout the world by organizations including: NWS / ASOS, German Weather Service, Hydro Quebec, Swedish Meteorological and Hydrological Institute, Danish Institute of Agriculture and Royal Netherlands Meteorological Institute. NADP sites now have the opportunity to take advantage of its unmatched performance and reliability.

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2006 Measurements of Atmospheric Mercury Species in Halifax, Nova Scotia

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This year Environment Canada's Atlantic Region has begun a sampling program to measure atmospheric mercury species from a site in Dartmouth, Nova Scotia. This program was undertaken to determine the levels of gaseous Hg species – elemental mercury (Hg^0), reactive gaseous mercury (RGM), and the particulate (Hg_p) fine fraction (<2.5 µm).

The analysis of gaseous mercury species began in January of 2006. The sampling is carried out using the Tekran integrated sampling and analysis system consisting of the 2537A analyser, the 1130 RGM sampler and the 1135 particulate Hg sampler. This poster will illustrate the trends observed in gaseous Hg species with the on-site meteorological data (winds speed and direction, air temperature, relative humidity and solar radiation) from January 30 to August 31, 2006.

The winter data set – January to March 31 - show Hg^0 having an average of 1.67ng/m^3 and a range of 1.23 to 3.33 ng/m^3; for RGM an average of 4.07 pg/m^3 with a range from the detection limit (dl) to 68.4 pg/m^3 and for Hg_p an average of 2.84 pg/m^3 and a range from dl to 27.5 pg/m^3. The levels of RGM and Hg_p are a small percentage of the TGM, 2.5% for RGM and 1.7% for Hg_p which are similar to levels observed by other researchers. The trends and events in the mercury data were also compared to the province of Nova Scotia's air quality measurements (NO, NO_x, SO_2, PM 2.5, O_3) from the Halifax air shed. The lack of correlation of the mercury species with these air quality parameters during this winter period will be discussed.

The most recent data set from the spring and summer (up to August) will be illustrated and discussed.

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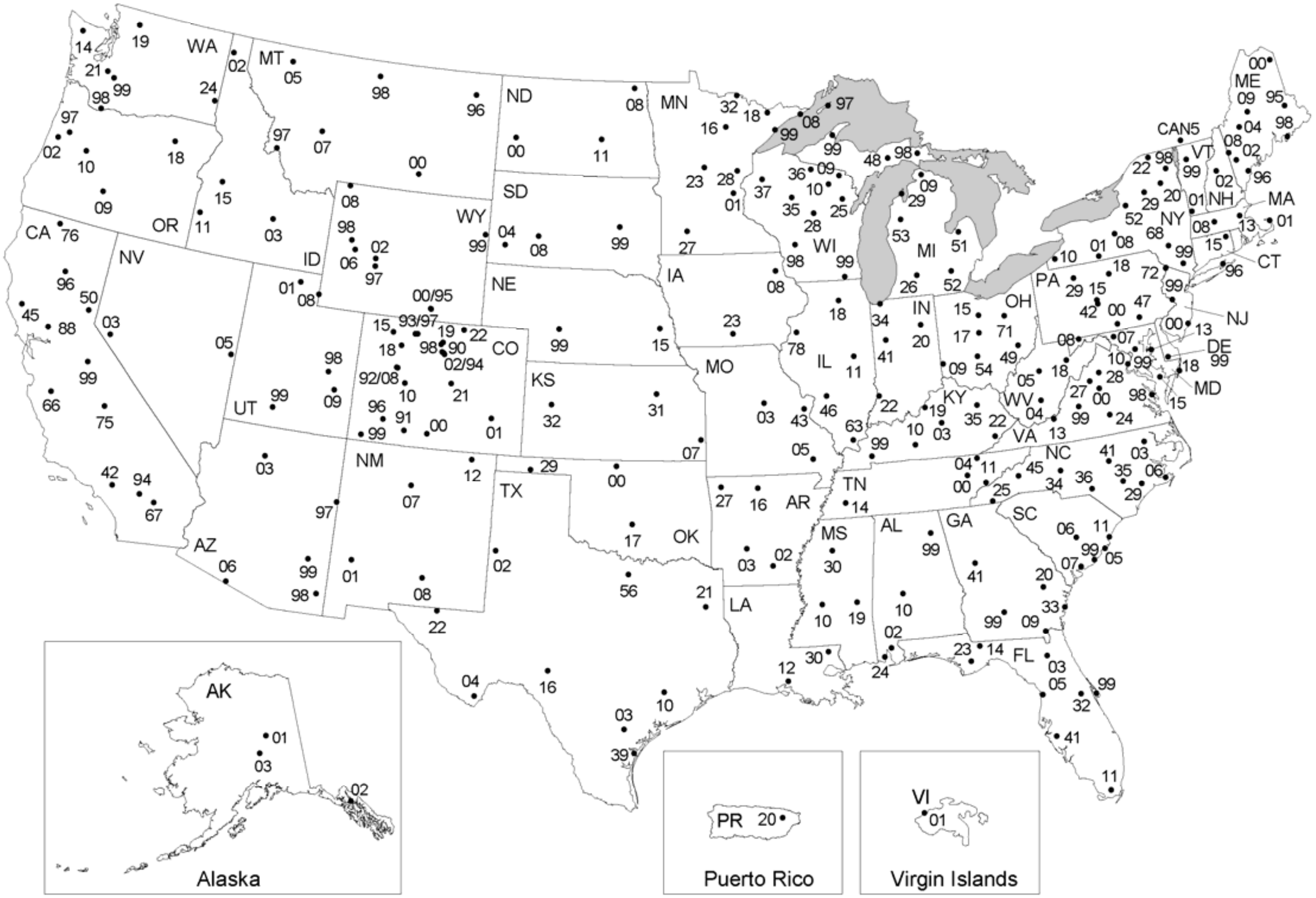
NTN MAP AND SITE LISTINGS

National Atmospheric Deposition Program
National Trends Network



National Atmospheric Deposition Program/National Trends Network Sites
August 31, 2006

State Site Code	Site Name	Collocation	Sponsoring Agencies	Start Date
Alabama				
AL02	Delta Elementary	MDN	US EPA/Mobile Bay Nat'l Estuary Prog & Dauphin Island Sea Lab	06/01
AL10	Black Belt Research & Extension Center		US Geological Survey	08/83
AL24	Bay Road	MDN	US EPA/Mobile Bay Nat'l Estuary Prog & Dauphin Island Sea Lab	05/01
AL99	Sand Mountain Research & Extension Center		Tennessee Valley Authority	10/84
Alaska				
AK01	Poker Creek		USDA Forest Service	12/92
AK02	Juneau		USDA Forest Service/University of Alaska Southeast	06/04
AK03	Denali NP - Mount McKinley		National Park Service - Air Resources Division	06/80
Arizona				
*AZ03	Grand Canyon NP - Hopi Point		National Park Service - Air Resources Division	08/81
AZ06	Organ Pipe Cactus NM		National Park Service - Air Resources Division	04/80
AZ97	Petrified Forest NP-Rainbow Forest		National Park Service - Air Resources Division	12/02
AZ98	Chiricahua		US Environmental Protection Agency-CAMD	02/99
AZ99	Oliver Knoll		US Geological Survey	08/81
Arkansas				
AR02	Warren 2WSW		US Geological Survey	05/82
AR03	Caddo Valley		US Geological Survey	12/83
AR16	Buffalo NR - Buffalo Point		National Park Service - Air Resources Division	07/82
AR27	Fayetteville		US Geological Survey	04/80
California				
CA42	Tanbark Flat		USDA Forest Service	01/82
CA45	Hopland		US Geological Survey	10/79
CA50	Sagehen Creek		US Geological Survey	11/01
CA66	Pinnacles NM - Bear Valley		National Park Service - Air Resources Division	11/99
CA67	Joshua Tree NP - Black Rock		National Park Service - Air Resources Division	09/00
CA75	Sequoia NP - Giant Forest	MDN	National Park Service - Air Resources Division	07/80
CA76	Montague		US Geological Survey	06/85
CA88	Davis		US Geological Survey	09/78
CA96	Lassen Volcanic NP - Manzanita Lake		National Park Service - Air Resources Division	06/00
CA94	Converse Flats	MDN	Big Bear Municipal Water District	05/06
CA99	Yosemite NP - Hodgdon Meadow		National Park Service - Air Resources Division	12/81
Colorado				
CO00	Alamosa		US Geological Survey	04/80
CO01	Las Animas Fish Hatchery		US Geological Survey	10/83
CO02	Niwot Saddle		NSF-Institute of Artic & Alpine Research/University of Colorado	06/84
CO08	Four Mile Park		US Environmental Protection Agency-CAMD	12/87
CO10	Gothic		US Environmental Protection Agency-CAMD	02/99
CO15	Sand Spring		Bureau of Land Management	03/79
CO18	Ripple Creek Pass		Air Sciences Incorporated	05/03
CO19	Rocky Mountain NP - Beaver Meadows		National Park Service - Air Resources Division	05/80
CO21	Manitou		USDA Forest Service	10/78
CO22	Pawnee		NSF-LTER/Colorado State University	05/79
CO90	Niwot Ridge-Southeast		NSF-Institute of Artic & Alpine Research/University of Colorado	01/06
CO91	Wolf Creek Pass		USDA Forest Service	05/92
CO92	Sunlight Peak		US Environmental Protection Agency-CAMD	01/88
CO93	Buffalo Pass - Dry Lake		USDA Forest Service	10/86
CO94	Sugarloaf		US Environmental Protection Agency-CAMD	11/86
CO96	Molas Pass		USDA Forest Service	07/86
CO97	Buffalo Pass - Summit Lake	MDN	USDA Forest Service	02/84
CO98	Rocky Mountain NP - Loch Vale		USGS/Colorado State University	08/83
CO99	Mesa Verde NP - Chapin Mesa	MDN	US Geological Survey	04/81
Connecticut				
CT15	Abington		US Environmental Protection Agency-CAMD	01/99

State Site Code	Site Name	Collocation	Sponsoring Agencies	Start Date
Delaware				
DE99	Trap Pond State Park		US EPA-CAMD/Chesapeake Bay Program	05/03
Florida				
FL03	Bradford Forest		St John's River Water Management District	10/78
FL05	Chassahowitzka NWR	MDN	US Fish & Wildlife Service - Air Quality Branch	08/96
FL11	Everglades NP - Research Center	MDN	National Park Service - Air Resources Division	06/80
FL14	Quincy		US Geological Survey	03/84
FL23	Sumatra		US Environmental Protection Agency-CAMD	01/99
FL32	Orlando	MDN	Seminole County Public Works Department	12/05
FL41	Verna Well Field		US Geological Survey	08/83
FL99	Kennedy Space Center		NASA/Dynamac Corporation	08/83
Georgia				
GA09	Okefenokee NWR	MDN	US Fish & Wildlife Service - Air Quality Branch	06/97
GA20	Bellville		US Environmental Protection Agency-CAMD	04/83
GA33	Sapelo Island		NSF/UGA, NOAA-NERR, & GA Dept of Natural Resources	11/02
GA41	Georgia Station		SAES-University of Georgia	10/78
GA99	Chula		US Geological Survey	02/94
Idaho				
ID02	Priest River Experimental Forest		USDA Forest Service	12/02
ID03	Craters of the Moon NM		National Park Service - Air Resources Division	08/80
ID11	Reynolds Creek		US Geological Survey	11/83
ID15	Smiths Ferry		US Geological Survey	10/84
Illinois				
IL11	Bondville	AIRMoN/MDN	US Environmental Protection Agency-CAMD	02/79
IL18	Shabbona		SAES-University of Illinois	05/81
IL46	Alhambra		US Environmental Protection Agency-CAMD	01/99
IL63	Dixon Springs Agricultural Center		SAES-University of Illinois	01/79
IL78	Monmouth		US Geological Survey	01/85
Indiana				
IN20	Roush Lake	MDN	US Geological Survey	08/83
IN22	Southwest-Purdue Agricultural Center		US Geological Survey	09/84
IN34	Indiana Dunes NL	MDN	National Park Service - Air Resources Division	07/80
IN41	Agronomy Center for Research and Extension		SAES-Purdue University	07/82
Iowa				
IA08	Big Springs Fish Hatchery		US Geological Survey	08/84
IA23	McNay Memorial Research Center		US Geological Survey	09/84
Kansas				
KS07	Farlington Fish Hatchery		US Geological Survey	03/84
KS31	Konza Prairie		SAES-Kansas State University	08/82
KS32	Lake Scott State Park		US Geological Survey	03/84
Kentucky				
KY03	Mackville		US Geological Survey	11/83
KY10	Mammoth Cave NP-Houchin Meadow	MDN	National Park Service - Air Resources Division	08/02
KY19	Seneca Park		US Geological Survey	10/03
KY22	Lilley Cornett Woods		NOAA-Air Resources Lab	09/83
KY35	Clark State Fish Hatchery		US Geological Survey	08/83
KY99	Mulberry Flats		TVA/Murray State University	12/94
Louisiana				
LA12	Iberia Research Station		US Geological Survey	11/82
LA30	Southeast Research Station		US Geological Survey	01/83
Maine				
ME00	Caribou		NOAA-Air Resources Lab	04/80
ME02	Bridgton	MDN	EPA/Maine Dept of Environmental Protection	09/80
ME04	Carrabassett Valley		US Environmental Protection Agency-CAMD	03/02
ME08	Gilead		US Geological Survey	09/99
ME09	Greenville Station	MDN	SAES-University of Maine	11/79
ME95	Wolapomomqot Ciw Wocuk	MDN	EPA/Passamaquoddy Tribe	06/02
ME96	Casco Bay - Wolfe's Neck Farm	MDN	EPA/Maine Dept of Environmental Protection	01/98
ME98	Acadia NP - McFarland Hill	MDN	National Park Service - Air Resources Division	11/81

State Site Code	Site Name	Collocation	Sponsoring Agencies	Start Date
Maryland				
MD07	Catoctin Mountain Park		National Park Service - Air Resources Division	05/03
MD08	Piney Reservoir	MDN	MD DNR/University of Maryland-Appalachian Lab	06/04
MD13	Wye		SAES-University of Maryland	03/83
MD15	Smith Island		NOAA-Air Resources Lab	06/04
MD18	Assateague Island NS - Woodcock		Maryland Department of Natural Resources	09/00
MD99	Beltswille	MDN	Maryland Department of Natural Resources	06/04
Massachusetts				
MA01	North Atlantic Coastal Lab	MDN	National Park Service - Air Resources Division	12/81
MA08	Quabbin Reservoir		Northeast States for Coordinated Air Use Management	03/82
MA13	East		Northeast States for Coordinated Air Use Management	02/82
Michigan				
MI09	Douglas Lake-University Michigan Biological Station		SAES-Michigan State University	07/79
MI26	Kellogg Biological Station		SAES-Michigan State University	06/79
MI29	Peshawbestown		US Environmental Protection Agency-CAMD	01/02
MI48	Seney NWR - Headquarters	MDN	US Fish & Wildlife Service - Air Quality Branch	11/00
MI51	Unionville		US Environmental Protection Agency-CAMD	01/99
MI52	Ann Arbor		US Environmental Protection Agency-CAMD	01/99
MI53	Wellston		USDA Forest Service	10/78
MI97	Isle Royale NP - Wallace Lake		National Park Service - Air Resources Division	05/85
MI98	Raco		US Environmental Protection Agency-CAMD	05/84
MI99	Chassell		National Park Service - Air Resources Division	02/83
Minnesota				
MN01	Cedar Creek		Minnesota Pollution Control Agency	12/96
MN08	Hovland		Minnesota Pollution Control Agency	12/96
MN16	Marcell Experimental Forest	MDN	USDA Forest Service	07/78
MN18	Fernberg	MDN	US Environmental Protection Agency-CAMD	11/80
MN23	Camp Ripley	MDN	US Geological Survey	10/83
MN27	Lamberton	MDN	Minnesota Pollution Control Agency	01/79
MN28	Grindstone Lake		Minnesota Pollution Control Agency	12/96
MN32	Voyageurs NP - Sullivan Bay		National Park Service - Air Resources Division	05/00
MN99	Wolf Ridge		Minnesota Pollution Control Agency	12/96
Mississippi				
MS10	Clinton		US Geological Survey	07/84
MS19	Newton		NOAA-Air Resources Lab	11/86
MS30	Coffeeville		Tennessee Valley Authority	07/84
Missouri				
MO03	Ashland Wildlife Area		US Geological Survey	10/81
MO05	University Forest		US Geological Survey	10/81
MO43	Tyson Research Center		Washington University-Tyson Research Center	08/01
Montana				
MT00	Little Bighorn Battlefield NM		US Geological Survey	07/84
MT05	Glacier NP - Fire Weather Station	MDN	National Park Service - Air Resources Division	06/80
MT07	Clancy		US Geological Survey	01/84
MT96	Poplar River		EPA/Fort Peck Tribes	12/99
MT97	Lost Trail Pass		USDA Forest Service	09/90
MT98	Havre - Northern Agricultural Research Center		US Geological Survey	07/85
Nebraska				
NE15	Mead		SAES-University of Nebraska	07/78
NE99	North Platte Agricultural Experiment Station		US Geological Survey	09/85
Nevada				
NV03	Smith Valley		US Geological Survey	08/85
NV05	Great Basin NP - Lehman Caves		National Park Service - Air Resources Division	01/85
New Hampshire				
NH02	Hubbard Brook		USDA Forest Service	07/78
New Jersey				
NJ00	Edwin B Forsythe NWR		US Fish & Wildlife Service - Air Quality Branch	10/98
NJ99	Washington Crossing		US Environmental Protection Agency-CAMD	08/81

State Site Code	Site Name	Collocation	Sponsoring Agencies	Start Date
New Mexico				
NM01	Gila Cliff Dwellings NM		EPA/New Mexico Environment Department	07/85
NM07	Bandelier NM		DOE-Los Alamos National Lab	06/82
NM08	Mayhill		US Geological Survey	01/84
NM12	Capulin Volcano NM		EPA/New Mexico Environment Department	11/84
New York				
NY01	Alfred		US Geological Survey	08/04
NY08	Aurora Research Farm		USDA/Cornell University	04/79
NY10	Chautauqua		US Geological Survey	06/80
NY20	Huntington Wildlife	MDN	EPA/SUNY-College of Environmental Science & Forestry	10/78
NY22	Akwesasne Mohawk - Fort Covington		US Environmental Protection Agency-CAMD	08/99
NY29	Moss Lake		US Geological Survey	07/03
NY52	Bennett Bridge		EPA/State Univ of New York-Oswego	06/80
NY68	Biscuit Brook	MDN	US Geological Survey	10/83
NY96	Cedar Beach, Southold		EPA/Suffolk Dept of Health Service-Peconic Estuary Program	11/03
NY98	Whiteface Mountain		US Geological Survey	07/84
NY99	West Point		US Geological Survey	09/83
North Carolina				
NC03	Lewiston		North Carolina State University	10/78
NC06	Beaufort		US Environmental Protection Agency-CAMD	01/99
NC25	Coweeta		USDA Forest Service	07/78
NC29	Hofmann Forest		North Carolina State University	07/02
NC34	Piedmont Research Station		North Carolina State University	10/78
NC35	Clinton Crops Research Station		North Carolina State University	10/78
NC36	Jordan Creek		US Geological Survey	10/83
NC41	Finley Farms		North Carolina State University	10/78
NC45	Mount Mitchell		North Carolina State University	11/85
North Dakota				
ND00	Theodore Roosevelt NP-Painted Canyon		National Park Service-Air Resources Division	01/01
ND08	Icelandic State Park		US Geological Survey	10/83
ND11	Woodworth		US Geological Survey	11/83
Ohio				
OH09	Oxford		US Geological Survey	08/84
OH15	Lykens		US Environmental Protection Agency-CAMD	01/99
OH17	Delaware		USDA Forest Service	10/78
OH49	Caldwell		US Geological Survey	09/78
OH54	Deer Creek State Park		US Environmental Protection Agency-CAMD	01/99
OH71	Wooster		US Geological Survey	09/78
Oklahoma				
OK00	Salt Plains NWR		US Geological Survey	12/83
OK17	Great Plains Apiaries		NOAA-Air Resources Lab	03/83
OK29	Goodwell Research Station		US Geological Survey	01/85
Oregon				
OR02	Alsea Guard Ranger Station		US Environmental Protection Agency-CAMD	12/79
OR09	Silver Lake Ranger Station		US Geological Survey	08/83
OR10	H J Andrews Experimental Forest	MDN	USDA Forest Service	05/80
OR18	Starkey Experimental Forest		US Geological Survey	03/84
OR97	Hyslop Farm		US Environmental Protection Agency-CAMD	04/83
Pennsylvania				
PA00	Arendtsville	MDN	US Environmental Protection Agency-CAMD	01/99
PA15	Penn State	AIRMoN	NOAA-Air Resources Lab	06/83
PA18	Young Woman's Creek		US Geological Survey	04/99
PA29	Kane Experimental Forest		USDA Forest Service	07/78
PA42	Leading Ridge		SAES-Pennsylvania State University	04/79
PA47	Millersville	MDN	Pennsylvania Department of Environmental Protection	11/02
PA72	Milford	MDN	USDA Forest Service	12/83
Puerto Rico				
PR20	El Verde		USDA Forest Service	02/85

State Site Code	Site Name	Collocation	Sponsoring Agencies	Start Date
South Carolina				
SC05	Cape Romain NWR	MDN	US Fish & Wildlife Service - Air Quality Branch	11/00
SC06	Santee NWR		US Geological Survey	07/84
SC07	Ace Basin NERR		NOAA/South Carolina Department of Natural Resources	12/01
SC11	North Inlet-Winyah Bay NERR		EPA/South Carolina Dept of Health and Environmental Control	01/02
SC99	Fort Johnson		EPA/South Carolina Dept of Health and Environmental Control	03/02
South Dakota				
SD04	Wind Cave National Park-Elk Mountain		National Park Service - Air Resources Division	11/02
SD08	Cottonwood		NOAA-Air Resources Lab	10/83
SD99	Huron Well Field		US Geological Survey	11/83
Tennessee				
TN00	Walker Branch Watershed	AIRMoN	DOE/Oak Ridge National Lab/Lockheed-Martin	03/80
TN04	Speedwell		US Environmental Protection Agency-CAMD	01/99
TN11	Great Smoky Mountain NP - Elkmont	MDN	National Park Service - Air Resources Division	08/80
TN14	Hatchie NWR		Tennessee Valley Authority	10/84
Texas				
TX02	Muleshoe NWR		US Geological Survey	06/85
TX03	Beeville		NOAA-Air Resources Lab	02/84
TX04	Big Bend NP - K-Bar		National Park Service - Air Resources Division	04/80
TX10	Attwater Prairie Chicken NWR		US Geological Survey	07/84
TX16	Sonora		US Geological Survey	06/84
TX21	Longview	MDN	Texas Commission on Environmental Quality	06/82
TX22	Guadalupe Mountains NP-Frijole Ranger Stn		US Geological Survey	06/84
TX39	Texas A & M Corpus Christi		EPA/Texas A&M University	01/02
TX56	LBJ National Grasslands		US Geological Survey	09/83
Utah				
UT01	Logan		US Geological Survey	12/83
UT08	Murphy Ridge		BP Amoco	03/86
UT09	Canyonlands NP - Island in the Sky		National Park Service - Air Resources Division	11/97
UT98	Green River		US Geological Survey	04/85
UT99	Bryce Canyon NP - Repeater Hill		National Park Service - Air Resources Division	01/85
Vermont				
VT01	Bennington		US Geological Survey	04/81
*VT99	Underhill	AIRMoN/MDN	US Geological Survey	06/84
Virgin Islands				
VI01	Virgin Islands NP - Lind Point		National Park Service - Air Resources Division	04/98
Virginia				
VA00	Charlottesville		US Geological Survey	10/84
VA10	Mason Neck Wildlife Refuge		Virginia Department of Environmental Quality	08/03
VA13	Horton's Station		Tennessee Valley Authority	07/78
VA24	Prince Edward		US Environmental Protection Agency-CAMD	01/99
VA27	James Madison University Farm		US Environmental Protection Agency-CAMD	07/02
VA28	Shenandoah NP - Big Meadows	MDN	National Park Service - Air Resources Division	05/81
VA98	Harcum	MDN	Virginia Department of Environmental Quality	08/04
VA99	Natural Bridge Station		Virginia Department of Environmental Quality	07/02
Washington				
WA14	Olympic NP - Hoh Ranger Station		National Park Service - Air Resources Division	05/80
WA19	North Cascades NP-Marblemount Ranger Stn		US Geological Survey	02/84
WA21	La Grande		US Environmental Protection Agency-CAMD	04/84
WA24	Palouse Conservation Farm		US Geological Survey	08/85
WA98	Columbia River Gorge		USDA Forest Service - Pacific Northwest Region	05/02
WA99	Mount Rainier NP - Tahoma Woods		National Park Service - Air Resources Division	10/99
West Virginia				
WV04	Babcock State Park		US Geological Survey	09/83
WV05	Cedar Creek State Park		US Environmental Protection Agency-CAMD	01/99
WV18	Parsons		USDA Forest Service	07/78

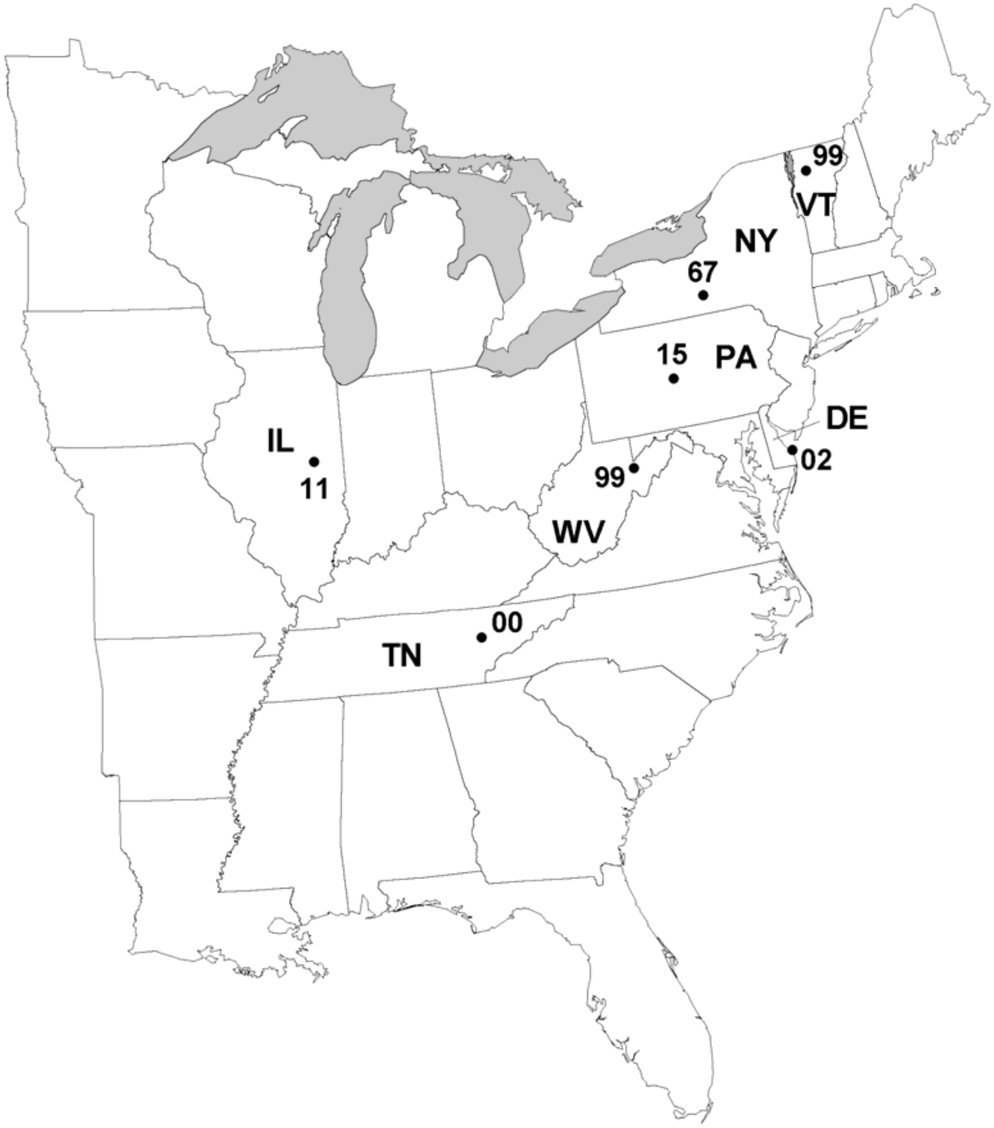
State Site Code	Site Name	Collocation	Sponsoring Agencies	Start Date
Wisconsin				
WI09	Popple River	MDN	Wisconsin Department of Natural Resources	12/86
WI10	Potawatomi	MDN	EPA/Forest County Potawatomi Community	06/05
WI25	Suring		Wisconsin Department of Natural Resources	01/85
WI28	Lake Dubay		Wisconsin Department of Natural Resources	06/82
WI35	Perkinstown		US Environmental Protection Agency-CAMD	01/99
WI36	Trout Lake	MDN	Wisconsin Department of Natural Resources	01/80
WI37	Spooner		Wisconsin Department of Natural Resources	06/80
*WI98	Wildcat Mountain		Wisconsin Department of Natural Resources	08/89
WI99	Lake Geneva	MDN	Wisconsin Department of Natural Resources	06/84
Wyoming				
WY00	Snowy Range		USDA Forest Service	04/86
WY02	Sinks Canyon		Bureau of Land Management	08/84
WY06	Pinedale		Bureau of Land Management	01/82
WY08	Yellowstone NP - Tower Falls	MDN	National Park Service - Air Resources Division	06/80
WY95	Brooklyn Lake		USDA Forest Service	09/92
WY97	South Pass City		USDA Forest Service/Rocky Mountain Region	04/85
WY98	Gypsum Creek		USDA Forest Service/Bridger Teton NF	12/84
WY99	Newcastle		Bureau of Land Management	08/81
Canada				
CAN5	Frelighsburg		US Geological Survey	10/01

*At these sites the U.S. Geological Survey (VT99 & WI98) and National Park Service - Air Resources Division (AZ03) sponsor a second collector for measuring network precision.

AIRMoN MAP AND SITE LISTING

National Atmospheric Deposition Program

Atmospheric Integrated Research Monitoring Network



NADP/Atmospheric Integrated Research Monitoring Network Sites
August 31, 2006

State Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Delaware				
DE02	Lewes		NOAA-Air Resources Laboratory	09/92
Illinois				
IL11	Bondville	MDN & NTN	NOAA-Air Resources Laboratory	10/92
New York				
NY67	Cornell University		NOAA-Air Resources Laboratory	09/92
Pennsylvania				
PA15	Penn State	NTN	NOAA-Air Resources Laboratory	10/92
Tennessee				
TN00	Oak Ridge National Lab	NTN	NOAA-Air Resources Laboratory	09/92
Vermont				
VT99	Underhill	MDN & NTN	NOAA-Air Resources Laboratory	01/93
West Virginia				
WV99	Canaan Valley Institute		NOAA-Air Resources Laboratory	06/00

MDN MAP AND SITE LISTINGS

National Atmospheric Deposition Program
Mercury Deposition Network

National Atmospheric Deposition Program/Mercury Deposition Network Sites
August 31, 2006

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Alabama				
AL02	Delta Elementary	NTN	US EPA/Mobile Bay National Estuary Prog & Dauphin Island Sea Lab	06/01
AL03	Centreville		Southern Company/Atmospheric Research and Analysis, Inc	06/00
AL24	Bay Road	NTN	US EPA/Mobile Bay National Estuary Prog & Dauphin Island Sea Lab	05/01
Arizona				
AZ02	Sycamore Canyon		Arizona Department of Environmental Quality	02/06
California				
CA20	Yurok Tribe-Requa		US Geological Survey	08/06
CA72	San Jose		San Francisco Estuary Institute	01/00
CA75	Sequoia NP-Giant Forest	NTN	National Park Service - Air Resources Division	07/03
CA94	Converse Flats	NTN	Big Bear Municipal Water District	04/06
Colorado				
CO97	Buffalo Pass - Summit Lake	NTN	USDA Forest Service-Rocky Mountain Research Station	09/98
CO99	Mesa Verde NP-Chapin Mesa	NTN	Colorado Department of Public Health and Environment	12/01
Florida				
FL04	Andytown		South Florida Water Management District	01/98
FL05	Chassahowitzka NWR	NTN	US Fish & Wildlife Service - Air Quality Branch	07/97
FL11	Everglades NP - Research Center	NTN	South Florida Water Management District	*03/96
FL32	Orlando	NTN	St Johns River Water Management District	09/03
FL34	Everglades Nutrient Removal Project		South Florida Water Management District	07/97
Georgia				
GA09	Okefenokee NWR	NTN	US Fish & Wildlife Service - Air Quality Branch	07/97
GA40	Yorkville		Southern Company/Atmospheric Research and Analysis, Inc	06/00
Illinois				
IL11	Bondville	AIRMoN/NTN	NADP/Illinois State Water Survey	*01/99
Indiana				
IN20	Roush Lake	NTN	Indiana Department of Environmental Management/USGS	10/00
IN21	Clifty Falls State Park		Indiana Department of Environmental Management/USGS	01/01
IN26	Fort Harrison State Park		Indiana Department of Environmental Management/USGS	04/03
IN28	Bloomington		Indiana Department of Environmental Management/USGS	12/00
IN34	Indiana Dunes NL	NTN	Indiana Department of Environmental Management/USGS	10/00
Kentucky				
KY10	Mammoth Cave NP-Houchin Meadow	NTN	National Park Service - Air Resources Division	08/02
Louisiana				
LA05	Lake Charles		Louisiana Department of Environmental Quality	10/98
LA10	Chase		Louisiana Department of Environmental Quality	10/98
LA23	Alexandria		Louisiana Department of Environmental Quality	02/01
LA28	Hammond		Louisiana Department of Environmental Quality	10/98
Maine				
ME02	Bridgton	NTN	EPA/Maine Department of Environmental Protection	06/97
ME09	Greenville Station	NTN	EPA/Maine Department of Environmental Protection	09/96
ME95	Wolapomomqot Ciw Wocuk	NTN	EPA/Passamaquoddy Tribe	10/05
ME96	Casco Bay - Wolfe's Neck Farm	NTN	EPA/Maine Department of Environmental Protection	01/98
ME98	Acadia NP - McFarland Hill	NTN	NPS-Acadia NP & EPA/Maine Dept of Environmental Protection	*03/96

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Maryland				
MD08	Piney Reservoir	NTN	MD DNR/University of Maryland-Appalachian Lab	06/04
MD99	Beltsville	NTN	Maryland Department of Natural Resources	06/04
Massachusetts				
MA01	North Atlantic Coastal Lab	NTN	NPS - Cape Cod National Seashore	07/03
Michigan				
MI31	Sterling		US Geological Survey	09/05
MI48	Seney NWR - Headquarters	NTN	US Fish & Wildlife Service-Air Quality Branch	11/03
Minnesota				
MN16	Marcell Experimental Forest	NTN	USDA Forest Service-North Central Research Station & MNPCA	*02/96
MN18	Fernberg	NTN	USDA Forest Service-Superior National Forest & MNPCA	*03/96
MN22	Mille Lacs Band of Ojibwe		EPA/Mille Lacs Band of Ojibwe	04/02
MN23	Camp Ripley	NTN	Minnesota Pollution Control Agency	07/96
MN27	Lamberton	NTN	Minnesota Pollution Control Agency	07/96
Mississippi				
MS22	Oak Grove		Southern Company/Atmospheric Research and Analysis, Inc	06/00
Missouri				
MO46	Mingo NWR		EPA/Missouri Department of Natural Resources	03/02
Montana				
MT05	Glacier NP - Fire Weather Station	NTN	National Park Service - Air Resources Division	10/03
New Jersey				
NJ30	New Brunswick		US Geological Survey	01/06
New Mexico				
NM10	Caballo		Bureau of Reclamation/New Mexico State University	05/97
New York				
NY20	Huntington Wildlife	NTN	EPA/Syracuse University	12/99
NY68	Biscuit Brook	NTN	US Geological Survey	03/04
North Carolina				
NC08	Waccamaw State Park		North Carolina Dept of Environment & Natural Resources	*02/96
NC26	Candor		North Carolina Dept of Environment & Natural Resources	11/05
NC42	Pettigrew State Park		North Carolina Dept of Environment & Natural Resources	*02/96
North Dakota				
ND01	Lostwood NWR		U S Environmental Protection Agency	11/03
Ohio				
OH02	Athens Super Site		EPA/Ohio University	12/04
Oklahoma				
OK15	Newkirk		EPA/Cherokee Nation	03/05
OK99	Stilwell		EPA/Cherokee Nation	04/03
Oregon				
OR01	Beaverton		EPA/Oregon Department of Environmental Quality	04/03
OR10	HJ Andrews Experimental Forest	NTN	EPA/Oregon Department of Environmental Quality	12/02

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Pennsylvania				
PA00	Arendtsville	NTN	PA Dept of Environmental Protection/Penn State University	11/00
PA13	Allegheny Portage Railroad NHS		PA Dept of Environmental Protection/Penn State University	01/97
PA19	Centralia		PA Dept of Environmental Protection/Penn State University	05/06
PA30	Erie		PA Dept of Environmental Protection/Penn State University	06/00
PA37	Holbrook		Electric Power Research Institute	05/99
PA47	Millersville	NTN	PA Dept of Environmental Protection/Penn State University	11/02
PA60	Valley Forge		PA Dept of Environmental Protection/Penn State University	11/99
PA72	Milford	NTN	PA Dept of Environmental Protection/Penn State University	09/00
PA90	Hills Creek State Park		PA Dept of Environmental Protection/Penn State University	01/97
South Carolina				
SC05	Cape Romaine NWR		US Fish & Wildlife Service - Air Quality Branch	03/04
SC09	Alibi Hunt Club		US Geological Survey	11/05
SC19	Congaree Swamp	NTN	South Carolina Dept of Health & Environmental Control	*03/96
Tennessee				
TN11	Great Smoky Mountains NP-Elkmont	NTN	National Park Service - Air Resources Division	01/02
Texas				
TX21	Longview	NTN	Texas Commission on Environmental Quality	*03/96
Virginia				
VA08	Culpeper		US Geological Survey	11/02
VA28	Shenandoah NP-Big Meadows	NTN	National Park Service - Air Resources Division	10/02
VA98	Harcum	NTN	Virginia Department of Environmental Quality	12/04
Vermont				
VT99	Underhill	AIRMoN/NTN	NOAA-ARL/University of Vermont	07/04
Washington				
**WA18	Seattle - NOAA		Illinois State Water Survey & Frontier Geosciences Inc	03/96
Wisconsin				
**WI08	Brule River		Wisconsin Department of Natural Resources	*03/96
WI09	Popple River	NTN	Wisconsin Department of Natural Resources	*03/96
WI10	Potawatomi	NTN	EPA/Forest County Potawatomi Community	06/05
WI22	Milwaukee		Wisconsin Department of Natural Resources	10/02
WI31	Devils Lake		Wisconsin Department of Natural Resources	01/01
WI32	Middle Village		EPA/Menominee Indian Tribe	01/02
WI36	Trout Lake	NTN	Wisconsin Department of Natural Resources	*03/96
WI99	Lake Geneva	NTN	Wisconsin Department of Natural Resources	01/97
Wyoming				
WY08	Yellowstone NP-Tower Falls	NTN	National Park Service - Air Resources Division	10/04
CANADA				
Alberta				
AB13	Henry Kroeger		ATCO Power	09/04
AB14	Genesee		TransAlta and EPCOR	07/06
Newfoundland				
NF09	Cormak		Environment Canada	05/00
Nova Scotia				
NS01	Kejimkujik NP		Environment Canada	07/96
Ontario				
ON07	Egbert		Environment Canada	03/00

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Quebec				
PQ04	Saint Anicet		Environment Canada	04/98
PQ05	Mingan		Environment Canada	04/98
Saskatchewan				
SK12	Bratt’s Lake BSRN		Environment Canada	05/01

*These dates mark the official start of NADP/MDN operations. Data for a transition network operating in 1995 and early 1996 are available from the NADP web site at http://nadp.sws.uiuc.edu/mdn/mdn_trandata_rpt.html.

**At this site the NADP Program Office sponsors a second collector for the purpose of measuring network precision.

PROCEEDINGS NOTES

Proceeding Notes

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