



NATIONAL ATMOSPHERIC DEPOSITION PROGRAM

**NADP 2005:
Science Supporting Resource Management**

27 – 30 September 2005 Jackson, Wyoming

**NADP 2005
Technical Committee Meeting**

September 27-30, 2005
Jackson, Wyoming

Technical Program Chair
Kristi Morris
National Park Service
Air Resources Division
Denver, Colorado

PROCEEDINGS

Prepared by

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September 2005

The cover photograph was taken by 15 year-old, Kyle Goetzelmann of Wheeling, Illinois. Kyle used a remote control plane to take the photo in Grand Teton National Park. He has graciously given the NADP permission to use his work. We thank Kyle for his generosity and compliment him on his talent in combining art with the hobby of flying remote control planes. You can see more of Kyle's aerial photographs at <http://www.kyle.rchomepage.com/pictures.html>.

Additional thanks to Roger Claybrooke for graphic support and Nichole Samson for her editing and clerical support.

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NADP TECHNICAL COMMITTEE MEETING AGENDA

NADP 2005 Technical Committee Meeting Block Agenda Jackson, Wyoming

27-Sep-2005		28-Sep-2005		
Time	Tuesday	Wednesday	Time	
0700	Registration Open	Registration Open	0700	
0730			0730	
0800	Joint Subcommittee Meeting (Open Membership)	Annual Technical Committee Business Meeting	0800	
0820			0820	
0840			0840	
0900			0900	
0920			0920	
0940		(break)	0940	
1000	(break)	Critical Loads: Perspectives from Regulatory and Land Management Agencies (Session Chair: <i>Kathy Tonnessen, NPS</i>)	Porter - Critical Loads and Target Loads for Atmospheric Deposition: Tools for Natural Resource Assessment and Protection	1000
1015	Subcommittee Meetings (Open Membership) Subcommittees: Network Operations (NOS) Data Management (DMAS) Environmental Research and Outreach (EROS)		Birnbaum - Protecting Ecosystems: An EPA Perspective on What Critical Loads Can Offer	1015
1020			Shaver - Critical Loads as a Management Tool: National Park Service Perspectives	1020
1030			Fisher - Where Science and Policy Meet: Critical Loads in the USDA Forest Service	1030
1045			D. Johnson - Critical Loads as a Policy Framework for Air Quality Management in Western States	1045
1100			Timoffee - Critical Loads: Assessing Atmospheric Deposition to Ecosystems in Canada	1100
1115			Panel Discussion	1115
1130				
1200	Lunch (on your own)	Lunch (on your own)	1200	
1230			1230	
1300			1300	
1330	Subcommittee Meetings (Open Membership)	Atmospheric Deposition: Source Investigation and Pollutant Cycling (Session Chair: <i>Rick Artz, NOAA</i>)	Elliott - A National Survey of Nitrate Isotopes in Precipitation: What Can Isotopes Tell Us about NO _x Sources at Multiple Scales?	1330
1350			Welker - Isotopes in Precipitation Across the US: Integration with National Programs and Data Highlights	1350
1410			Story - Greater Yellowstone Area Air Quality Assessment Update 2005	1410
1430			Aneja - Trends in Agricultural Ammonia Emissions and Ammonium Concentrations in Precipitation over the Southeast and Midwest United States	1430
1450			Butler - A History of NY67 (Ithaca NY) from Prenatal to Post Partum	1450
1510	Executive Committee Meeting	Lamb - AIRMoN at Penn State: Attempts to Link Wet Deposition to Atmospheric Processes	1510	
1530		(break)	1530	
1550		Spatial and Temporal Trends in Deposition (Session Chair - <i>Mark Nilles, USGS</i>)	Clow - Coherence of Variability in Precipitation Chemistry	1550
1610			Stensland - Comparison of Two Methods to Calculate Wet Deposition for 1985-2000	1610
1630			M. Williams - National Isoleth Maps of Inorganic N Under-represent Western Mountain Areas Because Completeness Criteria 4 Not Appropriate for Snowfall Dominated Areas	1630
1650	Ingersoll - Trends in Snowpack Chemistry During 1993-2004 in the Rocky Mountain Region, USA		1650	
1710			1710	
1730		Poster Session and Reception/Social Mixer	1730	
1800			1800	
1830			1830	
1900			1900	
1930			1930	
2000			2000	

NADP 2005 Technical Committee Meeting Block Agenda Jackson, Wyoming

29-Sep-2005 Registration Open Thursday		30-Sep-2005 Friday	
Time		Time	
0700	Estimating Total Deposition	0700	Field Trip
0730		0730	Grand Teton
0800	Measurements and Models (Session Chair: Gary Lear, U.S. EPA)	0800	National Park
0820		0820	
0840		0840	
0900		0900	
0920		0920	
0940		0940	
1000		1000	
1020	(break)	1020	
1040	Atmospheric Deposition (Session Chair: Pamela Padgett, USDA Forest Service)	1040	
1100		1100	
1120		1120	
1140		1140	
1200		1200	
1230		1230	
1300		1300	
1320		1320	
1340		1340	
1400		Origin, Transport, and Deposition of Mercury (Session Chair: Eric Prestbo, Frontier Geosciences)	1400
1420	1420		
1440	1440		
1500	1500		
1520	1520		
1540	1540		
1600	1600		
1620	1620		
1640	1640		
1700	1700		

**NADP Technical Committee Meeting
Jackson, Wyoming
September 27-29, 2005**

TUESDAY, September 27, 2005

Room Location

	Registration Desk Open All Day	
8:00 a.m. to 10:00 a.m.	Joint Committee Meeting NOS, DMAS, & EROS	Lodge Room
10:00 a.m. to 10:15 a.m.	Break	
10:15 a.m. to 12:00 p.m.	Subcommittee Meetings NOS DMAS EROS	Lodge Room Cougar Room Upper Concession Stand
12:00 p.m. to 1:30 p.m.	Lunch (on your own)	
1:30 p.m. to 2:50 p.m.	Subcommittee Meetings	
2:50 p.m. to 3:10 p.m.	Break	
3:10 p.m. to 5:00 p.m.	Executive Committee Meeting	Lodge Room

WEDNESDAY, September 28, 2005

Room Location

7:00 a.m.	Registration	
8:00 a.m. to 9:40 a.m.	Annual Technical Committee Business Meeting	Lodge Room
9:40 a.m. to 10:00 a.m.	Break	

TECHNICAL SESSION:	CRITICAL LOADS: PERSPECTIVES FROM REGULATORY AND LAND MANAGEMENT AGENCIES Session Chair: Kathy Tonnessen, National Park Service	Lodge Room
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10:00-10:15	<i>Critical Loads and Target Loads for Atmospheric Deposition: Tools for Natural Resource Assessment and Protection</i> Ellen Porter, National Park Service-Air Resources Division	
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10:15-10:30	<i>Protecting Ecosystems: An EPA Perspective on What Critical Loads Can Offer</i> Rona Birnbaum, US EPA, Office of Air and Radiation	
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10:30-10:45	<i>Critical Loads as a Management Tool: National Park Service Perspectives</i> Christine Shaver, NPS-Air Resources Division	
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10:45-11:00	<i>Where Science and Policy Meet: Critical Loads in the USDA Forest Service</i> Rich Fisher, USDA Forest Service	
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WEDNESDAY, September 28, 2005

Room Location

TECHNICAL SESSION:	CRITICAL LOADS: PERSPECTIVES FROM REGULATORY AND LAND MANAGEMENT AGENCIES (CONTINUED) Session Chair: Kathy Tonnessen, National Park Service	Lodge Room
11:00-11:15	<i>Critical Loads as a Policy Framework for Air Quality Management in Western States</i> Dan Johnson, Western States Air Resources Council (WESTAR)	
11:15-11:30	<i>Critical Loads: Assessing Atmospheric Deposition to Ecosystems in Canada</i> Kerri Timoffee, Environment Canada, Quebec	
11:30-12:00	Panel Discussion	
12:00 p.m. to 1:30 p.m.	Lunch (on your own)	
TECHNICAL SESSION:	ATMOSPHERIC DEPOSITION: SOURCE INVESTIGATION AND POLLUTANT CYCLING Session Chair: Rick Artz, National Oceanic and Atmospheric Administration	Lodge Room
1:30-1:50	<i>A National Survey of Nitrate Isotopes in Precipitation: What Can Isotopes Tell Us about NO_x Sources at Multiple Scales?</i> Emily M. Elliott, U. S. Geological Survey	
1:50-2:10	<i>Isotopes in Precipitation Across the US: Integration with National Programs and Data Highlights</i> Jeffrey Welker, University of Alaska, Anchorage	
2:10-2:30	<i>Greater Yellowstone Area Air Quality Assessment Update 2005</i> Mark T. Story, USDA Forest Service	
2:30-2:50	<i>Trends in Agricultural Ammonia Emissions and Ammonium Concentrations in Precipitation over the Southeast and Midwest United States</i> Viney P. Aneja, North Carolina State University	
2:50-3:10	<i>A History of NY67 (Ithaca NY) from Prenatal to Post Partum</i> Tom Butler, Institute of Ecosystem Studies	
3:10-3:30	<i>AIRMoN at Penn State: Attempts to Link Wet Deposition to Atmospheric Processes</i> Dennis Lamb, Penn State University	
3:30 p.m. to 3:50 p.m.	Break	
TECHNICAL SESSION:	SPATIAL AND TEMPORAL TRENDS IN DEPOSITION Session Chair: Mark Nilles, U. S. Geological Survey	
3:50-4:10	<i>Coherence of Variability in Precipitation Chemistry</i> David W. Clow, U. S. Geological Survey	

WEDNESDAY, September 28, 2005

Room Location

TECHNICAL SESSION:	SPACIAL AND TEMPORAL TRENDS IN DEPOSITION (CONTINUED)	Lodge Room
	Session Chair: Mark Nilles, U. S. Geological Survey	
4:10-4:30	<i>Comparison of Two Methods to Calculate Wet Deposition for 1985-2000</i> Gary J. Stensland, Dakota Science	
4:30-4:50	<i>National Isopleth Maps of Inorganic N Under-represent Western Mountain Areas Because Completeness Criteria 4 Not Appropriate for Snowfall Dominated Areas</i> Mark Williams, University of Colorado, Boulder	
4:50-5:10	<i>Trends in Snowpack Chemistry During 1993-2004 in the Rocky Mountain Region, USA</i> George P. Ingersoll, U. S. Geological Survey	
5:30 p.m. to 8:00 p.m.	POSTER SESSION - SOCIAL MIXER	Pavilion/Exhibition Hall

THURSDAY, September 29, 2005

Room Location

7:00 a.m.	Registration	Lodge Room
TECHNICAL SESSION:	ESTIMATING TOTAL DEPOSITION: MEASUREMENTS AND MODELS	Lodge Room
	Session Chair: Gary Lear, U. S. Environmental Protection Agency	
8:00-8:20	<i>A Brief Introduction to Dry Deposition Terminology and Methods</i> Gary Lear, U. S. Environmental Protection Agency	
8:20-8:40	<i>Instrument Evaluation of Real-time Monitoring of Gases and Aerosols</i> Michael Kolian, U. S. Environmental Protection Agency	
8:40-9:00	<i>Passive Samplers in Air Quality and Atmospheric Deposition Research</i> Andrzej Bytnerowicz, USDA Forest Service	
9:00-9:20	<i>Results of Cloudwater Deposition Research at Clingman's Dome, TN, from 2000 through 2004</i> Selma S. Isil, MACTEC	
9:20-9:40	<i>Using Ion Exchange Resin Columns to Measure Throughfall and Bulk Deposition Inputs to Forests</i> Mark E. Fenn, USDA Forest Service	
9:40-10:00	<i>An Empirical Model for Estimating Total Deposition in Complex Terrain</i> Kathleen C. Weathers, Institute of Ecosystem Studies	

THURSDAY, September 29, 2005

Room Location

	TECHNICAL SESSION: ESTIMATING TOTAL DEPOSITION: MEASUREMENTS AND MODELS (CONTINUED) Session Chair: Gary Lear, U. S. Environmental Protection Agency	Lodge Room
10:00-10:20	<i>Regional Atmospheric Modeling of Atmospheric Deposition</i> John Vimont, National Park Service	
10:20 a.m. to 10:40 a.m.	Break	
	TECHNICAL SESSION: ECOLOGICAL EFFECTS OF ATMOSPHERIC DEPOSITION Session Chair: Pamela Padgett, USDA - Forest Service	
10:40-11:00	<i>The Critical Load—A Useful Concept That Needs a Simplified Application</i> Greg Lawrence, U. S. Geological Survey	
11:00-11:20	<i>Soil Nitrogen Control of Alpine Forage Selenium Content and Its Bioavailability to Pika and Bighorn Sheep</i> Stephen E. Williams, The University of Wyoming	
11:20-11:40	<i>Negative Interactions of Air Pollutants on Thrushes in the Appalachian Mountains</i> David Evers, BioDiversity Research Institute	
11:40 a.m. to 1:00 p.m.	Lunch (on your own)	
	TECHNICAL SESSION: ECOLOGICAL EFFECTS OF ATMOSPHERIC DEPOSITION (CONTINUED) Session Chair: Pamela Padgett, USDA - Forest Service	Lodge Room
1:00-1:20	<i>Mercury In Wetlands of the Lostwood National Wildlife Refuge, North Dakota</i> Steven K. Sando, U. S. Geological Survey	
1:20-1:40	<i>Biomonitoring of Mercury in the Environment: Alaskan Seabirds and the Diamondback Terrapin as Sentinel Species</i> Rusty D. Day, National Institute of Standards and Technology	
1:40-2:00	<i>The Use of Local Mercury Deposition Measurements in Modeling the Fate, Transport and Bioaccumulation of Methylmercury on the Cheyenne River Sioux Tribal Lands</i> John M. Johnston, U.S. Environmental Protection Agency	
	TECHNICAL SESSION: ORIGIN, TRANSPORT, AND DEPOSITION OF MERCURY Session Chair: Eric Prestbo, Frontier Geosciences	
2:00-2:20	<i>Long-range Transport of Mercury to the U.S.</i> Dan Jaffe, University of Washington-Bothell	

THURSDAY, September 29, 2005

Room Location

TECHNICAL SESSION:	ORIGIN, TRANSPORT, AND DEPOSITION OF MERCURY (CONTINUED)	Lodge Room
	Session Chair: Eric Prestbo, Frontier Geosciences	
2:20-2:40	<i>Modeling of Atmospheric Mercury Deposition in the United States</i> Krish Vijayaraghavan, Atmospheric & Environmental Research, Inc.	
2:40-3:00	<i>Monitoring the Response to Changing Mercury Deposition</i> Robert P. Mason, University of Connecticut	
3:00 p.m. to 3:20 p.m.	Break	
TECHNICAL SESSION:	ORIGIN, TRANSPORT, AND DEPOSITION OF MERCURY (CONTINUED)	
	Session Chair: Eric Prestbo, Frontier Geosciences	
3:20-3:40	<i>Mercury Deposition at High-altitude and High-latitude Sites in the Western United States</i> Donald H. Campbell, U. S. Geological Survey	
3:40-4:00	<i>Atmospheric Mercury Concentrations near Salmon Falls Creek Reservoir, South-central Idaho—Where is the Mercury Coming From?</i> Michael L. Abbott, Idaho National Laboratory	
4:00-4:20	<i>Use of Geographic Information System Software to Evaluate Locations for Mercury-Deposition Monitoring in Indiana</i> Martin Risch, U.S. Geological Survey	
4:20-4:40	<i>Patterns Of Mercury Deposition and Concentration in Northeastern North America (1996-2004)</i> Alan VanArsdale, U. S. Environmental Protection Agency	
4:40-5:00	<i>Atmospheric Mercury in Rural Vermont</i> Eric K. Miller, Ecosystems Research Group, Ltd.	
5:00-5:20	<i>Mining MDN Data to Determine Local Effects of Mercury Emissions</i> John Sherwell, Maryland Dept. of Natural Resources	

Field Trip

Grand Teton National Park

September 30, 2005

Board bus at 8:00 a.m. in hotel lobby

Box lunch provided

The original Grand Teton National Park was established by Congress on February 29, 1929, which included the Teton Range and eight glacial lakes at the base of the mountains. In 1943, the Jackson Hole National Monument, decreed by Franklin Roosevelt, combined Teton National Forest acreage, other federal properties and 35,000 acres donated by John D. Rockefeller, Jr. On September 14, 1950, the original 1929 park and the 1943 National Monument were united into the present day Grand Teton National Park.

The Teton Range is an active fault-block mountain front, 40 miles long and 7 to 9 miles wide. The highest peak is Grand Teton with an elevation of 13,770 feet (4198 m). The park is a semi-arid mountain climate. Average snowfall is 191 inches (490 cm) with an average rainfall of 10 inches (26 cm). Temperatures range from an extreme high of 93 degrees F (34 degrees C) and an extreme low of -46 degrees F (-43 degrees C).

The wildlife at the park includes 17 species of carnivores, among them, black and grizzly bears. There are also six species of hoofed mammals, three species of rabbits, 22 species of rodents, six species of bats, four species of non-poisonous reptiles, five species of amphibians, 16 species of fishes and over 300 species of birds.

Flora includes seven species of coniferous trees and 900 plus species of flowering plants.

The park encompasses approximately 310,000 acres of wilderness and some of the most beautiful mountain scenery in the western United States. There are approximately 100 miles of paved roads in the park and nearly 200 miles of trails for hikers to enjoy.



2005 NADP SITE OPERATOR AWARDS

NTN Site	Site Name	Operator Name	Wet Start	Agency
10 Year Awards				
CO21	Manitou	Steve Tapia	17-Oct-78	U.S. Forest Service
MD15	Smith Island (AIRMoN (I) & NTN)	Francis "Hoss" Parks	1-Jun-04	NOAA-Air Resources Lab
NM07	Bandelier National Monument	Kay Beeley	22-Jun-82	DOE/Los Alamos National Lab
OK00	Salt Plains National Wildlife Refuge	Rodger Hill	13-Dec-83	U.S. Geological Survey
SD99	Huron Well Field	Frank Amundson	29-Nov-83	U.S. Geological Survey
TX04	Big Bend National Park-K-Bar	John Forsythe	10-Apr-80	National Park Service-ARD
TX22	Guadalupe Mountains National Park	John Cwiklik	5-Jun-84	U.S. Geological Survey
15 Year Awards				
CA88	Davis	Mike Mata	4-Sep-78	U.S. Geological Survey
IN22	Southwest Purdue Agriculture Center	Angie Thompson	25-Sep-84	U.S. Geological Survey
MT05	Glacier National Park-Fire Weather Station	Lindy Key	3-Jun-80	National Park Service-ARD
NC03	Lewiston	Margaret Pierce	31-Oct-78	North Carolina State University
NM01	Gila Cliff Dwellings National Monument	Daniel Galindo	29-Jul-85	New Mexico ED-AQB
SD08	Cottonwood	Ron Haigh	11-Oct-83	NOAA-ARL
20 Year Awards				
IA23	McNay Research Center	Jim Secor	11-Sep-84	U.S. Geological Survey
WI25	Suring	James Trochta	29-Jun-82	Wisconsin DNR
WY98	Gypsum Creek	Terry Pollard	26-Dec-84	USFS - Bridger-Teton National Forest
25 Year Awards				
FL03	Bradford Forest	Larry Korhnak	10-Oct-78	St Johns River Water Management District
ME02	Bridgton	Peter Lowell	30-Sep-80	U.S. EPA/Maine DEP
OR10	H.J. Andrews Experimental Forest	John Moreau	13-May-80	U.S. Forest Service

TECHNICAL SESSION:

**CRITICAL LOADS: PERSPECTIVES FROM REGULATORY
AND LAND MANAGEMENT AGENCIES**

Session Chair: Kathy Tonnessen, National Park Service

**Critical Loads and Target Loads for Atmospheric Deposition:
Tools for Natural Resource Assessment and Protection**

Ellen Porter
National Park Service-Air Resources Division
P.O. Box 25287
Denver, CO 80225

Atmospheric deposition of nitrogen and sulfur can cause ecosystem acidification, nitrogen saturation, and biotic community changes. Critical loads can be used to identify the amount of atmospheric deposition that will cause these adverse effects and are widely used in Europe and Canada. A critical load is defined as “the quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge.” Target loads are often used in conjunction with critical loads. While critical loads are science-based, target loads can be based on political or economic considerations and represent a policy or management decision about the amount of deposition that would result in an acceptable level of resource protection. The U.S. does not have a nationwide critical load program; however, federal land management agencies are adopting the critical load concept as a potentially valuable resource management tool. Scientists, federal managers, and air quality regulators all have specific roles in the development and implementation of critical and target loads. For example, scientists and federal managers may work together to identify resources of concern for an area. Then, federal managers determine what constitutes a harmful change to those resources, based on applicable mandates and management concerns; scientists calculate the atmospheric loading, i.e., the critical load, that would elicit the harmful change to a specific resource. Federal managers may work with regulators to develop target loads, based on critical loads, that could be used to inform emissions management strategies for clean air and, ultimately, to protect natural resources or promote their recovery.



Protecting Ecosystems: An EPA Perspective on What Critical Loads Can Offer

Rona Birnbaum
US EPA, Office of Air and Radiation
Office of Atmospheric Programs
Clean Air Markets Division

The Clean Air Act provides several mechanisms to evaluate the impacts of air pollution on ecosystems and to protect them. A recent study by the National Research Council/National Academy of Science called *Air Quality Management in the United States*, along with the Clean Air Act Advisory Committee (CAAAC) asked to examine the report's findings, resulted in a series of recommendations to the US Environmental Protection Agency. Two of those recommendations are ecosystem-focused and urge the Agency to assess how well the CAA provisions are doing to protect ecosystems and to consider innovative approaches to protecting ecosystems, including the role of critical loads. It was also recommended that the Agency could be doing more to track ecosystem response to air pollution control programs. The recent Clean Air Interstate Rule provides a good forum to discuss new opportunities and developments in ecosystem accountability.

Critical Loads as a Management Tool: National Park Service Perspectives

Christine Shaver
NPS-Air Resources Division
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Denver, CO 80225

The National Park Service is charged with protecting nationally-significant natural resources on public lands set aside by Congress for their outstanding qualities as our legacy to future generations. Ecosystem health is extremely important to the NPS, yet park scientists and managers have struggled to find suitable ways to characterize desired conditions in these natural systems, preferably in ways that can be monitored, reported and tracked over time. Using a critical load-based approach is attractive to the NPS because it would compel identification of appropriate indicators and effect thresholds; allow conditions to be assessed, tracked, and reported using a quantitative and scientifically-meaningful benchmark; and provide information that could be used to establish relationships between emission sources, emission changes, and resource effects. NPS activities related to critical loads will be described, including progress being made in establishing critical loads for some indicators in specific parks, as well as emerging collaborative efforts with States and stakeholders regarding options for incorporating critical load-related information into air quality planning and strategy development.



Where Science and Policy Meet: Critical Loads in the USDA Forest Service

Rich Fisher
USDA Forest Service
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Assessing the ability of ecosystems to tolerate air pollutant insult is not a new one to the Forest Service. Indeed, in the late 1980's we held a series of regional workshops that brought together subject expert scientists and decision-makers (DM) for the purpose of establishing pollution-impact screening values. These screening values, captured and explained in a series of agency publications, were designed to essentially triage new source applications for permits to construct and operate through the PSD process. Screening processes proved to add efficiency and consistency in FS impact assessment. The growing body of science and experience gained since that time has indicated that we can be much more confident in our analyses and projections of air pollution impact than we were 15 years ago. Thus we have begun moving into the more data rich environment of critical loads and target loads. Our first steps were to explore the execution of the Canadian and European models. Next, we established two prototype critical load monitoring sites; these will grow to four soon. The sites in WV, CA and WY are all in areas of with sizeable emissions growth occurring. NADP, lake and soil chemistry, flora tissue samples and other data will all be assessed together in the critical load models to allow DMs make better informed choices. If this appears like a promising decision tool, we plan to implement it in NEPA and Forest Planning as well.

Critical Loads as a Policy Framework for Air Quality Management in Western States

Dan Johnson
Western States Air Resources Council (WESTAR)

Using a critical loads approach to establish air quality management objectives appears to be a promising alternative to several ineffective, resource intensive programs currently being implemented under the Clean Air Act. Determining target and critical loads based on best available science is an important first step in our efforts to improve how we protect against adverse impacts from air pollution in our nation's parks and wilderness areas. However, before the critical loads approach can be considered as a viable alternative to an existing policy (for example, as an alternative to the Class I increment protection provisions of the Clean Air Act), it will be essential to translate the science used to establish critical loads into air quality goals that are meaningful to policy-makers and the public.



Critical Loads: Assessing Atmospheric Deposition to Ecosystems in Canada

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Transboundary Air Issues Branch
Environment Canada
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Since the early 1980s, acid rain policy in Canada has relied on deposition targets to guide the development of effective emission control programs. In 1982, Canada proposed a target load of 20 kilograms of wet sulphate deposition per hectare per year to protect “moderately” sensitive ecosystems. Deposition reduction to this level in sensitive regions of eastern Canada became the guiding principle for a 1985 eastern Canadian SO₂ emission control program. Critical loads for wet sulphate deposition to aquatic ecosystems were mapped for eastern Canada in 1990. These critical loads, defined as the level of wet sulphate deposition that could be deposited on the area and still maintain a pH of 6 in 95% of lakes, ranged from <8 to >20 kg/ha/yr. Atmospheric modelling predicted continued exceedances of critical loads over about 800,000 square kilometres of eastern Canada even with full implementation in 2010 of the Canadian and US acid rain programs. In 1998, a new long-term acid rain strategy for Canada set a long term goal “to meet the environmental threshold of critical loads for acid deposition across Canada”. As a first step towards this goal, jurisdictions developed new SO₂ emission reduction targets which, when combined with comparable further emission reductions in the United States, were predicted to reduce deposition to below the target load, while leaving a small area in Ontario and Quebec (about 220,000 km²) still receiving harmful levels of acid deposition i.e., in excess of critical loads. The science of critical loads has evolved since the early 1990s such that critical loads are now reported as total (wet + dry) deposition of both sulphur and nitrogen for both aquatic ecosystems and upland forest soils. Current scientific information, presented in the 2004 Canadian Acid Deposition Science Assessment, indicates that an area ranging from 0.5 to 1.8 million km² in eastern Canada continues to receive levels of acid deposition in excess of critical loads for aquatic or terrestrial ecosystems. The most realistic SO₂ and NO_x emission reduction scenario, as of 2004, predicts continued exceedances of critical loads over a 326,000 km² area of eastern Canada. Further actions will be required to reduce SO₂ and NO_x emissions that impact eastern Canadian ecosystems.

Panel Discussion

Moderator

Kathy Tonnessen
National Park Service

Panelists

Rona Birnbaum
US EPA, Office of Air and Radiation
Office of Atmospheric Programs
Clean Air Markets Division

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TECHNICAL SESSION:

**ATMOSPHERIC DEPOSITION: SOURCE INVESTIGATION AND
POLLUTANT CYCLING**

Session Chair: Rick Artz, National Oceanic and
Atmospheric Administration

A National Survey of Nitrate Isotopes in Precipitation: What Can Isotopes Tell Us about NO_x Sources at Multiple Scales?

Emily M. Elliott*¹, Carol Kendall¹, Scott Wankel¹, Rebecca Glatz¹, Doug Burns¹, Karen Harlin², Richard Carlton³, Elizabeth Boyer⁴, and Thomas Butler⁵

Atmospheric deposition of nitrogen (N), particularly wet deposition of nitrate, is an important input of fixed, bioavailable N to ecosystems worldwide. In order to effectively mediate the impacts of nitrate deposition, it is critical to understand inputs from various NO_x sources, atmospheric chemical transformations and transport, and the characteristics of the nitrate that is ultimately deposited. To address this research need, we conducted a national survey of nitrate isotopes in wet deposition collected as part of the National Atmospheric Deposition Program (NADP). Archived samples (2000) from 156 NADP sites across the United States (U.S.) were pooled into bimonthly, concentration-weighted composites and analyzed for δ¹⁵N, δ¹⁸O, and a subset for Δ¹⁷O using the microbial denitrifier method. We determined that nitrate concentrations in archived NADP samples were stable over several years, indicating that the probability of isotopic fractionation associated with sample storage is very low. We also analyzed all precipitation samples (2000) from one AIRMoN site (NY67) in order to assess the temporal variability associated with individual events and associated back-trajectories. Here we discuss our results and the applicability of this approach across national, regional, and local scales.

We investigate the critical question of whether variations in δ¹⁵N of nitrate wet deposition are a function of atmospheric processes (e.g., seasonal variations in reaction pathways) or contributions of NO_x from different sources (e.g., power plant emissions, vehicle exhaust). Correlations between isotopic values and major NO_x sources are explored using datasets for monthly, county-level emissions from two major NO_x sources: electric generating units and on-road vehicles.

Results from the Northeastern and Mid-Atlantic U.S. indicate that δ¹⁵N is a powerful tracer of stationary source NO_x emissions at the regional scale. δ¹⁵N values are strongly correlated with NO_x emissions within a 300-400 mile radius of NADP sites in the Northeastern and Mid-Atlantic U.S. Along the Northeastern N deposition gradient that spans western New York to Maine, δ¹⁵N values are significantly correlated with nitrate deposition, sulfate deposition, and mean annual pH. Conversely, in this region, δ¹⁸O values do not exhibit clear spatial patterns, but rather vary consistently with season. Moreover, δ¹⁸O values are not correlated with stationary or mobile source NO_x emissions, nitrate deposition, sulfate deposition, or pH. These results suggest that in this region, the δ¹⁸O of atmospheric NO₃⁻ largely reflects the relative contributions of different oxidation pathways to NO₃⁻ formation.

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²NADP, Central Analytical Laboratory, Champaign, Illinois

³EPRI, Palo Alto, California

⁴University of California - Berkeley

⁵Cornell University, Ithaca, New York



Isotopes in Precipitation Across the US: Integration with National Programs and Data Highlights

Jeffrey Welker*¹, J. White², R. Vachon², and D. Sjostrom¹

The isotopic characteristics of precipitation using the NADP network has been ongoing for almost 10 years now and is becoming an important component to both basic studies of geochemistry and to emerging initiatives such as NEON (National Ecological Observatory Network) and BASIN (Biosphere-Atmosphere Stable Isotope Network). We will present the integration of the US Network for Isotopes in Precipitation with these other networks and emerging issues across the US. As part of these integration activities we have developed longer-term time series for a chosen set of sites and have recently completed the full analysis of the AIRMoN sites that provide event-based data and an opportunity to interface with the meteorological community.

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¹University of Alaska-Anchorage

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Greater Yellowstone Area Air Quality Assessment Update 2005

Mark T. Story
Gallatin National Forest
Bozeman, Montana 57918

The primary purposes of the GYA Clean Air Partnership (GYACAP) is to provide a forum for communicating air quality information, regulatory issues, and to coordinate monitoring between states and federal agencies in the GYA.

In 1999 the GYACAP prepared an Air Quality Assessment to identify air quality issues, conditions, pollution sources and monitoring sites and summarize known information. In 2005 the GYCCAP update the GYACAP (1999) Air Quality Assessment Document with a focus on new information on the 4 primary air quality issues within the GYA.

- Urban and industrial emissions
- Oil and gas development in SW Wyoming
- Prescribed and wildfire smoke
- Snowmobile emissions

Air Quality in the Greater Yellowstone Area remains generally excellent.

Internal sources of emissions within NPS and USFS lands in the GYA consist primarily of prescribed fire smoke, transportation/recreational sources, and management activity sources such as mining, road construction, and ski areas. These sources are usually not significant air quality issues except for snowmobile emissions at concentrated winter use areas such as Yellowstone. The NPS has greatly reduced winter emissions with the use of “green” fuels and products, and requiring 4 stroke snowmobile engines in YNP and GTNP.

Wildfire emissions are not controllable by management except indirectly by fire suppression. During the last 3 years GYA prescribed fire emissions have increased and are anticipated to continue to increase by about 58% over the next 10 years. The overall smoke emissions (wildfire + prescribed) is expected to remain about the same. Much of the GYA, has a wildfire suppression related accumulation of fuels with wildfire levels anticipated to be high.

The greatest “threat” to air quality in the GYA is from urban and industrial air pollution. These sources are managed by the DEQ’s in Montana, Wyoming, and Idaho with collaboration from NPS, USFS, and BLM.

Currently the largest air quality concern the GYA is from gas field development in SW Wyoming and emissions from energy related industries. The Clean Air Act requires the NPS and USFS identify, monitor, and protect AQRV’s (Air Quality Related Values) in adjacent Class 1 areas. The Bridger Wilderness visibility, lake chemistry, and biota are being subjected to increasing levels of air pollution impacts from the upwind gas field development which is primarily on BLM administered land. The Fitzpatrick and Popo Agie Wilderness areas are also affected.

Compliance with NAAQS (National Ambient Air Quality Standards) and protection of AQRV’s (Air Quality Related Values) will require continued close coordination between the NPS, USFS, BLM, and the DEQ’s in Wyoming, Montana, and Idaho.



Trends in Agricultural Ammonia Emissions and Ammonium Concentrations in Precipitation over the Southeast and Midwest United States

Stephen Konarik¹, Viney P. Aneja*¹, and Dev Niyogi²

Emissions from agricultural activities, both crop and animal, are known to contain gaseous ammonia (NH_3) which through chemical reaction changes into ammonium ion (NH_4^+). Using wet deposition data of ammonium from several National Atmospheric Deposition Program/National Trends Network (NADP/NTN) and Clean Air Status Trends Network (CASTNet) sites as well as calculated ammonia emissions from North Carolina and the Southeast and Midwest regions of the United States, trends in ammonium concentrations in precipitation were analyzed for the period of 1983-2004. The beginning of 1997 coincides with the implementation of a swine population moratorium in the state of North Carolina. Results from the analysis in North Carolina indicate decrease of positive trends in NH_4^+ concentration in precipitation since the moratorium was placed into effect. Sampson County, NC, saw stable ammonium ion concentrations from 1983-1989, an average rise of 9.5% from 1989-1996, and an average increase of only 4% from 1997-2004. In addition, HYSPLIT back-trajectory model was used to determine that when ambient air arrived from the high ammonia emissions source region, ammonium concentrations in precipitation were enhanced. For the Southeast United States domain, analysis shows that NH_4^+ concentrations at various sites generally increased with increasing NH_3 emissions from within the same region. Similar analysis has been performed over the Midwest United States and the similarities and differences are discussed.

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A History of NY67 (Ithaca NY) from Prenatal to Post Partum

Tom Butler*¹ and Gene Likens¹

NY67 (Ithaca, NY) has been a precipitation chemistry monitoring and research site since the Fall of 1976 and a CASTNet dry deposition site since 1987. Besides monitoring wet and dry deposition, personnel at the site have been involved in:

- 1) The establishment of spatial and temporal trends in precipitation chemistry in the eastern US, where the spread of acid rain from the 1950's to the 1970's from the Northeast to the Midwest and Southeast was documented. Increasing acidity in Europe was also occurring over the same time span.
- 2) Comparison of rainfall chemistry in remote unpolluted regions to polluted regions. Acidity in the northeast appeared to be 2 -5 times greater than levels found in unpolluted areas. $\text{SO}_4^{=}$ and NO_3^- were 5 to 10 times higher.
- 3) A comparison of daily AIRMoN precipitation chemistry and MAP3S precipitation chemistry with NADP/NTN weekly chemistry at collocated sites showed that the AIRMoN and MAP3S records are compatible with each other for conductivity, H^+ , NO_3^- and $\text{SO}_4^{=}$. Comparisons in trends for NH_4^+ , Ca^{++} and Mg^{++} suggest that these species also represent a quality long-term database. A later, more detailed comparison has shown a <5% negative bias (AIRMoN<NTN) for $\text{SO}_4^{=}$, NO_3^- , Cl^- and precipitation amount. H^+ , K^+ , Mg^{++} and Ca^{++} show a <11% relative bias.
- 4) The documentation of declines in base cations ($-1 \mu\text{eq}/1/\text{yr}$) that corresponded with a $-1 \mu\text{eq}/1/\text{yr}$ for the eastern US for 1979-90. In Europe base cation declines were approximately $-1.2 \mu\text{eq}/1/\text{yr}$ and for sulfate, $-2.6 \mu\text{eq}/1/\text{yr}$. MAP3S sites showed no statistically significant declines in base cations but a statistically significant decline in H^+ (why? Slightly different time period, Hubbard Brook shows the same pattern).
- 5) A comparison of event based thrufall + stemflow as a measure of total deposition compared to wet (AIRMoN) + dry (CASTNet) deposition at NY67 showed that the two approaches annually were within 10% for total S and N. Stem flow accounted for 16% and 13% of the S and N total deposition.
- 6) Using NADP/NTN, NADP/AIRMoN, CASTNet and AIRMoN-dry data we have examined the relations between changing SO_2 and NO_x emissions and their impact on wet and dry S and N and H^+ deposition for the eastern US. The ratio of % change in emissions to % change in deposition is close to 1 for SO_2 emissions vs wet and dry S deposition components, and for SO_2+NO_x vs H^+ wet deposition. For NO_x vs wet and dry NO_3^- deposition components combined, the ratio of % change in emissions to % change in NO_3^- concentrations (and deposition) are 0.74 ± 0.12 for total NO_x emissions and 0.87 ± 0.08 for non-vehicle emissions. Wet deposition source areas are based on air masses associated with AIRMoN event samples.
- 7) Future work includes using the AIRMoN and CASTNet data (including new instrumentation for measuring gaseous NH_3 and NO_y) to assess nitrogen inputs into the upper Susquehanna watershed.

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¹Institute of Ecosystem Studies, Millbrook, NY



AIRMoN at Penn State: Attempts to Link Wet Deposition to Atmospheric Processes

Dennis Lamb* and Uri Dayan¹

The “daily” sampling protocol of AIRMoN has underpinned measurements at the Penn State site (PA15) since inception of the Network, and it has served as an important tool for identifying the causes of acidic wet deposition in the eastern United States. Located in rural central Pennsylvania, PA15 experiences a broad range of meteorological conditions and is only weakly influenced by local pollutant sources. Collocation of AIRMoN with CAPMoN at PA15 has allowed a unique reconstruction of daily/event data back to 1976, yielding a long record of precipitation chemistry data that can be linked to individual precipitation events.

Interpreting deposition data in terms of atmospheric processes has been actively pursued for many years. Associating precipitation chemistry data from the Penn State site over the years 1993-2001 with the corresponding meteorological data, for instance, shows that the highest sulfate concentrations arise in summer when the air comes from the southwest and the precipitation is convective in nature. Under such situations, moist air from the Gulf of Mexico, flowing northward under the influence of the Bermuda High, likely gains strong oxidants while passing over the VOC-rich southern states. When this air subsequently flows over the Ohio Valley and its rich sources of sulfur dioxide, the conditions are ripe for heavy sulfate deposition events in Pennsylvania. A case study from 1996 illustrates the important roles played by the aqueous-phase oxidation of sulfur dioxide and the nucleation scavenging of sulfate: A strong rain storm on 17 July 1996 in State College, PA, dumped over 120 mm of rain within a two-hour time interval. With a pH of 3.7 and a sulfate concentration in excess of 100 μM , this rain arose from a cloud that could scavenge ambient sulfate very efficiently. Other studies have shown that the sensitivity of sulfate deposition to changes in precursor emissions depends on the oxidation state of the atmosphere. Daily/event sampling of precipitation is crucial for understanding the physical and chemical mechanisms by which acidic deposition occurs.

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TECHNICAL SESSION:

SPATIAL AND TEMPORAL TRENDS IN DEPOSITION

Session Chair: Mark Nilles, U. S. Geological Survey

Coherence of Variability in Precipitation Chemistry

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MS 415 Federal Center
Building 53, Box 25046
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Precipitation chemistry in the United States exhibits substantial spatial and temporal variability due to variations in emissions and climate (eg., precipitation amount, prevailing wind direction and speed). Separating the effects of emissions and climate on atmospheric deposition is difficult, but is an important issue given the need for objectively evaluating the effectiveness of emissions controls mandated by Clean Air Act Amendments (Title IV Phase I and II). Improved methods for filtering out climate-induced variations in precipitation chemistry would provide increased confidence in assumptions that trends in precipitation chemistry are attributable to trends in emissions.

Principal components analysis (PCA) was used to evaluate the coherence of spatial and temporal variability in sulfate deposition at NADP/NTN sites in the United States for the 1985 – 2002 period. PCA has been used in previous studies to evaluate variations in precipitation, stream flow, and stream chemistry, but the method is not commonly applied to spatial variations in precipitation chemistry. The primary utility of PCA is to identify recurring geographic patterns in correlations among spatially distributed data.

The PCA results indicate that most of the variance (62%) in sulfate deposition was explained by five factors. The first factor accounted for 22% of the variability in sulfate deposition. Loadings for the first factor were strongly negative in the southwestern United States, and strongly positive in the northeast and northwest. The spatial patterns of the factors are likely to be caused primarily by spatially-varying changes in emissions or climate during the study period. The next step will be to identify correlations among variations in sulfate deposition, climate, and emissions.



Comparison of Two Methods to Calculate Wet Deposition for 1985-2000

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NADP/NTN calculates the annual deposition data for a site by summing the weekly deposition values for the weeks with valid samples. The weekly deposition value is the product of the measured ion concentration and the weekly precipitation amount, as measured by the recording raingage. To determine wet deposition over an area, such as a state, a computer objective analysis algorithm is used to convert the site deposition values to deposition at grid points. The mean of all the grid deposition values within an area, such as a watershed or a state, is used to calculate the deposition to the area. In this project we posed the question of how the ion deposition values to states or other areas would differ if the much denser National Weather Service (NWS) network of about 7000 raingages were used instead of the NADP network of about 200 raingages. Clearly the amount of water being deposited annually on a watershed or a state or the 48 contiguous states will be more accurately determined with the 7000 raingages as compared to the relatively sparse set of NADP raingages.

The vast majority of the 7000 NWS precipitation sites are cooperative weather observer (COOP) sites, where precipitation amounts are measured daily. Staff at the National Climatic Data Center (NCDC) performs various checks on the COOP data and each month adds the new data to the precipitation database. The 48 contiguous states are divided into 347 climate divisions. NCDC calculates the mean monthly precipitation amounts for each climate division, using all the sites that have valid precipitation data for the month. For this report the monthly precipitation data were obtained from NCDC for the period 1985-2000.

Annual deposition of ions and precipitation to each climate division was calculated by multiplying the annual average ion concentration from NADP by the NCDC annual precipitation amount for each climate division. We refer to this as the NCDC ion deposition, and we compare it to the “standard” NADP ion deposition.

The difference between NCDC deposition and NADP deposition will generally be greater for states that have mountains, since more raingages are needed to capture the precipitation patterns that vary greatly in such states.

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National Isopleth Maps of Inorganic N Under-represent Western Mountain Areas Because Completeness Criteria 4 Not Appropriate for Snowfall Dominated Areas

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NADP isopleth maps are used to characterize the “chemical climate” and observe its changes over time. Government agencies use the isopleth maps to inform policy decisions; scientists use the maps to understand deposition fluxes to evaluate changes in the chemical climate.

However, NADP sites located in mountain environments are generally not represented in the isopleth maps because they do not meet the NADP/NTN Completeness Criteria for most annual periods. Many mountain stations fail to meet Criterion 4: “For the entire summary period the total precipitation as measured from the sample volume must be at least 75 percent of the total precipitation measured by the rain gage for all valid samples where both values are available.” The reason for this failure is that as much as 80% of annual precipitation falls as snow. Rain gages and chemistry collectors have very different catch efficiencies for snowfall, which leads to discrepancies in the volume of precipitation reported. NADP stations dominated by snowfall will rarely, if ever, meet criteria 4 because of this problem.

Here we show that national isopleth maps for inorganic nitrogen and for precipitation amount would be substantially changed for the central Rocky Mountains and for the Sierra Nevada if these mountain sites were included.

Precipitation amounts for much of Colorado would increase by a factor of two, from about 50 cm per year to 100 cm per year. To illustrate for inorganic N in 2003, inclusion of the 14 mountain sites not included in national isopleth maps would increase values by 50% to 100%. For example, inorganic N deposition for Wolf Creek Pass in Colorado would increase from 1.30 kg/ha on the isopleth map of 2003 to 2.60 kg/ha, an increase of 100%.

The NADP site at Giant Forest in Sequoia National Park in California would increase from 1.51 to 6.26 kg/ha, an increase of 314% and among the highest N-deposition sites on the entire isopleth map.

We argue that NADP needs to change criterion 4 so that these snowfall dominated sites can be included on the national isopleth maps.

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Trends in Snowpack Chemistry During 1993-2004 in the Rocky Mountain Region, USA

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The U.S. Geological Survey, in cooperation with the National Park Service, U.S. Department of Agriculture Forest Service, and other organizations established a network of 52 snow-sampling sites in the Rocky Mountain region in 1993. The network was designed to gain a better understanding of atmospheric deposition to high-elevation ecosystems in the Rocky Mountains. In this study, a 12-year (1993-2004) record of snowpack chemistry data are examined to identify long-term trends in chemical concentrations in snow. The results will be useful for comparisons to regional and local trends in NH_3 , NO_x , and SO_2 emissions and to climatic patterns during the study period.

From 1993 to 2004, 85% of sites showed an increase in ammonium concentrations, 92% showed an increase in nitrate concentrations, and 81% showed a decrease in sulfate concentrations. Similar trends in ion concentrations have been observed at National Atmospheric Deposition Program stations in the region over the same period of study. During the latter part of the period drought conditions coincided with higher concentrations at many network sites. Further analyses of subregional trends and influences of precipitation are warranted.

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TECHNICAL SESSION:

**ESTIMATING TOTAL DEPOSITION: MEASUREMENTS
AND MODELS**

Session Chair: Gary Lear, U. S. Environmental
Protection Agency

A Brief Introduction to Dry Deposition Terminology and Methods

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Dry deposition is increasingly recognized as a significant component of atmospheric deposition of acids, nitrogen and mercury in the environment. However, the terminology and measurement techniques for dry deposition are not so readily recognized by everyone in the wet deposition community. This presentation will provide a brief introduction to some of the terminology of dry deposition discussions and an overview of the methods used in dry deposition measurement and estimation.



Instrument Evaluation of Real-time Monitoring of Gases and Aerosols

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To continue to meet emerging needs in air quality and environmental assessments, EPA has initiated a program to critically evaluate advanced, automated measurement systems for potential routine use in the Clean Air Status and Trends Network (CASTNET). The system selected for evaluation is Applikon, Inc's Monitoring Instrument for Gases and Aerosols (MARGA). The sampling component is comprised of a wetted rotating annular denuder (WRD) for adsorption of water-soluble gases followed by a steam-jet aerosol collector for obtaining aerosols. The respective sample solutions are drawn by syringe pumps into two 25 mL syringes over 60 minute sampling period for subsequent direct injection to the cation and anion configured ion chromatographs (ICs). The MARGA provides measurement of the following parameters: gaseous sulfur dioxide, nitric acid, nitrous acid, and ammonia; and particle sulfate, nitrate, ammonium, and base cations. Remote communication and data acquisition via the internet will allow data to be available within 24-hours of collection. Real-time atmospheric chemistry measurements will help characterize the extent of regional transport, allow for better dry deposition estimates, and help validate current and future air quality models. EPA will be evaluating three MARGA systems operating in collocation and individual existing CASTNET sites. Ultimately, the systems will be evaluated based upon specifications associated with rural, routine environmental monitoring and those associated with acceptance criteria for precision, accuracy, relative bias, and inter-comparison to existing measurement techniques.

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Passive Samplers in Air Quality and Atmospheric Deposition Research

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Aside from models, very limited information exists on the air pollution status in remote areas, especially in complex mountain terrain. Such information is needed for understanding air pollution threats to human health and ecosystems, calculation of N & S deposition, evaluation of O₃ effects on vegetation at the forest stand, landscape and regional levels, ground-testing of remotely-obtained data on air pollution and verification of air pollution concentration and deposition distribution models. Passive samplers have been used for monitoring concentrations of gaseous pollutants such as O₃, NO, NO₂, NH₃, HNO₃, SO₂ or H₂S. Passive samplers work on a principle of a passage of air through a diffusion barriers and absorption of the pollutants of interest on collecting media. Geostatistical Analyst, an extension of ARC GIS software, has been used to generate predictive surfaces from passive sampler data points using geostatistical tools and analyzing the error of the resulting estimations. Distribution maps of several pollutants in North America and Europe have been developed. Possibilities for using passive sampler data for estimates of N deposition to forest and other ecosystems will be discussed.



Results of Cloudwater Deposition Research at Clingman's Dome, TN, from 2000 through 2004

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Cloudwater deposition studies have been conducted, on and off, in the Appalachians since 1986 when the Environmental Protection Agency (EPA) introduced the Mountain Cloud Chemistry Project (MCCP). MCCP consisted of 6 sites from North Carolina to Maine and persevered from 1986 to 1989. MCCP was reincarnated as the Mountain Acid Deposition Program (MADPro) in 1994 using two of the original MCCP sites plus a new location at Clingman's Dome, TN. MADPro also included a mobile site in the Catskill Mountains of NY. MADPro results from 1994 through 1999 were summarized in an EPA report and mainly showed statistically significant decreasing temporal trends for sulfate and ammonium at Whiteface Mountain, NY; an increasing temporal trend for normalized sulfate concentration at Whitetop Mountain, VA, and an increasing temporal trend in concentrations of hydrogen, sulfate, nitrate and ammonium at Clingman's Dome, TN. Most importantly, it demonstrated that the majority of deposition at high elevation sites (elevation greater than 800 m) comes from cloud impaction and that the amount of deposition at such sites is 6 to 20 times greater than deposition amounts at lower elevation sites. Since 2001, EPA, the National Park Service (NPS) and the Tennessee Valley Authority (TVA) have exclusively operated only the Clingman's Dome, TN site while the State of New York has taken over operations at the Whiteface Mountain, NY site.

This presentation will summarize results from the Clingman's Dome site from 2000 through 2004 and compare results from 2000 to 2002 to results from Whiteface Mountain, NY. Emission summaries for Tennessee as well as neighboring states for 1999 and 2002 will also be correlated with concentration and deposition values at Clingman's Dome. The ecological impacts of cloud deposition to high elevation ecosystems, including locations in the western United States, will also be discussed. The presentation will conclude with a look at where future research needs to focus to expand our understanding of the impact of cloud deposition on these beautiful, remote and very fragile ecosystems.

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Using Ion Exchange Resin Columns to Measure Throughfall and Bulk Deposition Inputs to Forests

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In this paper, a throughfall collection method based on ion exchange resin (IER) column “passive” throughfall collectors is described. The use of IER throughfall and bulk deposition collectors can dramatically reduce the number of trips to field sites, sample numbers and analysis costs. In intensive field tests, annual throughfall and bulk deposition estimates for NH_4^+ and NO_3^- determined with IER throughfall collectors compared well with co-located conventional solution collectors. The IER collectors functioned well with field deployment times as long as 12 months (the longest time period tested), although IER columns are usually changed-out every six months. The IER collector is built of inexpensive materials and is designed and used similarly to conventional throughfall collectors except that instead of collecting and analyzing the solution on an event or weekly basis, the solution is funneled through an IER column where the anions and cations are reversibly adsorbed on a mixed-bed resin. Snow tubes can be attached to the collector funnels during winter for snow collection. Ions in snow are then adsorbed by the IER as the snow melts and percolates through the resin column. We routinely use the IER collectors to monitor deposition of NO_3^- , NH_4^+ and SO_4^{2-} , but other ions can also be monitored with this method. Detailed instructions on the construction and field and laboratory procedures for the IER collectors will soon be posted at <http://www.fs.fed.us/psw/programs/atdep/>.



An Empirical Model for Estimating Total Deposition in Complex Terrain

Kathleen C. Weathers*, Samuel M. Simkin¹, Gary M. Lovett², and Steven E. Lindberg³

Atmospheric deposition has long been recognized as an important source of pollutants and nutrients to ecosystems. The need for reliable, spatially-explicit estimates of total atmospheric deposition (wet + dry + cloud) is central, not only to air pollution effects researchers, but also to ecologists calculating ecosystem input-output budgets, and to decision-makers faced with the challenge of assessing the efficacy of policy initiatives related to deposition. But how well can we measure atmospheric deposition to any one point on the surface of the Earth? We have national monitoring programs that generate wet and dry deposition estimates for many sites in the US, however current estimates of total deposition have large uncertainties, particularly across heterogeneous landscapes such as montane regions. Our scaling-up research was designed to fill a critical gap in current knowledge about atmospheric deposition to heterogeneous terrain.

We developed an empirical modeling approach that predicts total deposition as a function of landscape features such as elevation, vegetation type, slope and aspect. We measured indices of total deposition to the landscapes of Acadia (ACAD; 121 km²) and Great Smoky Mountains (GRSM; 2074 km²) National Parks. Using ~300-400 point measurements and corresponding landscape variables at each park, we constructed a statistical (general linear) model relating the deposition index to landscape variables measured in the field. The deposition indices ranged over an order of magnitude; vegetation type and elevation, together explained ~40% of the variation in deposition. Then, using the independent landscape variables that were also available in GIS datalayers, we created a GIS-relevant statistical model (LANDMod). We applied this model to create park-wide maps of total deposition which were scaled to wet and dry deposition data from the closest national network monitoring stations. The resultant deposition maps showed high spatial heterogeneity and a four- to six-fold variation in “hot-” and “cold-spots” of N and S deposition ranging from 3 to 31 kg N/ha/yr and from 6 to 42 kg S/ha/yr across these park landscapes. Area-weighted total deposition of N was found to be between 47 and 67% greater (ACAD and GRSM, respectively) than estimates of wet plus dry deposition from NADP and CASTNet monitoring stations. Model validation results suggest that the model slightly overestimates deposition for deciduous and coniferous forests at low elevation, and underestimates deposition for high elevation coniferous forests. The spatially-explicit deposition estimates derived from our LANDMod are a substantial improvement over single-point deposition estimates. Future research should be focused on testing the LANDMod in other mountainous environments and refining it to account for (currently) unexplained variation in deposition.

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Regional Atmospheric Modeling of Atmospheric Deposition

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The Clean Air Act requires States to address visibility degradation at certain national parks and wilderness areas. The States and the Environmental Protection Agency, in cooperation with federal land management agencies and other stakeholders, established Regional Planning Organizations (RPOs) to address the interstate nature of pollutants that affect visibility. Regional atmospheric modeling is a key element of the RPOs' analyses. This type of modeling is being called one-atmosphere modeling because it tries to simulate all of the relevant atmospheric processes simultaneously, including transport, dispersion, chemical conversion and removal through wet and dry deposition. The National Park Service (NPS) is also conducting one-atmosphere modeling to address visibility, ozone, and deposition issues. The atmospheric deposition results from some of the RPO and NPS modeling will be presented and compared with National Atmospheric Deposition Program measurements. Atmospheric deposition of nitrogen at Rocky Mountain National Park is affecting park resources. A field study to examine the transport of oxidized and reduced nitrogen to Rocky Mountain National Park is currently being planned and preliminary measurements are being taken. The results of this study will be used to evaluate one-atmosphere modeling and to identify and better quantify sources of atmospheric nitrogen reaching the park. The study plan will be discussed.

TECHNICAL SESSION:

ECOLOGICAL EFFECTS OF ATMOSPHERIC DEPOSITION

Session Chair: Pamela Padgett, USDA Forest Service

The Critical Load—A Useful Concept That Needs a Simplified Application

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The concept of a critical load, the level of acidic deposition above which an ecosystem is degraded, provides a straightforward framework for the translation of technical information to policymakers. However, determination of critical load values has relied largely on physically-based models that are far from straightforward. These models require values for parameters that are often not possible to estimate within meaningful constraints. For example, the Simple Mass Balance (SMB) model, used to determine critical loads in Europe, requires input values for weathering rates, soil water flux, total deposition of base cations, and net productivity (above and below-ground) when the critical criterion of soil Ca to Al ratio is incorporated. None of these parameters can be measured directly. Furthermore, values for critical criteria are often not well defined, as with the Ca to Al ratio, which is based largely on seedling experiments in greenhouses.

The shortcomings of critical load modeling to date suggest the need for an alternative, empirically-based approach. As a first step, the multiple criteria for setting the critical load could be replaced by a single criterion representing the fundamental ecological problem caused by acidic deposition—mobilization of inorganic Al (Al_i) within the soil. Although many organisms are also sensitive to acidity (H^+), healthy ecosystems can develop under naturally acidic conditions, such as those in forest soils, in the absence of mobile Al_i . Mobilization of Al_i only occurs when a geochemical threshold is exceeded. This threshold, which is independent of dissolved organic carbon concentrations, can be determined from stream chemistry, by subtracting acid anions ($SO_4^{2-} + NO_3^- + Cl^-$) from base cations ($Ca^{2+} + Mg^{2+} + Na^+ + K^+$); a quantity termed the base-cation surplus. In 222 streams in the Adirondack region of NY, the threshold occurred at a value of $+20 \mu eq L^{-1}$. The base-cation surplus was also found to be correlated ($R^2 = 0.70$) with the base saturation of the Oa horizon of 11 watersheds in this region. The critical load can be estimated by plotting atmospheric deposition against base saturation of the Oa horizon. Watersheds in which Al_i is mobilized, cluster in the upper left of the graph (high acidic deposition, low base saturation), whereas watersheds in which Al_i does not appear in stream water, cluster in the lower right (low acidic deposition, high base saturation). The diagonal line that divides these groups provides the critical load estimate. The distance above the critical load estimate indicates the reduction in acidic deposition required to prevent Al_i mobilization at a particular base saturation. The critical load can be regionalized on the basis of stream chemistry and a spatial model of acidic deposition by estimating base saturation with the base-cation surplus.

Base saturation is decreasing under present conditions in watersheds that fall above the line. Base saturation may either be increasing or decreasing in watersheds that fall below the line, but these watersheds are not currently being degraded by Al_i . This approach does not estimate the magnitude or rate of future changes in base saturation. These important questions can be best addressed through soil monitoring of selected watersheds. Preliminary efforts have already provided important data on temporal trends of soil exchange chemistry, and have demonstrated the feasibility of soil monitoring for assessment of recovery from acidic deposition.



Soil Nitrogen Control of Alpine Forage Selenium Content and Its Bioavailability to Pika and Bighorn Sheep

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Elevated levels of inorganic nitrogen have been observed episodically in summer precipitation at a high altitude (3400 m) observatory in the Northern Wind River Range (Fitzpatrick Wilderness Area) over the last six summers. There is evidence that micronutrient availability in alpine forage from this area is a function of soil nitrogen and summer precipitation. Our hypothesis is that increased soil nitrogen, perhaps originating from precipitation, activates specific soil microorganisms, and these reduce bioavailability of some micronutrients, especially Selenium (Se). As a result, herbivores are subsisting on diets low in Se resulting in their compromised health. Trace Se amounts are necessary to maintain immune systems and sustain reproduction. Evidence for our hypothesis includes: (1) Nitrogen deposition as measured in various media (precipitation and ice) by various agencies, has increased by as much as 100-fold in the last 25 years in the Wind River Range. Our own summer storm measurements support this finding. (2) Alpine soils at the observatory, and elsewhere, have very high (10 to 20 fold more) inorganic nitrogen as compared to measurements made 20 years ago. (2) Soil microbial analysis has demonstrated the presence of bacteria and fungi capable of reducing Se to biologically inert forms. (3) Se in summer forage is negatively but significantly correlated with summer precipitation. (4) A recent study of pika (*Ochotona princeps*) at the observatory suggests that these animals are living on a very low Se diet especially during wet summers. Other wildlife, specifically Rocky Mountain Bighorn Sheep (*Ovis canadensis subspecies canadensis*), at the observatory also exhibit signs of Se deficiency, although episodically.

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Negative Interactions of Air Pollutants on Thrushes in the Appalachian Mountains

David Evers* and Stefan Hames¹

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

The atmospheric deposition of Hg has the potential to have negative landscape-level impacts on bird populations. Further, Hg methylation by sulfate-reducing anaerobic bacteria that convert non-toxic inorganic mercury (Hg) into toxic organic methylmercury (MeHg) is enhanced in acidic environments. Acidic environments are also typically poor in calcium (Ca) and Ca-rich prey needed by many birds to successfully reproduce. Further, both the uptake and the effects of Hg are increased by low dietary Ca. Insectivorous birds in acidified areas also receiving Hg deposition are thus particularly susceptible to Hg toxicity because they occur at high trophic levels (e.g., susceptible to biomagnification), are long-lived (e.g., susceptible to bioaccumulation), are dependent on Ca-rich supplemental prey items for breeding, are vulnerable to neurological and reproductive impacts from elevated Hg levels.

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

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Mercury In Wetlands of the Lostwood National Wildlife Refuge, North Dakota

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The Lostwood National Wildlife Refuge (LNWR) encompasses 42 square miles in the Coteau du Missouri in northwestern North Dakota. The refuge, formally designated as a Globally Important Bird Area, is located near the middle of the prairie pothole region. The prairie pothole region is a large glaciated area in north-central North America that provides breeding habitat that accounts for about 50 percent of continental migratory waterfowl production. LNWR has a very high density of depressional wetlands (an average of about 100 wetlands per square mile). Because of the complex hydrogeologic setting of the refuge and differences in inundation patterns among wetlands, water quality is highly variable among individual wetlands in LNWR.

During the past several years, the North Dakota Department of Health (NDDH), in cooperation with the U.S. Environmental Protection Agency (USEPA), has implemented programs to assess and protect the quality of North Dakota wetlands. Of particular concern with respect to LNWR wetlands are effects of methylmercury contamination on bird embryos during egg development. Wetlands are known to be active sites for mercury methylation, and LNWR is close to several coal-combustion powerplants, which are major sources of atmospheric mercury. Thus, the NDDH and USEPA, in cooperation with the U.S. Geological Survey and the U.S. Fish and Wildlife Service, initiated a study to investigate the occurrence of mercury and methylmercury in LNWR wetlands. The study investigated the occurrence of mercury and methylmercury in several ecosystem components that include water, bed sediment, biota, and the atmosphere. This presentation focuses on factors associated with the occurrence of mercury and methylmercury concentrations in wetland water and bed sediments.

During the springs of 2003 and 2004, water and bed-sediment samples were collected from 44 LNWR wetlands distributed among four different wetland hydrologic regimes (temporary, seasonal, semipermanent, and permanent). Samples were analyzed for properties and constituents that are most directly related to mercury chemistry in natural aquatic systems. During 2003, median methylmercury concentrations in water samples collected from seasonal and semipermanent wetlands were quite large, exceeding 1 nanogram per liter, and maxima were as large as about 10 nanograms per liter. During 2003 and 2004, median methylmercury concentrations for seasonal and semipermanent wetlands were larger than concentrations for temporary and permanent wetlands. Median methylmercury concentrations were larger for temporary and permanent wetlands during 2003 than during 2004 and substantially larger for seasonal and semipermanent wetlands during 2003 than during 2004.

Preliminary results indicate that methylmercury concentrations in LNWR wetlands are strongly correlated with pH, organic carbon, and sulfate in the water column. Seasonal and semipermanent wetlands that had methylmercury concentrations greater than 1 nanogram per liter had pH values less than about 7.5 standard units, organic carbon concentrations greater than about 30 milligrams per liter, and sulfate concentrations between about 10 and 100 milligrams per liter. LNWR wetland mercury results provide valuable information about the importance of wetland environmental factors on the methylation of inorganic mercury that probably is deposited uniformly over a relatively small geographic area.

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Biomonitoring of Mercury in the Environment: Alaskan Seabirds and the Diamondback Terrapin as Sentinel Species

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Mercury (Hg) is responsible for more public health advisories than any other contaminant in the United States. The widespread concern about Hg related neurotoxic and developmental effects and evidence that Hg is still increasing in the arctic make monitoring this toxin a high management priority. Sentinel species have been widely used for monitoring contaminant trends, with the degree of success often depending on how appropriate the selected species are for the objectives. Data presented here are from two projects using sentinel species to monitor geographic and temporal trends of Hg in the environment. The Seabird Tissue Archival and Monitoring Project (STAMP) is a collaborative US Fish and Wildlife Service (USFWS), US Geological Survey (USGS), Bureau of Indian Affairs (BIA), and National Institute of Standards and Technology (NIST) study designed to provide long-term monitoring of contaminant trends in the Alaskan marine environment using seabird tissues. Current STAMP results show that murre (*Uria* spp.) eggs effectively detect regional and temporal variability in Hg, and they appear to be ideal matrices for long-term monitoring. Egg Hg levels were significantly higher in the Gulf of Alaska than in the Bering Sea ($p < 0.0001$). Within the Bering Sea, egg Hg levels were higher at the colony in the Bering Strait compared to the southern colonies ($p = 0.0073$). The latter trend may reflect the higher atmospheric Hg deposition in the arctic where reactive halides and atmospheric mercury depletion episodes are more common.

The diamondback terrapin is an estuarine turtle that is found from Massachusetts to Texas and exhibits high site fidelity. Keratinized shell material (scute) was non-lethally collected and analyzed to compare Hg levels among four South Carolina estuaries with moderate to light anthropogenic impact and one creek near a superfund site in Brunswick, Georgia. Scute Hg levels were ~ 15X higher ($p < 0.0001$) at the Brunswick site, which had previously been remediated. This evidence suggests the diamondback terrapin is useful for assessing local Hg contamination in estuarine environments. Future work will determine if similar trends are detectable in less severely contaminated habitats, and whether Hg levels in terrapins away from local point sources reflect regional/national patterns in coastal Hg deposition. Because the biogeochemical cycling of Hg plays a major role in its uptake into biota, atmospheric input is only one factor that could contribute to observed trends in a sentinel species. While differences in Hg methylation efficiency can create a disjunct between input and uptake, the primary focus of environmental policy on Hg is managing atmospheric Hg emissions and issuing advisories for human consumption of wildlife. Therefore stronger links should be established between future biomonitoring efforts and atmospheric deposition in order to move toward a more integrated Hg monitoring framework.

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The Use of Local Mercury Deposition Measurements in Modeling the Fate, Transport and Bioaccumulation of Methylmercury on the Cheyenne River Sioux Tribal Lands

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Chris Knightes¹, and Robert Ambrose¹

Managed farm ponds on Sioux Tribal lands were monitored as a part of a two year study to address the variation in methylmercury bioaccumulation in fishes from 2003-2004. Initial tissue residue monitoring suggested that larger ponds posed less risk for human exposure to methylmercury than smaller ponds; however, variation in hydrology, chemistry, food web dynamics and patterns of local deposition among ponds was uncharacterized. Ponds were selected throughout a region encompassing 500 square miles and included variables such as pond size, watershed size, soil type and dominant fish community. Rainfall, surface water, groundwater and soil/sediment samples were collected seasonally (in addition to biotic samples) and analyzed for total and methylmercury. Wet deposition data were used to parameterize models of pond fate and transport at the scale of study ponds and their surrounding watersheds. Total mercury concentrations were found to be higher than estimated by atmospheric models such as REMSAD and CMAQ.

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TECHNICAL SESSION:

ORIGIN, TRANSPORT, AND DEPOSITION OF MERCURY

Session Chair: Eric Prestbo, Frontier Geosciences, Inc.

Long-range Transport of Mercury to the U.S.

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For the past several years we have been focused on quantifying the atmospheric transport mercury to the U.S. To do this, we have made observations of speciated mercury at several sites including the Cheeka Peak Observatory in Washington State, the Mt. Bachelor Observatory in Oregon and Hedo Station on the island of Okinawa, Japan.

These observations have led us to the following conclusions:

- 1) At Okinawa, mercury is very well correlated with other tracers of Asian pollution (e.g. CO, aerosols). Using the observed Hg(0)/CO correlation, we have calculated emissions of elemental mercury from Asia to be 1460 metric tons/year (+/- 30%). This is approximately two times the value in the existing emission inventories;
- 2) Transport of mercury out of Asia largely occurs as gaseous elemental mercury, very little export occurs as RGM or particulate;
- 3) At Okinawa in the marine boundary layer, reactive gaseous mercury exhibits a clear diurnal cycle driven by photochemistry;
- 4) We have identified transport of Hg(0) from Asia to our free tropospheric site on the summit of Mt. Bachelor (MBO) at 2.7 km above sea level;
- 5) At MBO, RGM concentrations are sometimes significantly elevated in dry subsiding air. This is consistent with accumulation of RGM from oxidation of Hg(0) in air masses that have not seen recent precipitation.

Currently we are conducting an analysis of MDN data to help elucidate the sources of mercury (global vs regional) in US wet deposition. In this presentation, I will focus on our results to date, especially with respect to the implications for deposition of mercury in the U.S.

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Modeling of Atmospheric Mercury Deposition in the United States

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A state-of-the-science 3-D Eulerian atmospheric mercury model was used to simulate the fate and transport of atmospheric inorganic mercury over the United States. The multiscale modeling system used consists of a global mercury cycling model and a continental/regional-scale model; the former provides seasonally and spatially varying boundary conditions for the latter. The origin, transport, chemical and physical transformations, and deposition of atmospheric mercury (in elemental, gaseous divalent, and particulate-bound form) was simulated using detailed chemical, meteorological, and geographic data. The model was used to estimate the wet, dry, and total (i.e., wet plus dry) deposition of mercury. Annual NADP precipitation measurements were further used to determine the model sensitivity to input precipitation fields. The performance of the model in simulating the annual wet deposition of mercury at the NADP/MDN stations is shown to be satisfactory. Modeled concentrations of speciated mercury are also comparable with measured ambient concentrations.

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Monitoring the Response to Changing Mercury Deposition

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There is a crucial need to document the impact and effectiveness of the proposed regulation of anthropogenic mercury (Hg) emissions in the USA on human, wildlife and ecosystem health to ascertain the need for further controls. The impact of elevated methylmercury (MeHg) levels in fish on human and wildlife populations is well documented and is the driver for current and impending controls. Scientists and policy makers however need to develop a monitoring framework to accurately evaluate the effectiveness of any regulation. The monitoring strategy that will be discussed in this presentation was the result of such an effort by a group of 32 Hg scientists from academia, industry, government and non-profit organizations, who met in the Fall of 2003. The proposed monitoring strategy details the need for a comprehensive investigation (in air, water and the watershed) at a relatively small number of locations (termed *intensive sites*), as well as the collection of samples on a subset of indicators at a large number of sites that are widely distributed at a continental scale, and across ecosystems (termed *cluster sites*) to monitor change in Hg loadings to aquatic systems and the resultant alteration in MeHg incorporation into fish and wildlife. The program would be built around existing programs and studies, to the extent possible, and the Mercury Deposition Network (MDN) would likely be one program whose sites would be used for the proposed monitoring investigation. At the cluster sites, weekly wet Hg deposition would be measured in conjunction with seasonal sediment collections for total Hg and MeHg. Aquatic biota and wildlife sampling would consist of yearling fish and non-destructive wildlife sampling, and on a 3-5 year timescale, the sampling of piscivorous fish and larger piscivorous wildlife. Such a framework would answer the question of whether change is occurring in atmospheric Hg input and how this change is reflected as MeHg within a variety of aquatic ecosystems and in their organisms. In addition, this program would provide the information necessary to demonstrate the impact of Hg emission reductions from anthropogenic sources in the USA on fish MeHg concentration.



Mercury Deposition at High-altitude and High-latitude Sites in the Western United States

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Cold condensation processes may enhance mercury accumulation at high-altitude and high-latitude sites, where annual temperatures are low and seasonal snowpacks persist throughout much of the year. Buffalo Pass in Colorado, the highest Mercury Deposition Network (MDN) site at 3,234 meters elevation, received mercury wet deposition loading of 6.4 to 10.2 $\mu\text{g m}^{-2} \text{y}^{-1}$ during water years 1999-2004—values comparable to those in the upper Midwestern United States, where statewide fish advisories prevail. However, because there are 2 coal-fired power plants less than 75 km upwind, it was uncertain whether Buffalo Pass was representative of other mountain areas in the region. In recent years, a combination of seasonal snowpack sampling for winter deposition, and bulk precipitation sampling during warmer months, was used to measure mercury deposition at three additional mountain sites in Colorado. One site in Rocky Mountain National Park (downwind about 130 km from the power plants) and two sites in the White River National Forest (upwind) had mercury deposition comparable to Buffalo Pass, indicating that moderately high mercury deposition may be typical in the Colorado Rocky Mountains.

Mercury measured in seasonal snowpacks in eight National Parks in the Western United States provides additional insight into mercury deposition in cold environments. Cold-season (November-March) deposition at these sites ranged from 0.3 to 2.6 $\mu\text{g m}^{-2}$ in 2003 and 2004, and varied considerably between years because of differences in precipitation amounts. Concentrations ranged from 1.4 to 4.4 ng L^{-1} , with spatial patterns following a general pattern of Rocky Mountain > Glacier > Sequoia = Rainier = Olympic = Denali = Noatak = Gates of the Arctic. Similarity in concentrations for the Far West and Alaska parks suggests the predominance of a global background source of atmospheric mercury in those areas, which is likely augmented by North American sources upwind of sites in the Rocky Mountains.

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**Atmospheric Mercury Concentrations near Salmon Falls Creek Reservoir,
South-central Idaho—Where is the Mercury Coming From?**

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We measured elemental and reactive gaseous mercury (EGM/TGM) concentrations, atmospheric oxidants, and surface meteorology over a two week period in July/August 2005 near Salmon Falls Creek Reservoir (SFCR), a popular fishery located 40 miles southwest of Twin Falls, Idaho. A fish consumption advisory for mercury was posted here in 2002 by the Idaho Department of Health and Welfare. The air measurements are part of a multi-media (water, sediment, precipitation, air) study initiated by the Idaho Department of Environmental Quality and EPA Region 10 to identify potential sources of mercury contamination in the lake. SFCR is located about 80 miles northeast of large gold mining operations in Nevada which are known to emit large amounts of mercury to the atmosphere. This paper will discuss the preliminary results of these measurements, the potential for atmospheric oxidation of regional EGM loads and deposition in the watershed, and compare the data to 2 years of speciated mercury measurements made at the Idaho National Laboratory, 140 miles directly downwind. We will also discuss some methods to identify air emission sources that may be contributing to SFCR Hg contamination (back-trajectories, principal component analysis).

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Use of Geographic Information System Software to Evaluate Locations for Mercury-Deposition Monitoring in Indiana

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States such as Indiana that have sites in the National Atmospheric Deposition Network (NADP) Mercury Deposition Network (MDN) chose the locations for the monitoring stations based on several factors. Some of the factors include NADP criteria, geographic region, efficiency and cost of operation, and emphasis of a site sponsor. Because the number of MDN sites in a state typically is limited, it could be useful to evaluate the location of existing and potential monitoring stations in a systematic manner. This presentation describes an approach used for evaluating these locations.

Geographic information system (GIS) software was used to assess the spatial relation (patterns or clusters) among mercury-monitoring data, mercury-source inventories, and environmental features in Indiana. Mercury-monitoring data included multi-year analyses of mercury concentrations in atmospheric deposition, surface water, and fish tissue. Mercury-source inventories included stationary emissions to the air and discharges to surface water from wastewater treatment. Environmental features included land cover (forested, non-forested) and land use (urban, rural). Some spatial relations were used to identify optimal locations and to evaluate existing locations for mercury-deposition monitoring.

The GIS enabled the mercury-monitoring data and mercury-source inventories to be organized by watershed and mapped with the environmental features. The assessment examined the spatial distribution of fish-tissue mercury concentrations because of the potential risks to human health and wildlife. For selected watersheds, explanatory variables (mercury deposition, mercury loads in surface water, mercury emissions, treated-wastewater discharges, land use, and land cover) were evaluated for their relation to mercury concentrations in fish.

Watersheds where higher fish-tissue concentrations and combinations of explanatory variables appeared to spatially coincide provided optimal locations for mercury-deposition monitoring. An optimal location for monitoring was considered to have a capability to detect corresponding changes in mercury deposition, mercury loads, and fish-tissue concentrations. For comparison, watersheds with existing mercury-deposition monitoring were evaluated for the relation between the associated fish-tissue mercury and explanatory variables.

As a result of the evaluations, advantages and limitations of the existing deposition monitoring locations were identified. In addition, insights were obtained about the locations for monitoring mercury in surface water and fish tissue.

**Patterns Of Mercury Deposition and Concentration
in Northeastern North America (1996-2004)**

Alan VanArsdale*, Jeri Weiss¹, Gerald Keeler², Eric Miller³,
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Data from thirteen National Atmospheric Deposition Program Mercury Monitor Network (NADP/MDN) monitoring stations (1996-2004) and the Underhill (VT) event-based monitoring site (1993-2004) were evaluated for spatial and temporal trends. More precipitation and mercury deposition occurred in the southern and coastal MDN sites, except for the Underhill site, which received more mercury deposition than surrounding sites. Precipitation patterns varied within the region. Regionally, higher concentrations of mercury were recorded during the late spring and summer months. Several sub-regional clusters of MDN sites were evident, based on mercury deposition patterns. In general, more mercury was deposited during the summer months. "Enhanced" weekly deposition (>250 ng/m²) and distinct seasonal deposition patterns were evident at all MDN sites. Regionally, high depositional periods contributed significantly to annual loads (<20% - ~60%). Southern and coastal sites measured more frequent periods of high deposition than inland sites. Spring and summer, "enhanced" deposition may be important contributing factors to mercury bioaccumulation during the growing season. Recent regional reductions of mercury emissions were not reflected in the regional mercury concentration or deposition data. Few sites showed linear relations between the concentration of mercury and acid rain co-contaminants (sulfates and nitrates) in precipitation.

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Atmospheric Mercury in Rural Vermont

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Integrated measurements of gaseous elemental mercury, reactive gaseous mercury, particulate mercury, and mercury in precipitation at Underhill, VT are shedding light on the dynamics of mercury in the rural atmosphere. Recent modeling studies suggest that only one-half to one-third of the total atmospheric deposition of mercury is being measured by existing wet deposition monitoring stations (Miller et al. 2005). Dry deposition of reactive gaseous mercury (RGM = $\text{HgCl}_2 + \text{Hg Br}_2$) and gaseous elemental mercury (GEM) is likely to be very significant in forested landscapes. Some fraction of the deposited mercury is re-volatilized and re-emitted to atmosphere. The mechanisms controlling ecosystem mercury emissions are not well understood and the magnitude of these emissions has not been well quantified. There have been only a few short-term measurements of RGM concentrations in rural environments (Poissant et al. 2004). A small number of total gaseous mercury (TGM) and GEM flux measurements have been made during short-term (weeks – months) studies mostly over wetlands (e.g. Lee et al. 2000, Lindberg et al. 2002, Poissant et al. 2004) with just a few days of measurements made over forests (Lindberg et al. 1998).

Ecosystems Research Group Ltd., in cooperation with the Vermont Monitoring Cooperative, University of Vermont, University of Michigan, and the Vermont Agency of Natural Resources, is conducting the first multi-year, high time-resolution measurements of RGM concentrations and mercury vapor fluxes to and from the atmosphere over a forested landscape. Measurements are being conducted at the University of Vermont Proctor Sugar Maple Research Center in Underhill, VT. The measurements are co-located with existing monitoring programs for wet deposition of mercury, acid deposition and atmospheric chemistry. A Tekran® mercury speciation system is used to measure the ambient air concentrations of RGM, GEM, and particulate mercury in addition to the concentration gradient of TGM above the forest canopy. A suite of micrometeorological instruments is deployed to measure atmospheric turbulence and surface energy balance.

Diurnal patterns in RGM concentrations suggest frequent periods of local RGM production via photochemistry (c.f. Poissant et al. 2004). Other periods of elevated RGM from late day through the overnight hours suggest the possibility of RGM transport events. Under certain atmospheric conditions, RGM appears to be rapidly scavenged by particles. Periods of mercury vapor deposition and emission were observed. These preliminary results confirm that dry deposition of mercury is an important deposition pathway. Understanding all of the major mercury fluxes and the mechanisms controlling those fluxes is critical to assessing the persistence of mercury pollution in the environment.

References available upon request

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Mining MDN Data to Determine Local Effects of Mercury Emissions

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Tools for knowledge discovery through databases (KDD) can provide air quality planners with descriptions of long-term behavior at monitor sites. The investigators used the Cubist® program to construct a piecewise linear regression model to describe mercury deposition rates and concentrations at two sites in terms of hourly power plant heat input (a surrogate for emissions) and meteorological variables. The ambient mercury measurements represented more than five years of data at the Marcell, Minnesota and Chassahowitzka, Florida sites of the Mercury Deposition Network. The daily heat input data represented two power plants (Boswell Energy Center and Florida Power's Crystal River Energy Complex) that are predominantly coal-fired.

The advantages of local versus regional controls for mercury emissions have recently been debated. This work aimed to identify the meteorological conditions that lead to an effect of local emissions on local ambient mercury conditions. The long time series of ambient mercury deposition data at Marcell, Minnesota and Chassahowitzka, Florida were compared with the simultaneous heat input quantities at the two nearby power plants.

Meteorological conditions were included in the data sets, and the Cubist software generated piecewise linear regression fits that describe the deposition data based on heat input and meteorological parameters. The software created models of several linear expressions that apply under particular meteorological conditions and sometimes overlap. The investigation showed that the effect of power plants on nearby mercury deposition sites only manifested itself under particular meteorological conditions. The data analyses and findings are discussed in detail.

The investigation pointed to a rise in mercury deposition at the Marcell site associated with rate increases in heat input at the Boswell Energy Center, likely occurring during boiler startup. During hot, stagnant conditions, Crystal River heat input rates sometimes affected mercury concentrations and deposition at the Chasshowitzka station.

POSTER SESSION
(IN ALPHABETICAL ORDER BY CORRESPONDING AUTHOR)

An Evaluation of Wet, Dry, and Total N and S Deposition at Primenet Monitoring Locations

Paul Abood^{*}, Mark Williams¹, Kathy Tonnessen², and Kristi Morris³

NADP/NTN data are used to characterize the “chemical climate” of the US and observe its changes over time. However, NADP sites collect “wet” only deposition because of the much greater costs and analytical uncertainty involved in sampling “dry” deposition. An outstanding question is the contribution of “dry” deposition to total annual chemical deposition. Here we evaluate the role of dry deposition in total deposition at Park Research and Intensive Monitoring of Ecosystems Network (PRIMENet) sites. We report on the percent contribution of dry deposition to total deposition, year to year variations in the ratio of wet to dry deposition at each site, and evaluate whether the results support converting NADP wet deposition values to total deposition by using a simple wet:dry ratio based on the PRIMENet data.

PRIMENet was established by the National Park Service and the U.S. EPA in 1996 in response to calls for improved environmental monitoring in the United States, with emphasis on UV radiation monitoring in the fourteen PRIMENet parks. The NPS contributed both existing wet and dry deposition monitoring sites, and then added NADP/NTN wet deposition and CASTNet dry deposition sites in those parks that did not have these monitoring stations.

Total N deposition for a majority of the sites was low, below 4 kg N/ha annually. Total S deposition was also low (< 5 kg S/ha) at a majority of sites. Sites with higher annual deposition measurements were closer to pollution sources. For example, Shenandoah NP (7.7 kg N/ha/yr and 9.5 kg S/ha/yr) and Great Smoky Mountains NP (8.7 kg N/ha/yr and 9.0 kg S/ha/yr) are located in close proximity to several coal-fired power plants. High S levels at Hawaii Volcanoes NP (13.7 kg S/ha/yr) are likely due to high S concentrations in sea salt that enter the atmosphere from the ocean along with sulfuric acid and hydrogen sulfide emissions from ongoing volcanic activity.

Dry N deposition, as a percentage of total N deposition, generally decreases with increasing precipitation amount. For example, the two driest parks in the network, Big Bend NP (20 cm/yr) and Canyonlands NP (27cm/yr) had the two highest percentages of dry N deposition, both exceeding 50%; the second-wettest park location, Hawaii Volcanoes NP, had the lowest percentage (12%). However, the inverse relationship between precipitation and dry deposition percentage does not hold for all park locations. The wettest site, Olympic NP (326 cm/yr) had an average dry N deposition percentage of 29%, while one of the dry locations, Glacier NP (64 cm/yr) had a very low N deposition percentage of 16%. Dry S deposition as a percentage of total S deposition depended less on precipitation amounts and more on factors such as local emission sources.

Wet to dry deposition ratios vary on a yearly basis at most of the locations. At Acadia NP, the wet to dry S ratio reaches a high of 6.72 in 2000 and falls to a low of 1.99 the very next year. The wet to dry N ratio at Acadia follows the same pattern, falling from 6.12 in 2000 to 1.61 in 2001. At Rocky Mountain NP, wet to dry N ratios range from 2.66 to 8.02. This is also the case for wet to dry deposition ratios within seasons across years. During the winter at Denali NP, wet to dry S ratios range from 0.08 to 0.59 and wet to dry N ratios range from 0.58 to 3.16.

In its simplest form, this ratio does not appear to be stable enough to accurately reflect total deposition if only wet deposition is measured.

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Isotopic and Back Trajectory Analysis on Rainfall Chemistry for Developing Source-Receptor Relationships in Fine PM Formation

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The Hybrid Single Particle Lagrangian Integrated Trajectory (HY-SPLIT) model was used to determine potential sources of nitrogen in rainwater collected at an urban site in Raleigh, North Carolina, during the first three quarters of 2004. The delta ¹⁵N isotope ratio signatures of each sample were used to further differentiate between sources of the same compound. This study examined the importance of pollutant sources such as animal agricultural activity and coastal meteorology on rainfall chemistry as well as their implications on fine particulate matter formation.

Samples that transited across the dense crop and animal (swine) agricultural region of east-south-eastern North Carolina (major sources of oxides of nitrogen (NO_x) and ammonia (NH₃) emissions) had lower delta ¹⁵N isotope ratios in the nitrate ion averaging -2.1 ± 1.7 per mil than those which averaged 0.1 ± 3.0 per mil from the nonagricultural counterparts. However, the limited data set does not offer any conclusive evidence of similar patterns in ammonium ions. An increase in PM fine mass concentrations was also found to correspond to air transport over the hog farm regions. For the dates when air was transported to Raleigh from the agricultural area PM_{2.5} concentrations at the Wake County Department of Air Quality site averaged 15.1 ± 5.8 $\mu\text{g}/\text{m}^3$ yearly compared to a yearly average of 11.7 ± 5.8 $\mu\text{g}/\text{m}^3$ for air which was not.

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Hindcasting Nitrogen Deposition to Determine an Ecological Critical Load

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Using an estimated background nitrogen (N) deposition value of $0.5 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ in 1900, and a 19 year record of measured values from Loch Vale (NADP site CO98), I reconstructed a N deposition history using exponential equations that correlated well with EPA-reported NO_x emissions from Colorado and from the sum of emissions of 11 western states. The mean wet N deposition values for the period 1950-1964 was approximately $1.5 \text{ kg N ha}^{-1} \text{ yr}^{-1}$, corresponding to the reported time of alteration of diatom assemblages attributed to N deposition in alpine lakes in Rocky Mountain National Park. This value becomes the critical load defining the threshold for ecological change from eutrophication. Thus if a N deposition threshold for ecological change can be identified, and the date at which that threshold was crossed is known, hindcasting can derive the amount of atmospheric deposition at the time of change, at least for alpine lakes. Independent support for the technique and the deposition amount comes from experimental studies, ecosystem modeling, and paleolimnological records from northern Wyoming.



Assessing the Contribution of Mobile Source N Emissions Near Roadways Using Paired Transects of Net Through Fall and Bulk Collectors

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While road transportation and other mobile sources make up more than half of the NO_x sources their contribution to local N deposition has been neglected. In order to assess the contribution of these sources to local N budgets on Cape Cod, we use methods similar to Lovett et al (2000) in which bulk and net through fall precipitation collectors were used to estimate dry deposition. Our study used paired transects of net through fall and bulk collectors placed at 10, 50, 100, 150, and 300 meters away from a moderately heavy traveled road of $\sim 15,000$ - $25,000$ vehicles day^{-1} , as well as a third transect of net through fall collectors adjacent to a road less clearing (power line right of way) to control for edge effects. Samples for NO_3^- , NH_4^+ , TDN, pH, cations and anions were collected immediately following each rain event during June, July, and August from 2003 - 2005. In the transect adjacent to the roadway the inorganic nitrogen concentration in the net through fall collectors was higher than that of the bulk collectors, with the inorganic N composed of $\sim \frac{1}{2}$ NO_3^- and $\frac{1}{2}$ NH_4^+ , while in the transect adjacent to the road less the net through fall collectors had a lower N concentrations than that of the bulk collectors. The amount of N in the net though fall decreased with distance from the roadway while the amount of N in the adjacent bulk collectors did not change across the transect. The amount of additional N in net through fall collectors was ~ 1.5 - 2 x more within 10- 20 meters of the roadway but this decreased rapidly with distance.

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**Western Airborne Contaminants Assessment Project (WACAP):
Assessing Deposition and Impacts of Persistent Organic Pollutants and Metals
in Eight National Parks in the Western U.S.**

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NPS has initiated the “Western Airborne Contaminants Assessment Project” (WACAP) to determine the risk to ecosystems and food webs in western national parks from airborne contaminants. The objectives of the six year project are to: (1) determine if contaminants are present in western national parks, (2) if present, determine where contaminants are accumulating (geographically and by elevation), (3) if present, determine which contaminants pose a potential ecological threat, (4) determine which indicators appear to be the most useful to address contamination, (5) determine the sources for contaminants measured at national park sites. NPS is concerned about deposition of airborne contaminants because they can pose serious health threats to wildlife and humans, as some of these compounds tend to “biomagnify” in the food chain. Biological effects of airborne contaminants include impacts on reproductive success, growth, behavior, disease, and survival. Inventories of contaminants from five ecosystem components (snow, water, sediment, vegetation, and fish) are currently being conducted in eight key parks in the west and Alaska. EPA, USGS, the USDA Forest Service, Oregon State University, and University of Washington are working with the NPS on this assessment.



**Mercury Deposition Network: Field Intercomparison of Existing and
Prototype Mercury Wet Deposition Collectors**

Bob Brunette¹, Gerard Van der Jagt¹, Nicholas McMillan¹, Megan Vogt¹,
Ryan Nelson¹, Doug Disney¹, Buffy Raelph¹, Jason Kalstrom¹, and David Gay²

Abstract Unavailable

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**Mercury Deposition Network: Sample Collection, Digestion and Analytical
Methods For Measuring Trace Metals In Wet Deposition**

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Abstract Unavailable

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Hg Emissions Evaluation of a Coal Fired-Utility Measuring Total and Speciated Mercury In Coal Combustion Flue Gas Using Solid Sorbent Based Methods: US EPA 324 and FAMS

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Abstract Unavailable

The Impact of Changing Nitrogen Oxide Emissions on Wet and Dry Nitrogen Deposition in the Northeastern USA

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Electric utility emissions account for $\frac{1}{4}$, and vehicle emissions account for over $\frac{1}{2}$ of the total NO_x emissions in the eastern USA. Canadian NO_x emissions from the 7 easternmost provinces (Manitoba and east) represent less than 10% (1.2 Tg NO_x) of the NO_x emissions compared with those from the eastern USA. Emissions from eastern Canada are dominated by vehicle NO_x emissions, which account for $\frac{2}{3}$ of the total NO_x emissions from eastern Canada.

Data from the EPA National Emissions Inventory show, for the period 1991 to 2001, that nitrogen oxide (NO_x) emissions in the eastern USA have declined by 17% to from 16.1 to 13.1 teragrams (Tg). Large declines in vehicle emissions in 2001 may be questionable. If 2001 data are excluded the decline in total NO_x is only 7%. A recent assessment of EPA's emissions estimates suggest that vehicle NO_x emissions may be underestimated, and total NO_x emissions reductions may be less than what is reported by the EPA.

The CASTNet (Clean Air Status and Trends Network) measurements of N dry deposition include HNO_3 , particulate NO_3^- and NH_4^+ . The dominant nitrogen (N) dry deposition product measured is HNO_3 , which represents 80% of measured N dry deposition for the sites used in this study. Amounts of NH_3 , NO_2 , organic nitrate and PAN dry deposition are not measured by CASTNet. The NH_3 and NO_2 deposition are probably significant, and may be major N dry deposition components in some areas.

Random coefficient models with total NO_x emissions as the independent variable, and HNO_3 concentrations as the dependent variable, show that reducing total NO_x emissions by 50% should reduce HNO_3 concentrations by 36%. The average efficiency (the ratio of % change in HNO_3 to % change in NO_x emissions) is 72%. Random coefficient models with non-vehicle NO_x emissions as the independent variable, and HNO_3 concentrations as the dependent variable, show a 50% decline in non-vehicle NO_x emissions (which is a 23% decline in total NO_x emissions) should reduce HNO_3 by 17% to 20%. The average efficiency in this case is 81%. Because non-vehicle NO_x emissions data are more reliable than vehicle NO_x emissions, non-vehicle NO_x models are likely more accurate than the total NO_x models.

Combining the results of this study with previous work, which examined the relation between NO_x emissions and wet NO_3^- concentrations, show that reducing total NO_x emissions by 50% should reduce total NO_3^- deposition by 37% (wet+dry combined efficiency is 74%), and total N deposition (as measured by CASTNet sites in the northeastern USA) by 25%. A decline in total NO_x emissions of 23%, from a 50% reduction in non-vehicle NO_x emissions should, on average, reduce total NO_3^- deposition by 20% (wet+dry combined efficiency is 87%), and total N deposition, as measured by CASTNet sites, by 15%.

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Distinguishing Contributions of Wet and Dry Mercury Deposition in New England

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Atmospheric deposition is an important source of mercury (Hg) to terrestrial and aquatic ecosystems across the globe. However, despite substantial advances over the past decade in our understanding of the sources and transport pathways of Hg in the atmosphere, the relative contributions of wet and dry depositions to any particular location remains poorly understood. The east coast metropolitan corridor (Washington D.C. to Boston) is one of the few areas in the U.S. where models estimate greater rates of dry deposition than wet deposition. Hg in wet and dry deposition in New England was investigated using sediment cores and wet-deposition collectors. Sediment cores were collected in 2000 as a part of a national study of trends in particle-associated contaminants. Cores were collected from two lakes, one a remote reference site (Bethel, ME), and the other an urban reference site (near Boston, but with no development in the watershed). Wet-deposition was measured at two sites in rural Maine by the National Atmospheric Deposition Program Mercury Deposition Network (NADP-MDN) between 1996 and 2004, one rural site in New Hampshire by NADP-MDN and the U.S. Geological Survey (USGS) between 2001-2004, and three sites in the Boston metropolitan area (USGS) between 2002-2004. Total Hg deposition (wet plus dry) estimated from sediment cores and measured wet deposition, support the conclusion that dry deposition is much more important in the metropolitan corridor. The ten-year average total Hg deposition near Boston was estimated to be 95 $\mu\text{g}/\text{m}^2/\text{yr}$, more than 10 times the median wet-deposition rate for metropolitan Boston of 8.9 $\mu\text{g}/\text{m}^2/\text{yr}$. In contrast, total Hg deposition at the remote reference site was about 10 times less than near Boston at 10 $\mu\text{g}/\text{m}^2/\text{yr}$, and dry deposition was estimated to be about one-third of the total deposition. These comparisons indicate that dry deposition can dominate (about 90% for this study) the atmospheric flux of Hg in urban settings.

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Spatial Rainfall Patterns, Metals and Nutrient Deposition in Waters Surrounding KSC

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A pilot study was begun as a SHARP student project to understand the spatial variability of nutrients and metals found in precipitation and dry deposition at Kennedy Space Center and Cape Canaveral Air Force Station. The study was conducted during the summer of 1999 and continued for eighteen weeks (6-15-99 to 11-02-99). Continuously open 2-liter soda bottles, set on 1-meter high poles at 16 sites, were used to collect 'total' (wet and dry) deposition. Samples were collected weekly on Tuesday (same as NADP samples) and the collectors were cleaned with DI water and re-deployed. The samples were analyzed for $\text{NO}_2+\text{NO}_3\text{-N}$, $\text{NH}_4\text{-N}$, $\text{PO}_4\text{-P}$, Cl, and metals. The data in mg/L was converted into loading rates ($\text{mg} / \text{m}^2 / \text{wk}$). The $\text{NO}_2+\text{NO}_3\text{-N}$ ranged from <0.068 to $30.366 \text{ mg} / \text{m}^2 / \text{wk}$, the 18-week total ranged from 31.46 to $72.17 \text{ mg} / \text{m}^2$, and the mean total across the domain was $53.02 \text{ mg} / \text{m}^2$. The $\text{NH}_4\text{-N}$ ranged from <0.068 to $79.752 \text{ mg} / \text{m}^2 / \text{wk}$, the 18-week total ranged from 12.748 to $99.963 \text{ mg} / \text{m}^2$, and the mean total across the domain was $50.043 \text{ mg} / \text{m}^2$. The $\text{PO}_4\text{-P}$ ranged from <0.068 to $26.83 \text{ mg} / \text{m}^2 / \text{wk}$, the 18-week total ranged from 5.127 to $35.225 \text{ mg} / \text{m}^2$, and the mean total across the domain was $17.908 \text{ mg} / \text{m}^2$.

The following metals were found above detection limits and will be presented: Ag, Al, Cd, Ni, and Zn. Silver (Ag) ranged from 0.0001 to $0.991 \text{ mg} / \text{m}^2 / \text{wk}$, the 18-week mean was $0.004 \text{ mg} / \text{m}^2$, and the mean total across the domain was $0.018 \text{ mg} / \text{m}^2$. Aluminum (Al) ranged from 0.0046 to $5.868 \text{ mg} / \text{m}^2 / \text{wk}$, the 18-week mean was $0.036 \text{ mg} / \text{m}^2$, and the mean total across the domain was $0.370 \text{ mg} / \text{m}^2$. Cadmium (Cd) ranged from 0.003 to $1.003 \text{ mg} / \text{m}^2 / \text{wk}$, the 18-week mean was $0.0079 \text{ mg} / \text{m}^2$, and the mean total across the domain was $0.102 \text{ mg} / \text{m}^2$. Nickel (Ni) ranged from 0.0001 to $0.307 \text{ mg} / \text{m}^2 / \text{wk}$, the 18-week mean was $0.004 \text{ mg} / \text{m}^2$, and the mean total across the domain was $0.029 \text{ mg} / \text{m}^2$. Zinc (Zn) ranged from 0.0066 to $1.984 \text{ mg} / \text{m}^2 / \text{wk}$, the 18-week mean was $0.013 \text{ mg} / \text{m}^2$, and the mean total across the domain was $0.174 \text{ mg} / \text{m}^2$.

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Complementary Use of Throughfall Fluxes and Monitoring Station Data to Estimate Deposition Across Landscapes

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Accurate estimates of total deposition to ecosystems in complex terrain are elusive, despite decades of atmospheric deposition research. There are two methods that have commonly been used to estimate deposition: 1) measured (wet) combined with modeled (dry and cloud) deposition from monitoring networks, and 2) the measurement of throughfall flux (TF), which is a measure of total deposition (wet + dry + cloud) to the forest floor, and for biologically conservative ions, to forest canopies. The TF method has the advantages of being inexpensive and integrating deposition over complex forest canopies and/or complex terrain, which are the landscapes where model assumptions for calculating dry and cloud deposition fluxes are tenuous, at best. The monitoring data allow site-to-site comparisons and accurate flux numbers for regions adjacent to monitoring station locations. Here we compare the two methods for a small watershed in the Catskill Mountains of New York. Sulfur flux in throughfall measured from October 2000 to mid-September 2002 across an elevational gradient in the Dry Creek watershed did not differ from CASTNet dry + NADP wet (total) deposition. Total S throughfall flux at collectors within the watershed ranged from 9.14 to 7.17 kg S/ha/yr; dry + wet deposition over this time period was 7.34 kg S/ha/yr. Our comparison suggests that for this site, either method can be used to estimate total deposition of sulfur to the watershed; and other work indicates that total sulfur deposition can be used to estimate total nitrogen deposition. However, in regions with a greater range of elevation and with more heterogeneous canopies, CASTNet-derived dry, and modeled cloud deposition estimates are likely to be insufficient. To estimate total deposition across the Catskill region, we describe a project in which we will be scaling up point deposition measurements from individual sites to create a Catskill Mountain deposition map.

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Evaluating Nitrogen Critical Loads for the Great Smoky Mountains National Park

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Nitrogen critical load values are calculated to determine ecosystem health based on the deposition of a given area, thus they may act as a tool to identify sensitive ecosystems in further need of protection. However, difficulty lies in determining critical loads for a variety of spatial scales and ecosystems as a whole. Establishing an overall national critical load value would be difficult because not all ecosystems would exhibit a uniform response to deposition levels. This is due to differing bedrock geology, soils, vegetation, elevation, amounts of deposition, and a variety of other finite parameters.

High elevation ecosystems in the southern Appalachian Mountains are considered sensitive to nitrogen deposition and acidification. We compared the parameters most often used to evaluate chemical criteria limits for nitrogen critical loads (stream water acid neutralizing capacity and wet/dry/total nitrate and ammonia deposition) from the Great Smoky Mountains National Park in the southeastern U.S. with published values from Rocky Mountain National Park in the western U.S. These comparisons demonstrate the regional differences that exist among Class 1 ecosystems in the U.S. and allow policy makers the opportunity to visualize the different range of values considered critical for each region.

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Predictive Tool for Mercury Wet Deposition in Florida

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Wet deposition collectors in Florida consistently report the highest levels of mercury in the United States. The cause of this increased deposition and the impact it has on water bodies is not fully established. Lacking for many site specific studies are adequate wet deposition data. The goal of this study was to create a simple regression equation to calculate wet deposition from rainfall. Weekly precipitation sampling in Orlando, Florida was conducted from September 2003 and presently continues. Rainfall and Hg deposition data were gathered from this site and 7 others located in and around Florida, to investigate regional and seasonal trends. Approximately 80% of Florida's rainfall and Hg deposition occur during the wet season. A positive linear relationship was observed between rainfall depth and Hg deposition ($R^2 = 0.80$). Also constructed for each season, were 95% confidence and prediction intervals. This tool can be applied to predict mercury deposition at any location in Florida using rainfall data.

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Monthly and Annual Bias in Weekly (NADP/NTN) Versus Daily (AIRMoN) Precipitation Chemistry Data in the Eastern USA

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Previous comparisons of the data from the National Atmospheric Deposition Program (NADP) National Trends Network (NTN) against collocated event- and daily-sampled data suggest a bias in the concentration of ammonium [NH_4^+] and concentrations of several base cations, while the comparability of other ion concentrations ranges among the studies. Eight years of collocated data from five NADP NTN and Atmospheric Integrated Research and Monitoring Network (AIRMoN) sites are compared here. Unlike previous analyses, the data from these two datasets were analyzed in the same laboratory using the same analytical methods; therefore, factors that influence concentration differences can be isolated to sampling frequency and sample preservation techniques.

Results suggest that significant monthly variations exist in relative bias for [NH_4^+], [SO_4^-] and [H^+]. Large biases in [SO_4^-] on monthly time scales have not been detected in previous analyses where data for all time periods were considered together. The results suggest a relative bias of about 10% in NTN [NH_4^+], which is smaller than previous estimates that included the influence of inter-laboratory comparisons. The NTN and AIRMoN data are also compared on monthly and annual time scales to consider whether there are strong seasonal or interannual differences between the networks. The annual relative bias of NTN [H^+] increases over the analysis period, which also results in a larger total relative bias for [H^+] than found in a previous analysis of AIRMoN and NTN data.

When comparing NTN and AIRMoN data on monthly time scales, strong seasonal variations are evident in the relative bias for NTN [H^+], [NH_4^+], and [SO_4^-]. Large biases in [SO_4^-] on monthly time scales have not been detected in previous analyses where data for all seasons were considered together. Similar to previous studies, the NTN and AIRMoN [NO_3^-] and [Cl^-] compare well, while the base cations, a small component of the total deposition, exhibit large discrepancies.

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Overview of the National Air Emissions Monitoring Study

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This monitoring study is designed to provide quality-assured air emission data from representative swine, egg layer, dairy and broiler production facilities in the U.S. Following sound scientific principles and using accepted instrumentation and methods, this project will collect new data from 10 to 25 farms across the country to form a database to which additional studies of air emissions and effectiveness of control technologies can be compared. These benchmark data and accompanying analysis and interpretation will allow U.S. EPA and livestock and poultry producers to reasonably determine which farms are subject to the regulatory provisions of the Clean Air Act and reporting requirements of CERCLA and EPCRA.

Air emissions from both barns and open waste storage facilities will be determined over a two year period to capture the variation in emissions with time of year, stability of the atmosphere, and changes in facility operation. Gaseous emissions (NH_3 , H_2S , some VOCs) from open waste storage facilities (lagoons and waste basins) and open feedlots will be made at many farms using open path optical remote sensing in conjunction with micrometeorological measurements and various plume modeling techniques. Gaseous and aerosol emissions (NH_3 , NO_x , H_2S , CO_2 , total VOCs, TSP, PM_{10} and $\text{PM}_{2.5}$) from barns at many farms of varying character will be determined by measuring exhaust concentrations and airflow while closely monitoring internal processes.

**Calculating Pre-measurement Atmospheric Deposition,
Stream Chemistry, and Soil Chemistry for an Alpine Watershed
in Rocky Mountain National Park, Colorado**

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Wet and dry deposition of N and S species have been measured for 25 years or less in the United States, making it impossible to know with certainty atmospheric deposition amounts from earlier in the 20th century. Likewise, measurements of ecosystem status, such as surface water chemistry and soil base saturation, for the first half of the 20th century are largely unavailable. We used DayCent-Chem, a daily timestep ecosystem-hydrogeochemical model, and daily historic VEMAP climate to investigate the changes in soil and stream water chemistry that may have occurred in an alpine ecosystem over the past century. Hindcasts of NO_3^- , NH_4^+ , and SO_4^{2-} concentrations in precipitation were based on emissions of NO_x and SO_2 . We ran DayCent-Chem from the known ecosystem state in 1999 backwards to 1900 to estimate stream water pH, stream acid neutralizing capacity (ANC), and soil base saturation that may have existed in the past. The model showed that mean annual stream pH and ANC were greater in 1900 than today, and that annual dynamics were highly responsive to SO_4^{2-} deposition. Minimum pH and ANC occurred in conjunction with the highest SO_2 emissions in the late 1960s-70s, before measurements began. Soil base saturation was higher in 1900 compared to the late 1990's. Over the past century, simulated stream $[\text{NO}_3^-]$, like precipitation $[\text{NO}_3^-]$, increased exponentially with NO_x emissions, while stream $[\text{SO}_4^{2-}]$ reflected the interannual variability of SO_2 emissions.

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**Mercury Pollution in Northeast Nevada Air: A Screening Level Survey
of the Potential Impacts Of Gold Processing Facilities on Air Quality. August 2005**

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Multiple air samples from several sites in the vicinity of large gold processing facilities in Northeast Nevada were collected and analyzed with an Ohio Lumex RA-915+ Mercury Analyzer. Comparison of data collected both upwind and downwind of gold processing facilities demonstrates that downwind air masses had significantly greater concentrations of mercury than upwind air masses. Downwind mercury concentrations 5 to 10 times greater than the measured background mercury concentrations were common. Mercury concentrations 10 times greater than the background were recorded within the city limits of Carlin, Nevada. In addition, air mercury concentrations greater than 100 times background were recorded in the vicinity of the gold processing facilities.

**Using Watershed Sulfate Retention Derived from NADP and HBN Data
to Infer Response to Sulfur Emission Reduction**

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Understanding sulfate retention in forest soils can lend insight into likely responses to historical and potential future reductions in sulfur deposition. The decline in sulfur emissions in the eastern US during recent decades has been accompanied by a corresponding decline in sulfur deposition and by declining sulfate concentrations in most surface waters. However, in many areas in the eastern US and eastern Canada surface water alkalinity has not increased substantially and calcium and magnesium concentrations have remained constant or continued to decline. Forest soil inventories of exchangeable calcium have also been declining in many locations in this eastern North American region during this period. In most of the northeastern US and eastern Canada there is little if any net sulfate retention due to low sulfate adsorption capacity because of the clay mineralogy. In central and southeastern US soils have substantially more sulfate adsorption capacity and mass balance studies have shown considerable net sulfate retention. The adsorption and net retention of sulfate in forest soils serves to decrease the loss of base cations by reducing the rate of leaching of the mobile sulfate acid anion. In this study sulfur budgets are investigated using paired NADP deposition and US Geological Survey Hydrologic Benchmark Network (HBN) and other available stream water data to track temporal trends in annual sulfate retention. Trends in sulfate retention in relation to deposition rates are used to infer surface water response to future rates of sulfur deposition. Preliminary data indicate declining sulfate retention capacity in some locations under historical and current sulfate deposition regimes.



Perchlorate Deposition in the Continental United States and Selected Northern Hemisphere Locations: Initial Results

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While most large scale perchlorate occurrences have been attributed to anthropogenic sources, in a number of cases the sources have not been identified and natural sources have been proposed. For almost a century perchlorate has been known to exist in Chilean nitrate deposits that are 16 million years old, and recent isotopic evidence has confirmed its source to be predominantly atmospheric. However, there is almost no data available concerning the deposition rate of perchlorate from precipitation. This research effort was designed to investigate the range of concentrations, and geographical variations in perchlorate deposition. Sub-samples of precipitation collected through the National Atmospheric Deposition program were analyzed for perchlorate. Sample locations included 14 continental states, Hawaii, and Puerto Rico. In addition these samples have been supplemented by intensive event sampling at one location (Lubbock TX), as well as other scattered samples (e.g. Greenland). Perchlorate has been detected in a portion of samples from the majority of locations tested. Concentrations were generally low and quite variable and ranged from ND to 250 ng/L. Data to be presented will include results from 6 months of sample collection as well as analysis of general trends. Results from this study will have important implications to the national perchlorate issue and may aid in explaining the occurrence of non-anthropogenic perchlorate being reported in arid and semi-arid areas.

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An Investigation of Atmospheric Mercury Deposition and Wildfire Smoke

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Background: Atmospheric mercury deposition from anthropogenic sources is currently the subject of numerous studies. Natural sources must also be addressed to adequately model deposition risk regions. Wildfire, prescribed, and agricultural smoke, known to contain mercury, is the emission source being identified in this study.

Methods: Seasonal data for large fires and regional data for number of acres burned was obtained from U.S. Forest Service and National Interagency Fire Center (NIFC) for the years 2001-2004. Several single forest fire events were also identified by ignition date, location, and number of acres burned. Graphs were constructed comparing seasonal and regional data to actual deposition measurements obtained from the Mercury Deposition Network (MDN). Deposition rates were graphed over time and distance in a five week period following a specific fire's ignition date. All specified fires graphed in this data were >6,900 acres. Soil samples were also obtained from numerous forest areas throughout the United States to analyze for general mercury content.

Results: Seasonal atmospheric mercury deposition rates were found to correspond with large fire season data. Heaviest deposition rates and largest number of timber/grassland fires were consistently found in the meteorological season of summer (June, July, August), while lowest rates were in the winter (December, January, February). Strong compatibility was also identified in regional deposition rates and regional acres burned data. In every researched year the number of burned acres in the Southern Area (defined by the U.S. Forest Service) was at or over 2,000,000 acres. This value was >1,000,000 acres burned in any other region and corresponds to the area containing the heaviest actual deposition data.

Actual weekly deposition measurements following specific large fire incidents indicated increasing regional deposition within a 250km radius of the fire's location during the first five weeks following ignition. Increasingly elevated deposition levels were also identified within 250km to 500km in the region surrounding a fire in the same five week period. The region extending beyond 500km in the first five weeks following a large fire's ignition remained relatively flat. This information indicates that a correlation may exist between fire activity and increased atmospheric mercury deposition within a 500km radius of the location of the burn.

Soil analysis for mercury content was unsuccessful in this experiment due to inadequate detection equipment.

Conclusions: Broad data comparison indicates strong compatibility between fire activity and heavy atmospheric mercury deposition. Continued investigation of mercury deposition from vegetation smoke as a point source should be closely monitored as global mercury budgets continue to be assessed.



Total & Organic Nitrogen in Precipitation

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Total soluble nitrogen (TN) measurements in precipitation samples from the National Atmospheric Deposition Program (NADP) were determined by flow injection analysis from samples received in 2004 and 2005. Other researchers have reported the presence of significant levels of organic nitrogen (ON) in precipitation; therefore, a study was undertaken to measure TN and ON in precipitation samples from selected NADP sites. Organic nitrogen levels were determined using the formula $ON = TN - (NO_3\text{-N} + NH_4\text{-N})$. Precipitation samples for this study were collected from the Atmospheric Integrated Monitoring Network (AIRMoN) sites because samples from this network are obtained within 24 hours of a precipitation event, are immediately refrigerated, and remain chilled during shipment to the NADP Central Analytical Laboratory (CAL) in Champaign, IL. At the CAL, these samples were analyzed within seven days for inorganic nitrogen as ammonium and nitrate by flow injection analysis and ion chromatography, respectively, and for TN by flow injection analysis. The TN method detection limit was determined to be 0.008 mg/L N. Complete conversion to TN by organic and inorganic nitrogen compounds was determined by including three quality control standards (QCS) every twelve samples during analysis. The recovery in 2005 for a 2.0 mg/L N sulfanilamide digestion QCS was found to be $77.8\% \pm 1.2$ (typical recovery for this compound by this method is 80.5%). Four additional QCS, containing ammonium and nitrate in varying amounts, were also used with concentrations of 0.050, 0.199, 0.730, and 1.00 mg/L N. The percent recoveries for these QCS were $103.4\% \pm 6.7$, $98.8\% \pm 2.9$, $98.9\% \pm 1.3$, and 99.8 ± 1.4 , respectively. Seasonal data from 2004 and 2005 will be presented for an AIRMoN site in east central Illinois. Recent ON results for the eight site AIRMoN network will also be presented as well as the effects of sample filtration on TN measurements.

A Co-located Comparison of the National Atmospheric Deposition Program Raingage and Collector with Modern Instruments

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Increasing maintenance and replacement costs for aging sampling equipment, coupled with the emergence of new, more efficient technologies motivated the National Atmospheric Deposition Program (NADP) to modernize sampling equipment. In 2004, the U.S. Geological Survey (USGS) field evaluated: the OTT PLUVIO (OTT) raingage; the ETI Noah III (Noah) raingage; and the N-CON Systems ADS 100 (N-CON) precipitation collector, as possible replacements for the Belfort raingage and Aerochem Metrics (ACM) sampler. Standard NADP sample-collection and data-retrieval protocols were used. Weekly wet-deposition samples from both the N-CON and ACM collectors were submitted to the laboratory for analysis of major ions, pH and specific conductance. Precipitation depth and event recorder records from the three raingages, the wet-deposition chemistry from the two samplers, and the overall reliability of the equipment were compared.

The OTT and Noah raingages provided digital 15-minute records over the May-September 2004 study period. The Belfort produced a 7-day strip chart, requiring manual interpretation of weekly precipitation. The weekly mean precipitation depth was calculated for measurements recorded by the three raingages and used as the most probable value (MPV). The median weekly depth measured by the Belfort exceeded the MPV by 3.6%, while median weekly depths for the OTT and Noah were lower than the MPV by 1.8% and 2.8%, respectively. During the 150-day study period, OTT recorded 45 positive daily precipitation events that the Belfort and Noah did not measure. OTT reported that it has since corrected its software to minimize false recordings. Performance of the OTT and Noah raingages was similar for cumulative weekly events, while the Belfort consistently showed higher weekly cumulative totals. The three gages operated trouble-free during the study period. The new OTT PLUVIO and ETI Noah IV, an upgraded version of the Noah, have been selected by the NADP to replace the Belfort gage. The small weekly depth differences between the measured values and the MPVs for the OTT and Noah support NADP's selection.

The study period for comparing the ACM and N-CON collectors was January-September 2004. Median percent differences between weekly concentrations for samples collected by the N-CON and ACM collectors showed greater concentrations for all major ions for samples collected by the N-CON collector; ranging from 6% (calcium) to 17% (potassium). Median weekly specific conductance measurements were 8% higher for N-CON samples. The N-CON collector lid did not seal the sample collection bucket completely. This may have allowed air-borne debris to enter the bucket and/or allowed the sample to evaporate, which could elevate analyte concentrations. Collector lid openings during precipitation events correlate for the ACM and the N-CON. However, N-CON lid openings with no associated precipitation or corresponding ACM openings occurred at least twice per week during the study period. The N-CON was observed open during light precipitation on several occasions while the ACM was closed. The N-CON collector may be a suitable candidate for replacing the ACM collector if the bucket lid seal is improved to eliminate wind-borne contamination. The data indicate that a positive shift in annual mean concentrations should be expected where N-CON collectors replace ACM collectors.



Twenty-year NADP/NTN Seasonal Ammonium and Sulfate Trends

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Data from the National Atmospheric Deposition Program-National Trends Network (NADP-NTN) indicate significant changes in precipitation chemistry in North America over the last twenty years. A Seasonal Kendall Trend (SKT) analysis was performed on annual and seasonal ammonium and sulfate concentration data of 159 NADP-NTN sites in the continental U.S. from December 1984 to November 2004.

Statistically significant and seasonally homogeneous increasing trends were observed in annual ammonium concentrations at 95 (60%) of the sites studied, with a median continental U.S. trend of +28.5% for the 20-year period of record. Decreasing ammonium trends were significant and homogeneous at only 2 sites on an annual basis. Maximum increasing trends were observed in summer, with a median continental U.S. trend of +33.5%, with statistically significant and homogeneous increasing trends observed at 71 sites. Minimum trends were observed in spring at +17.4%, with significant and homogeneous trends at 37 sites. No more than three sites showed a significant trend in any one season.

Sulfate concentrations were found to decrease at the majority of sites. Statistically significant and homogeneous decreasing trends were observed in annual sulfate concentrations at 124 (78%) of the sites studied, with a median continental U.S. trend of -45.7%. The highest magnitude of decreasing (i.e., minimum) trends was observed in summer, although both spring and summer had an approximately equal median continental U.S. trend of -46.3%. For spring and summer data, decreasing trends were observed at 101 sites in summer and 114 sites in spring. Minimum decreases were observed in fall, with a median continental U.S. trend of -39.6%, with a statistically significant and homogeneous decreases observed at 91 sites. No sites showed a statistically significant and homogeneous increasing trend on either an annual or seasonal basis.

Concentration, Size Distribution, and Dry Deposition Rate of Particle-associated Trace Metals in the Los Angeles Region

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Daily averaged atmospheric concentrations and dry deposition fluxes of particulate trace metals were measured seasonally at six urban and one non-urban coastal sites throughout the Los Angeles region using a conventional total suspended particulate (TSP) filter, surrogate surface deposition plates, and a Noll Rotary Impactor (NRI), which provides information about particle size distribution in four size ranges above 6 microns. With the exception of the non-urban site, particulate metal concentrations and deposition fluxes are remarkably uniform spatially and temporally.

At all sites there are significant metal concentrations on particles greater than 10 microns, a commonly used upper limit for many air quality monitoring studies, and these large particles are estimated to be responsible for most of the deposited mass of metals. Annual averaged values of measured deposition rates are in good agreement with values estimated using theoretical deposition velocities in conjunction with measured size segregated particle concentrations.

Image analysis of particles deposited on NRI stage indicates night time metal concentrations and deposition at the non-urban coastal site may be higher than in the day time because of offshore advection of urban air associated with the diurnal land breeze. Measured enrichment of crustal and trace metals are correlated, indicating efficient mixing of natural and anthropogenic material from different sources, hypothesized to be the result of cyclical resuspension and deposition of dust by moving vehicles and wind.

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**Reactive Gaseous Mercury Concentrations and Distribution in the East USA:
A Comparison of Data from Three Locations—
Solomons and Beltsville, MD, and Star Island, NH**

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The atmosphere is the most important source of mercury (Hg) to many aquatic systems and Hg input comes from both wet and dry deposition. The MDN network has characterized wet deposition inputs of Hg nationally but there is still a dearth of information on Hg in the atmosphere and of Hg dry deposition. In the atmosphere, Hg exists as elemental Hg (Hg^0), reactive gaseous (ionic) Hg (RGHg) and as Hg associated with particulate matter. It is now clear that RGHg is not only released by various anthropogenic sources, but also, in some remote locations, such as in Polar Regions and over the ocean, the source of RGHg is primarily through elemental mercury (Hg^0) oxidation in the atmosphere. These recent studies have highlighted the importance of in situ RGHg formation and its dry deposition in contributing to Hg deposition in remote environments. In Maryland, studies have shown measurable concentrations of RGHg, and evidence of a photochemically-driven diurnal pattern of RGHg, at a rural location on the shores of the Chesapeake Bay (CBL, Solomons, MDS, USA). There also appear to be occasions where local inputs of RGHg are likely contributing as high RGHg concentrations coincide with elevated Hg^0 . During a month-long study off the coast of New Hampshire (Star Island), Hg speciation was monitored in conjunction with measurements of a suite of trace gases and other indicators of pollution. It was again seen that RGHg exhibited a diurnal pattern but with relatively low concentrations. There was no correlation between the RGHg peaks and those of pollution indicators, such as elevated ozone and SO_2 . However, elevated Hg^0 concentrations did appear to coincide with the elevated levels of the other parameters. The poster will provide an evaluation of the data available for the three sites and contrast their differences, and will examine our current understanding of the factors controlling RGHg formation and deposition. As RGHg is rapidly removed from the atmosphere, its anthropogenic signal was not seen at this more remote location; however, there was evidence of its in situ production. To examine RGHg distributions as a result of anthropogenic inputs, an intensive study was undertaken at a site in Beltsville, MD in August 2005, where Hg speciation was again monitored in conjunction with that of other atmospheric species. The preliminary results from this study will also be shown and discussed. Overall, the poster will provide an evaluation of these data, and through a comparison with other datasets examine our current understanding of the factors controlling RGHg formation, and those determining its rate of deposition.

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**Effects of Emission Reductions at the Hayden Powerplant on
Deposition Chemistry in the Mount Zirkel Wilderness Area, Colorado, 1996-2003**

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Precipitation and snowpack samples collected during 1995–2003 were analyzed to evaluate the effects of emission reductions at the Hayden powerplant on deposition chemistry in the Mount Zirkel Wilderness Area. The Hayden powerplant, one of two large coal-fired powerplants in the Yampa Valley, was retrofitted with control systems during 1999 to reduce emissions of sulfur dioxide and nitrogen oxide. Concentrations and deposition rates of selected constituents were compared for the periods before and after emission reductions at the Hayden powerplant. Data collected during 1995–98 were used to represent the pre-control period, and data collected during 2000–2003 were used to represent the post-control period.

Ten precipitation stations in the NADP were evaluated; two stations were directly downwind from the Hayden powerplant (Dry Lake and Buffalo Pass) and eight stations were upwind or more distant from the powerplant. Precipitation amounts at all 10 stations were lower during the post-control period than the pre-control period because of a regional drought that persisted during the post-control period. Nitrate, ammonium, and base cation concentrations were higher during the post-control period than during the pre-control period at all 10 stations, most likely because of a concentrating effect of the drought. In contrast, there was no consistent pattern of change in sulfate concentrations between periods, indicating that the drought did not have a concentrating effect on sulfate or that trends in regional sulfur dioxide emissions masked its influence. Sulfate concentrations increased at three stations between periods, remained the same at three stations, and decreased at four stations. Change in average annual sulfate concentration was largest at the two precipitation stations downwind from the Hayden powerplant, decreasing by $3.3 \mu\text{eq/L}\cdot\text{yr}^{-1}$ at Dry Lake and by $2.2 \mu\text{eq/L}\cdot\text{yr}^{-1}$ at Buffalo Pass. Declines in annual sulfate deposition also were greater at Dry Lake ($3.4 \text{ kg/ha}\cdot\text{yr}^{-1}$) and Buffalo Pass ($3.3 \text{ kg/ha}\cdot\text{yr}^{-1}$) than at the other stations, where the change in deposition only ranged from 0.2 to $1.7 \text{ kg/ha}\cdot\text{yr}^{-1}$. These results indicate that emission reductions at the Hayden powerplant have been a factor in declines in atmospheric deposition of sulfate downwind of the powerplant.

Twenty-two snowpack sites in the Rocky Mountain snowpack network also were evaluated; 4 sites were located directly downwind from the Hayden powerplant and 18 sites were upwind or more distant from the powerplant. Water content of the snowpack at maximum accumulation was lower during the post-control period than during the pre-control period reflecting the regional drought. Although there were small declines in snowpack sulfate concentrations at the downwind stations between the pre- and post-control periods, the difference was not statistically significant indicating that emission reductions had a weaker effect on snowpack chemistry than rainfall chemistry. Sulfate deposition decreased at all four downwind sites in the post-control period reflecting lower water content and concentrations in the snowpack. As observed at the precipitation stations, nitrate, ammonium, and base cation concentrations at all 22 sites were significantly higher during the post-control period than during the pre-control period, reflecting the drought.

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Northeast Assessment of Forest Sensitivity to Sulfur and Nitrogen Deposition: Application to Air, Forest, and Water Quality Management

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In their 1998 Acid Rain Action Plan the Conference of New England Governors and Eastern Canadian Premiers (NEG/ECP), under the direction of its Committee on the Environment, called for the formation of a Forest Mapping Working Group to conduct a regional assessment of the sensitivity of northeastern North American forests to current and projected sulfur and nitrogen emissions levels. This presentation will discuss some of the results of the NEG/ECP Forest Sensitivity Assessment for the New England States and the relationship between current air quality targets and future acidification risk to forests.

Evaluating forest sensitivity to acidic deposition requires information on: pollution loading to forest landscapes; the interaction of pollutants with forest canopies; plant nutrient requirements; and the ability of soils to buffer acid inputs and replenish nutrients lost due to acidification. Recent scientific advances in estimating each of these factors have made it feasible to produce maps of forest sensitivity to acid inputs from atmospheric nitrogen and sulfur. An integral part of this project was an open dialog with scientists, air resource specialists, foresters, and members of provincial, state and federal governments about data, methodology, and interpretation of results.

Factors that increase forest sensitivity include: high levels of nitrogen and sulfur deposition, low mineral weathering rates, and tree species with high nutrient demands. High-elevation forests and areas closest to emission sources experience the highest levels of nitrogen and sulfur deposition. Low mineral weathering rates occur in association with particular geologic and climatic factors. Requirements for soil nutrients vary according to the species currently growing in a forest, because tree species have different nutrient requirements for health and growth. Watershed-scale assessments using the NEG/ECP Forest Sensitivity Model show good correspondence with independent calculations of acid sensitivity for lakes. The NEG/ECP Forest Sensitivity Model results and underlying data should be useful for integrated assessment of risks to terrestrial and aquatic ecosystem health under different air pollution scenarios.

**Assessment of Alpine and Subalpine Lake Sensitivity to
Atmospheric Deposition of Pollutants in Grand Teton National Park
and Yellowstone National Park, Wyoming**

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The sensitivity of 400 lakes in Grand Teton and Yellowstone National Parks to acidification from atmospheric deposition of nitrogen and sulfur was estimated based on statistical relations between acid-neutralizing capacity concentrations and basin characteristics to aid in the design of a long-term monitoring plan for Outstanding Natural Resource Waters. Acid-neutralizing capacity concentrations that were measured at 52 lakes in Grand Teton and 23 lakes in Yellowstone during synoptic surveys were used to calibrate the statistical models. Basin-characteristic information was derived from Geographic Information System data sets. The explanatory variables that were considered included bed-rock type, basin slope, basin aspect, basin elevation, lake area, basin area, soil type, and vegetation type. A multivariate logistic regression model was developed and applied to lake basins greater than 1 hectare in Grand Teton (n = 106) and Yellowstone (n = 294).

A higher percentage of lakes in Grand Teton than in Yellowstone were predicted to be sensitive to atmospheric deposition of nitrogen and sulfur. For Grand Teton, 36 percent of lakes had a greater than 60-percent probability of having ANC concentrations less than 100 microequivalents per liter. For Yellowstone, results indicated that 13 percent of lakes had a greater than 60-percent probability of having ANC concentrations less than 100 microequivalents per liter. The lakes that exceeded 60-percent probability of having an ANC concentration less than 100, and therefore had the greatest sensitivity to acidification from atmospheric deposition, are located at elevations greater than 2,790 meters in Grand Teton, and greater than 2,590 meters in Yellowstone. Modeling results were validated through sampling at lakes in Grand Teton and Yellowstone National Parks during September 2004. Results indicate that 85 percent of the lakes sampled were accurately identified by the model as having a greater than 60 percent probability of ANC concentrations less than 200 microequivalents per liter. Average annual atmospheric deposition maps of nitrate and sulfate were overlaid on the sensitivity estimates to identify lakes that warrant additional monitoring, based on having both high sensitivity and high deposition.



Pick Your Season: Under-estimation (Summer) and Over-estimation (Winter) of Total Mercury Deposition by MDN Collection Methods at Acadia National Park, Maine

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Kenneth B. Johnson⁴, and J. Steve Kahl⁵

Atmospheric deposition of mercury (Hg) is a concern at Acadia National Park (ANP) in Maine, where surface waters and biota have higher concentrations of Hg than expected for a location remote from major industrial centers. Throughfall (water that has fallen through the forest canopy) has been used as a surrogate for the sum of wet and dry deposition, each of which can account for about half of total deposition of Hg. We collected rain throughfall at 21 sites and snow throughfall at 11 sites in 2004-2005. These sites were chosen to capture the range of land cover types in two calibrated watersheds. We hypothesized that year-round throughfall deposition of Hg would be greater than MDN deposition measured 6 km from our throughfall network (site ME98), due to scavenging by the forest canopy and orographic enhancement. We collected rain throughfall at two- to three- week intervals, when sample bottles contained a cumulative total of ~4 cm. We collected snow throughfall in Teflon snow bags, after major snowfall (>15 cm) and within 24 hr of the snowfall event ending to minimize Hg loss through blowing, sublimation, or volatilization. To estimate Hg volatilization from snow, we collected samples that accumulated snow for the entire collection period, co-located at seven of the sites (hereafter, seasonal snow samples). MDN under-estimates total deposition of Hg to forested watersheds during the growing season because dry deposition is excluded. Mean rain throughfall Hg was 41.9 ng/m²/day in conifer-dominated sites, 46.8 ng/m²/day in sites with mixed conifer-deciduous vegetation, 32.1 ng/m²/day in deciduous-dominated sites, and 38.4 ng/m²/day in sites dominated with shrub vegetation. These deposition rates exceeded open-funnel deposition (21.9 ng/m²/day) measured at MDN site ME98. Also, snow throughfall deposition at the forested sites exceeded Hg deposition measured in our co-located collector at the open MDN site for the same time period (10.7 ng/m²/day). Snow throughfall Hg averaged 76.2 ng/m²/day in conifer-dominated sites, 49.3 ng/m²/day in mixed conifer-deciduous sites, 26.8 ng/m²/day in sites dominated by deciduous vegetation, and 10.7 ng/m²/day in shrub-dominated sites. Deposition of Hg in the seasonal snow samples ranged 6.1 – 23.2 ng/m²/day, depending on vegetation type. Snow Hg deposition calculated by summing snow throughfall samples for the entire period at the same sites ranged 9.4 – 67.9 ng/m²/day, or, on average, 2.7 times the seasonal snow sample estimate. Although deposition values based on event sampling (snow throughfall) may represent total deposition to the watersheds, Hg can rapidly volatilize. Thus the events-based approach for measuring throughfall deposition may over-estimate the winter flux of Hg to the forest floor. Similarly, snow deposition of Hg may be over-estimated by the MDN monitoring program, because MDN samplers close after events and are collected weekly, thereby limiting volatilization of Hg. Our results suggest that (1) dry deposition of Hg can be significant relative to wet deposition, varying by canopy type and (2) MDN deposition estimates should be scaled up in summer and down in winter, using coefficients that probably need to be determined for each location.

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**Winter Recreational Vehicle Emissions and Ambient Air Quality in
Yellowstone and Grand Teton National Parks**

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In recent years the use of snowmobiles in Yellowstone and Grand Teton National Parks has become quite controversial. The sport became very popular with park visitors in the late 1990's while air quality was approaching the national standards for carbon monoxide (CO). Organic compounds, ammonium, sulfur, and particulate matter (PM) were being emitted and deposited to the snow along the roads. A winter use plan cut the number of snowmobiles allowed to enter the park each day, encouraged the use of cleaner snowmobile engines, and promoted the use of snow coaches. Substantial improvements in air quality have resulted with the introduction of the 4-stroke engine in snowmobiles and a significant reduction in the amount of traffic. The CO and PM2.5 concentrations are now approaching the lower concentrations seen during the summer when there are many more visitor vehicles. Direct measurements of snow coach emissions show a very wide range in emissions. The fleet average on a per person basis was found to emit more pollutants than the 4-stroke snowmobiles. However, newer conversion vans and retro-fitted snow coaches are much cleaner. The changes in ambient air quality from the winter use plan vehicle requirements are clear from the monitoring records at both the entrance stations and at Old Faithful.



An Assessment of Ammonia Emissions from Alternative Technologies for Swine Waste

Wayne P. Robarge*, Viney P. Aneja¹, Pal Arya¹, Lori Todd² and Kathleen Mottus²

Research efforts to identify and implement “Environmentally Superior Technologies” (EST) for handling swine waste were initiated in 2000 by the Attorney General of North Carolina via an agreement with Smithfield Foods and its subsidiaries, and a similar agreement with Premium Standard Farms. A third agreement, related to this initiative was established between the Attorney General of North Carolina and Frontline Farmers in 2002. The Agreements define an EST as “any technology, or combination of technologies that (1) is permissible by the appropriate governmental authority; (2) is determined to be technically, operationally, and economically feasible for an identified category or categories of farms as described in the Agreements and (3) meets the following performance standards: 1. Eliminate the discharge of animal waste to surface waters and groundwater through direct discharge, seepage, or runoff; 2. Substantially eliminate atmospheric emissions of ammonia; 3. Substantially eliminate the emission of odor that is detectable beyond the boundaries of the parcel or tract of land on which the swine farm is located; 4. Substantially eliminate the release of disease transmitting vectors and airborne pathogens; and 5. Substantially eliminate nutrient and heavy metal contamination of soil and groundwater.” In 2001, an interdisciplinary multi-institutional research science team, Project OPEN (Odor, Pathogens, and Emissions of Nitrogen) was funded to conduct evaluations of the ESTs for performance standards 2, 3 and 4. Presented in this poster is the approach adopted by Project OPEN to evaluate the ability of the ESTs to reduce ammonia emissions (performance standard 2). Successful evaluation of the ESTs and their ability to reduce ammonia emissions required an approach that allowed comparison of measurements differing in space and time due to the large number of ESTs to be evaluated (18), the desire for both and cold (winter) and warm (summer) evaluations, and the need to complete all the evaluations to meet the timeline and budget restraints established by the Agreements (limited resources). The approach selected does NOT contrast absolute measurements. Rather, emissions of N as ammonia (%E) from baseline farms (conventional technology) are compared to those measured for EST sites, after suitable corrections for differences in animal numbers, feed composition, housing ventilation, N excreted, size of lagoons, and weather parameters. The numerical difference between $\%E_{\text{conventional}}$ minus $\%E_{\text{alternative technology}}$ was chosen such that when positive the EST decreased emissions of ammonia. This difference then served as the index calculated for comparison between ESTs. Although not optimal in design due to resource restrictions, the approach has proven successful in identifying alternative technologies which succeed in meeting performance standard 2 – substantially eliminate or reduce atmospheric emissions of ammonia.

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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 6+ 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 ($\text{NH}_4\text{-N}$) 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, $\text{NH}_4\text{-N}$ 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 $\text{NH}_4\text{-N}$ deposition to the forest floor (from both wet and dry deposition) was 14.5 kg N/ha. The dry deposition of $\text{NH}_4\text{-N}$ 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 SO_4 /ha), and perhaps $\text{NO}_3\text{-N}$ (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 $\text{NH}_4\text{-N}$ to forest canopies in the vicinity of production facilities should be accompanied by enhanced dry deposition of Cl and SO_4 , and possibly $\text{NO}_3\text{-N}$.

Measurable amounts of dry deposition of $\text{NH}_4\text{-N}$ 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; $\text{NH}_4\text{-N}$ plus $\text{NO}_3\text{-N}$) 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 $\text{NH}_4\text{-N}$ 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.



CASTNET Monitoring in Coastal Ecosystems

Christopher M. Rogers* and Margaret Lasi, Ph.D.¹

In existence since 1991, EPA's Clean Air Status and Trends Network (CASTNET) provides a nation-wide, long-term monitoring platform designed to estimate dry deposition. It was created to answer the mandate of the Clean Air Act Amendments of 1990 and incorporated the approximately 50 sites that made up EPA's National Dry Deposition Network (NDDN), which began operation in 1987. Since 1991, many sites have been added to the network, frequently through partnerships with other organizations such as the National Park Service (NPS). Currently, there are 86 CASTNET sites across the United States.

The CASTNET database includes dry deposition data for a seventeen year period, 1987 through 2003. The values are produced using the Multi-layer Model (MLM), which estimates deposition velocity based on meteorological and site vegetation profile inputs. The product of deposition velocities and atmospheric concentrations is then calculated to provide an estimate of dry deposition flux. CASTNET data can be obtained from the EPA CASTNET data access web page: www.epa.gov/castnet/data.html.

CASTNET includes numerous sites in sensitive ecosystems such as coastal/estuarine environments along the east coast of the United States. CASTNET sites along the east coast of the United States, including 3 sites representing estuaries in EPA's National Estuary Program (NEP), show significant differences in deposition with higher levels in the mid-Atlantic region. At the site at Florida's Indian River Lagoon, modeling has shown that atmospheric deposition contributes approximately 13% of the total nutrient load to the lagoon.

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Determining Precision, Accuracy, and Bias for the Monitoring Instrument for Aerosols and Gases (MARGA)

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During the months of August and September 2005, a wide variety of measurements will be undertaken at the Clean Air Status and Trends Network (CASTNET) site at Beltsville, MD, which was the location of the first installation of the Monitoring Instrument for Aerosols and Gases (MARGA). The proposed measurements include:

- Hourly concentrations of gases and aerosols from two (2) collocated MARGAs
- 12-hour day-night concentrations of gases and aerosols from annular denuder/filter packs
- Weekly or monthly NH₃ concentrations from Ogawa passive samplers
- Weekly or monthly concentrations of HNO₃, NH₃, and NH₄⁺ from low-flow denuders
- Standard CASTNET weekly concentration measurements
- Concentrations from various precursor gas analyzers in resolutions ranging from 10 seconds to 1 hour: SO₂, CO, NH₃, NO, NO_y, and O₃.

These data are being collected to determine completeness, precision, and accuracy of the MARGA measurements and to estimate any biases between the MARGA data and other measurements including the CASTNET filter measurements, which have been collected since 1987. Data will be aggregated to various time periods to allow for the intercomparison of the different methods. Along with a year-long field study that will incorporate a similar, reduced set of measurements at two other CASTNET sites (Big Bear, CA and Bondville, IL), these analyses and comparisons will be used to evaluate the performance and viability of the MARGA as the “next-generation” instrument for CASTNET.

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Update On Modeling Mercury Deposition In Maryland Using CALPUFF

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This poster presents an overview of recent advances in atmospheric mercury deposition modeling undertaken by the Maryland Power Plant Research Program (PPRP) to evaluate the impacts of regional sources on deposition of mercury in the State of Maryland. Mercury exists in the atmosphere in three primary forms: elemental (Hg^0), reactive (Hg^{2+}) and particulate (Hg_p). Transformations can occur in the atmosphere between these different forms, through several different mechanisms. These mechanisms include the gas-phase oxidation of Hg^0 to Hg^{2+} by ozone, hydrogen peroxide (H_2O_2), hydroxy radicals (OH), Cl_2 and HCl. In the aqueous phase, adsorption of Hg^{2+} onto elemental carbon particles, as well as both oxidation and reduction reactions, can occur. The REMSAD and CAMx grid models are among several models developed by researchers that contain algorithms to estimate the atmospheric transformation and fate mercury species. The REMSAD and CAMx algorithms were used to create a box model to investigate the relative importance of the different mechanisms, and to develop a simplified transformation scheme appropriate for implementation in a lagrangian model. The CALPUFF model was modified to incorporate this transformation scheme, and was evaluated by comparing model predictions to deposition measurements at wet deposition MDN sites. This poster will present an overview of the transformation scheme development and of the evaluation of CALPUFF with mercury chemistry compared to measurements.

**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 field testing conducted through 2005, the OTT Pluvio from Hach Environmental is now approved 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 functionality.

The version of the OTT Pluvio that has been specifically designed for the NADP network includes integrated data logging capability for both precipitation measurement and sampler status. Downloading data is quickly and easily accomplished by infrared transmission to a standard Windows Mobile-based PDA. The NADP design of the OTT Pluvio is available for delivery in September.



Atmospheric Mercury in the Atlantic Provinces, Canada from 1995-2004

Robert Tordon*, John Dalziel¹ and Stephen Beauchamp¹

In order to determine the levels of atmosphere mercury in the Atlantic Provinces, measurements of mercury in the gas phase and total mercury in precipitation have been measured at two locations, Kejimikujik National Park, Nova Scotia, Canada and St. Andrews, New Brunswick, Canada. Measurements have been made since 1995 for total gaseous mercury (TGM) and since 1996 for total mercury in precipitation. An additional site for measurements of total mercury in precipitation was set up in Cormak, Newfoundland in 2000.

These measurements have been undertaken to quantify mercury concentrations in the atmosphere, to examine the temporal and spatial variability of mercury in air and precipitation. The trend observed for TGM data show highest concentrations in winter and the lowest during the spring months. Median values for TGM are about 1.4 ng/m³ with maximum values around 4 ng/m³. Back trajectories have been used to determine the possible local, regional and international source regions for the highest levels of TGM observed. Concentrations of total mercury in precipitation show a slightly decreasing trend in volume weighted concentration from New Brunswick (yearly average 7.2 ng/l) to Newfoundland in the northeast (yearly average 5 ng/l). Measurements indicate that TGM concentrations in ambient air and concentrations of mercury in precipitation have not changed significantly from year to year over the sampling period of 1996 to 2004.

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**Mercury Flux from Tidal Sediments Located in an Isolated Cove
in the Great Bay Estuary, New Hampshire**

Alan VanArsdale*¹, Dr. Byard Moshur², and Dr. Stephen Jones³

An investigation of mercury flux from undisturbed estuarine tidal sediments was conducted as part of an EPA-ORD funded Regional Applied Research Effort (RARE) Study of mercury dynamics in the Great Bay Estuary of New Hampshire. Measurements of mercury flux were made during several tidal cycles from exposed sediments and overlying water for day and night conditions. Multi-day experiments were conducted during the spring and summer of 2001. Open water and above sediment measurements were made using a free-floating Teflon coated flux chamber. Changes in the concentration of gaseous elemental mercury were measured with a TEKTRAN Model 2537A mercury vapor analyzer, located on-shore near to the flux chamber. Measurements confirm mercury flux from exposed tidal sediments and overlying water that rival measurements of mercury flux from soils, lake surfaces, and open ocean water. Mercury emissions from sediments and overlying water exhibited a strong diurnal pattern.

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Dry Deposition of Nitrogen Over a Forest Experiencing Free Air CO₂ Enrichment: Estimates Derived From Measurements and Modeling During the CELTIC Study

Jed Sparks¹, John Walker*, Andrew Turnipseed²,
Wayne Robarge³, and Alex Guenther²

The Chemical Emission, Loss, Transformation and Interactions within Canopies (CELTIC) study was conducted at the Duke Forest Free Air CO₂ Enrichment (FACE) site during the summer of 2003. The goal of CELTIC is to develop a quantitative understanding of the processes controlling the exchange of gas and aerosol carbon and nitrogen between the atmosphere and vegetated canopies. Here we present measurement and model estimates of dry NO_y, NH₃, NO₃⁻, and NH₄⁺ deposition during the two week study period along with estimates of total annual N deposition. During CELTIC, fluxes of total gas phase oxidized nitrogen (NO_y) were measured by eddy covariance using a fast response chemiluminescence analyzer. NH₃, HNO₃, and particulate NO₃⁻, and NH₄⁺ (PM_{2.5}) were measured above and below the canopy by annular denuder/filter pack. Fluxes of NH₃, HNO₃, NO₃⁻, and NH₄⁺ were then estimated by applying measured concentrations to deposition velocities derived from compound specific inferential models. During the two week study period, NO_y was the primary contributor to dry N deposition, followed in importance by NH₃, NH₄⁺ and NO₃⁻, respectively. Annual total N deposition is estimated using scaled measurements taken during CELTIC and additional observations from the nearest CASTNet and NADP sites. Total dry and wet N deposition were approximately 7.5 and 5.8 kg N ha⁻¹, respectively, at this site during 2003. NO_y, NH₃, NH₄⁺, and NO₃⁻ contributed 56%, 21%, 19%, and 4% of total annual dry N deposition, respectively. Our results show that NH₃ and reactive oxidized nitrogen compounds other than NO_x and HNO₃ (e.g. PAN) contribute significantly to total dry N deposition and should therefore be included in forest N budgets. Accurate estimates of exogenous N inputs are critical for predicting forest response to future scenarios such as increased CO₂.

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Fog Inputs and Edge Effects from Canopy to Soil in a California Redwood Forest

Kathleen C. Weathers*, Amanda Elliott¹, and Holly A. Ewing²

As a horizontally-driven vector, fog interacts with the structure of the landscape to create spatial patterns of deposition not seen in the more even distribution of vertically-delivered rainwater inputs. In coastal CA, fog arrives during the summer growing season when trees are most physiologically active and rainfall is negligible, thus it may be an ecologically significant source of water and nutrients. We are examining the interaction of horizontal and vertical inputs with forest structure, and the influence of these inputs on plant physiology, ecosystem fluxes, and soil characteristics in coastal redwood forests, Sonoma, CA. Fog water flux to the forest floor via throughfall (TF) was approximately 5 times greater at the windward (ocean-facing) edge than at sites on the interior of the patch, while rain delivery was more even across the whole forest patch. This edge effect for TF showed an exponential decline away from the windward forest edge; all sites greater than about 75 m from the edge received comparable fog inputs. Soil moisture patterns reflected the input pattern: the surface soil horizon at the windward edge had consistently greater water content than did interior sites throughout the fog season. After a large fog event, throughfall added to edge soils roughly doubled the moisture content at the soil surface. The absence of such input in the forest interior left relative water content lower by a factor of two to three compared to the edge site. While both tension and gravity lysimeters collected water at all sites in the forest during the rainy season, only tension lysimeters near the windward forest edge collected water in the fog season. These results suggest water availability at edge and interior locations can differ markedly during the fog water season and that fog may affect rates of primary production, biogeochemical cycling, and soil development.

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NTN MAP AND SITE LISTINGS

**National Atmospheric Deposition Program/National Trends Network Sites
August 31, 2005**

State	Site Code	Site Name	Collocation	Sponsoring Agencies	Start Date
Alabama					
	AL02	Delta Elementary	MDN	EPA/Mobile Bay Nat Est Prog & Dauphin Is.Sea Lab	06/01
	AL10	Black Belt Agricultural Experiment Substation		US Geological Survey	08/83
	AL24	Bay Road	MDN	EPA/Mobile Bay Nat Est Prog & Dauphin Is.Sea Lab	05/01
	AL99	Sand Mountain Agricultural Experiment Substation		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 National Park-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
	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-INSTAAR/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 Science, 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
	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
Delaware					
	DE99	Trap Pond State Park		US EPA-CAMD/Cheapeake Bay Program	05/03
Florida					
	FL03	Bradford Forest		St. John's River Water Management District	10/78
	FL05	Chassahowitzka NWR	MDN	US Fish & Wildlife Serv - 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
	FL41	Verna Well Field		US Geological Survey	08/83
	FL99	Kennedy Space Center		NASA/Dynamac Corporation	08/83

State	Site Code	Site Name	Collocation	Sponsoring Agencies	Start Date
Georgia					
	GA09	Okefenokee NWR	MDN	US Fish & Wildlife Serv - Air Quality Branch	06/97
	GA20	Bellville		US Environmental Protection Agency-CAMD	04/83
	GA33	Sapelo Island		NSF/UGA, NOAA-NERR, & Georgia Dept. of Nat. Res.	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	SAES-University of Illinois	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		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
Maryland					
	MD07	Catoctin Mountain Park		National Park Service - Air Resources Division	05/03
	MD08	Piney Reservoir	MDN	MD-DNR/Univ. 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	Beltsville	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		N.E. States for Coord. Air Use Management	03/82
	MA13	East		N.E. States for Coord. Air Use Management	02/82

State	Site Code	Site Name	Collocation	Sponsoring Agencies	Start Date
Michigan					
	MI09	Douglas Lake-Univ. Michigan Biological Station		USDA/Michigan State University	07/79
	MI26	Kellogg Biological Station		USDA/Michigan State University	06/79
	MI29	Peshawbestown		US Environmental Protection Agency-CAMD	01/02
	MI48	Seney NWR - Headquarters	MDN	US Fish & Wildlife Serv - 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	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/Ft. 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 Serv - Air Quality Branch	10/98
	NJ99	Washington Crossing		US Environmental Protection Agency-CAMD	08/81
New Mexico					
	NM01	Gila Cliff Dwellings NM		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		New Mexico Environment Department	11/84
New York					
	NY01	Alfred		US Geological Survey	06/04
	NY08	Aurora Research Farm		USDA/Cornell University	04/79
	NY10	Chautauqua		US Geological Survey	06/80
	NY20	Huntington Wildlife	MDN	EPA/SUNY-College of Env. Science & Forestry	10/78
	NY22	Akwesasne Mohawk-Fort Covington		US Environmental Protection Agency-CAMD	08/99
	NY29	Moss Lake		U.S. 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 Prog	11/03
	NY98	Whiteface Mountain		US Geological Survey	07/84
	NY99	West Point		US Geological Survey	09/83

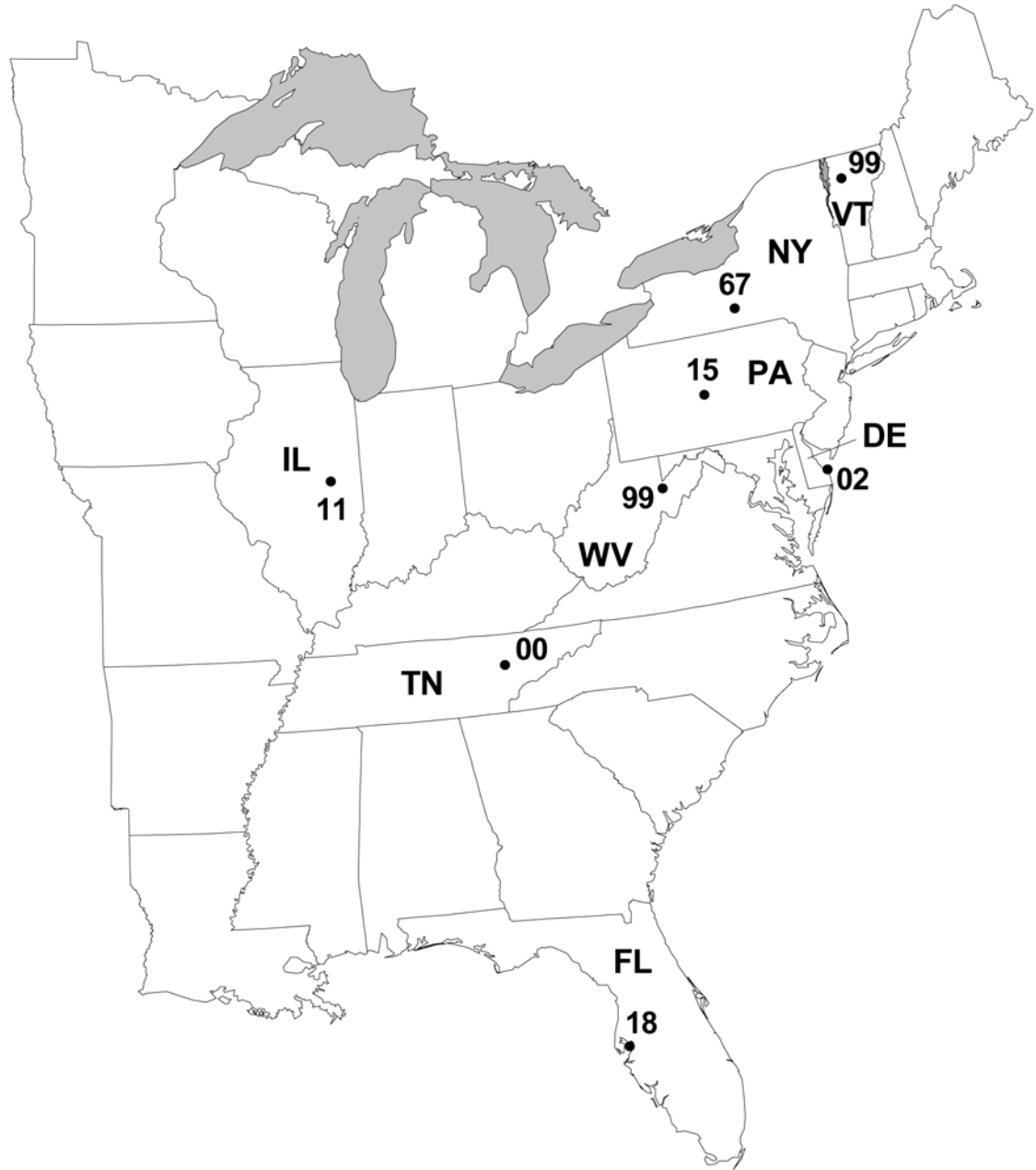
State	Site Code	Site Name	Collocation	Sponsoring Agencies	Start Date
North Carolina					
	NC03	Lewiston		North Carolina State University	10/78
	NC06	Beaufort		US Environmental Protection Agency-CAMD	01/99
	NC25	Coweeta		USDA Forest Service	07/78
	NC29	Hofmann Forest		North Carolina State University	07/02
	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 Women'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	PA Dept of Environmental Protection/Penn State Univ	11/02
	PA72	Milford	MDN	USDA Forest Service	12/83
Puerto Rico					
	PR20	El Verde		USDA Forest Service	02/85
South Carolina					
	SC05	Cape Romain NWR	MDN	US Fish & Wildlife Serv - Air Quality Branch	11/00
	SC06	Santee NWR		US Geological Survey	07/84
	SC07	Ace Basin NERR		NOAA/SC Department of Natural Resources	12/01
	SC11	North Inlet-Winyah Bay NERR		EPA/SC Dept of Health and Environmental Control	01/02
	SC99	Fort Johnson		EPA/SC Dept of Health and Environmental Control	03/02
South Dakota					
	SD04	Wind Cave National Park-Elk Mountain		National Park Service - Air Resources Div	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 Natl 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 Div	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

State	Site Code	Site Name	Collocation	Sponsoring Agencies	Start Date
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		VA 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
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
	WI32	Middle Village	MDN	EPA/Menominee Indian Tribe	01/02
	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-West Glacier Lake		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 Div.	06/80
	WY95	Brooklyn Lake		USDA Forest Service	09/92
	WY97	South Pass City		USDA Forest Service/Bridger Teton NF	04/85
	WY98	Gypsum Creek		USDA Forest Service/Bridget-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 the purpose of measuring network precision.

AIRMoN MAP AND SITE LISTINGS

National Atmospheric Deposition Program Atmospheric Integrated Research Monitoring Network

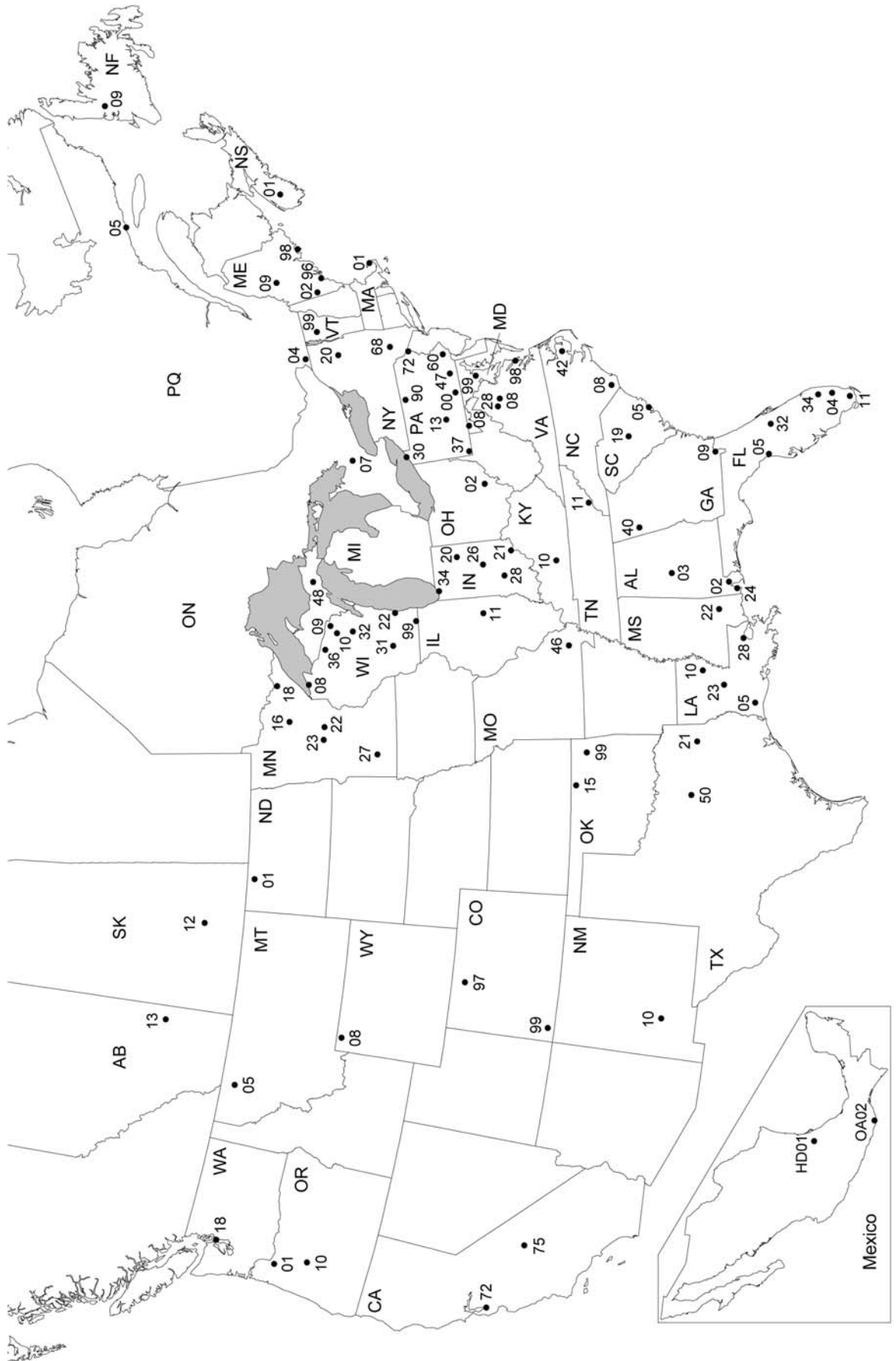


**NADP/Atmospheric Integrated Research Monitoring Network Sites
August 31, 2005**

State	Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Delaware					
	DE02	Lewes		NOAA-Air Resources Laboratory	09/92
Florida					
	FL18	Tampa Bay		FL Department of Env. Protection	08/96
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, 2005**

State/Province	Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Alabama					
	AL02	Delta Elementary	NTN	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	Mobile Bay National Estuary Prog & Dauphin Island Sea Lab	05/01
California					
	CA72	San Jose		San Francisco Estuary Institute	01/00
	CA75	Sequoia NP-Giant Forest	NTN	National Park Service - Air Resources Division	07/03
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 and Wildlife Service - Air Quality Branch	07/97
	FL11	Everglades NP - Research Center	NTN	South Florida Water Management District	*03/96
	FL32	Orlando		US Geological Survey	09/03
	FL34	ENRP		South Florida Water Management District	07/97
Georgia					
	GA09	Okefenokee NWR	NTN	US Fish and 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
	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/ME Dept of Environmental Protection	*03/96
Maryland					
	MD08	Piney Reservoir	NTN	MD DNR/Univ 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					
	MI48	Seney NWR - Headquarters	NTN	US Fish and Wildlife Service - Air Quality Branch	11/03
Minnesota					
	MN16	Marcell Experimental Forest	NTN	USDA Forest Service-North Central Res Station & MNPCA	*02/96
	MN18	Fernberg	NTN	USDA-FS - Superior NF & MN Pollution Control Agency	*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		Missouri Department of Natural Resources	03/02
Montana					
	MT05	Glacier NP - Fire Weather Station	NTN	National Park Service - Air Resources Division	10/03
New Mexico					
	NM10	Caballo		Bureau of Reclamation/New Mexico State University	05/97

State/Province		Collocation	Sponsoring Agency	Start Date
Site Code	Site Name			
New York				
NY20	Huntington Wildlife	NTN	NYS Energy Research & Development Authority/Syracuse Univ.	12/99
NY68	Biscuit Brook	NTN	NYS Energy Research & Development Authority/USGS in NY	03/04
North Carolina				
NC08	Waccamaw State Park		North Carolina Dept of Environment & Natural Resources	*02/96
NC42	Pettigrew State Park		North Carolina Dept of Environment & Natural Resources	*02/96
North Dakota				
ND01	Lostwood NWR		US Environmental Protection Agency	11/03
Ohio				
OH02	Athens Super Site		US DOE-National Energy Technology Lab/CONSOL Energy, Inc.	12/04
Oklahoma				
OK15	Newkirk		EPA/Cherokee Nation	03/05
OK99	Stilwell		EPA/Cherokee Nation	04/03
Oregon				
OR01	Beaverton		US Geological Survey	04/03
OR10	H. J. Andrews Experimental Forest	NTN	US Geological Survey	12/02
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
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	NTN	US Fish and Wildlife Service - Air Quality Branch	03/04
SC19	Congaree Swamp		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
TX50	Fort Worth		EPA/City of Fort Worth-Dept. of Environmental Management	08/01
Vermont				
VT99	Underhill	AIRMoN/NTN	NOAA-ARL/University of Vermont	07/04
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
Washington				
**WA18	Seattle - NOAA		NADP/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		US Geological Survey	10/02
WI31	Devil's Lake		Wisconsin Department of Natural Resources	01/01
WI32	Middle Village	NTN	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		National Park Service - Air Resources Division	10/04

State/Province		Collocation	Sponsoring Agency	Start Date
Site Code	Site Name			
CANADA				
Alberta				
AB13	Henry Kroeger		ATCO Power	09/04
Newfoundland				
NF09	Cormak		Environment Canada	05/00
Nova Scotia				
NS01	Kejimikujik NP		Environment Canada	07/96
Ontario				
ON07	Egbert		Environment Canada	03/00
Quebec				
PQ04	Saint Anicet		Environment Canada	04/98
PQ05	Mingan		Environment Canada	04/98
Saskatchewan				
SK12	Bratt's Lake BSRN		Environment Canada	05/01
MEXICO				
Hidalgo				
HD01	Huejutla		North American Commision for Environmental Cooperation	10/04
Oaxaca				
OA02	Port Angel		North American Commision for Environmental Cooperation	09/04

*These dates mark the official start of NADP/MDN operations. Data for a transition network operating in 1995 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

