NADP Proceedings 1999-01

NADP TECHNICAL COMMITTEE MEETING PROCEEDINGS

Sacramento, California
October 25-28, 1999

NATIONAL ATMOSPHERIC DEPOSITION PROGRAM

A Cooperative Research Support Program of the
State Agricultural Experiment Stations (NRSP-3)
Federal and State Agencies
and Private Research Organizations

Last year, researchers, students, decision makers, and others interested in National Atmospheric Deposition Program (NADP) data made more than 13,000 data retrievals and viewed more than 30,000 maps from the NADP World Wide Web site. NADP data are used to address important questions about the impact of the wet deposition of nutrients on eutrophication in coastal estuarine environments, the relationship between wet deposition to unmanaged forests and the depletion of base cations from forest soils, the impact of pollutant emissions changes on precipitation chemistry, and the rate at which precipitation delivers mercury to remote lakes and streams.

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

In October 1981, the federally supported National Acid Precipitation Assessment Program (NAPAP) was established to increase understanding of the causes and effects of acidic precipitation. This program sought to establish a long-term precipitation chemistry network of sampling sites distant from point source influences. Because of its experience in organizing and operating a national-scale network, NADP agreed to coordinate operation of NAPAP's National Trends Network (NTN). Having common siting criteria, identical operating procedures, and sharing a common analytical laboratory, NADP and NTN merged with the designation NADP/NTN. Many sampling sites are supported by the U.S. Geological Survey (USGS), NAPAP's lead federal agency for deposition monitoring. Under Title IX of the federal Clean Air Act Amendments of 1990, NAPAP continues. Today there are nearly 220 sites in the network, and the network designation has been shortened to NTN.

In the 1990s, NADP expanded to include two additional networks. A research network, the Atmospheric Integrated Research Monitoring Network (AIRMoN), currently with nine sites, joined NADP in October 1992. AIRMoN sites collect samples daily when precipitation occurs. Samples are refrigerated until analysis at the CAL for the same constituents measured in NTN samples. AIRMoN seeks to identify pollutant source/receptor relationships and the effect of emissions changes on precipitation chemistry, combining measurements with atmospheric models. AIRMoN also evaluates new sample collection and preservation methods. Another NADP network, the Mercury Deposition Network (MDN), currently has nearly 40 sites and joined NADP in 1996. MDN sites collect one-week, wet-only deposition samples, which are sent to a lab that specializes in mercury measurements. Frontier Geosciences, Inc., analyzes all samples for total mercury and some for methyl mercury. MDN collects data on the wet deposition of mercury to surface waters, forested watersheds, and other receptors. Nearly 40 states have advisories against consuming fish from certain lakes because of high mercury concentrations in fish tissues. MDN data enable researchers to investigate the importance of the atmospheric deposition of mercury as a cause of this problem.

A number of federal agencies support NADP including: U.S. Geological Survey (USGS), Cooperative State Research, Education, and Extension Service (CSREES), Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), National Park Service (NPS), U.S. Forest Service (USFS), Bureau of Land Management (BLM), U.S. Fish & Wildlife Service (USFWS), and Tennessee Valley Authority (TVA). Additional support is provided by various other federal agencies, State Agricultural Experiment Stations, state agencies, universities, and public and private research organizations.

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

NADP TECHNICAL COMMITTEE MEETING

Proceedings

Sacramento, California
October 25-28, 1999

Technical Program Chair
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October 1999

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Session Chair: Ellen Porter, U.S. Fish and Wildlife Service

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NADP Technical Committee Meeting Agenda

NADP Technical Committee Meeting
Sacramento, California
October 25-28, 1999

MONDAY October 25th	**Event**	**Room Location**
8:00 a.m. to 12:00 p.m.	Registration Desk Open (and poster set-up)	El Dorado/Diablo
8:00 a.m. to 10:00 a.m.	Executive Committee Meeting	Granada
10:00 a.m. to 12:00 p.m.	Technical Committee: Opening Business Meeting Welcome and Introductions - Dennis Lamb Meeting Overview - Jim Lynch Program Advisors NRSP-3/AES - Wayne Banwart CSREES - Dan Jones NAPAP - Mike Uhart NTN - Mark Nilles AIRMoN - Rick Artz NADP Reports Program Office - Van Bowersox MDN/Toxics - Clyde Sweet CAL - Karen Harlin HAL - Eric Prestbo Subcommittee Agenda Topics Network Operations - John Gordon Data Management and Analysis - Luther Smith Environmental Effects - Ellen Porter/John Sherwell	El Dorado/Diablo
12:00 p.m. to 1:30 p.m.	Lunch (on your own)	
1:30 p.m. to 5:00 p.m.	Registration Desk Open (and poster set-up)	
1:30 p.m. to 3:00 p.m.	Joint Subcommittee Meetings Network Operations Data Management and Analysis Environmental Effects	Hermosa
3:00 p.m. to 3:30 p.m.	Break	
3:30 p.m. to 5:00 p.m.	Individual Subcommittee Meetings	Hermosa, Monterey Placer

MONDAY October 25th	**Event**	**Room Location**
6:00 p.m. to 8:00 p.m.	**Poster Session and Social Mixer**	Fresno

Evaluation of Long-term Storage on NADP/NTN Sampling Supplies: Black Box Bagged Bucket and Bottle Blanks Study - B^6 Study. Sue Bachman, Karen Harlin, Tracie Patten, Brigita Demir, and Pam Bedient, NADP Central Analytical Laboratory, Illinois State Water Survey.

Modernizing NTN Equipment, A Look at Two Candidates: the NOAH II Precipitation Gage and the Canadian MIC Precipitation Collector. Roger D. Claybrooke and Van C. Bowersox, University of Illinois, Illinois State Water Survey and James A. Lynch, Pennsylvania State University.

Nitrate, Sulfate, and Ammonium Trends in NADP/NTN Data From 1981 Through 1998. Brooke Conley, Colorado School of Mines and Mark Nilles, U.S. Geological Survey.

The Maryland Power Plant Research Program Internet Resource for Precipitation Chemistry Data. Louis A. Corio and William B. Jones, Versar, Inc. and John Sherwell, Maryland Department of Natural Resources.

Estimation of Atmospheric Deposition of Ammonium and Nitrate in North Carolina and Coastal Plain River Basins. Ellis Cowling and Cari Furiness, North Carolina State University and Luther Smith and Mark Henderson, ManTech Environmental Technology.

National Atmospheric Deposition Program/National Trends Network–1998 Map Products. Scott Dossett, Van C. Bowersox, Roger D. Claybrooke, Karen S. Harlin, and Bob Larson. University of Illinois, Illinois State Water Survey.

Results from the Inter-laboratory Comparison Program Operated for the National Atmospheric Deposition Program/National Trends Network, 1983-1998. John D. Gordon and Laura L. Hult, U. S. Geological Survey.

Deposition Chemistry in National Park Service Units: Spatial and Temporal Analyses. Kristi Heuer and Kathy Tonnessen, National Park Service.

New Developments on the NADP Web Site. Bob Larson and Roger D. Claybrooke, University of Illinois, Illinois State Water Survey.

Trends ***in Rainwater Chemistry for Central Florida: An Update.*** Brooks C. Madsen, University of Central Florida and Thomas W. Dreschel and Lee A. Maull, Dynamac Corporation.

Thymol Preservation in Daily Precipitation Samples. Jane Rothert, Brigita Demir, Kaye Surratt, and Van C. Bowersox, University of Illinois, Illinois State Water Survey

Northwestern Rangeland Watershed and Regional Settings for NADP Monitoring. Charles W. Slaughter and Clayton L. Hanson, USDA, Agricultural Research Service.

Isotopic ($\delta\,^{18}O$) Characteristics of Weekly Precipitation Collected by the NADP: An Initial Analysis with Application to Water Source Studies. Jeff M. Welker, University of Wyoming.

TUESDAY October 26th	**Event**	**Room Location**
8:00 a.m. to 12:10 a.m.		El Dorado/Diablo
Technical Session I:	***Clean Air Act Amendments of 1990: Emission Reductions and Impacts*** Session Chair: Rick Artz, NOAA Air Resources Lab	
08:00 - 08:30	***The Acid Rain Program: SO_2 and NO_X Emissions Trends and a Perspective on SO_2 Allowance Trading***. Rona Birnbaum, U.S. EPA, Acid Rain Office.	
08:30 - 08:50	***Environmental Effects of SO_2 Trading and Banking***. Dallas Burtraw, Resources for the Future, and Erin T. Mansur, University of California Energy Institute.	
08:50 - 0920	***Changes in Sulfate Deposition in Eastern USA Following Implementation of Phase I of Title IV of the Clean Air Act Amendments of 1990***. James A. Lynch, Pennsylvania State University; Van C. Bowersox, University of Illinois, Illinois State Water Survey; and J. W. Grimm, Pennsylvania State University	
09:20 - 09:40	***Regional Level Air and Precipitation Chemistry and Their Relationship to Changing Emissions***. Tom Butler, Gene Likens and Barbara Stunder, Cornell University.	
09:40 - 10:10	***Effects of the Clean Air Act on Streams in Northeastern Forested Watersheds - Preliminary Evidence.*** Peter S. Murdoch, U.S. Geological Survey.	
10:10 a.m. to 10:40 a.m.	Break	
10:40 - 11:00	***Acid Wet Deposition and Critical Loads in Eastern Canada.*** Chul-Un Ro, Robert Vet, and David McTavish, Environment Canada	
11:00 - 11:20	***Acid Precipitation Events in a Massachusetts Pond Revisited.*** Hannah Melnitsky and William G. Hagar, University of Massachusetts, Boston.	
11:20 - 11:50	***Atmospheric Deposition of Nutrients and Trace Metals In New Jersey.*** Stuart J. Nagourney, New Jersey Dept. of Environmental Protection and Steven J. Eisenreich, Yuan Gao, and John Reinfelder, Rutgers University***;*** ***Atmospheric Deposition of Persistent Organic Pollutants in New Jersey***. Stuart J. Nagourney, New Jersey Dept. of Environmental Protection and Steven J. Eisenreich, Rutgers University.	
11:50 - 12:10	***Status of New England/Eastern Canada Acid Rain Action Plan.*** Rich Poirot, Vermont Department of Environmental Conservation.	
12:10 a.m. to 1:30 p.m.	Lunch (on your own)	

TUESDAY October 26th	**Event**	**Room Location**
1:30 p.m. to 5:10 p.m.		El Dorado/Diablo

Technical Session II: ***Atmospheric Deposition Monitoring and Assessment: A Western Perspective***
Session Chair: Mary Ann Allan, Electric Power Research Institute

1:30 - 1:50	***Atmospheric Transport of Pollution Plumes to the Central Sierra Nevada Mountains***. John Carroll. University of California, Davis.
1:50 - 2:10	***Dry Deposition of Nitric Acid to Soils and Soil Components in Mediterranean Ecosystems.*** Pamela E. Padgett and Andrzej Bytnerowicz, USDA, Forest Service
2:10 - 2:30	***Throughfall and Fog Deposition of Nitrogen and Sulfur at an N-limited and N-saturated Site in the San Bernardino Mountains, Southern California***. Mark A. Poth and Mark E. Fenn, USDA, Forest Service.
2:30 - 3:00	***Causes and Effects: The Early Onset of Eutrophication in Ultraoligotrophic Lake Tahoe.*** Charles R. Goldman, University California, Davis.
3:00 p.m. to 3:30 p.m.	Break
3:30 - 3:50	***Preliminary Evaluation of Dissolved Organic Nitrogen (DON) in Wet Atmospheric Deposition at the Niwot Ridge NADP Site, Colorado, USA.*** Mark Losleben, Mark Williams, and Christine Seibold, INSTARR, University of Colorado.
3:50 - 4:10	***Comparing Atmospheric Bulk Deposition Chemistry to NADP Wetfall Chemistry in and near Rocky Mt. National Park, Colorado.*** George Ingersoll, Don Campbell, and Ben Glass, USGS and Kathy Tonnessen, National Park Service.
4:10 - 4:30	***Monitoring of Air Pollution in California Ecosystems: Present Status and Research Needs.*** Andrzej Bytnerowicz, USDA, Forest Service
4:30 - 4:50	***San Francisco Bay Atmospheric Deposition Pilot Study.*** Pam Tsai, San Francisco Estuary Institute; Eric Papp, City of San Jose Environmental Services Department; and Rainer Hoenicke, San Francisco Estuary Institute.
4:50 - 5:10	***Organic and Inorganic Nitrogen in Fog Waters and Particulate Matter.*** Cort Anastasio, Qi Zhang, Mike Jimenez-Cruz, and John Carroll, University of California, Davis.

Dinner (On your own)

WEDNESDAY October 27th	**Event**	**Room Location**
8:00 a.m. to 11:50 a.m.		El Dorado/Diablo
Technical Session III:	***Atmospheric Deposition Monitoring and Assessment: An Eastern Perspective*** Session Chair: Luther Smith ManTech Environmental Tech.	
08:00 - 08:20	***Effects of Ten Years of Elevated N and S Additions on Watershed Processes: The Fernow Whole Watershed Acidification Study***. M. B. Adams, P. J. Edwards, J. N. Kochenderfer, and F. Wood, USDA, Forest Service, NEFES.	
08:20 - 08:40	***Trends in Ammonium Concentration in Precipitation and Atmospheric Ammonia Emissions at a Coastal Plain Site in North Carolina, USA.*** John Walker. US EPA and Viney P. Aneja and Dena Nelson, North Carolina State University.	
08:40 - 09:00	***Dry Deposition Data for Sulfur and Nitrogen Species at a Rural Monitoring Site in Illinois - A Comparison of Two Concurrent Datasets.*** Gary J. Stensland, Illinois State Water Survey.	
09:00 - 09:20	***Acid Deposition, Aluminum Buffered Soils, Tree Decline and Forest Regeneration Failure in Pennsylvania: Random Occurrences or Related Phenomena.*** William E. Sharpe, Pennsylvania State University.	
09:20 - 09:40	***Evaluating the Impact of Increased Nitrogen Deposition in the Chesapeake Bay Basin: An Application of the PnET-CN Regional Ecosystem Model.*** John Hom and Yude Pan, U.S. Forest Service, NEFES, John Aber, University of New Hampshire	
09:40 - 10:00	***Sources and Source Regions Contributing to Atmospheric Deposition of Toxic Pollutants to the Great Lakes***. Mark Cohen, Roland Draxler, and Richard Artz, NOAA, Air Resources Laboratory.	
10:00 a.m. to 10:30 a.m.	Break	
10:30 - 10:50	***Pesticides in the Atmosphere of the Mississippi River Valley***. Michael S. Majewski, William T. Foreman, and Donald A. Goolsby, U.S. Geological Survey.	
10:50 - 11:10	***Topographic Enhancement of Wet Deposition Estimates Using Modeled Precipitation.*** James A. Lynch and Jeffrey W. Grimm, Pennsylvania State University.	
11:10 - 11:30	***Final Report on the Testing and Evaluation of Alternative Rain Gages for the NADP***. Laura L. Hult, Oak Ridge Associated Universities and John Gordon, USGS.	
11:30 - 11:50	***Atmospheric Nitrogen Loading to the Delaware Inland Bays: New Perspectives***. Joseph Scudlark and Thomas Church, University of Delaware	
11:50 a.m. to 1:20 p.m.	Lunch (On your own)	

WEDNESDAY October 27th	**Event**	**Room Location**
1:20 p.m. to 3:00 p.m.		El Dorado/Diablo

Technical Session IV: ***Trace Metal (Hg) Deposition: Current Concerns and Observations, Future Needs***
Session Chair: Ellen Porter, U.S. Fish and Wildlife Service

1:20 - 1:40 ***International Monitoring/Measurement Activities for Atmospheric Mercury***. John Munthe, Swedish Environmental Research Institute and Eric M. Prestbo, Frontier Geosciences.

1:40 - 2:00 ***Nutrient and Metal Deposition to Corpus Christi Bay, Texas***. Terry L. Wade, Steve Sweet, and Neil Tindale, Texas A & M University; Sandra Alvarado, Corpus Christi Bay National Estuaries Program; Clyde W. Sweet, University of Illinois, Illinois State Water Survey.

2:00 - 2:20 ***Wet Deposition of Mercury in the U.S. and Canada***. Clyde W. Sweet, University of Illinois and Eric Prestbo and Bob Brunette, Frontier Geosciences.

2:20 - 2:40 ***Methyl Mercury Deposition in the Upper Midwest: Seasonal Trends, Comparison with Other Regions, Possible Sources and Estimated Ecosystem Impact.*** Eric M. Prestbo and Robert C. Brunette, Frontier Geosciences, Inc. and Clyde W. Sweet, Illinois State Water Survey.

2:40 - 3:00 ***Are Sources Other than Anthropogenic Point Sources Significant Contributors to the Atmospheric Mercury Budget?*** Mae S. Gustin, University of Nevada, Reno, and Steven E. Lindberg, Oak Ridge National Lab.

2:50 p.m. to 3:30 p.m.	Break	
3:30 p.m. to 5:00 p.m.	Joint Subcommittee Meetings Network Operations Data management and Analysis Environmental Effects	El Dorado/Diablo

Dinner (On your own)

THURSDAY October 28th	**Event**	**Room Location**
7:00 a.m. to 9:00 a.m.	Executive Committee Meeting	JQ Lounge
9:00 a.m. to 11:00 a.m.	Technical Committee: Closing Business Meeting	JQ Ballroom

- Executive Committee Report - Jim Lynch
- Subcommittee Resolutions
  - Network Operations
  - Data Management and Analysis
  - Environmental Effects
- New Business
  - Election of Officers
  - Selection of Location for 2000 Technical Meeting

11:00	Adjourn	
11:00 a.m. to 6:00 p.m.	Field Trip to Lake Tahoe to discuss atmospheric deposition impact on the ecosystem. Box lunch included.	

I. POSTER PRESENTATIONS

Evaluation of Long-term Storage on NADP/NTN Sampling Supplies:
Black Box Bagged Bucket and Bottle Blanks Study - B^6 Study

Sue Bachman, Karen Harlin, Tracie Patten, Brigita Demir, and Pam Bedient
University of Illinois
Illinois State Water Survey
2204 Griffith Drive
Champaign, Illinois 61820

In an ongoing effort to provide clean, contaminant-free collection supplies to the National Atmospheric Deposition Network/National Trends Network (NADP/NTN) sites, a special storage evaluation study was undertaken at the Central Analytical Laboratory (CAL) of the Illinois State Water Survey. An assessment was made of the long-term storage effects of buckets and bottles enclosed in plastic bags and stored inside the black mailers, as to the impaction on analytical results. The black box mailers (filled with collection supplies) sent to sites across the nation are often not returned to the CAL on a regular rotational basis. Some buckets/bottles could remain at a site inside the black box for several months before being used for sample collection and then returned to the lab for processing and cleaning.

With the increased number of anticipated sites added to the network in January of 1999, a large supply of black boxes and their contents were prepared. Several of these sites did not come online immediately and the prepared supplies were then used to examine the buckets and bottles for the effects of long-term storage. Duplicating the “in field” situation was not entirely possible since the boxes and their contents were stored at ambient temperature and were not exposed to transportation and handling influences.

Sampling buckets and 1-liter bottles were cleaned, sealed in plastic bags, and packed into the black mailers, per CAL standard operating procedures, in early January, 1999. Beginning with week ten, 5 black mailers were removed from storage and 150 milliliters of either deionized water (DI) or Faux Rain 25 (in-house prepared quality control synthetic solution targeted to the 25th percentile concentration of all samples in the NADP/NTN) were added to five empty bottles and buckets. They were stored in the lab for one week and then 50 mL aliquots were removed from each container for analytical testing. Analytical analyses included pH, conductance, Ca^{++}, Mg^{++}, Na^+, and K^+ (by atomic absorption), Cl^-, NO_3^-, SO_4^{2-} by (by ion chromatography) and NH_4^+ and PO_4^{3-} (by flow injection analysis). This process was repeated at weeks 12, 16, 20, 24, and 28 for a total of six separate testing dates.

Results of the long-term storage effects for each analyte will be presented. Conclusions of the study will be made as to the overall effects of long-term storage on bottles and buckets in black boxes as it pertains to possible chemical contamination and continued usage by the NADP/NTN.

Modernizing NTN Equipment, a Look at Two Candidates:
the NOAH II Precipitation Gage and Canadian MIC Precipitation Collector

Roger D. Claybrooke and Van C. Bowersox[1]
University of Illinois
Illinois State Water Survey
and
James A. Lynch[2]
Pennsylvania State University

The National Trends Network (NTN) requires that every site use two commercially available instruments for precipitation collection and measurement: the Aerochem Metrics (ACM) precipitation collector and the Belfort B5-780 recording gage. The electrically powered ACM collector automatically collects precipitation samples for chemical analysis, and the Belfort gage mechanically measures and records precipitation amounts. Both instruments have simple designs and proven reliability. However, many NTN sites are approaching two decades of network participation, raising concerns about the continued reliability of these aging instruments. More than 180 equipment failures occurred in the ~200-site NTN in 1997. An ad hoc NADP committee has prepared a plan for identifying and evaluating suitable replacements for the ACM collector and Belfort gage. A new electronic gage and the MIC precipitation collector used in the Canadian Acid Precipitation Monitoring Network are being tested at the Illinois State Water Survey as potential replacements for NTN use.

One experiment evaluated the NOAH II precipitation gage, manufactured by ETI Instrument Systems, Inc. This electronic gage has virtually no moving parts. Precipitation falls into an open cylinder, and a load cell records the accumulated mass in 0.01-inch increments. Electronic filters reduce false readings caused by wind, temperature, and evaporation. The signal from the NOAH II gage was compared with the Belfort gage used by NTN. To increase the sensitivity of the Belfort gage for measuring small precipitation amounts, the standard 8-inch-diameter top was replaced with a 12-inch top. Liquid depth measurements from both gages were compared with reference measurements from a co-located National Weather Service stick gage. This experiment continued for one year (July 1998 - July 1999), and 96 precipitation events were measured, including light and heavy rain and snow events. Using a paired T-test and a Wilcoxon signed rank test, NOAH II and Belfort measurements were not significantly different. Both gages captured significantly less precipitation ($p < 0.01$) than the reference stick gage. Differences between the Belfort or NOAH II gages and stick gage averaged ~0.01 inches per event. One problematic observation of the NOAH II gage is that it consistently recorded false positive responses that appear to be temperature-related.

Another experiment compared the precipitation sensor efficiencies of the Canadian MIC and NTN ACM precipitation collectors. Both sensors are designed to signal the collectors to open during precipitation and close during dry weather. The ACM sensor uses a 7-element aluminum grid held approximately 0.5 mm from a sensor plate. When precipitation fills this gap at any point, the ACM collector opens. The MIC sensor is a flat plastic surface embedded with wires, much like a printed-circuit board. The wires are approximately 0.2 mm apart, and precipitation spanning this gap opens the MIC collector. In this experiment, the MIC sensor also opens a second ACM collector. Exposure times, sample volumes, and sample chemistries from the standard and MIC-driven ACM collectors were compared. Over 81 precipitation samples, the MIC-driven collector averaged 0.01 inches more precipitation and was open 2 hours longer per sample than the ACM collector. This longer exposure to the atmosphere demonstrates the greater sensitivity of the MIC sensor and resulted in higher average concentrations of every analyte measured. Sample chemistry differences are being evaluated for the effects of precipitation catch differences, differences in dry deposition exposure, and evaporation.

These experimental results will inform NADP's ongoing evaluation of new technologies. Data gathered from this and other experiments will be used to select modern new replacements for the aging ACM collector and Belfort gage.

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Nitrate, Sulfate, and Ammonium Trends in NADP/NTN Data from 1981 Through 1998

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and
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The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) provides a long-term, high-quality data base that is useful for assessing the magnitude and trends of wet atmospheric deposition of acids, base cations and nutrients throughout the United States. Today the NADP/NTN consists of approximately 220 sites. Precipitation samples are collected weekly and sent the Central Analytical Laboratory where levels of hydrogen (acidity as pH), sulfate, nitrate, ammonia, chloride, orthophosphate, and base cations (such as calcium, magnesium, potassium, and sodium) are determined. From this data long term trends analysis is possible.

NADP/NTN data from 1981 through 1998 was used following a multi-step process. For a site to be included in the trends analysis it must have had:

Data from at least the last quarter of 1985 through the first quarter of 1997
Greater than or equal to 66.6% on NADP/NTN completeness criteria 1, 3, and 4
Retained at least 66.6% of its original data after the previous steps

Of the 220 NADP/NTN sites, 147 sites passed all three criteria.

Once the data set was established, NH_{4+}, SO_{42-}, and NO_{3-} trends were calculated and analyzed for significance. General conclusions were NH_{4+} is increasing in some areas, SO_{42-} is decreasing nationwide, and NO_{3-} is unchanged.

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The Maryland Power Plant Research Program
Internet Resource for Precipitation Chemistry Data

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John Sherwell[1]
Maryland Department of Natural Resources

The Maryland Department of Natural Resources Power Plant Research Program (PPRP) initiated a project in 1998 to make available on the World Wide Web, precipitation chemistry data from monitoring sites located in the Chesapeake Bay watershed. To that end, PPRP obtained, from various organizations, background information on atmospheric deposition monitoring programs (some of which are still ongoing), as well as special studies. For those programs and studies with available precipitation chemistry data of known quality (data was not available for all programs and studies), PPRP obtained, processed, and uploaded the data to its web-site (esm.versar.com/pprp/features/aciddep/aciddep.htm). These data can either be viewed on the web site or downloaded as a zipped file in either comma-delimited or Excel spreadsheet format. PPRP also provides descriptions of the monitoring programs/studies, including information on measurement methods and quality assurance procedures, where available. For the few monitoring programs (e.g., NADP) with existing web sites that allow on-line access to data, PPRP provides links to these sites. PPRP currently is working with the National Oceanic and Atmospheric Administration Air Resources Laboratory in a cooperative effort to make more precipitation chemistry data easily available to the scientific community.

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Estimation of Atmospheric Deposition of Ammonium and Nitrate in North Carolina and Coastal Plain River Basins

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The specific objective of this analysis, as part of a larger research plan to assess the environmental impacts of animal agriculture operations, was to develop spatially refined estimates of atmospheric deposition of ammonium and nitrate to river basins of North Carolina over time. Three different sources of information were utilized: 1) National Atmospheric Deposition Network (NADP) and Clean Air Status and Trends Network (CASTNet) data on amounts of ammonium ion (NH_4+) and nitrate ion (NO_3^-) deposited as rain and snow; 2) National Weather Service data on amounts of precipitation; and 3) CASTNet estimates of amounts of dry deposition of NH_4^+ and NO_3^- deposited as atmospheric gases and particles. The data were integrated within a Geographic Information System-based framework delineating the river sub-basins in North Carolina, using interpolation techniques to produce estimates for a 5 X 5 km grid. Because of limitations of funding, this initial analysis concentrated on only two years, 1989 and 1994.

We conclude from the analyses that: a) a substantial part of the scientific evidence is consistent with the hypothesis that recently increased populations of swine in NC have contributed to an increased transfer of NH_4^+ from the atmosphere to land and surface waters of the state, and b) a less substantial part of the evidence is not fully consistent with this hypothesis.

Five steps in further analyses are recommended: a) utilizing data for all years of the historical record, b) checking the temporal and geographical representativeness of NADP and CASTNet sites, c) conducting more detailed time-series analyses at all sites, d) considering dry deposition more adequately, and e) using nutrient deposition data as a critical test of emissions inventory methods.

National Atmospheric Deposition Program/national Trends Network–1998 Map Products

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Illinois State Water Survey

The NTN maps portray spatial variability in the concentration and deposition of selected acids, nutrients, and base cations on regional and national scales. Only sites that meet prescribed data completeness criteria are included. In 1998, 162 sites met these criteria. Black dots mark the site locations. Annual concentration or deposition values are printed next to each site. The concentrations are volume-weighted averages. (To download or view additional map products or for an explanation of the data completeness criteria or how the volume-weighted averages or deposition fluxes were calculated, see the NADP Web site at http://nadp.sws.uiuc.edu/.)

To make the color contours on the NTN maps, site values were used to compute an array of regularly spaced grid-point values covering the country. Sites within 500 kilometers of each grid point were used in computations. Color contours were drawn on this array of grid-point values. Each contour represents the class of concentrations or depositions indicated in the legend. (For a more complete description of the algorithm used to compute grid-point values, see the NADP Web site.)

Color contour maps in this display show 1998 precipitation data for: 1) active sites in the network, 2) laboratory pH, 3) sulfate (SO_4^{2-}) concentration and 4) ammonium (NH_4^+) deposition. Concentration and deposition data for the other analytes are available from the NADP Web site.

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Results from the Interlaboratory Comparison Program Operated for the National Atmospheric Deposition Program/National Trends Network, 1983-1998

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Laura L. Hult[2]
Earth Science Intern

The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) operates a network of precipitation-chemistry monitoring sites throughout the United States. An interlaboratory comparison program is one of five programs operated by U.S. Geological Survey to document the quality of NADP/NTN data. When a researcher evaluates precipitation-chemistry data from a long-term monitoring network, it is critical that the precision of the data be taken into account. The interlaboratory comparison program has been operated for 15 years to provide an external assessment of the results from the NADP/NTN laboratory. Participation in the program by nine other laboratories that routinely analyze precipitation samples throughout North America provides a meaningful context for evaluating the results of the NADP/NTN contract laboratory. Laboratory precision was evaluated from 1983 to 1998 by calculating the median absolute differences for each analyte from replicate natural and synthetic precipitation samples. For the NADP/NTN laboratory, the calcium concentration precision estimate based on the 50th percentile median absolute difference was 0.000 mg/L. Calcium concentration precision estimates at the 50th percentile for nine other laboratories in North America ranged from 0.000 to 0.010 mg/L. Sulfate concentration precision estimates at the 50th percentile exhibited slightly greater variability with a median absolute difference of 0.01 mg/L at the NADP/NTN laboratory and 0.01 to 0.02 mg/L at the other participating laboratories.

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Deposition Chemistry in National Park Service Units: Spatial and Temporal Analysis

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In 1998 there were 32 operating NTN/NADP sites in national park units, representing a range of ecosystem types and environmental conditions. We present the deposition chemistry at these sites for 1998, with comparisons of the nitrate and sulfate concentrations. These point data are overlaid on the NTN isopleth maps of nitrate and sulfate concentrations to determine how these sites compare with the rest of the network. The 1998 concentration data are compared among parks in the six regions of the National Park Service (NPS), with temporal data displayed for one site in each region: Pacific West, Alaska, Intermountain, Southeast, Midwest, and Northeast. We discuss the use of these data relative to preservation of natural resources in the NPS, with case studies of how the NTN data have been used in New Source Review of air pollution sources and in regional air quality control initiatives. The future of the NPS involvement in NTN/NADP will be discussed.

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New Developments on the NADP Web Site

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No abstract available at time of printing

Trends in Rainwater Chemistry for Central Florida: an Update

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The National Aeronautics and Space Administration (NASA) established a multisite monitoring network at the Kennedy Space Center in 1977. One site located on the University of Central Florida (UCF) campus was part of the original network. That site has operated continuously since 1977 and represents an uninterrupted 20 year record of daily sampling. One NADP site was established in north Florida in 1978 and four additional Florida sites were established during the early 1980's. Linear regression evaluation of annual data suggests the existence of temporal trends in concentration and deposition for nitrate. Collection intervals at UCF have typically been 24 hr periods ending on Tuesday through Friday and 72 hr periods ending on Monday, which differs from the NADP sampling interval protocol.

In typical years sulfate is the most abundant anion in rainwater collected at UCF. Because of site proximity to the ocean, chloride is typically the most abundant anion at FL99. Annual amounts of rain show substantial variations that occur from site to site and from year to year with two-fold changes in extreme cases. Acidity difference and rainfall amount collectively account for the substantial differences in deposition quantities. The variation in annual acid deposition generally follows changes in both nitrate and excess sulfate deposition. Variations from year to year are dramatic. In addition, pronounced summertime maxima and winter time minima are observed for acidity, nitrate and sulfate concentrations and deposition. Previous studies have suggested that temporal trends for select chemical constituents in East-Central Florida rain do exist. A simplified data set that consisted of annual data from each of the sites was subjected to linear regression to evaluate possible temporal trends. No trend in acidity is suggested however nitrate is observed to show an upward trend suggesting a 57% increase at UCF (20 years) and a 118% increase at FL99 (14 years). These observations are consistent when concentration data, log transformed concentration data (e.g. pH) and deposition data for individual species are considered. The results of monitoring the chemical composition of rain in central Florida have shown that the rain is moderately acid. The measured acidity of rain is less than that observed in other regions of the U. S., however, it does suggest that the level of acidity is substantial.

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Thymol Preservation in Daily Precipitation Samples

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Orthophosphate and organic acids in precipitation samples are not generally stable, changing concentration over time. In addition, ammonium and nitrate in some samples change if not preserved. Various methods have been used to preserve all of these parameters. Using a biocide to preserve samples has long been considered the best method for preservation. Several different biocides have been used. This study looks at the use of thymol as a preservative for precipitation samples. The daily samples were collected at the Walker Branch Station, Oak Ridge, TN AIRMoN site (TN00). 0.8 g thymol was added to precipitation collection buckets which were placed on an Aerochem Metrics collector that opened and closed at the same time as the standard AIRMoN collector. All samples collected, therefore, are identical to the standard AIRMoN samples except for the addition of the thymol. The refrigerated AIRMoN samples and the samples with thymol as the preservative were sent to the Illinois State Water Survey and analyzed for pH, conductivity, NH_4^+, PO_4^{-3}, Cl^-, NO_3^-, and SO_4^{-2}. Analytical concentrations of the thymol-preserved samples versus the refrigerated samples are given for NH_4^+, PO_4^{-3}, pH, and conductivity.

Northwestern Rangeland Watershed and Regional Settings for NADP Monitoring

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Research watersheds in rangeland, forest and agricultural settings are widely employed as tools in hydrologic research. The National Atmospheric Deposition Program (NADP) complements the objectives of watershed research programs. Reynolds Creek Experimental Watershed (RCEW) was established in 1960 as a long-term study site which is representative of interior Pacific Northwest mountainous rangelands, with a hydrologic regime dominated by winter precipitation and seasonal snow. The 234 km^2 RCEW at 43° 10' N, 116° 46' W, in the Owyhee Mountains 70 km south of Boise, Idaho, has high relief and diversity of geology, soils, aspect, vegetation and land use. The elevation range of RCEW is 1098 m to 2254 m. Mean annual precipitation varies from 23 cm at the lowest elevations to over 110 cm (over 75% as snow) at the headwaters. Climate, precipitation and streamflow are measured in RCEW with an array of 18 dual-gauge precipitation sites, five comprehensive climate stations, seven snow courses and nine stream gaging stations.

The Reynolds Creek NADP station (ID11) was established in November,1983. ID11 is co-located with a valley climate station of RCEW, at 1198 meters elevation. NADP precipitation data for ID11 from 1984 through 1998 are considered in the temporal context of the long-term RCEW data base, 1960 to present; the complex local spatial diversity of RCEW; and the regional context as represented by five other NADP stations: Craters of the Moon National Monument (ID03, 1807 m elevation), Smiths Ferry (ID15, 1442 m elevation), Starkey Experimental Forest (OR18, 1252 m elevation), Vines Hill (OR11, 904 m elevation) and Saval Ranch (NV01, 1872 m elevation). Data from these NADP sites are useful in characterizing the regional setting, while the comprehensive RCEW information base provides a framework for evaluating the ID11 data set.

Reynolds Creek Experimental Watershed is a landscape-scale research facility available to scientists and resource managers from private, university, state, and federal entities; cooperation in research and in application of findings is welcomed.

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Isotopic ($\delta^{18}O$) Characteristics of Weekly Precipitation Collected by the NADP: An Initial Analysis with Application to Water Source Studies

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A study was undertaken to test the extent to which the $\delta^{18}O$-values of precipitation collected at a suite of sites across the United States exhibited similar traits as those in other regions of the globe. The sites used in this study were chosen to test the following postulates across the continental U. S.: 1) that the average $\delta^{18}O$-content of precipitation from the Gulf of Mexico and the subtropical Atlantic is enriched compared to that in the Pacific Northwest and that in the Northern Great Plains where air masses from the Arctic converge on the U. S. in winter, 2) that precipitation becomes gradually depleted in $\delta^{18}O$ as storms move inland from the Pacific Ocean and from the Gulf of Mexico, 3) that winter precipitation will be depleted in $\delta^{18}O$ compared to summer rain especially at high altitude locations and at sites where large temperature extremes exist between summer and winter, and 4) that the seasonal patterns in the $\delta^{18}O$ content of precipitation can be applied to ecological studies examining water sources used by plants in riparian and grassland ecosystems.

Over three years (1989-1991) the results indicate: 1) that the average $\delta^{18}O$-content of precipitation from the Gulf of Mexico is enriched by 4‰ compared to that derived from the Pacific Northwest, 2) that a continental effect between western and eastern Oregon results in a depletion rate of approximately 1.2‰/100 km, suggesting strong degrees of water recycling due to high rates of continental evapotranspiration, 3) that the $\delta^{18}O$-values of precipitation may vary by up to 20‰ between winter snow and summer rain, especially for high altitude and continental sites and 4) water source studies indicate that grass and shrubs may utilize different sources of water in grasslands while in riparian ecosystems, summer rain is of little importance to willow plants compared to stream water derived from adjacent alpine snowfields. In general, these results agree with findings from other precipitation networks in W. Europe (IAEA) while providing new insights as to the complexity of storm patterns and landscape interactions across the United States affecting the isotopic characteristics of precipitation.

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II. ORAL PRESENTATIONS

Technical Session I

Clean Air Act Amendments of 1990: Emission Reductions and Impacts

Session Chair: Rick Artz
NOAA Air Resources Lab

The Acid Rain Program:SO_2 and No_x Emissions Trends and a Perspective on SO_2 Allowance Trading

Rona Birnbaum
USEPA
Acid Rain Office

No abstract available at time of printing

Environmental Effects of SO_2 Trading and Banking

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Resources for the Future
and
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The widely acknowledged innovation of Title IV of the 1990 Clean Air Act Amendments is sulfur dioxide allowance trading, which is designed to encourage the electricity industry to minimize the cost of reducing emissions. Few studies have examined the environmental effects of trading and none have explored the effects of banking. We exercise an integrated assessment computer model, the Tracking and Analysis Framework, to evaluate changes in emissions of SO2, atmospheric concentrations of sulfates and deposition of sulfur, and public health benefits from reduced exposure to SO2 and particulate matter. We assess geographic and temporal changes at the state level that result from trading and banking, and compare them with estimated cost savings. Our findings are not consistent with the fears of the program's critics. In the East and Northeast including New York State, an area of particular concern, we find health benefits increase and sulfur deposition decrease slightly as a result of trading. Nationally, trading results in health-related benefits in addition to significant cost savings. Banking changes the timing of emissions, but the geographic consequence of banking is varied.

[Ψ] Dallas Burtraw is a Senior Fellow at Resources for the Future. *Erin Mansur is a Graduate Student at the University of California, Berkeley. The authors are grateful to Martin Heintzelman, Joe Cook and to the development team of the Tracking and Analysis Framework. David Evans and three reviewers provided useful comments. Lumina Decision Systems, the developers of *Analytica*, provided technical support. Financial support was provided by the U.S. Environmental Protection Agency. ΨDirect correspondence to Burtraw: Resources for the Future, 1616 P Street NW, Washington DC 20036; 202-328-5087; fax: 202-939-3460 (burtraw@rff.org).

Changes in Sulfate Deposition in Eastern USA Following Implementation of Phase I of Title IV of the Clean Air Act Amendments of 1990

J. A. Lynch*, V. C. Bowersox†, and J. W . Grimm‡

Phase I of Title IV of the Clean Air Act Amendments of 1990 (CAAA) was implemented on 1 January 1995. On that date limitations were imposed on sulfur dioxide (SO_2) emissions from 110 coal-fired electric utility plants (263 units) in 21 states of which 17 are east of the Mississippi River. Sulfur dioxide emissions at these plants dropped an average 2.86 million tons (39%) from 1995 through 1997, when compared to mean 1993-1994 emissions from these plants. As a result of these reductions, wet sulfate (SO_4^{2-}) deposition decreased an average of 2.4 kg ha^{-1} to 4.0 kg ha^{-1} (10% to 25%) over a large area of the eastern USA. Based on more than 15 years of data, the decrease in wet deposition was unprecedented in magnitude and spatial extent. The largest decrease occurred across the Mid-Appalachian and Northeast regions of the country, the regions specifically targeted by Phase I for reductions in acidic deposition. Although the reductions in wet SO_4^{2-} deposition were generally consistent with observed reductions in SO_4^{2-} concentrations, deviations in precipitation volumes between the pre- and post-Phase I periods did result in some sites recording significantly ($p<0.05$) lower post-Phase I concentrations but higher wet depositions. Deviations in precipitation within and between regions also influenced the magnitude and spatial distribution of the observed changes in wet SO_4^{2-} deposition. Clearly, deviations in the amount and distribution of precipitation need to be considered along with concentration changes in evaluating the CAAA effectiveness in reducing acidic deposition. This is particularly important in the eastern USA, since many of the most acid-sensitive ecosystems are located in regions, mostly mountainous and forested, that are subject to considerable fluctuations in precipitation volumes and subsequently acidic wet deposition.

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Regional Level Air and Precipitation Chemistry and Their Relationships to Changing Emissions.

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Emissions source regions for various parts of the eastern US (northern New England, New York, Pennsylvania, Mid Atlantic, Ohio, Tennessee, and Illinois) were estimated using two years of back trajectories for a representative AIRMoN site in each region.. Three different-sized source regions were established based on 12-18 hour back trajectories, 18-24 hour back trajectories, and all states lying within a 1500 km NW to south quadrant from the respective AIRMoN site.

Comparing the change in SO_2 emissions from 1991-1994 (pre-CAAA implementation) to 1995 - 1997 (post-CAAA) to the change in wet (NADP and AIRMoN-wet) and dry (CASTNET and AIRMoN-dry) sulfur concentrations for a number of sites in each region we find the average slopes of the regression lines show an approximately 1:1 relationship between % declines in emissions and declines in concentrations of sulfur, for most regions (northern New England, New York, Pennsylvania, Mid Atlantic, Ohio). In fact as the source region gets larger there are greater declines in sulfur concentrations than in emissions! This suggests that a smaller source region may be more appropriate for such a comparison between emissions and concentrations. There also may be climatic factors which are influencing air and precipitation concentrations that are independent of emissions reductions. A very similar pattern holds when comparing combined emissions of SO_2 and NOx with H+ concentrations in precipitation.

In the Tennessee (Southern Appalachians) and Illinois regions the relationships are not as clear. These two regions have not been impacted by Phase I of the CAAA as much as the other regions.

NOx reductions have been very minor or non-existent so far for all the regions. Finally ecosystem impacts resulting from CAAA so far have been insignificant.

Effects of the Clean Air Act on Streams in Northeastern Forested Watersheds - Preliminary Evidence.

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Despite a general decline in sulfate concentration in deposition during the 1990's, ANC in 3 large streams that drain forested watersheds in north-central Pennsylvania, the Catskill Mountains of southeastern New York, and the White Mountains of eastern New Hampshire show no trend for the same period. Temporal trends in sulfate concentrations over 14 years of record (1982-1995) in Biscuit Brook ($10km^2$) and the Neversink River ($168km^2$) in the Catskills paralleled decreasing trends in sulfate deposition. Average volume-weighted sulfate concentration in deposition decreased during Water Year 1995 from previous annual values, consistent with decreased emissions in response to the 1990 Clean Air Act Amendments. Concentrations in deposition increased again in Water Year 1996, then decreased slightly through 1997 and 98. No trends in sulfate or ANC concentrations are apparent after 1995 in the streams being monitored. N concentrations (nitrate plus ammonium) in deposition in the Catskills generally decreased over the period 1982-98. Stream nitrate concentrations do not show any relation to annual deposition values at either the Neversink River or the Biscuit Brook scale. A close correlation between nitrate concentrations in Biscuit Brook and annual average air temperature suggests that rates of N mineralization and nitrification in soils determined the rate of N leaching to the stream in any given year.

Acid Wet Deposition and Critical Loads in Eastern Canada

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In Canada, acid rain has been recognized as a serious ecological problem since the late 1970s. In response to continued lake and stream acidification, the government of Canada and its provinces implemented a sulphur dioxide emission control program in the mid-1980s. The goal of the program was to reduce emissions to levels such that sulphate wet deposition would not exceed a "target load" of 20 kg/ha/yr anywhere in eastern Canada. This target load was expected to protect moderately sensitive aquatic environments from the effects of acid rain. Recognizing that much of the sulphate wet deposition in Canada was due to U.S. sulphur dioxide emissions being transported across the border, the Canadian government entered into an Acid Rain Treaty with the United States of America by which both countries agreed to specific cutbacks in SO_2 emissions.

As a result of Canadian and U.S. emission reduction programs, sulphur dioxide emissions in both Canada and the U.S. have declined substantially since the early 1970s. Under the current agreements, total emissions from both countries are expected to drop from 28.2 MT (Canada 4.6 + U.S. 23.6) to 18.3 MT (Canada 2.9 + U.S. 15.4) by 2010. In eastern Canada alone, sulphur dioxide emissions have declined markedly over the past 16 years and, by 1995, had been reduced to roughly 43% below the 1980 level. In response to the decline in SO_2 emission reductions, eastern North America has experienced a substantial reduction in wet sulphate deposition. Based on maps of non-sea-salt sulphate wet deposition patterns in the early 1980s and the early 1990s, the area in eastern Canada receiving more than the target load of 20 kg/hr/yr declined by 46% between the two periods. Although the 20 kg/ha/yr target loaded will likely be met all over eastern Canada by 2010, many sensitive lakes and forest areas will still remain vulnerable to acidification. This is because the lakes and soils in different regions vary considerably in their capacity to neutralize or buffer the acids they receive from the atmosphere. To ensure the protection of these lakes and soils, the *critical load* concept was used to determine suitable wet deposition targets for the future.

For eastern Canada, the critical load concept was applied to aquatic ecosystems. The critical load was defined as the amount of wet sulphate deposition that must not be exceeded in order to protect at least 95% of the lakes in a region from acidifying to a pH level of less than 6.0. Based on wet deposition monitoring data, an assessment was carried out to estimate the area of eastern Canada which still receives sulphate wet deposition in excess of the critical load. It was estimated that, in 1995, this area was approximately 510,000 square kilometers and encompassed approximately 60,000 lakes. This area is roughly equivalent to the area of France. For the future, computer predictions by long range transport models suggest that it may be necessary to reduce SO_2 emissions in Canada and the U.S.A. by a further 75% over those already planned in order to eliminate all exceedances of the critical loads in eastern Canada.

The critical load concept has proved to be a very valuable tool for assessing the impact of past, present and future SO_2 emission levels on acid sensitive aquatic ecosystems in Canada. The concept is now being extended to forests and forest soils.

Acid Precipitation Events in a Massachusetts Pond Revisited

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Information gathered and processed by the National Atmospheric Deposition Program (NADP) has shown that the New England region experiences acidic depositions. Our laboratory group has been using on site pH meters and data loggers to study acid sensitive ponds in Massachusetts before and after the enactment of the Clean Air Act of 1990. These investigations included monitoring, on a constant basis, the pH and temperature of Maquan Pond in Hanson, Massachusetts. From 1990 to 1992, precipitation from individual rainstorms, producing transient acid spikes in the pond pH, were correlated with disturbances in *Lepomis* sunfish hatching profiles (Stallsmith et al.,1996, *Freshwater Biology 36*: 730- 740). Since 1991, factories and power plants, as mandated by the Clean Air Act of 1990, have reduced their emissions of sulfur dioxide. Thus, through a comparison of the data collected from the same site of this acid-sensitive pond eight years later, we hoped to determine whether or not these laws have alleviated the problem with respect to ponds like Maquan. Although there was not much rain this summer, storms from the southwest caused similar acid spikes. These results along with comparison with information from area NADP monitoring sites will be discussed.

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Atmospheric Deposition of Nutrients and Trace Metals in New Jersey

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and
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Rutgers University

The effect of non-point source pollution and the composition and magnitude of out-of-state sources are critical to scientists and policy makers as we develop watershed-based management strategies and regional solutions to environmental issues. To examine the impact of atmospheric deposition, the New Jersey Department of Environmental Protection, in collaboration with the United States Environmental Protection Agency, the Hudson River Foundation and New Jersey Sea Grant/National Oceanic and Atmospheric Administration, has engaged Professor Steven J. Eisenreich of Rutgers University to implement the New Jersey Atmospheric Deposition Network (NJADN) a nine-site network to help answer these and other scientific and policy questions.

More than one year of data has been acquired at New Brunswick and Sandy Hook in the New York - New Jersey harbor estuary for N, Pb, Cd, Zn, Cu, Cr and total Hg. The remaining NJADN sites are being made operational in calendar year 1999.

This paper will present some of the inorganic data and will discuss future monitoring and research objectives.

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Atmospheric Deposition of Persistent Organic Pollutants in New Jersey

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The effect of non-point source pollution and the composition and magnitude of out-of-state sources are critical to scientists and policy makers as we develop watershed-based management strategies and regional solutions to environmental issues. To examine the impact of atmospheric deposition, the New Jersey Department of Environmental Protection, in collaboration with the United States Environmental Protection Agency, the Hudson River Foundation and New Jersey Sea Grant/National Oceanic and Atmospheric Administration, has engaged Professor Steven J. Eisenreich of Rutgers University to implement the New Jersey Atmospheric Deposition Network (NJADN) a nine-site network to help answer these and other scientific and policy questions.

More than one year of data has been acquired at three sites in the New York - New Jersey harbor estuary for PAHs, PCBs, chlorinated pesticides, dioxin, and estrogenic nonylphenols. The remaining six NJADN sites are being made operational in calendar year 1999. Significant information has been obtained on the impact of long-range transport, temporal and spatial trends and partioning at the air-water interface.

This paper will present some recent data and will discuss future monitoring and research objectives.

Status of New England/Eastern Canada Acid Rain Action Plan

Rich Poirot
Vermont Department of Environmental Conservation

In June 1998, the Conference of New England Governors and Eastern Canadian Premiers adopted an ambitious "Acid Rain Action Plan", which calls for additional national emissions reductions of 50% SO2 and 20 to 30% NOx beyond the current commitments in both countries. The plan also establishes several technical workgroups, which are focused on:

Forest Mapping - to assess the continuing loss of productivity in regional forest soils,
Surface Water Quality - to assess the status and trends of acidified surface waters,
Fine Particulate - to establish a regional $PM_{2.5}$ monitoring network to document transport,
Data Exchange - to collect, exchange and merge regional emissions, air quality and deposition data, and to model the multiple benefits of future emissions controls,
Public Education and Outreach - (a joint effort for acid rain and mercury).

The workgroups are composed of state and provincial agency staff, with assistance from the academic community and federal agencies like US EPA, Environment Canada, and US and Canadian Forest Services. NADP-NTN data provide a key resource for all of these workgroups. NADP scientists may also have invaluable ideas, insights or data to contribute For example, we are seeking best estimates of wet and dry deposition with high spatial resolution over a large region of complex terrain. Workgroup membership is open to anyone with time and interest.

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Technical Session II

Atmospheric Deposition Monitoring and Assessment: A Western Perspective

Session Chair: Mary Ann Allan
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Atmospheric Transport of Pollution Plumes to the Central Sierra Nevada Mountains.

John Carroll[1]
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Air passing over the central Sierra Nevada Mountains of California often travels trough the San Francisco Bay Area, along heavily traveled transportation corridors, and then through the Sacramento Metropolitan area before moving up the slopes. An ensemble of urban, industrial, transportation and agricultural sources contribute to the accumulation of a variety of air pollutants in the air reaching these alpine watersheds. Among these pollutants are inorganic and organic nitrogen species, photochemical smog products, industrial organic compounds and agricultural chemicals and their derivatives. Many of these pollutants are deposited along the western slopes and there is concern that they impact Lake Tahoe and its environs. Among recent studies conducted by our group were a series of summer season measurements made east of Sacramento and in the Tahoe basin to examine the dispersion of pollutants as they travel eastward from Sacramento to the mountains. These measurements were made from an instrumented light aircraft and include NO, NOy, particulate, and ozone concentrations, and on several occasions the collection of samples which were analyzed for a wide range of nitrogen containing compounds (cf: Anastasio et.al., this volume). We also measured meteorological conditions and collected navigation data. Several flights were conducted with a prototype wind measuring system providing wind information that is collocated with the other measurements. These data show that, at least in summer, the maximum concentration of secondary pollutants such as ozone occurs 30 to 50 km downwind of the city. The pollutant plumes then disperse (primarily vertically) prior to reaching the Sierra crest and do not appear to mix downward into the Tahoe basin in significant amounts. Conversely, fine particles, which degrade visibility in the Tahoe basin, appear to be of local, in-basin origin. The results of these studies will be presented.

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Dry Deposition of Nitric Acid to Soils and Soil Components in Mediterranean Ecosystems

Pamela E. Padgett[1] and Andrzej Bytnerowicz
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Dry deposition of nitrogenous pollutants is a serious problem in western ecosystems. In wildlands adjacent to urban centers, nitric acid (HNO_3) is often the most ecologically important atmospheric pollutant. Although it is often in lower atmospheric concentrations than other oxidized forms of nitrogen, its higher deposition velocity leads to disproportionally high terrestrial accumulations. However, the exact determination of dry deposition rates to any given ecosystem has been technically challenging. Southern California is in a unique physiographic position to analyze dry deposition and its effects on plant communities and ecosystems independent of wet deposition. A gradient in air pollution has been established along 70-km corridor between the Los Angeles Basin and San Diego. The native vegetation in this area is a shrub-type called coast sage scrub unique to Mediterranean climates. Over the last 30 years much of these shrublands have shifted to annual grasslands. Hypotheses relating this shift in vegetation structure to nitrogen deposition have been developed and are being tested. One piece of information that has emerged from this work is the significance of dry deposition to soils and other abiotic surfaces. Using ambient conditions and controlled fumigation chambers as treatments, experimental evidence indicates that the accumulation rates for deposited nitric acid are controlled by particle size, moisture content and total exposure.

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Throughfall and Fog Deposition of Nitrogen and Sulfur at an N-limited and N-saturated Site in the San Bernardino Mountains, Southern California

Mark A. Poth and Mark E. Fenn
USDA
Forest Service

Dichotomized atmospheric deposition (dry deposition mobilized by precipitation) was examined in the San Bernardino Mountains. Nitrogen and sulfur deposition in throughfall and fog were determined at two sites located at opposite ends of a pollution gradient in the Mountains. Camp Paivika (CP) is an N-saturated site on the western end of the gradient, and Barton Flats (BF) is an N-limited site on the eastern end of the deposition gradient. Plot-level averages for total annual inorganic N and S deposition in throughfall in 1996 were 18.8 and 2.9 kg ha^{-1} at CP and 2.9 and 0.4 kg ha^{-1} at BF. Spatial variability in throughfall deposition was high, due to heterogenous canopy cover and varying exposure to air pollution. Total N deposition to the forest may be approximately 40% greater than throughfall deposition due to canopy retention of atmospheric N based on previous studies. Deposition of N and S in fog was determined at the same two sites in 1997. Fogwater flux rates were determined with passive string collectors placed within the forest canopy, while fog samples for chemical analysis were collected with an active fog collector designed to exclude dry deposition and precipitation. Ionic concentrations of fogwater, fogwater deposition fluxes, fog occurrence, and fog density were all higher at CP compared to BF. Annual estimated stand-level deposition of N and S in fog were 10.9 and 1.9 kg ha^{-1} respectively at CP. Analogous values for BF were 0.6 and 0.2 kg ha^{-1}. We estimated that N deposition in fog contributed 35% of the total annual N deposition at CP and 13% at BF. Analogous values for S were 39% at CP and 26% at BF. Ammonium deposition in throughfall and fog at CP were 72 and 122 percent as high as NO_3^- deposition because of NH_3 emissions from dairy farms in the Chino area 34 km southwest of CP. These results and other recent studies of N deposition in the transverse ranges of southern California suggest that N deposition thresholds at which elevated NO_3^- losses occur are similar to thresholds reported for European forested watersheds. Our findings also demonstrate the two par, or dichotomous, nature of the deposition process that is typical of western climate conditions.

Causes and Effects:
The Early Onset of Eutrophication in Utraoligotrophic Lake Tahoe

Charles R. Goldman
University of California, Davis

No abstract available at time of printing

Preliminary Evaluation of Dissolved Organic Nitrogen (DON) in Wet Atmospheric Deposition at the Niwot Ridge NADP Site, Colorado, USA

Mark Losleben, Mark Williams, and Christine Seibold
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University of Colorado

Mass balance analyses have shown that dissolved organic nitrogen (DON) is an important and often unmeasured component of nitrogen export in surface waters. However, little is known about the magnitude, timing, source areas and character of DON in wetfall. Moreover, there are outstanding questions concerning sample collection and analytical techniques for measuring DON.

Here we present preliminary information on DON collected from a pilot study at the Niwot Ridge NADP site, located at an elevation of 3,500 m in the Colorado Front Range. DON concentrations from precipitation collected in amber glass bottles were consistently 15% greater than that collected in HDPE bottles ($p < 0.001$). This 15% loss suggests reviewing the use of plastic buckets in a DON analysis program.

Concentrations of DON in precipitation events during 1997 ranged from undetectable to about 10 µmoles/L, an order of magnitude less than contributions from dissolved inorganic nitrogen. An analysis of atmospheric circulation at 700 mb, relevant to the source-receptor issue, showed high DON concentrations to be associated with wind direction from the southwest, and low concentrations with wind from the northwest. Further, circulation indices show higher DON concentrations in wetfall to be correlated with less vigorous airflow, and to have little correlation with vorticity. Higher concentrations also tended to be associated with vector magnitudes of increasing southerly and decreasing westerly components, conditions that favor transport from local sources.

Comparing Atmospheric Bulk Deposition Chemistry to NADP Wetfall Chemistry in and near Rocky Mt. National Park, Colorado

George Ingersoll[1], Kathy Tonnessen[2], Don Campbell[1], and Ben Glass[1]

The National Atmospheric Deposition Program (NADP) operates a long-term national network monitoring wetfall chemistry; sampling stations are limited in the Rocky Mountain region. Acid deposition in federally-protected mountainous areas such as Rocky Mountain National Park, Colorado, is a concern as urban, industrial, and agricultural development continues near the park. A network of 15 bulk-atmospheric-deposition collectors was installed in and around Rocky Mt. National Park to study deposition patterns of nitrate and sulfate compounds during the 1999 water year (beginning October 1998). NADP chemical data for the months October through December 1998 are compared to the USGS bulk-collector chemical data for the same period as a measure of the efficiency of the USGS method for augmenting the NADP network. The additional sampling locations along latitudinal and longitudinal transects within the study area gave a greater density of sampling points. Nitrate and sulfate data from both networks exhibit similar patterns of higher concentrations near regional emissions sources such as the Denver Metropolitan area. As NADP chemical data for 1999 become available, further evaluation of the similarities between the wetfall and bulk deposition chemistry will be made to see if additional bulk-deposition sampling provides meaningful augmentation to the NADP network.

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Monitoring of Air Pollution in California Ecosystems – Present Status and Research Needs

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In California, as well as in other western states, air pollution is deposited to ecosystems mainly *via* dry deposition processes. Pollutants of greatest importance to forests and other ecosystems are ozone (O_3) and nitrogenous (N) pollutants. At ambient levels, O_3 and peroxyacetyl nitrate (PAN) may have toxic effects on vegetation. Theoretically, nitric acid vapor (HNO_3), ammonia (NH_3), nitrogen dioxide (NO_2) and nitric oxide (NO) also present a phytotoxic potential. In addition to the direct toxic effects, deposition of N compounds has long-lasting indirect effects on forests and other ecosystems. Relatively little is known on distribution of concentrations and deposition of ozone and N pollutants in remote locations in California. An adequate monitoring network (based on reliable techniques) is needed for evaluation of air pollution concentrations and deposition to the California urban areas and natural ecosystems. Such information is essential for understanding existing changes and for and prediction of potential future effects on western ecosystems.

Present monitoring efforts, including application and development of methodologies for remote locations, will be presented in this talk. In addition, research needs, specifically development of data bases and models required for evaluation of risks in forests of the Sierra Nevada and the San Bernardino Mountains, will be discussed.

San Francisco Bay Atmospheric Deposition Pilot Study

Pam Tsai[1], Eric Papp[2], and Rainer Hoenicke[1]

Existing information indicates that air deposition may be a significant pathway for certain pollutant loading to the San Francisco Bay. Gross calculations based on ambient air monitoring results and results from a preliminary study indicated that contribution of atmospheric deposition to the total loading ranged from less than 1% up to 20% for certain toxic pollutants. No definitive conclusions can be drawn from these retroactive calculations and preliminary results. So far, no systematic studies have been conducted to evaluate the magnitude of air deposition and its relative significance of contribution to the total pollutant loading to the Bay.

Under the umbrella of the Regional Monitoring Program for Trace Substances ("RMP"), the primary objectives of the San Francisco Bay Atmospheric Pilot Study ("Pilot Study") is to use the best available methods in obtaining seasonal and annual estimate of the deposition of selected pollutants from the air directly to the surface of the Bay. The Pilot Study is a collaborative effort among many environmental protection and resource agencies as well as industrial partners from the San Francisco Bay area.

A phased-in approach is used to address the primary objectives of the Pilot Study. Phase 1 of the Pilot Study focuses on monitoring certain selected trace elements (i.e. cadmium, chromium, copper, mercury, and nickel) in the air and precipitation. Phase 2 trace organics component of the Pilot Study is currently pending due to funding constraints. This paper presents the study design, methodology, and some preliminary results of the trace elements component of the Pilot Study.

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Organic and Inorganic Nitrogen in Fog Waters and Particulate Matter

Cort Anastasio, Qi Zhang, Mike Jimenez-Cruz, and John J. Carroll
University of California, Davis

There is growing evidence that organic nitrogen (ON) is an important component of both wet and dry deposition and that a significant portion of deposited ON is biologically available. Despite this, there is currently relatively little information regarding the concentrations and relative importance of organic nitrogen in atmospheric condensed phases, especially in California. We will present results from a year-long study of $PM_{2.5}$ (particulate matter with aerodynamic diameters £ 2.5 microns) and winter-time fog waters that were collected at Davis, CA and analyzed for both organic and inorganic nitrogen (IN). The relative concentrations of ON and IN, and the importance of free and combined amino acids as components of organic nitrogen, will be discussed. Preliminary data of particulate and gaseous IN and ON concentrations from a few aircraft flights will also be presented. In addition, we have carried out laboratory experiments to examine how atmospheric photochemical reactions degrade and transform atmospheric organic nitrogen. The results from these experiments, and their potential impact on the bioavailability of organic nitrogen in wet and dry deposition, will also be presented.

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Technical Session III

Atmospheric Deposition Monitoring and Assessment: An Eastern Perspective

Session Chair: Luther Smith
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Effects of Ten Years of Elevated N and S Additions on Watershed Processes: the Fernow Whole Watershed Acidification Study

M. B. Adams[1], P. .J. Edwards, J. N. Kochenderfer, F. Wood
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Since 1989, two forested watersheds on the Fernow Experimental Forest in the central Appalachian mountains of West Virginia have been treated with ammonium sulfate applications, at twice ambient deposition rates of N and S, to evaluate the effects of elevated acidic deposition on solution chemistry and ecosystem processes. This site historically has received some of the highest N and S deposition in the U.S. In recent years, S deposition has decreased dramatically. Robust locally-weighted regression was used to identify temporal trends in solution chemistry data, using residual differences to identify trends in the flow-adjusted concentrations due to treatment effects. Cation concentrations in soil solution collected below the A horizon were relatively unaffected by treatment, although significant increases were detected in solution collected below the B and C horizons for most cations. NO_3 concentrations in soil solution below the B and C horizons increased over time, while A horizon concentrations increased slightly then decreased after 1993. SO_4 concentrations increased until 1995, when a slight decrease in concentrations was recorded. Stream water concentrations of all analytes (NO_3, SO_4, Cl, Ca, Mg, K), except Na, increased significantly as a result of treatment, although timing of the initial responses differed between baseflow and peakflow. Peakflow and soil water chemistry suggest that stormflow originates largely from the B-horizon. Baseflow:soil water relations are not as straight forward as for stormflow, but suggest some processing by soil and biota. N cycling in soils is rapid, and N mineral soil pools are high.

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Trends in Ammonium Concentration in Precipitation and Atmospheric Ammonia Emissions at a Coastal Plain Site in North Carolina, USA

John Walker[1]
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and
Dr. Viney P. Aneja and Dena Nelson
Department of Marine, Earth, and Atmospheric Sciences[2]

The temporal characteristics of ammonium (NH_4^+) ion concentration in precipitation and local ammonia (NH_3) emissions are investigated over the period 1982-1997 at National Atmospheric Deposition Program/ National Trends Network site NC35, located in Sampson County, North Carolina. Multiple regression analysis of annual volume-weighted values of NH_4^+ concentration in precipitation identifies a statistically significant ($p<0.01$) 4-year cycle and increasing trend during the period. The cycle is likely a function of mean annual ambient surface temperature, which is shown to be a significant ($p<0.01$) predictor variable for annual NH_4^+ concentrations in precipitation. Regression analysis of monthly volume-weighted NH_4^+ concentration is used to illustrate a significant ($p<0.01$) increasing trend of approximately 0.083 ± 0.04 % yr^{-1} over the period 1990-1997 (period 2) and lack of trend during the period 1982-1989 (period 1). An analysis of estimated population-based annual NH_3 emissions from individual sources in an intensively managed agricultural region surrounding NC35 shows that emissions from swine ($p<0.01$), fertilizer ($p<0.10$), turkeys ($p<0.05$), and broilers ($p<0.05$) were significantly greater during period 2. Emissions from chickens were significantly ($p<0.01$) lower during period 2. Cattle emissions were not significantly different (10% level) during the two periods. The increase in average annual swine emissions between periods accounts for ≈ 84% of the increase in average annual emissions from all sources between periods. Variability in local ammonia emissions from swine and mean ambient surface temperature explain approximately 95% of the variation in annual volume-weighted NH_4^+ concentrations in precipitation at NC35 during the period 1982-1997.

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Dry Deposition Data for Sulfur and Nitrogen Species at a Rural Monitoring Site in Illinois: A Comparison of Two Concurrent Datasets

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Illinois State Water Survey

Since 1978 the Illinois State Water Survey has been monitoring air and precipitation quality at a field site 10 kilometers southwest of Champaign, Illinois A primary objective has been to get other agencies to utilize the site for both short term and long term measurements, recognizing that everyone's measurements become more valuable due to the other measurements being made at the site. The first national network to place equipment at the site, in 1979, was the National Atmospheric Deposition Program (NADP). Currently nine state, regional, or national scale networks are operating at the site. As an example of the synergism resulting from multiple agency measurements at the site, results from the Clean Air Status and Trends Network (CASTNet) and the Atmospheric Integrated Research and Monitoring Network (AIRMoN) air quality measurements for sulfur and nitrogen species will be summarized and compared for the 1989-1994 period. Good agreement is found for sulfur species and ammonium. Substantial differences are found for nitrate particles and nitric acid vapor. A large number of journal papers exist on the subject of nitrogen species measurements to assist in understanding the differences.

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Acid Deposition, Aluminum Buffered Soils, Tree Decline and Forest Regeneration Failure in Pennsylvania: Random Occurrences or Related Phenomena

William E. Sharpe
Pennsylvania State University

In Pennsylvania, the deposition of acidifying elements from the atmosphere has been quite high throughout the period of recorded measurements. Sensitive soils and watersheds exist throughout the State, and the occurrence of acidic runoff episodes and associated biological impacts as a consequence of aluminum leaching from forest soils have been well documented in the scientific literature. Soils are significantly more acidic than they were a few decades ago. Tree mortality, growth decline and failed forest regeneration also occur on acid deposition sensitive, aluminum buffered Pennsylvania soils, but the linkages between these problems and acidic deposition and soil acidity are less studied. New data clearly show that acid-sensitive tree species on ridge-top locations where soils are aluminum buffered are in decline. Regeneration of these species on these sites has been difficult. Liming has resulted in decline reversal and improvements in regeneration and growth of acid sensitive forest species confirming the role of soil acidification in these problems. As more data become available, it is increasingly apparent that accelerated soil acidification as a consequence of acid deposition is a major predisposing stress factor in the higher elevation forests of Pennsylvania and thus partially responsible for the current widespread health and regeneration problems in these forests.

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Evaluating the Impact of Increased Nitrogen Deposition in the Chesapeake Bay Basin: An Application of the PnET-CN Regional Ecosystem Model

John Hom, Yude Pan
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and
John Aber
University of New Hampshire[2]

Considerable effort has been made by the Chesapeake Bay Program, to reduce nutrient loading to the largest estuary in the United States. This paper will describe the application of the PnET-CN regional ecosystem model to assess the impacts of nitrogen loading on the forested watersheds of the Chesapeake Bay Basin. Forests make up 60% of the Chesapeake Bay Basin, the largest land use classification, totaling 24.5 million acres. The health and productivity of forested watersheds play an important role in water yield and nitrogen retention. In this paper, the model was run in conjunction with high-resolution (1 km) geographic information system providing basic data planes on monthly temperature, precipitation and radiation, as well as a forest vegetation-type map. At current N deposition levels, average N leaching loss is 1.3 kg ha^{-1} yr^{-1}, suggesting 85% retention of the N input. At twice the current N deposition rate, N retention in forests dropped to 76%. Model results were validated with USGS historical runoff and water quality data.

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Sources and Source Regions Contributing to Atmospheric Deposition of Toxic Pollutants to the Great Lakes

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The governments of the United States and Canada are working together, under the auspices of the Great Lakes Water Quality Agreement, to "virtually eliminate" persistent toxic substances being deposited in the Great Lakes basin, including those subject to long-range transport via the atmospheric pathway. There are many toxic pollutants of potential concern in the Great Lakes that have been officially identified under various international treaties as well as a number of current use compounds such as atrazine which are just beginning to appear on lists of pollutants of concern for the region. Atmospheric deposition is believed to be a significant loading pathway for many persistent bioaccumulative pollutants.

A U.S./Canadian multi-agency project, coordinated by the International Air Quality Advisory Board of the IJC, has been initiated (a) to attempt to determine the relative importance of different sources and source regions contributing to the atmospheric deposition of these toxic pollutants to the Great Lakes, and (b) to determine the extent of control and prevention approaches in place to ameliorate these impacts. As a part of this project, the availability and adequacy of U.S. and Canadian emissions inventories for various substances of concern has been determined. In three cases where sufficient information exists, an atmospheric fate and transport model has been utilized to elucidate source-receptor relationships for the Great Lakes. For these three pollutants, dioxin, atrazine, and cadmium, results from NOAA's HYSPLIT model will be presented.

Pesticides in the Atmosphere of the Mississippi River Valley

Michael S. Majewski, William T. Foreman, and Donald A. Goolsby
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Weekly composite high-volume air and wet-only deposition samples were collected from April through September 1995 at paired urban and agricultural areas in Mississippi, Iowa, and Minnesota and at a background site in the upper Michigan peninsula. The principal objectives of the study were to document the occurrence and detection frequency for a wide variety of pesticides in the atmosphere, and to compare the types of pesticides detected among three geographically different regions of the Mississippi River Valley. Each sample was analyzed for 49 compounds including several pesticides not examined in previous atmospheric studies. 85 % of the herbicides, 70 % of the insecticides, and 100% of the transformation products analyzed for were detected in one or more samples at each paired site. Herbicides were the predominant type of pesticide detected at each site in the air and the rain. The detection frequencies were comparable at the paired sites in Iowa and Minnesota, but higher at the agricultural site in Mississippi. The corn herbicides atrazine, acetochlor, alachlor, and metolachlor were frequently detected in both air and rain at each of the paired sites. The depositional amounts (μg/m²) for many herbicides in precipitation were frequently higher at the urban sites than at the agricultural sites. Insecticide detections were greater at the urban sites in Mississippi and Iowa. Atrazine, CIAT (triazine transformation product), cyanazine, and dacthal were detected frequently in both air and rain at the background site indicating the possibility of long-range atmospheric transport for these compounds.

Topographic Enhancement of Wet Deposition Estimates using Modeled Precipitation

James A. Lynch, Ph.D.[1], Professor of Forest Hydrology and Jeffrey W. Grimm[2], Research Assistant
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A model was developed to improve the accuracy and spatial resolution of wet deposition measurements in the Eastern United States. The model incorporates precipitation volume measurements (a major determinant in the amount of wet deposition at a given point) from NOAA/NWS monitoring sites, digital elevation data, and other topographic variables (e.g., aspect, slope) that affect the amount and distribution of precipitation in the region. The model provides estimates of precipitation for any latitude and longitude within the region for any month or seasonal summary period from 1984 through 1997. When combined with interpolated ionic concentrations found in precipitation samples collected by the National Atmospheric Deposition Program (NADP), estimates of wet deposition can be obtained. Application of model output to three distinct physiographic regions of the Eastern United States revealed measurable improvement in mean quarterly and annual wet deposition estimation error when compared to a two-dimensional spatial interpolation algorithm using data from the NADP. Application of model output in assessing the importance of nitrogen deposition (ammonium and nitrate) to the Chesapeake Bay Watershed and in evaluating critical load issues in Maryland will be illustrated.

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Final Report on the Testing and Evaluation of Alternative Rain Gages for the National Atmospheric Deposition Program

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Oak Ridge Associated Universities
and
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USGS

Continuing research and development within the rain gage industry has resulted in a variety of precipitation-measuring schemes, including vibrating wire technology, simulated tipping-buckets, and high-resolution weighing-type gages. Four of these recently developed precipitation gages -- the Belfort 3200, Eti NOAH II, Geonor Model T-200, and the Ott PLUVIO – have been tested against the Belfort 5-780 and the National Weather Service 8" stick gage to identify potential replacements for the Belfort 5-780 rain gages presently in use by the National Atmospheric Deposition Program. Testing performed at the Hydrologic Instrumentation Facility (HIF) in Bay St. Louis, Miss. was done in two phases. Phase I testing involved the application of artificial rainfall to compare accuracy-versus-range for all gages in this study. Long-term performance of all study gages was compared during Phase II of this study at the HIF, where gages were monitored weekly in a single outdoor environment. Final results of Phase I and Phase II testing will be presented.

The use of trade, product, industry, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Atmospheric Nitrogen Loading to the Delaware Inland Bays: New Perspectives

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Delaware's Inland Bays consist of two inter-connected estuaries, Rehoboth Bay and Indian River Bay, which in many regards are typical of the small, shallow, poor-flushed estuaries that are common along of the U.S. mid-Atlantic and Gulf coasts. Like many similar systems, eutrophication has been identified as the primary environmental stress resulting from intense agricultural, commercial and residential development. In order to allocate and establish goals for nutrient reduction (*e.g.,* the EPA **T**otal **M**aximum **D**aily **L**oad), a scientifically-defensible estimate of atmospheric loading is critically needed.

Atmospheric wet and dry deposition of NO_3^-, NH_4^+ and organic nitrogen were gauged based on NADP-AIRMoN and EPA- CASTNet data. For wet deposition, the Lewes (DE02) data indicate that N inputs are significantly greater during summer than winter for both NO_3^- (~2X) and NH_4^+ (~4X), reflecting seasonal differences in emissions and storm trajectories. This is significant because the ecological effects of eutrophication are most acute during summer, and surface waters are otherwise impoverished in N due to seasonally depressed freshwater inputs and elevated rates of phytoplankton utilization. Conversely, dry deposition appears to be somewhat lower during summer, perhaps indicative of lower average wind speed and turbulence.

A comparison of regional precipitation chemistry data indicate generally greater wet deposition of NH_4^+ at Lewes compared with "upwind" sites. In fact, over the past two decades, the NH_4^+ concentration has increased by nearly 60%, which parallels a similar increase in broiler (chicken) production in Delaware over this period. Ongoing experiments, directed at identifying a gradient in airborne NH_3 concentrations, and spatial variability in precipitation composition across the Inland Bays watershed, will be discussed.

On an annual basis, atmospheric input (wet + dry) of N delivers between 14% (Rehoboth Bay) and 26% (Indian River Bay) of the total N loading to these estuaries, more than half of which is directly to the surface waters. However, for a number of reasons these may be conservative estimates.

Technical Session IV

Trace Metal (Hg) Deposition: Current Concerns and Observations, Future Needs

Session Chair: Ellen Porter
U.S. Fish and Wildlife Service

International Monitoring/Measurement Activities for Atmospheric Mercury

John Munthe
Swedish Environmental Research Institute
and
Eric M. Prestbo
Frontier Geosciences

This presentation will focus on historical and current air and deposition measurements of mercury in Northern Europe. Past monitoring of total Hg air concentrations in Sweden indicate a significant decrease starting in 1990, which was likely caused by the closing of major industrial source region in former East Germany. A description and data from the current European Union (EU) programs, Mercury Over Europe (MOE) and Mediterranean Atmospheric Mercury Cycling System (MAMCS) will also be presented.

Nutrient and Metal Deposition to Corpus Christi Bay, Texas

Terry L. Wade[1], Steve Sweet, and Neil Tindale
Geochemical and Environmental Research Group
Texas A&M University

Sandra Alvarado
Corpus Christi Bay National Estuaries Program

Clyde W. Sweet
University of Illinois
Illinois State Water Survey
University of Illinois

Atmospheric deposition is an important pathway by which toxic chemicals and nutrients reach coastal waters, including ecologically important and highly productive areas such as estuaries. In order to assess the importance of atmospheric deposition of nutrients and trace metals to Corpus Christi Bay an important Texas estuary, two sampling sites were established in 1997. The concentrations of nutrients and trace metals were determined in rain and in dry deposition. Rain-water for nutrient analysis was collected using standard NADP buckets and samplers. A separate rain sample was collected for trace metals analysis using an all-Teflon sampling train and a modified NADP sampler. Dry deposition samples were obtained by exposing a layer of de-ionized water in the dry-side bucket. Analysis was by standard NADP methods for nutrients and by ICP-MS for trace metals. Standard meteorological data were also collected (wind speed, wind direction, rain fall amount, temperature and solar irradiance). Samples were collected at both sites every week for over a year. Estimates of the atmospheric deposition of nutrients and metals to Corpus Christi Bay will be presented. These inputs will be compared to other inputs to the Bay. Temporal trends will be discussed. Spatial differences between the two sites were investigated with respect to their locations on opposite sides of the Bay, one in an agricultural setting and the other in an urban/industrial setting. Results will also be compared to long term monitoring data from NADP stations.

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Wet Deposition of Mercury in the U.S. and Canada

Clyde W. Sweet[1]
University of Illinois
Illinois State Water Survey
and
Eric Prestbo and Bob Brunette[2]
Frontier Geosciences Inc.

Beginning with a pilot program in 1995, the Mercury Deposition Network (MDN) has been monitoring total mercury in rain and snow as part of NADP. Weekly precipitation samples are collected at over 30 sites in the U.S. and eastern Canada using a precleaned sampling train, a sample preservative, and special handling procedures. Samples are shipped to a central laboratory, Frontier Geosciences in Seattle, for analysis of total mercury by cold vapor atomic fluorescence spectrometry (USEPA Method 1631). Data from samples collected between 1995 and 1998 will be discussed in this report. Concentrations of total mercury in rain are usually between 0 and 25 ng/L with a volume-weighted mean concentration for the network of about 10 ng/L in 1998. Weekly wet deposition of mercury depends on both concentration and total rainfall. The average wet deposition value for the network is about 200 ng/m^2/week or 10 µg/m^2/year. Mercury deposition is highest in the summer and lowest in the winter at most sites in eastern North America. This is attributable to both higher mercury concentrations and higher precipitation amounts during the summer months. The average wet deposition of mercury tends to be highest in south Florida and lowest in New England and eastern Canada.

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Methyl Mercury Deposition in the Upper Midwest: Seasonal Trends, Comparison with Other Regions, Possible Sources and Estimated Ecosystem Impact

Eric M. Prestbo and Robert C. Brunette[1]
Frontier Geosciences Inc.
and
Clyde W. Sweet[2]
University of Illinois
Illinois State Water Survey

The determination of the wet-deposition rate of total mercury (Hg) is one of the most significant measurements used to characterize the Hg atmospheric cycle and Hg loading to sensitive aquatic ecosystems. The Mercury Deposition Network (MDN), part of the National Atmospheric Deposition Program (NADP), is currently measuring weekly total Hg wet-deposition at 37 sites in the U.S. and Canada. In addition to total Hg wet-deposition, 13 MDN sites are routinely measuring monomethyl Hg (MMHg). The measurement of MMHg wet-deposition is important due to its high toxicity and potential contribution to enhance our understanding of the atmospheric-aquatic Hg cycle. Nearly 2.5 years of continuous MMHg wet-deposition data will be presented for the 9 sites in Minnesota, Wisconsin and Ontario. The current data set shows a trend where both MMHg concentration and wet-deposition rates are significantly higher (5 to 10 fold) in the summer compared to winter. This contrasts with MMHg wet-deposition pattern at MDN site WA18 in Seattle where both concentration and deposition are higher in the winter than summer. Concentration ranges from 0.02-1.1, 0.01-1.29 and 0.02-0.42 ng/l at the Wisconsin, Minnesota and Ontario sites, respectively. Deposition ranges from 1-20, 1-35 and 1-12 ng/m^2/month at the Wisconsin, Minnesota and Ontario sites, respectively. MMHg concentration in rain shows strong regional patterns with highest annual volume weighted mean values (~0.3 ng/l) in the Pacific Northwest and the lowest values in Florida (<0.01 ng/l). Several potential sources of atmospheric organic Hg have been investigated within the past 4 years and will be discussed in light of the seasonal patterns of MMHg wet-deposition. These include direct emissions from anthropogenic point sources, sewage sludge applied to land, contaminated river flood plains, municipal waste landfills, oceans, as well as in-situ gas-phase and cloud-water methylation of Hg. Using seasonal mean wet-deposition rates, geochemical calculations will be presented which will constrain the aquatic ecosystem impact due to the input of MMHg from the atmosphere.

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Are Sources Other than Anthropogenic Point Sources Significant Contributors to the Atmospheric Mercury Budget?

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Oak Ridge National Laboratories

Mercury is emitted to the atmosphere from natural and anthropogenic point and non point sources. In order to understand if reduction in emissions of mercury from anthropogenic point sources will have an impact on deposition, we must quantify the emissions from other sources and have a good understanding of the biogeochemical cycle of mercury. Other sources that may be of importance include undisturbed and disturbed areas of naturally Hg-enriched substrate and broad areas of anthropogenic contamination. In September of 1997, an international workshop was held at the Steamboat Springs Geothermal Area, Reno to intercompare the methods used to measure mercury emissions *in situ*. This workshop served as a spring board for the beginning of the development of a data base of emissions from broad areas that are naturally enriched in mercury. Data is being collected that characterizes Hg emissions from districts of natural enrichment and that will be used within a GIS data base to quantify emissions from natural sources on local and regional scales. Other area sources from which emissions are being measured include contaminated mine waste and waste from industrial processes. Data developed thus far indicates that Hg emissions from these sources is more significant that previously thought and has implications for our understanding of global mercury cycling.

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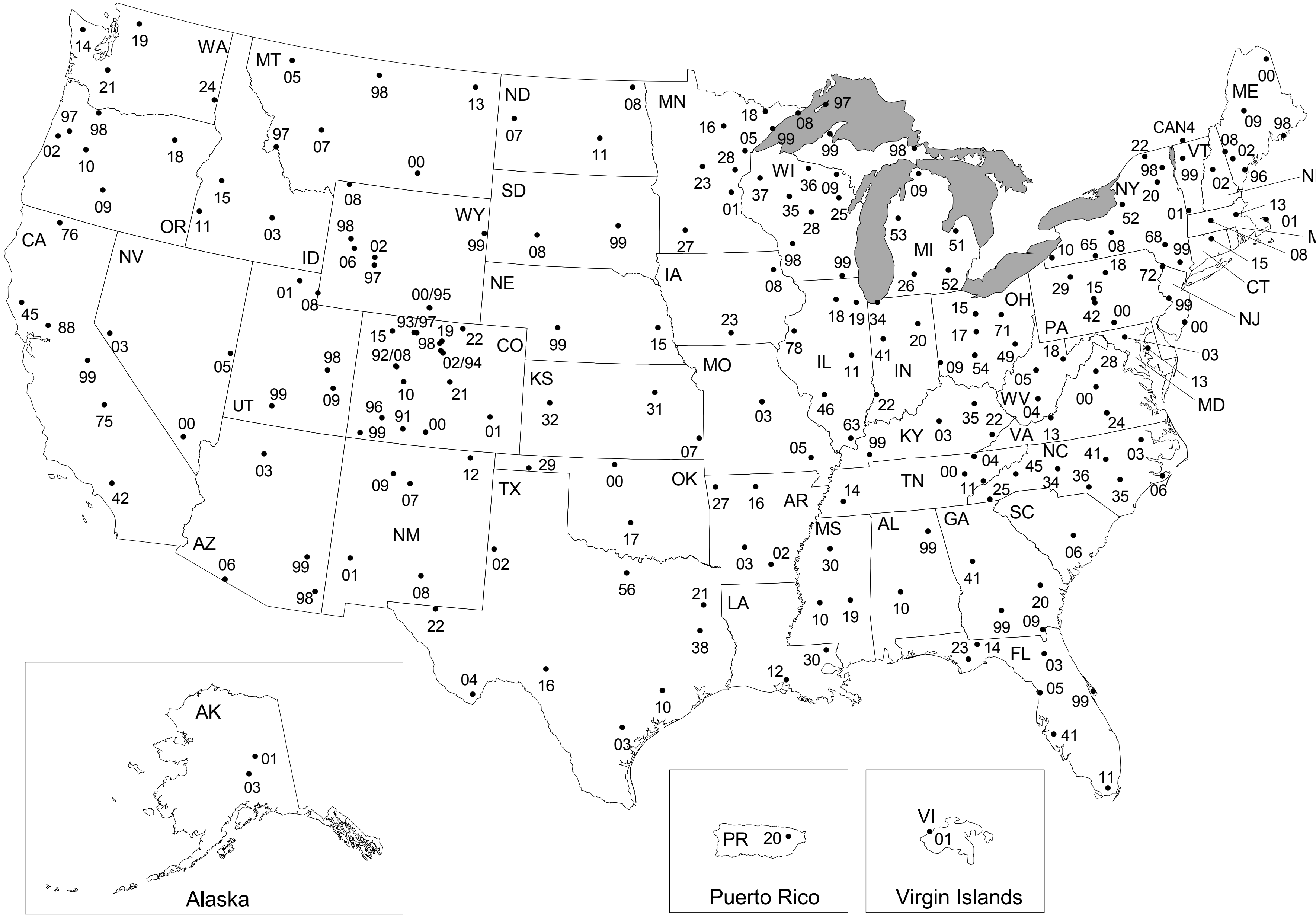
III. NADP/NTN MAP AND SITE LISTINGS

National Atmospheric Deposition Program

National Trends Network



National Atmospheric Deposition Program/National Trends Network Sites Through October 1, 1999

Site	Site Code	Site Name	County	Sponsoring Agency	Start Date
Alabama					
	AL10	Black Belt Ag Substation	Dallas	US Geological Survey	08/83
	AL99	Sand Mtn Ag Exp Station	DeKalb	Tennessee Valley Authority	10/84
Alaska					
	AK01	Caribou - Poker Creek	Fairbanks	USDA Forest Service	12/92
	AK03	Denali NP - Mt McKinley	Denali	National Park Service - Air Resources Div	06/80
Arizona					
	AZ03	Grand Canyon NP - Hopi Pt Organ Pipe	Coconino	National Park Service - Air Resources Div	08/81
	AZ06	Cactus NM	Pima	National Park Service - Air Resources Div	04/80
	AZ98	Chiricahua	Cochise	US EPA-Office of Air and Radiation	02/99
	AZ99	Oliver Knoll	Graham	US Geological Survey	08/81
Arkansas					
	AR02	Warren 2WSW	Bradley	US Geological Survey	05/82
	AR03	Caddo Valley	Clark	US Geological Survey	12/83
	AR16	Buffalo NR - Buffalo Pt	Marion	National Park Service - Air Resources Div	07/82
	AR27	Fayetteville	Washington	US Geological Survey	04/80
California					
	CA42	Tanbark Flat	Los Angeles	USDA Forest Service	01/82
	CA45	Hopland	Mendocino	US Geological Survey	10/79
	CA75	Sequoia NP - Giant Forest	Tular	National Park Service - Air Resources Div	07/80
	CA76	Montague	Siskiyou	US Geological Survey	06/85
	CA88	Davis	Yolo	US Geological Survey	09/78
	CA99	Yosemite NP - Hodgdon Meadow	Tuolumne	National Park Service - Air Resources Div	12/81
Colorado					
	CO00	Alamosa - WSO	Alamosa	US Geological Survey	04/80
	CO01	Las Animas Fish Hatchery	Bent	US Geological Survey	10/83
	CO02	Niwot Saddle	Boulder	NSF/INSTAAR-University of Colorado	06/84
	*CO08	Four Mile Park	Garfield	US EPA-Office of Air and Radiation	12/87
	CO10	Gothic	Gunnison	US EPA-Office of Air and Radiation	02/99
	CO15	Sand Spring	Moffat	Bureau of Land Management	03/79
	CO19	Rocky Mtn NP-Beaver Meadows	Larimer	National Park Service - Air Resources Div	05/80
	CO21	Manitou	Teller	USDA Forest Service	10/78
	CO22	Pawnee	Weld	SAES-Colorado State University	05/79
	CO91	Wolf Creek Pass	Mineral	USDA Forest Service	05/92
	CO92	Sunlight Peak	Garfield	US EPA-Office of Air and Radiation	01/88
	CO93	Buffalo Pass-Dry Lake	Routt	USDA Forest Service	10/86
	CO94	Sugarloaf	Boulder	US EPA-Office of Air and Radiation	11/86
	CO96	Molas Pass	San Juan	USDA Forest Service	07/86
	CO97	Buffalo Pass-Summit Lake	Routt	USDA Forest Service	02/84
	CO98	Rocky Mtn NP - Loch Vale	Larimer	USGS/Colorado State University	08/83
	CO99	Mesa Verde NP - Chapin Mesa	Montezuma	US Geological Survey	04/81
Connecticut					
	CT15	Abington	Windham	US EPA-Office of Air and Radiation	01/99

Site	Site Code	Site Name	County	Sponsoring Agency	Start Date
Florida					
	FL03	Bradford Forest	Bradford	St. John’s River Water Management District	10/78
	FL05	Chassahowitzka NWR	Citrus	US Fish & Wildlife Service	08/96
	FL11	Everglades NP - Research Ctr	Dade	National Park Service - Air Resources Div	06/80
	FL14	Quincy	Gadsden	US Geological Survey	03/84
	FL23	Sumatra	Liberty	US EPA-Office of Air and Radiation	01/99
	FL41	Verna Well Field	Sarasota	US Geological Survey	08/83
	FL99	Kennedy Space Center	Brevard	NASA/Dynamac Corp.	08/83
Georgia					
	GA09	Okefenokee NWR	Charlton	US Fish & Wildlife Service	06/97
	GA20	Bellville	Bellville	US EPA-Office of Air and Radiation	04/83
	GA41	Georgia Station	Pike	SAES-University of Georgia	10/78
	GA99	Chula	Tift	US Geological Survey	02/94
Idaho					
	ID03	Craters of the Moon NM	Butte	National Park Service - Air Resources Div	08/80
	ID11	Reynolds Creek	Owyhee	US Geological Survey	11/83
	ID15	Smiths Ferry	Valley	US Geological Survey	10/84
Illinois					
	IL11	Bondville	Champaign	SAES-University of Illinois	02/79
	IL18	Shabbona	DeKalb	SAES-University of Illinois	05/81
	IL19	Argonne	DuPage	DOE-Argonne National Laboratory	03/80
	IL46	Alhambra	Madison	US EPA-Office of Air and Radiation	01/99
	IL63	Dixon Spring Ag. Ctr.	Pope	SAES-University of Illinois	01/79
	IL78	Monmouth	Warren	US Geological Survey	01/85
Indiana					
	IN20	Huntington Reservoir	Huntington	US Geological Survey	08/83
	IN22	Southwest Purdue Ag. Ctr.	Knox	US Geological Survey	09/84
	IN34	Indiana Dunes NL	Porter	National Park Service - Air Resources Div	07/80
	IN41	Purdue University Ag Farm	Tippecanoe	SAES-Purdue University	07/82
Iowa					
	IA08	Big Springs Fish Hatchery	Clayton	US Geological Survey	08/84
	IA23	McNay Memorial Research Ctr	Lucas	US Geological Survey	09/84
Kansas					
	KS07	Farlington Fish Hatchery	Crawford	US Geological Survey	03/84
	KS31	Konza Prairie	Riley	SAES-Kansas State University	08/82
	KS32	Lake Scott SP	Scott	US Geological Survey	03/84
Kentucky					
	KY03	Mackville	Washington	US Geological Survey	11/83
	KY22	Lilley Cornett Woods	Letcher	NOAA-Air Resources Lab	09/83
	KY35	Clark State Fish Hatchery	Rowan	US Geological Survey	08/83
	**KY99	Mulberry Flats	Trigg	TVA/Murray State University	12/94
Louisiana					
	LA12	Iberia Research Station	Iberia	US Geological Survey	11/82
	LA30	Southeast Research Station	Washington	US Geological Survey	01/83
Maine					
	ME00	Caribou	Aroostook	NOAA-Air Resources Lab	04/80
	ME02	Bridgton	Cumberland	Maine Department of Environmental Protection	09/80
	ME08	Gilead	Oxford	US Geological Survey	09/99
	ME09	Greenville Sta	Piscataquis	SAES-University of Maine	11/79
	ME96	Casco Bay/Wolfe’s Neck Farm	Cumberland	EPA/University of Southern Maine	01/98
	ME98	Acadia NP - McFarland Hill	Hancock	National Park Service - Air Resources Div	11/81
Maryland					
	MD03	White Rock Substation	Carroll	Baltimore Gas & Electric Co.	10/84
	MD13	Wye	Queen Anne	SAES-University of Maryland	03/83

Site	Site Code	Site Name	County	Sponsoring Agency	Start Date
Massachusetts					
	MA01	North Atlantic Coastal Lab	Barnstable	National Park Service - Air Resources Div	12/81
	MA08	Quabbin Reservoir	Franklin	NESCAUM	03/82
	MA13	East	Middlesex	NESCAUM	02/82
Michigan					
	MI09	Douglas Lake-UM Biological Sta	Cheboygan	SAES-Michigan State University	07/79
	MI26	Kellogg Biological Sta	Kalamazoo	SAES-Michigan State University	06/79
	MI51	Unionville	Tuscola	US EPA-Office of Air and Radiation	01/99
	MI52	Ann Arbor	Washtenaw	US EPA-Office of Air and Radiation	01/99
	MI53	Wellston	Wexford	USDA Forest Service	10/78
	MI97	Isle Royale NP-Wallace Lake	Keneenaw	National Park Service - Air Resources Div	05/85
	MI98	Raco	Chippewa	US EPA-Office of Air and Radiation	05/84
	MI99	Chassell	Houghton	National Park Service - Air Resources Div	02/83
Minnesota					
	MN01	Cedar Creek	Anoka	Minnesota Pollution Control Agency	12/96
	MN05	Fond du Lac	Carlton	EPA/Fond du Lac Reservation	11/96
	MN08	Hovland	Cook	Minnesota Pollution Control Agency	12/96
	MN16	Marcell Exp. Forest	Itasca	USDA Forest Service	07/78
	MN18	Fernberg	Lake	US EPA-Office of Air and Radiation	11/80
	MN23	Camp Ripley	Morrison	US Geological Survey	10/83
	MN27	Lamberton	Redwood	Minnesota Pollution Control Agency	01/79
	MN28	Grindstone Lake	Pine	Minnesota Pollution Control Agency	12/96
	MN99	Wolf Ridge	Lake	Minnesota Pollution Control Agency	12/96
Mississippi					
	MS10	Clinton	Hinds	US Geological Survey	07/84
	MS19	Newton	Newton	NOAA-Air Resources Lab	11/86
	MS30	Coffeeville	Yalobusha	Tennessee Valley Authority	07/84
Missouri					
	MO03	Ashland Wildlife Area	Boone	US Geological Survey	10/81
	MO05	University Forest	Butler	US Geological Survey	10/81
Montana					
	MT00	Little Big Horn Battlefield	Big Horn	US Geological Survey	07/84
	MT05	Glacier NP-Fire Weather Sta	Flathead	National Park Service - Air Resources Div	06/80
	MT07	Clancy	Jefferson	US Geological Survey	01/84
	MT13	Give Out Morgan	Roosevelt	EPA/Ft. Peck Reservation	09/82
	MT97	Lost Trail Pass	Ravalli	USDA Forest Service	09/90
	MT98	Havre	Hill	US Geological Survey	07/85
Nebraska					
	NE15	Mead	Saunders	SAES-University of Nebraska	07/78
	NE99	North Platte Ag Sta	Lincoln	US Geological Survey	09/85
Nevada					
	NV00	Red Rock Canyon	Clark	Bureau of Land Management	01/85
	NV03	Smith Valley	Smith	US Geological Survey	08/85
	NV05	Great Basin NP-Lehman Caves	White Pine	National Park Service - Air Resources Div	01/85
New Hampshire					
	*NH02	Hubbard Brook	Grafton	USDA Forest Service	07/78
New Jersey					
	NJ00	Edwin B. Forsythe NWR	Atlantic	US Fish & Wildlife Service	10/98
	NJ99	Washington Crossing	Mercer	US EPA-Office of Air and Radiation	08/81
New Mexico					
	NM01	Gila Cliff Dwellings NM	Catron	EPA/New Mexico Environment Dept.	07/85
	NM07	Bandelier NM	Los Alamos	DOE-Los Alamos National Lab	06/82
	NM08	Mayhill	Otero	US Geological Survey	01/84
	NM09	Cuba	Sandoval	Bureau of Land Management	02/82
	NM12	Capulin Volcano NM	Union	EPA/New Mexico Environment Dept.	11/84

Site	Site Code	Site Name	County	Sponsoring Agency	Start Date
New York					
	NY08	Aurora Research Farm	Cayuga	SAES-Cornell University	04/79
	NY10	Chautauqua	Chautauqua	US Geological Survey	06/80
	NY20	Huntington Wildlife	Essex	EPA/State Univ of New York-Syracuse	10/78
	NY22	St. Regis Mohawk-Ft. Covington	Franklin	US EPA-Office of Air and Radiation	08/99
	NY52	Bennett Bridge	Oswego	EPA/State Univ of New York-Oswego	06/80
	NY65	Jasper	Steuben	US Geological Survey	02/80
	NY68	Biscuit Brook	Ulster	US Geological Survey	10/83
	NY98	Whiteface Mtn	Essex	US Geological Survey	07/84
	NY99	West Point	Orange	US Geological Survey	09/83
North Carolina					
	NC03	Lewiston	Bertie	North Carolina State University	10/78
	NC06	Beaufort	Carteret	US EPA-Office of Air and Radiation	01/99
	NC25	Coweeta	Macon	USDA Forest Service	07/78
	NC34	Piedmont Res Sta	Rowan	North Carolina State University	10/78
	NC35	Clinton crops Res Sta	Sampson	North Carolina State University	10/78
	NC36	Jordan Creek	Scotland	US Geological Survey	10/83
	NC41	Finley Farms	Wake	North Carolina State University	10/78
	NC45	Mt. Mitchell	Yancey	North Carolina State University	11/85
North Dakota					
	ND07	Theo Roosevelt NP-N Unit HQ	McKenzie	National Park Service - Air Resources Div	05/81
	ND08	Icelandic SP	Pembina	US Geological Survey	10/83
	ND11	Woodworth	Stutsman	US Geological Survey	11/83
Ohio					
	OH09	Oxford	Butler	US Geological Survey	08/84
	OH15	Lykens	Crawford	US EPA-Office of Air and Radiation	01/99
	OH17	Delaware	Delaware	USDA Forest Service	10/78
	OH49	ldwell	Noble	US Geological Survey	09/78
	OH54	Deer Creek State Park	Pickaway	US EPA-Office of Air and Radiation	01/99
	OH71	Wooster	Wayne	US Geological Survey	09/78
Oklahoma					
	OK00	Salt Plains NWR	Alfalfa	US Geological Survey	12/83
	OK17	Great Plains Apiaries	McClain	NOAA-Air Resources Lab	03/83
	OK29	Goodwell Research Sta	Texas	US Geological Survey	01/85
Oregon					
	OR02	Alsea Guard RS	Benton	US EPA-Office of Air and Radiation	12/79
	OR09	Silver Lake RS	Lake	US Geological Survey	08/83
	OR10	H.J. Andrews Exp. Forest	Lane	USDA Forest Service	05/80
	OR18	Starkey Exp. Forest	Union	US Geological Survey	03/84
	OR97	Hyslop Farm	Benton	US EPA-Office of Air and Radiation	04/83
	OR98	Bull Run	Clackamas	USGS-City of Portland	07/82
Pennsylvania					
	PA00	Arendtsville	Adams	US EPA-Office of Air and Radiation	01/99
	PA15	Penn State	Centre	NOAA-Air Resources Lab	06/83
	PA18	Young Woman’s Creek	Clinton	US Geological Survey	04/99
	PA29	Kane Exp. Forest	Elk	USDA Forest Service	07/78
	PA42	Leading Ridge	Huntingdon	SAES-Pennsylvania State University	04/79
	PA72	Milford	Pike	USDA Forest Service	12/83
Puerto Rico					
	PR20	El Verde	Rio Grande	USDA Forest Service	02/85
South Carolina					
	SC06	Santee NWR	Clarendon	US Geological Survey	07/84
South Dakota					
	SD08	Cottonwood	Jackson	NOAA-Air Resources Lab	10/83
	SD99	Huron Well Field	Huron	US Geological Survey	11/83

Site Site Code	Site Name	County	Sponsoring Agency	Start Date
Tennessee				
TN00	Walker Branch Watershed	Anderson	DOE/Oak Ridge Natl Lab/Lockheed-Martin	03/80
TN04	Speedwell	Claiborne	US EPA-Office of Air and Radiation	01/99
TN11	Great Smoky Mtn NP-Elkmont	Sevier	National Park Service - Air Resources Div	08/80
TN14	Hatchie NWR	Haywood	Tennessee Valley Authority	10/84
Texas				
TX02	Muleshoe NWR	Bailey	US Geological Survey	06/85
TX03	Beeville	Bee	NOAA-Air Resources Lab	02/84
TX04	Big Bend NP - K-Bar	Brewster	National Park Service - Air Resources Div	04/80
TX10	Attwater Prairie Chicken NWR	Colorado	US Geological Survey	07/84
TX16	Sonora	Edwards	US Geological Survey	06/84
TX21	Longview	Gregg	Texas Natural Resource Conservation Comm	06/82
TX22	Guadalupe Mtns NP-Frijole RS	Culberson	US Geological Survey	06/84
TX38	Forest Seed Center	Nacogdoches	Texas Natural Resource Conservation Comm	08/81
TX56	LBJ National Grasslands	Wise	US Geological Survey	09/83
Utah				
UT01	Logan	Cache	US Geological Survey	12/83
UT08	Murphy Ridge	Rich	BP Amoco	03/86
UT09	Canyonlands NP	San Juan	National Park Service - Air Resources Div	11/97
UT98	Green River	Emery	US Geological Survey	04/85
UT99	Bryce Can. NP-Repeater Hill	Garfield	National Park Service - Air Resources Div	01/85
Vermont				
VT01	Bennington	Bennington	US Geological Survey	04/81
VT99	Underhill	Chittenden	US Geological Survey	06/84
Virgin Islands				
VI01	VINP-Lind Point	St. John	National Park Service - Air Resources Div	04/98
Virginia				
VA00	Charlottesville	Albemarle	US Geological Survey	10/84
VA13	Horton's Station	Giles	Tennessee Valley Authority	07/78
VA24	Prince Edward	Prince Edward	US EPA-Office of Air and Radiation	01/99
VA28	Shenandoah NP-Big Meadows	Madison	National Park Service - Air Resources Div	05/81
Washington				
WA14	Olympic NP - Hoh RS	Jefferson	National Park Service - Air Resources Div	05/80
WA19	N Cascades NP-Marblemount RS	Skagit	US Geological Survey	02/84
WA21	La Grande	Pierce	US EPA-Office of Air and Radiation	04/84
WA24	Palouse Conservation Farm	Whitman	US Geological Survey	08/85
West Virginia				
WV04	Babcock SP	Fayette	US Geological Survey	09/83
WV05	Cedar Creek State Park	Gilmer	US EPA-Office of Air and Radiation	01/99
WV18	Parsons	Tucker	USDA Forest Service	07/78
Wisconsin				
WI09	Popple River	Florence	Wisconsin Department of Natural Resources	12/86
WI25	Suring	Oconto	Wisconsin Department of Natural Resources	01/85
WI28	Lake Dubay	Portage	Wisconsin Department of Natural Resources	06/82
WI35	Perkinstown	Taylor	US EPA-Office of Air and Radiation	01/99
WI36	Trout Lake	Vilas	Wisconsin Department of Natural Resources	01/80
WI37	Spooner	Washburn	Wisconsin Department of Natural Resources	06/80
WI98	Wildcat Mountain	Vernon	Wisconsin Department of Natural Resources	08/89
WI99	Lake Geneva	Walworth	Wisconsin Department of Natural Resources	06/84

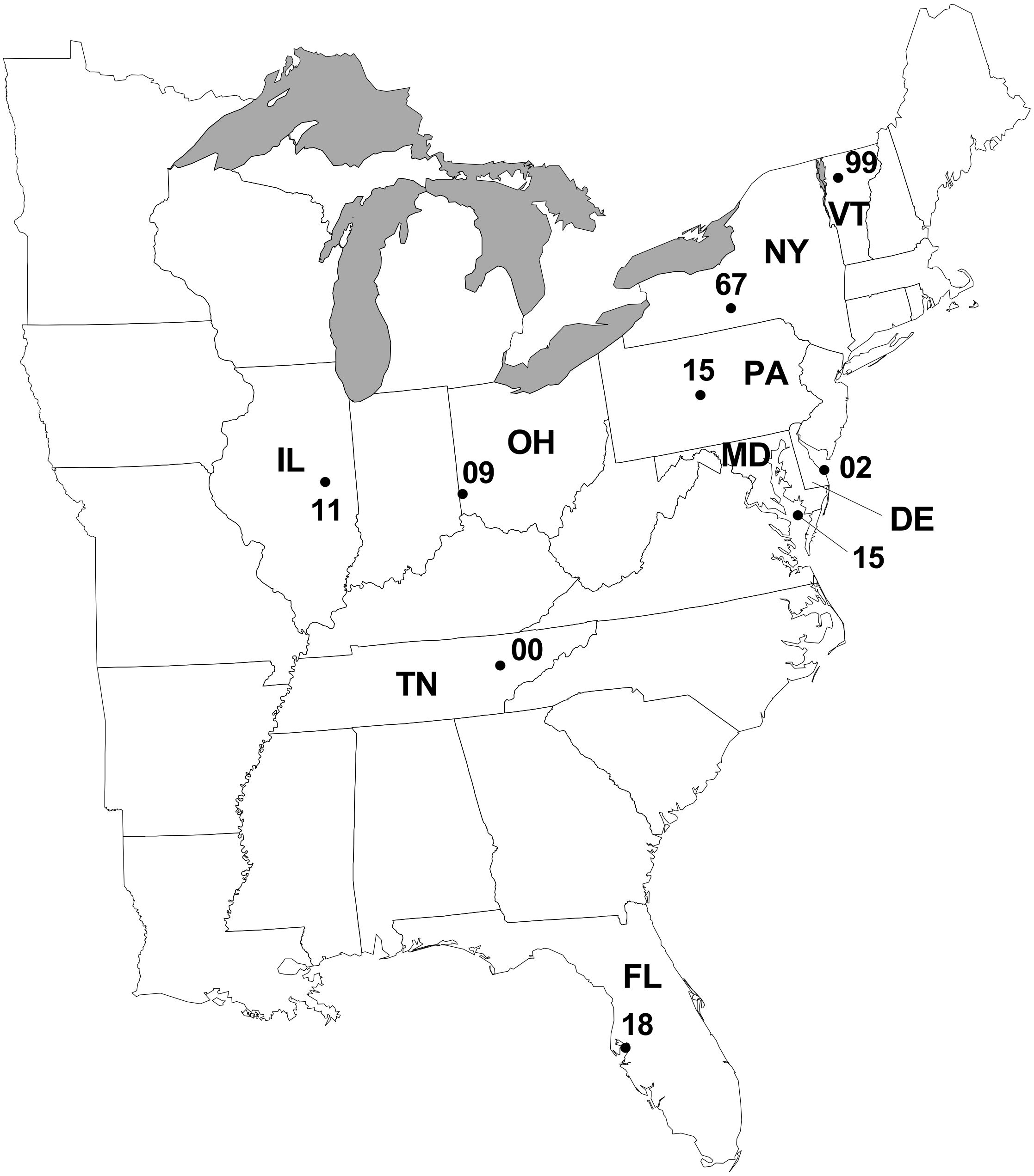
Site Site Code	Site Name	County	Sponsoring Agency	Start Date
Wyoming				
WY00	Snowy Range-W. Glacier Lake	Albany	USDA Forest Service	04/86
WY02	Sinks Canyon	Fremont	Bureau of Land Management	08/84
WY06	Pinedale	Sublette	Bureau of Land Management	01/82
WY08	Yellowstone NP - Tower	Park	National Park Service - Air Resources Div	06/80
WY95	Brooklyn Lake	Albany	USDA Forest Service	09/92
WY97	South Pass City	Fremont	SF Phosphates Ltd	04/85
WY98	Gypsum Creek	Sublette	Exxon Co.	12/84
WY99	Newcastle	Weston	Bureau of Land Management	08/81
Canada				
CAN4	Sutton	Brome	US Geological Survey	09/86

*Intercomparison sites

**Restart - Site discontinued operations 03/96 and restarted 03/99

IV. AIRMoN MAP AND SITE LISTINGS

National Atmospheric Deposition Program
Atmospheric Integrated Research Monitoring Network

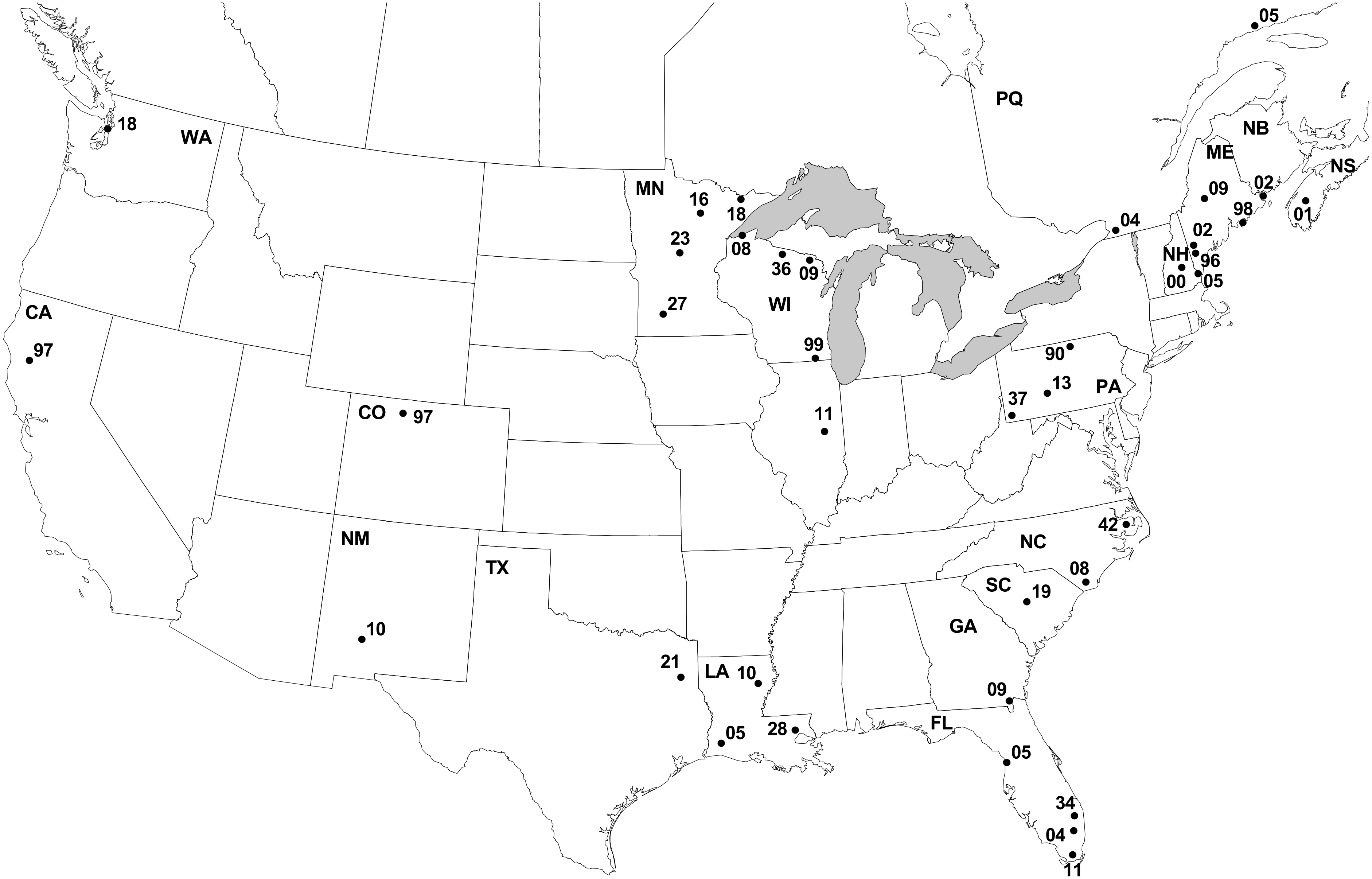


NADP/Atmospheric Integrated Research Monitoring Network Sites
Effective October 1, 1999

State Site Code	Site Name	County	Sponsoring Agency	Start Date
Delaware				
DE02	Lewes	Sussex	NOAA-Air Resources Laboratory	09/92
Florida				
FL18	Tampa Bay	Hillsborough	EPA/Tampa Bay Regional Planning Council	08/96
Illinois				
IL11	Bondville	Champaign	NOAA-Air Resources Laboratory	10/92
Maryland				
MD15	Smith Island	Somerset	NOAA-Air Resources Laboratory	11/95
New York				
NY67	Cornell University	Thompkins	NOAA-Air Resources Laboratory	09/92
Ohio				
OH09	Oxford	Butler	NOAA-Air Resources Laboratory	10/92
Pennsylvania				
PA15	Penn State	Centre	NOAA-Air Resources Laboratory	10/92
Tennessee				
TN00	Oak Ridge National Lab	Anderson	NOAA-Air Resources Laboratory	09/92
Vermont				
VT99	Underhill	Chittenden	NOAA-Air Resources Laboratory	01/93

V. MDN MAP AND SITE LISTINGS

National Atmospheric Deposition Program
Mercury Deposition Network



National Atmospheric Deposition Program/Mercury Deposition Network Sites
Effective October 1, 1999

State/Province Site Code	Site Name	County	Sponsoring Agency	Start Date
California				
CA97	Covelo	Mendocino	Electric Power Research Institute	12/97
Colorado				
CO97	Buffalo Pass - Summit Lake	Routt	USDA/Forest Service-Rocky Mtn Forest & Range Exp. Sta.	10/98
Florida				
FL04	Andytown	Broward	South Florida Water Management District	01/98
FL05	Chassahowitzka NWR	Citrus	US Fish and Wildlife Service	07/97
FL11	Everglades NP - Research Ctr	Dade	South Florida Water Management District	10/95
FL34	ENRP	Palm Beach	South Florida Water Management District	07/97
Georgia				
GA09	Okefenokee NWR	Chulton	US Fish and Wildlife Service	07/97
Illinois				
IL11	Bondville	Champaign	Illinois State Water Survey	01/99
Louisiana				
LA05	Lake Charles	Calcasieu	Louisiana Dept. of Environmental Quality	10/98
LA10	Chase	Franklin	Louisiana Dept. of Environmental Quality	10/98
LA28	Hammond	Tangipahoa	Louisiana Dept. of Environmental Quality	10/98
Maine				
ME02	Bridgton	Cumberland	EPA/NESCAUM	06/97
ME09	Greenville Station	Piscataquis	Maine Dept. of Environmental Protection	09/96
ME96	Casco Bay Wolfe's Neck Farm	Cumberland	EPA/University of Southern Maine	01/98
ME98	Acadia NP - McFarland Hill	Hancock	NPS/Acadia NP/Maine Dept. of Environmental Protection	09/95
Minnesota				
MN16	Marcell Experimental Forest	Itasca	USDA/Forest Service-North Central Forest Exp. Sta.	02/95
MN18	Fernberg	Lake	USDA/Forest Service & MN Pollution Control Agency	03/95
MN23	Camp Riley	Morrison	Minnesota Pollution Control Agency	07/96
MN27	Lamberton	Redwood	Minnesota Pollution Control Agency	07/96
New Hampshire				
NH00	Laconia	Belknap	New Hampshire Air Resources Agency	01/98
NH05	New Castle	Rockingham	EPA/University of New Hampshire	10/97
New Mexico				
NM10	Caballo	Sierra	New Mexico State University	05/97
North Carolina				
NC08	Wauccamaw State Park	Columbus	NC Dept of Environment, Health & Natural Resources	05/95
NC42	Pettigrew State Park	Washington	NC Dept of Environment, Health & Natural Resources	05/95
Pennsylvania				
PA13	Allegheny Portage Railroad NHS	Cambria	PA Dept. of Environmental Resources/ Penn State Univ.	01/97
PA37	Holbrooke	Green	USDOE/Federal Energy Technology Center	05/99
PA90	Hills Creek State Park	Tioga	PA Dept. of Environmental Resources/ Penn State Univ.	01/97

State/Province Site Code	Site Name	County	Sponsoring Agency	Start Date
South Carolina				
SC19	Congaree Swamp State Park	Richland	South Carolina Dept. of Health & Environmental Quality	03/95
Texas				
TX21	Longview	Gregg	Texas Natural Resource Conservation Commission	11/95
Washington				
*WA18	Seattle	King	Frontier Geosciences, Inc	03/96
Wisconsin				
WI08	Brule River	Douglas	Wisconsin Department of Natural Resources	03/95
WI09	Popple River	Florence	Wisconsin Department of Natural Resources	06/95
WI36	Trout Lake	Vilas	Wisconsin Department of Natural Resources	05/95
WI99	Lake Geneva	Walworth	Wisconsin Department of Natural Resources	01/97
CANADA				
New Brunswick				
NB02	St. Andrews	Charlotte	Environment Canada, Atmospheric Environment Branch	07/96
Nova Scotia				
NS01	Kejimkujik National Park	Queens	Environment Canada, Atmospheric Environment Branch	07/96
Quebec				
PQ04	St. Anicet		Environment Canada, Atmospheric Environment Branch	04/98
PQ05	Mingan		Environment Canada, Atmospheric Environment Branch	04/98

*Intercomparison Site

VI. PROCEEDINGS NOTES

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