NADP 2009
Technical Committee Meeting

October 6 – 8, 2009
Saratoga Springs, New York

Scientific Symposium Chair
Mark Nilles
U.S. Geological Survey

PROCEEDINGS

Prepared by

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Acknowledgements

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CONTENTS

i

Technical Session 3: A Focus on Monitoring and Research in the Adirondacks

Technical Session 4: The Development and Application of Critical Loads of Sulfur and Nitrogen (Part II)

Technical Session 5: Atmospheric Mercury Measurement and Assessment in the Northeast

Technical Session 6: Agricultural Emissions and Ecosystem Effects

Technical Session 7: Evaluating Trends for Air Concentration, Deposition, Aquatic and Terrestrial Effects

Poster Session

vi

NADP Scientific Symposium Agenda

NADP Annual Meeting and Scientific Symposium
Saratoga Springs, New York
October 6 – 8, 2009

Tuesday, October 6, 2009   **Room Location**
     Registration Desk Open All Day

8:00 a.m. - 9:15 a.m.   Joint Subcommittee Meeting   **Daily Double Rear**

9:15 a.m. – 9:30 a.m.   Break

9:30 a.m. – 12:00 noon   Subcommittee Meetings
                               Network Operations   **Daily Double Rear**
                               Data Management & Analysis   **Place**
                               Ecological Response and Outreach   **Show**
                               Critical Loads (ad hoc)   **Quinella**

12:00 noon - 1:30 p.m.   Lunch - On your own

1:30 p.m. - 3:30 p.m.   Joint Subcommittee Meeting   **Daily Double Rear**

3:30 p.m. - 3:45 p.m.   Break

3:45 p.m. - 6:00 p.m.   Executive Committee Meeting   **Daily Double Rear**

Wednesday, October 7, 2009   **Room Location**
     Registration Desk Open All Day   **Daily Double Rear**

8:30 a.m. - 9:10 a.m.   **Welcome, Program Office Report,**
                               Awards and Announcements
                               Mark Nilles: NADP Vice Chair, Symposium Chair
                                              U.S. Geological Survey
                               David Gay: NADP Coordinator
                               Eric Prestbo: NADP Chair
                                              Tekran Instrument Corporation,

Keynote Addresses

9:10 – 9:40	**Coupled Biogeochemical Cycles: How They Arise and What They Mean** Bill Schlesinger, Director Cary Institute of Ecosystem Studies
9:40 – 10:10	**The Response of Acid-impacted Lake-watersheds in the Adirondack Region of New York to Decreases in Atmospheric Deposition** Charles Driscoll, Syracuse University
10:10 – 10:40	Break

Technical Session 1:   **Are Ecosystems Responding to Emission Reductions?**
Session Chair: Doug Burns
U.S. Geological Survey and NAPAP Chair

10:40 – 11:00	**Changes in Fish Communities in Adirondack Lakes** Karen Roy, New York State Department of Environmental Conservation
11:00 – 11:20	**Trends in Sulfate Deposition and Stream Water Base Cation Concentrations in the Catskill Mountains of New York** Mike McHale, U.S. Geological Survey
11:20 – 11:40	**Discrepancies in Watershed S Budgets in Southeast Canada and Northeast U.S.: A Comparison of Mass-Balance Approach** Myron Mitchell, SUNY College of Environmental Science and Forestry
11:40 – 12:00	**Examining Sulfate Behavior along a North-South Gradient of Unglaciated Eastern U.S. Catchments** Karen Rice, U.S. Geological Survey
12:00 noon – 1:30 p.m.	Lunch – On your own

4

Technical Session 2: The Development and Application of Critical Loads of Sulfur and Nitrogen (Part I)
Session Chair: Tamara Blett
National Park Service

1:30p.m. – 1:50p.m.　　**Critical Loads Development and Use in Europe: Applicable to USA?**
Jean Paul Hettelingh, Coordination Centre for Effects-PBL

1:50 – 2:10　　**Critical Loads: Science and Policy**
Gary Lovett, Institute for Ecosystem Research

2:10 – 2:30　　**Lichen-Based Critical Loads for Nitrogen Deposition in Western Oregon and Washington Forests**
Linda Geiser, USDA Forest Service

2:30 – 2:50　　**Methodologies for Determining Empirical Nitrogen Critical Loads and Exceedances for CA Ecosystems**
Mark Fenn, USDA Forest Service

2:50 – 3:10　　**Development of Critical N Loads Using Diatom N Proxies: Distribution of Indicator Species in Lakes of the Sierra Nevada of California**
Danuta Bennett, University of California, Santa Barbara

3:10 – 3:30　　Break

Technical Session 3:　A Focus on Monitoring and Research in the Adirondacks
Session Chair: Greg Lampman
New York State Energy Research & Development Authority

3:30 - 3:50　　**Assessing the Impact of Long-term Mercury Contamination on Wildlife Health in New York, Using the Common Loon as a Sentinel Species**
Nina Schoch, BioDiversity Research Institute

3:50 – 4:20　　**Zooplankton Recovery in Chemically Recovering, Acidified Adirondack Lakes**
William Shaw, Sullivan County Community College (Retired)

Wednesday, October 7, 2009   **Room Location**
                                                  Daily Double Rear

Technical Session 3:   **A Focus on Monitoring and Research in the Adirondacks**
   (Continued)   Session Chair: Greg Lampman
                           New York State Energy Research & Development Authority

4:20p.m. - 4:40p.m.   **Acid-deposition-induced Calcium Depletion from**
                           Adirondack Forests and the Response of Biotic
                           Communities to Calcium Amendment
                           Timothy McCay, Colgate University

4:40 - 5:00   **Laboratory and Field Data Indicate that Acidic**
                           Deposition-induced Calcium Depletion Disrupts
                           the Nutrition and Physiology of Trees, Predisposing
                           Them to Decline
                           Paul Schaberg, USDA Forest Service

5:00 – 5:20   **Measuring Soil Change to Assess Recovery Potential**
                           Greg Lawrence, U.S. Geological Survey

5:30 p.m. – 8:00 p.m.   **Poster Session and Reception**
                           Recognition for the Adirondack Council and
                           address to attendees by Brian Houseal, Director

Thursday, October 8, 2009   **Room Location**
                                                  Daily Double Rear

8:30 a.m. – 8:40 a.m.   **Opening remarks, announcement and**
                           overview of Day 2 – Mark Nilles, NADP Vice Chair,
                                         U.S. Geological Survey

Technical Session 4:   **The Development and Application of Critical**
                           Loads of Sulfur and Nitrogen (Part II)
                           Session Chair: Rich Pouyat
                           USDA Forest Service

8:40 – 9:00   **Critical Loads for Protection of Aquatic Resources**
                           in the Blue Ridge, Ridge and Valley, and Appalachian
                           Plateau Ecoregions of Virginia and West Virginia
                           Tim Sullivan, E&S Environmental Services

9:00 – 9:20   **Maryland Critical Loads and the Maryland Biological**
                           Stream Survey
                           Raymond Morgan, University of Maryland

Technical Session 4:   **The Development and Application of Critical**
      (Continued)   **Loads of Sulfur and Nitrogen (Part II)**
                             Session Chair: Rich Pouyat
                             USDA Forest Service

9:20 a.m. – 9:40 a.m.   **Adapting CMAQ Deposition Fields for Critical**
                             Loads Analyses
                             Robin Dennis, U.S. Environmental Protection Agency

9:40 – 10:00   **Critical Loads as a Policy Tool: Highlights of**
                             the NOx/SOx Secondary National Ambient Air
                             Quality Standard Review
                             Anne Rea, U.S. Environmental Protection Agency

10:00 – 10:20   Break

Technical Session 5:   **Atmospheric Mercury Measurement and**
                             Assessment in the Northeast
                             Session Chair: David Schmeltz
                             U.S. Environmental Protection Agency

10:20 – 10:40   **Sources and Regional Transport of Mercury to the**
                             Northeast: Insights from Air Observations at VT99
                             Eric Miller, Ecosystems Research Group, Ltd.

10:40 – 11:00   **Atmospheric Mercury (Hg) Concentrations in**
                             New York: A Comparison between Urban and
                             Rural Areas
                             Hyun-Deok Choi, Clarkson University

11:00 – 11:40   **Atmospheric Mercury Monitoring in Canada**
                             Pierrette Blanchard, Environment Canada

11:40 – 12:00   **Atmospheric Deposition of Mercury and Its Impact**
                             on Aquatic Ecosystems Draining Forested Watersheds
                             in Pennsylvania
                             Elizabeth Boyer, Penn State University

12:00 noon – 1:30 p.m.   Lunch – On your own

Thursday, October 8, 2009   Room Location

Technical Session 6:   **Agricultural Emissions and Ecosystem Effects**
Session Chair: Beth Boyer
Pennsylvania State University
State Agricultural Experiment Station

1:30 p.m. – 1:50 p.m.   **A Process-based Soil Ammonia Emission Model for Agricultural Soils**
Ellen Cooter, U.S. Environmental Protection Agency

1:50 – 2:10   **Mechanism of Ammonia Loss in Swine Effluent**
Sang Ryong Lee, North Carolina State University

2:10 – 2:30.   **Quality Assurance and Monitoring Results of the NADP's Passive Ammonia Network**
Melissa Rury, U.S. Environmental Protection Agency

2:30 - 2:50   **Agricultural Ammonia Emissions and Ammonium Concentrations Associated with Precipitation in the Southeast United States**
Viney Aneja, North Carolina State University

2:50 – 3:15   **Multi-air Pollutant Impacts on Forage Yields: A Case Study of Alfalfa Responses in West Central Alberta, Canada**
Sagar Krupa, University of Minnesota

3:15 – 3:35   Break

Technical Session 7:   **Evaluating Trends for Air Concentration, Deposition, Aquatic and Terrestrial Effects**
Session Chairs: Kathleen Weathers (invited)
and Tom Butler
Cary Institute of Ecosystems Studies

3:35 – 3:55   **Recent Evidence of Biological Recovery from Acidification in the Adirondacks**
Kristina Arseneau, Queen's University, Ontario, Canada

3:55 – 4:15   **Nitrogen Deposition Increases Tree Carbon Storage and Shifts Species' Competitive Balance**
R. Quinn Thomas, Cornell University

Technical Session 7:   **Evaluating Trends for Air Concentration,**
  (Continued)   **Deposition, Aquatic and Terrestrial Effects**
                               Session Chairs: Kathleen Weathers (invited)
                                     and Tom Butler
                                     Cary Institute of Ecosystems Studies

4:15 p.m. – 4:35 p.m.   **Interactions of Climate Change with Acidic Deposition**
                               in a Forest Watershed over the 21st Century Using a
                               Dynamic Biogeochemical Model (PnET-BGC)
                               Afshin Pourmokhtarian, Syracuse University

     4:35 – 4:55   **A National Assessment of the Ecological Effects**
                               of Nitrogen and Sulfur Oxides
                               Tara Greaver, U.S. Environmental Protection Agency

     4:55 – 5:15   **Trends in Cloud and Rain Water Chemistry**
                               from 1984-2007 on Mount Washington, NH (1,534 M)
                               Georgia Murray, Appalachian Mountain Club

Friday, October 9, 2009

                               Field Trip to Huntington Forest Research Center
                               Organized by Doug Burns, U.S. Geological Survey and
                                     Myron Mitchell, SUNY-ESF

2009 NADP Site Operator Awards

National Atmospheric Deposition Program Operator Awards

5 – YEAR AWARDS

SITE	OPERATOR NAME	SITE NAME	WET START	AGENCY
LA30-NTN	Jerry Simmons	Southeast Research Station	Jan-83	U.S. Geological Survey and LSU State Agricultural Experiment Station-Southeast Research Stn.
MD08-MDN and NTN	Mark Castro	Piney Reservoir	MDN-Jun-04 NTN-Jun-04	University of Maryland Appalachian Laboratory and Maryland Department of Natural Resources
ME04-NTN	Bill Thompson	Carrabassett Valley	Mar-02	U.S. Environmental Protection Agency and Penobscot Indian Nation
MT07-NTN	Evonne Mitton	Clancy	Jan-84	U.S. Geological Survey
VA28-MDN and NTN	Liz Garcia	Shenandoah National Park-Big Meadows	MDN-Oct-02 NTN-May-81	National Park Service Shenandoah National Park

10 – YEAR AWARDS

SITE	OPERATOR NAME	SITE NAME	WET START	AGENCY
CO10-NTN	Billy Barr	Gothic	Feb-99	U.S. Environmental Protection Agency - Clean Air Markets
FL23-NTN	Jimmy Bishop	Sumatra	Jan-99	U.S. Environmental Protection Agency - Clean Air Markets
GA99-NTN	Charles Welsh	Chula	Feb-94	U.S. Geological Survey and U.S. Department of Agriculture - Agricultural Research Service
IL46-NTN	Betty Steiner	Alhambra	Jan-99	U.S. Environmental Protection Agency - Clean Air Markets
IL78-NTN	Marty Johnson	Monmouth	Jan-85	U.S. Geological Survey and University of Illinois - State Agricultural Experiment Station
KY99-NTN	Gary Rice	Mulberry Flat	Dec-94	Tennessee Valley Authority and Murray State University
NC06-NTN	Nathan Hall	Beaufort	Jan-99	U.S. Environmental Protection Agency - Clean Air Markets
OH54-NTN	Sally Hammond	Deer Creek State Park	Jan-99	U.S. Environmental Protection Agency - Clean Air Markets
OK29-NTN	Craig Chesnut	Goodwell Research Station	Jan-85	U.S. Geological Survey and Panhandle Research Station
OR97-NTN	Lynn Conley	Hyslop Farm	Apr-83	U.S. Environmental Protection Agency - Clean Air Markets
PA00-NTN	Sharon Scamack	Arendtsville	Jan-99	Pennsylvania Department of Environmental Protection

15 – YEAR AWARDS

SITE	OPERATOR NAME	SITE NAME	WET START	AGENCY
AR03-NTN	Harrell Beckwith	Caddo Valley	Dec-83	U.S. Geological Survey
CA42-NTN	Mike Oxford	Tanbark Flat	Jan-82	U.S. Forest Service and Riverside Forest Fire Laboratory
NV03-NTN	Laurie Bonner	Smith Valley	Aug-85	U.S. Geological Survey
PR20-NTN	John Bithorn	El Verde	Feb-85	U.S. Forest Service and University of Puerto Rico-CEER

20 – YEAR AWARDS

SITE	OPERATOR NAME	SITE NAME	WET START	AGENCY
AL10-NTN	Peggy Seekers	Black Belt Research & Extension Center	Aug-83	U.S. Geological Survey
CO08-NTN	Wayne Ives	Four Mile Park	Dec-87	U.S. Environmental Protection Agency - Clean Air Markets and White River National Forest
IN41-NTN	Ken Scheeringa	Agronomy Center for Research & Extension	Jul-82	Purdue University-State Agricultural Experiment Station
OR18-NTN	Cheryl Borum	Starkey Experimental Forest	Mar-84	U.S. Geological Survey and Forestry & Range Sciences Lab
TX02-NTN	Glenda Copley	Muleshoe National Wildlife Refuge	Jun-85	U.S. Geological Survey and U.S. Fish and Wildlife Service

25 – YEAR AWARDS

SITE	OPERATOR NAME	SITE NAME	WET START	AGENCY
MN18-NTN	Christine Barton	Fernberg	Nov-80	U.S. Environmental Protection Agency -Clean Air Markets and U.S. Forest Service
MN23-NTN	Mary McGuire	Camp Ripley	Oct-83	U.S. Geological Survey
MS10-NTN	Eddie Morris	Clinton	Jul-84	U.S. Geological Survey
WI99-NTN	Ted Peters	Lake Geneva	Jun-84	Wisconsin Department of Natural Resources
WY02-NTN	Greg Bautz	Sinks Canyon	Aug-84	U.S. Bureau of Land Management

In memory of NADP/NTN operator Clara Emstrom

1927-2009

NADP greatly appreciates Clara's hard work and diligence as NTN Site WI35 operator for the past ten years.

Keynote Speaker:

Bill Schlesinger, Director, Cary Institute of Ecosystem Studies

William H. Schlesinger

On 1 June 2007, William H. Schlesinger was named President of the Cary Institute of Ecosystem Studies, a private ecological research institute on the grounds of the Cary Arboretum in Millbrook, NY. He assumed this position after 27 years on the faculty of Duke University. Completing his A.B. at Dartmouth (1972), and Ph.D. at Cornell (1976), he moved to Duke in 1980, where he retired in spring 2007 as Dean of the Nicholas School of the Environment and Earth Sciences and as James B. Duke Professor of Biogeochemistry.

He is the author or coauthor of over 200 scientific papers on subjects of environmental chemistry and global change and the widely-adopted textbook Biogeochemistry: An analysis of global change (Academic Press, 2nd ed. 1997). He has published editorials and columns in the *Charlotte Observer, Chicago Tribute, Los Angeles Times, Philadelphia Inquirer,* and the Raleigh *News and Observer.*

Schlesinger was among the first to quantify the amount of carbon held in soil organic matter globally, providing subsequent estimates of the role of soils and human impacts on forests and soils in global climate change. He was elected a member of The National Academy of Sciences in 2003, and was President of the Ecological Society of America for 2003-2004. He is also a fellow in the American Academy of Arts and Sciences, the American Geophysical Union, and the Soil Science Society of America.

His past work has taken him to diverse habitats, ranging from Okefenokee Swamp in southern Georgia to the Mojave Desert of California, and three times as a Duke alumni tour guide to Antarctica. His research has been featured on NOVA, CNN, NPR, and on the pages of *Discover, National Geographic,* the *New York Times,* and *Scientific American.* Schlesinger has testified before U.S. House and Senate Committees on a variety of environmental issues, including preservation of desert habitats, global climate change and carbon sequestration.

Schlesinger currently serves on the Board of Trustees for the Doris Duke Charitable Foundation (New York), the Natural Resources Defense Council (NRDC; New York), and the Southern Environmental Law Center (Charlottesville) and on the Board of Scientific Advisors for Terrapass LLC (San Francisco).

He and his wife, Lisa, live in Millbrook, where they enjoy birdwatching, gourmet cooking, and collecting southwestern art.

Keynote Speaker:

Charles Driscoll, Syracuse University

The Response of Lake-Watersheds in the Adirondack Region of New York To Decreases in Acidic Deposition and Linkages to Climate Change and Mercury Deposition

Charles T. Driscoll[1], Kimberley M. Driscoll[1], Karen Roy[2], Qintao Zhao[1], Afshin Pourmokhtarian[1], Timothy Sullivan[3] and Myron Mitchell[4]

Watersheds in the Adirondack region of New York USA are sensitive to air pollution and climate change. In ecosystems there are interesting interactions among acidic and Hg deposition and changing climate. Marked decreases in concentrations of SO_4^{2-} and H^+ have occurred in wet deposition at Huntington Forest and Whiteface Mountain since the late 1970s which are consistent with long-term declines in emissions of SO_2. Decreases in wet NO_3^- deposition and nitrogen oxides (NO_x) emissions have been less over the same interval. All 48 Adirondack Long Term Monitoring (ALTM) lakes, exhibited significant decreases in concentrations of SO_4^{2-} since 1992 (mean rate -2.31 µeq/L-yr), which coincides with decreases in atmospheric S deposition. Concentrations of NO_3^- have also decreased in 29 of 48 ALTM lakes. This trend is generally consistent with decreases atmospheric N deposition over this period, although others mechanisms may also contribute to this pattern. Decreases in concentrations of SO_4^{2-} + NO_3^- have resulted in increases in acid neutralizing capacity (ANC) (mean change + 0.98 µeq/L-yr with significant increases in 40 lakes) and pH (mean change 0.20 µeq H^+/L-yr, with 37 lakes showing significant decreases in H^+ and two lakes showing increases), and a shift in the speciation of monomeric Al from toxic inorganic species toward less toxic organic forms in some lakes. 23 ALTM lakes have shown significant long-term changes in concentrations of dissolved organic carbon (DOC) (mean change +6.67 µmol C/L-yr, with 20 lakes showing increases and 3 lakes showing decreases). Increases in DOC are likely driven by long-term decreases in SO_4^{2-}+NO_3^- possible due to increases in pH.

Fish in the Adirondacks exhibit elevated concentrations of Hg. There are interesting linkages between acidic and Hg deposition, including the role of sulfur processing in transformations of Hg, and increases in fish Hg concentrations with acidification.

Model calculations using the biogeochemical model PnET-BGC provide a framework for understanding the response of Adirondack lake watersheds to hypothetical future decreases in acidic deposition and are useful to calculate critical loads of acidity to help guide future emission controls. The responses of ecosystems to decreases in acidic deposition are likely influenced by changes in climate and CO_2. This presentation is linked with a presentation by K. Roy on changes in fish communities in ALTM lakes and the relations of these changes with changes in lake chemistry.

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[2] New York State Department of Environmental Conservation, Division of Air, Ray Brook, NY
[3] E&S Environmental Chemistry, Corvallis OR
[4] SUNY ESF, Syracuse, NY 13210

TECHNICAL SESSION 1:   ARE ECOSYSTEMS RESPONDING TO EMISSION REDUCTIONS?

Session Chair: Doug Burns, U.S. Geological Survey and National Acid Precipitation Assessment Program Director

Changes in Fish Communities in Adirondack Lakes

Karen M. Roy[1], Arthur J. Bulger[2] and Charles T. Driscoll[3]

The Adirondack Long Term Monitoring (ALTM) Program collects monthly chemistry in 52 lake watersheds on an ongoing basis since June 1992. During 1994-2005, 45 lakes were surveyed for fish following the same methods of the earlier (1984-87) Adirondack Lakes Survey (ALS) in the region. Fish community changes over the 14-year average interval by class showed: 10 lakes with no fish in either surveys; 8 lakes with no change; 15 lakes gained (mean gain 1.9 species); 8 lakes gained and lost (mean gain 0.9 species), and 4 lakes lost only (mean loss 1.25 species). Fish class comparisons with chemistry means and trends showed the strongest patterns between the fish gain and gain/loss classes with ANC increases and between fish gain with greatest decreases in nitrate. The no fish class was characterized by the highest concentrations of inorganic monomeric aluminum as well as the greatest long-term decreases in inorganic monomeric aluminum.

In the 45 lakes, the 85-87 survey identified 147 fish populations and the 94-05 identified 176, thus adding 29 populations. The median populations increased from 3 to 4 per lake, the maximum number of species increased from 10 to 12, and the average number of species increased from 3.27 to 3.91. Fish community sensitivity metrics developed from the ALS found the greatest gains in the study lakes with starting median pH conditions around 5.5 increasing to about 6.0. Of the 13 sensitive minnows identified in the ALS, three (blacknose dace, fallfish and fathead minnow) were determined to be sensitive and ubiquitous enough to serve as potential indicators. Of these 3 species, one population was observed in 84-87 and four populations in the 94-05 survey. Changes to potential water chemistry critical load indicators (i.e. ANC of 50 ueq/L) were relatively small over the time period with 36 lakes below that level during the 85-87 survey and 33 lakes still below that level in the 94-05 survey. The overall conclusion is that there are signs of recovery in fish species number in some ALTM lakes over the 14 year interval between the two periods. The fish response appears to be modest and mixed, but generally consistent with trends in water chemistry.

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[3] Syracuse University, 151 Link Hall, Syracuse, NY 13244, 315-443-4443, ctdrisco@mailbox.syr.edu

Trends in Sulfate Deposition and Stream Water Base Cation Concentrations in the Catskill Mountains of New York

Michael R. McHale[1], Douglas A. Burns, U.S. Geological Survey[1] and Angelika Winner[2]

The Catskill Regional Long-Term Monitoring Network includes four USGS gaging stations where stream water quality samples are collected through the range in flow. The stations are located in the Catskill Mountains in southeastern New York which receive some of the highest rates of acid deposition in the United States. The purpose of the network is to measure changes in stream water quality in response to reductions in acid deposition mandated by Title IV of the *Clean Air Act Amendments* of 1990. There was a significant decrease in sulfate concentrations of 1.15 microequivalents per liter per year from 1991 to 2005 in wet-only precipitation at the National Atmospheric Deposition Program station in the Biscuit Brook watershed. In both soil water and stream water sulfate decreased at about twice that rate. There were no significant trends in nitrate concentration in precipitation, soil water or stream water. Reduction in magnesium, rather than calcium, appeared to balance the reduction in sulfate concentration in stream water. There were significant decreasing trends in magnesium at all sites and those trends were stronger during low flow. Silica also showed significant decreasing trends in stream water concentration that were stronger during low flow. Furthermore, annual mean concentrations of magnesium and silica were strongly correlated with each other (r^2=0.83) and with sulfate (r^2=0.74 for magnesium; r^2=0.84 for silica). These results suggest that the decrease in sulfate deposition may be causing a decrease in the weathering rate in these watersheds which are underlain by horizontally bedded sedimentary bedrock consisting of sandstone and conglomerate with some interbedded shale and siltstone. A decrease in the soil and bedrock weathering rate could significantly delay ecosystem recovery from acid deposition, as models suggest that recovery is highly sensitive to changes in the weathering rate.

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[2] University of Freiburg

Discrepancies in Watershed S Budgets in Southeast Canada and Northeast U.S.: A Comparative Mass-Balance Approach

Myron Mitchell[1], Cathy Eimers[2], Gary Lovett[3], Daniel Houle[4], Scott Bailey[5], Dean Jeffries[6], Fred Beall[7], Gene Likens[3], Steve Norton[8], Doug Burns[9], Donna Schwede[10], Don Buso[11], Thomas A. Clair[12], Jamie Shanley[13], Kathleen Weathers[3], Francois Courchesne[14], Robert Vet[15] and Louis Duchesne[4]

Atmospheric deposition of S has declined in eastern North America resulting in the partial recovery of watersheds from acidification. This partial recovery may be reduced by internal sources of S that can contribute sulfate to surface waters. To evaluate the role of various S sources we developed S budgets at 15 locations with well-studied forested watersheds in the Northeast U.S. and Southeast Canada. A major limitation in deriving accurate S budgets is obtaining an unbiased estimate of dry S deposition. We developed an empirical model using dry deposition values from the U.S. CASTNET and the Canadian CAPMoN networks. Our analyses included latitude, longitude, and the sulfur dioxide emissions for predicting SO_2 concentrations in the atmosphere (r^2=0.88). There was a strong relationship between estimated sulfur dioxide concentrations and estimates of total dry S deposition for both the CASTNET (r^2 =0.90 and CAPMoN (r^2 =0.93) networks. These estimates of SO_2 concentrations and total dry S deposition were also compared to the regional CMAQ and AURAMS model for 2002. For each watershed dry deposition estimates were combined with measured wet deposition estimates. There were substantial differences in S budgets both within and among sites. Our results suggest that there is strong evidence of a substantial internal source of S in many of these watersheds. In a few cases this internal source includes the weathering of S minerals while in other cases this contribution appears to be derived from the mineralization of organic S in the soil. As atmospheric S deposition continues to decline the relative importance of these internal S sources as contributors to sulfate to drainage waters increases. Evaluating the contribution of these internal S sources is critical for making long-term predictions of the recovery of surface waters from acidification.

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Examining Sulfate Behavior along a North-South Gradient of Unglaciated Eastern U.S. Catchments

Karen C. Rice[1], James R. Webb[2], Frank A. Deviney, Jr.[2] and James P. Schaberl[3]

The U.S. EPA's Direct/Delayed Response Project (DDRP) concluded that stream recovery from acidification would vary with the ability of the receiving catchment soils to store sulfur by sulfate (SO_4^{2-}) adsorption. In the northeastern U.S., where Wisconsinan glaciation scraped away soils and gouged into bedrock, soils generally are young, thin, rocky, and largely unable to retain SO_4^{2-}. In the unglaciated southeast, soils are older, thicker, have higher clay contents, and thus are more likely to retain SO_4^{2-}. As such, there is a regional difference in SO_4^{2-} retention, with higher retention in southeastern catchments. This suggests that northeastern streams should recover more quickly than southeastern streams from reduced sulfur dioxide (SO_2) emissions resulting from the Clean Air Act Amendments of 1990 and subsequent reduced atmospheric deposition of SO_4^{2-}. As SO_4^{2-} deposition subsides, therefore, northeastern streams should experience an almost immediate decrease in SO_4^{2-} export, whereas southeastern streams should continue to "leak" (desorb) SO_4^{2-} stored on adsorption sites in the thicker soils. The DDRP indicated that streams in the Mid Appalachian Region range from being at steady state (input = output) with respect to SO_4^{2-} to having greater than 90% net sulfur retention. Long-term monitoring in multiple forested catchments in the southeastern U.S. reveals that effects of the decreased SO_2 emissions in stream waters have been mixed. There are decreases in SO_4^{2-} concentrations in some streams but little change at others, indicating varying degrees of retention.

We tested the DDRP hypothesis by examining sulfate behavior along a north-south gradient of unglaciated catchments in the eastern U.S. By analyzing the cumulative net flux (input – output) of SO_4^{2-} at the catchment scale with the longest-term data available, we can determine if the catchment is: 1) at steady state; 2) exporting SO_4^{2-} (desorbing from soil sorption sites or there may be an internal source of SO_4^{2-}); or 3) retaining SO_4^{2-} (more SO_4^{2-} being deposited by atmospheric deposition than is exported by stream water) and examine why nearby catchments respond differently. For example, at Catoctin Mountain, Maryland, we observe three catchments, each one demonstrating the three different SO_4^{2-} dynamics described.   Likewise, at Shenandoah National Park, Virginia, we observe a range of SO_4^{2-} behavior. We offer ideas that may help explain SO_4^{2-} retention variability across a large spatial gradient, and we conclude that the DDRP was on target with the prediction that Mid Appalachian Region streams would be diverse and slow to respond to decreased atmospheric SO_2 emissions.

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TECHNICAL SESSION 2: **THE DEVELOPMENT AND APPLICATION OF CRITICAL LOADS OF SULFUR AND NITROGEN (PART I)**

Session Chair: Tamara Blett, National Park Service

Critical Loads Development and Use in Europe: Applicable to USA?

Jean-Paul Hettelingh, Max Posch and Jaap Slootweg
Coordination Centre for Effects (CCE)

Critical loads are *developed* as early warning indicators for excessive regional deposition of air pollutants that ultimately can affect the sustainability of a good ecological state and of ecosystem services. Critical loads have been *used* to assess the effectiveness of policy alternatives to abate air pollution. Critical loads for acidification, eutrophication and heavy metals have been modeled and mapped for European terrestrial ecosystems and surface waters under the Convention on Long-range Transboundary Air Pollution (LRTAP Convention).

About 29 Parties to the LRTAP Convention participate in the development of the European critical load database under the International Cooperative Programme on Modelling and Mapping. They all have a clearing house institute, which is not always officially established as "National Focal Centre" (NFC) with the secretariat to the Convention. The *CCE European background database* is used to compute critical loads for the 18 remaining parties within the EMEP modeling domain.The critical loads database includes both empirical and computed critical loads on varying spatial scales. In 2008, National Focal Centres together reported computed critical loads for eutrophication with about 700,000 data points to represent the sensitivity of about 3 million km^2 of natural areas. Empirical critical loads of nutrient nitrogen are also reported with about 700,000 data points covering 1.5 million km^2. For acidification, about 1 million data points are used to represent about 5.5 million km^2. The resolution of critical loads is higher than that of computed depositions within 50x50 km^2 grid cells. The latter comes with three numbers. This difference in resolution is not relevant when *developing* critical loads.

It can be argued that many of the *development*-elements of the European critical load approach can also be applied to natural systems in the USA. These could be designed in a collaborative effort under a Pilot NFC project. In addition to the compilation of existing critical loads data for natural areas in the USA, it is recommended to also draw a framework of a generic method allowing for the computation, or expert-estimation, of tentative critical loads for other areas. The development of such a framework may benefit from approaches that have led to the *European background database.*

For the *use*-elements other requirements need to be identified, such as the availability of operational models for the simulation of atmospheric dispersion of air pollutants and best applicable (local and regional) spatial scales for the assessment of exceedances for natural areas in the USA.

Currently located at PBL, www.pbl.nl/cce, P.O.Box 303, NL-3720 AH Bilthoven, The Netherlands, jean-paul.hettelingh@pbl.nl

Critical Loads: Science and Policy

Gary Lovett[1] and Timothy Tear[2]

Air pollution is having a serious impact on species, communities and ecosystems in the eastern U.S. We evaluated and synthesized the research on these impacts and concluded that there are two key policy issues that need to be addressed at the state, regional and federal levels. First, there is a need for ecologically relevant air pollution standards such as critical loads. Second, there is a need for more comprehensive and integrated monitoring programs to track the status of key species and ecosystem properties and their response to continued deposition of air pollutants. We produced a report that summarized the science and explained the policy needs, and we have been working in partnership with other NGOs to advance these policy initiatives in the federal and New York State governments. We will discuss the current status of these initiatives and our view of prospects for future progress.

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Lichen-Based Critical Loads for Nitrogen Deposition in Western Oregon and Washington Forests

Linda H. Geiser[1], Doug A. Glavich[2] and Matthew Porter[3]

Critical loads (CLs) define maximum atmospheric deposition levels that will not harm ecosystems. We calculated first CLs for nitrogen in the North American west coast marine forests ecological region. Using lichen survey data from grid-based sampling in western Oregon and Washington and multiple linear regression, we related epiphytic lichen community composition to wet deposition from the National Atmospheric Deposition Program; to wet, dry, and total deposition N deposition modeled by CMAQ/MM5; and to ambient particulate nitrogen measured by IMPROVE. Multiple deposition measures yielded consistent critical loads: scarcity of highly sensitive lichens was associated with 1-5 and 3-9 kg N ha^{-1} yr^{-1} in wet and total deposition, respectively. Annual precipitation was very important at the landscape level. Lichen-based CLs increased with precipitation, perhaps due to dilution or leaching of pollutants. Tight linear correlation between lichen and IMPROVE data suggests a rapid screening technique for CL exceedance.

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Methodologies for Determining Empirical Nitrogen Critical Loads and Exceedances for California Ecosystems

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In recent years it has become apparent that chronic N deposition is affecting various ecosystem types in California, from desert, grassland and shrub vegetation to mixed conifer forests. Because of the difficulty in measuring dry deposition to these ecosystems several approaches have been used to estimate N deposition. Broad scale estimates were made with the CMAQ simulation model and site-specific measurements were determined with ion exchange resin (passive) throughfall collectors or the inferential method using data from passive samplers of atmospheric pollutant concentrations. Likewise, a variety of biological or chemical indicators have been used to determine empirical critical load (CL) values for these Mediterranean ecosystems. CL in California ecosystems have also been estimated with various models, but empirical CL are important for evaluating how realistic the modeled CL values are. Prominent endpoints used to estimate empirical CL include lichen functional groups, streamwater nitrate concentrations, mycorrhizal community changes, and increases in invasive annual grasses. Preliminary empirical CL are also proposed for soil acidification, ponderosa pine fine root biomass and forest sustainability. At relatively low CL values (5-8 kg N/ha/yr) grassland and coastal sage scrub are susceptible to type conversion due to enhanced risk of invasion by exotic annual grasses. Similarly, in the desert, CL exceedance favors grass invasion which greatly increases the risk of fire in areas where fires are normally infrequent, again with high potential for catastrophic vegetation type change. Areas of potential N CL exceedance in California are indicated by overlaying vegetation and N deposition maps.

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Development of Critical N Loads Using Diatom Proxies: Distribution of Indicator Species in Lakes of the Sierra Nevada of California

Dr. Danuta Bennett[1], Andrea Heard[2], Delores Lucero[2] and Dr. James O. Sickman[2]

Mountain lakes are recognized as excellent indicators of regional environmental change and are increasingly being used by regulatory agencies to establish critical loads for atmospheric pollutants. Long-term monitoring of lakes throughout the montane western United States indicates that aquatic ecosystems are responding to increasing nutrient inputs most likely from atmospheric deposition. In the Rocky Mountains, several species of lake diatoms have been identified as indicators of recent eutrophication by N and include: *Cyclotella bodanica var. lemanica, Asterionella formosa* and *Fragilaria crotonensis*. However, relatively little is known of the current distribution of these indicator species in the Sierra Nevada of California which contains over 6,000 alpine and subalpine lakes. In order to explore whether a similar trend in changes of diatom species composition is occurring in Sierra Nevada alpine lakes we present preliminary results from an ongoing paleolimnology investigation designed to establish critical N loads for the region. This study is using data from a calibration set of 50 high-elevations lakes with large variation in nitrate concentrations, along with long sediment cores from four lakes in the Central Sierra Nevada. The diatom flora and nutrient chemistry in a subset of the calibration lakes will be described and compared, with special attention paid to the occurrence and distribution of nitrogen enrichment indicator species to evaluate if lakes in the Sierra Nevada have been affected by atmospheric deposition of N during the 20th Century.

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TECHNICAL SESSION 3:   A FOCUS ON MONITORING AND RESEARCH IN THE ADIRONDACKS

Session Chair: Greg Lampman, New York State Energy Research and Development Authority

Assessing the Impact of Long-term Mercury Contamination on Wildlife Health in New York, Using the Common Loon as a Sentinel Species

Dr. Nina Schoch[1], Dr. David Evers[1], Dr. Keith Grasman[2] and Dr. Stephanie James[3*],

This study utilizes the common loon (*Gavia immer*) as a sentinel species for aquatic ecosystems to assess the effect of long-term mercury accumulation on wildlife health in New York's Adirondack Park. Exposure of loons to mercury through atmospheric deposition and biomagnification is a concern throughout the upper Midwestern and Northeastern US and Canada due to depositional, geological, and pedological characteristics of the area. In the laboratory, mercury suppresses immune function in young loons. By evaluating the immune function of loons in relation to their mercury burden, this project will lead to an increased scientific knowledge of the (possibly synergistic) interactions between multiple stressors on the health of wildlife. Loons were captured using nightlighting and playback techniques. Blood samples were collected for evaluation of mercury levels, health parameters, and immune function. Birds were banded with USFWS bands and a unique color combination of plastic bands to facilitate subsequent observations to determine reproductive success and long-term survival/site fidelity. Loon immune function was measured by adapting in-vitro methods using cryopreserved lymphocytes. Lymphocytes were isolated using a slow spin technique that worked well for loons, although thrombocyte and heterophil contamination was higher than in other species. Lymphocyte samples were frozen in culture medium containing 10% DMSO. The samples were then thawed, and lymphocyte proliferation was induced via mitogens. Proliferation was assessed by an ELISA measuring the incorporation of Bromodeoxyuridine into newly synthesized DNA. These cryopreservation and cell culture methods will be used in future studies on the immunotoxicity of mercury in wild loons. The results of this project will address a primary data gap of how mercury interacts with other stressors by suppressing the immune system and increasing the susceptibility of birds to other stressors, thus contributing to an improved understanding of potential causes of population changes. In addition, this research will contribute to the management of wildlife populations and regulation of environmental pollutants by providing a direct measure of evaluating the risks contaminants pose to wildlife health. The results of this project will provide policy-makers with essential scientific information for making informed decisions about critical environmental protections, including monitoring and regulating emissions of anthropogenic pollutants, based on the health and reproductive impacts to common loons, a top piscivorous predator, and an iconic representative of freshwater ecosystems in North America.

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Zooplankton Recovery in Chemically Recovering, Acidified Adirondack Lakes

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and Sandra A. Nierzwicki-Bauer[4]

Microcrustaceans and rotifers were examined from 30 Adirondack lakes from 1994- 2006 as part of the Acidification Effects Assessment Program (AEAP). One goal of this effort was to generate baseline data to assess recovery should water column pH of the study lakes rise, as was expected to occur as a result of the 1991 Clean Air Act Amendments. The 28 species of microcrustaceans and 53 species of rotifers displayed differential sensitivity to acidic conditions and showed direct correlations of species richness and diversity with pH that was readily apparent during 1994-1996, the most acidic period of the study. Although some chemical recovery has occurred, during the 13 year period, only 13 lakes have shown a pH increase > 0.4 units and only 3 sites exceeded pH 6.0, a critical level where community changes are believed to occur. Changes in species richness, diversity and densities of acid sensitive species were used to evaluate biotic recovery in sites exhibiting pH improvement. Acid sensitive species were identified by Detrended Correspondence Analysis (DCA). Regression analysis revealed only 3 minor improvements in community variables relative to pH or elapsed time for microcrustaceans and 5 strong and 4 weak improvements for rotifers in 9 lakes. There was 1 strong improvement for microcrustaceans alone in a 10th lake. While it is clear that some biotic recovery is occurring, overall, it appears to be insufficient to overcome individual lake variability in zooplankton species richness and community composition and the annual variation in weather and local ecological conditions.

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Acid-deposition-induced Calcium Depletion from Adirondack Forests and the Response of Biotic Communities to Calcium Amendment

Timothy McCay[1], Michele Hluchy[2], Richard April[3] and Randall Fuller[1]

We aimed to better understand how calcium availability has changed in forests of the Adirondacks and determine how biotic communities respond to calcium amendment at one acid-deposition-impacted forest in the western Adirondacks. We re-sampled soils at sites initially sampled in the 1980s and analyzed samples for total exchangeable calcium and other soil parameters. We amended soil calcium in forest uplands by adding powdered limestone (lime) to each of four 1590-m^2 plots to effect a treatment of 10 tonnes lime per hectare. Each limed plot was paired with an untreated plot, and a stream ran between the two plots. We added $CaCl_2$ to one of these episodically acidified streams and both $CaCl_2$ and $NaHCO_3$ to another episodically acidified stream for 6 weeks. Preliminary analysis suggests that total cation abundance at Adirondack forests has decreased since the 1980s and that the greatest decreases have occurred at sites in the central and eastern Adirondacks where losses had been modest prior to the 1980s. Liming raised the soil pH in the upper horizons of our plots as expected and, over time, that effect is being translated lower into the soil profile. Similarly, exchangeable calcium is increased in the upper horizons of limed soils, although that increase is only seen down to about 15 cm – even 3 years after the first application of lime. Leaves of overstory plants showed an increased concentration of elemental calcium within 6 months of the first application of lime, thus increasing calcium availability for animals that consume leaf litter. Responses by animal taxa have been mixed with some groups, such as snails, increasing and many others decreasing after liming. Generally, this community of forest organisms is acidophilic and community change may require immigration of taxa from less acidified habitats. In streams, increasing Ca concentrations alone had no effect on alkalinity and no effect on abundance of macroinvertebrates and periphyton or rate of leaf decomposition. In the stream receiving both $CaCl_2$ and $NaHCO_3$, we observed an increase in alkalinity; however, again there was no effect on macroinvertebrates, periphyton, or rate of leaf decomposition. Thus, our 6 week manipulations of calcium and bicarbonate in these streams were probably not long enough to overcome the legacy effects of episodic acidification events. In sum, our results suggest that recovery of forests from chronic acidification will be slow because of cation loss and the adaptation of forest and stream communities to acidified conditions.

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Laboratory and Field Data Indicate that Acidic Deposition-induced Calcium Depletion Disrupts the Nutrition and Physiology of Trees, Predisposing Them to Decline

Paul G. Schaberg[1], Gary J. Hawley[2], Joshua M. Halman[2] and Paula F. Murakami[1]

Substantial evidence indicates that high acid loading from atmospheric deposition that promotes calcium (Ca) leaching and mobilizes aluminum in the soil disrupts biogeochemical cycles and depletes Ca from forest ecosystems in the northeastern US. Because Ca is an essential plant nutrient, Ca depletion raises important questions concerning the continued health and sustainability of forest ecosystems. Ca plays critical roles in plant cell function, including enhancing the stability of cell walls and membranes, and signal transduction processes that allow cells to sense and respond to stress. Considering the fundamental role that Ca plays in plant stress response, biological Ca depletion could suppress the ability of trees to adequately sense and respond to stress, and predispose them to decline following exposure to even "normal" levels of stress that otherwise would pose no threat.

Initial evidence that Ca depletion reduces tree stress tolerance was obtained via investigation of the mechanism through which acid deposition increases freezing injury in red spruce (*Picea rubens* Sarg.). Experiments demonstrated that acid deposition directly leached Ca from the plasma membranes of red spruce foliar cells and that this loss of Ca destabilized cells, depleted pools of signal Ca, and increased the susceptibility of cells to freezing injury. Increased freezing injury also resulted from soil-based Ca depletion. In 2003 (a year of extensive region-wide injury in New York and New England), freezing injury was greatest in areas where acidic inputs were elevated, and injury was significantly reduced in a watershed fertilized with Ca. New experimental evidence indicates that Ca depletion down-regulates other Ca-dependent processes in red spruce, including stomatal closure, antioxidant enzyme activity, and foliar sugar accumulation – indicating that Ca depletion has physiological impacts beyond influences on foliar winter injury. Furthermore, data indicates that other tree species (e.g., eastern hemlock (*Tsuga canadensis* (L.) Carr.), balsam fir (*Abies balsamea* (L.) Mill.), eastern white pine (*Pinus strobus* L.) and sugar maple (*Acer saccharum* Marsh)) experience mechanistic changes in Ca nutrition and physiology similar to those documented for red spruce. Indeed, decline symptoms (crown deterioration, slow growth and reduced wound closure) for sugar maple trees in the field can be alleviated via Ca fertilization. Together, these data suggest that the negative influences of Ca depletion on the health and productivity of forest trees are not limited to red spruce winter injury, but have broader relevance to a variety of species and physiological processes.

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Measuring Soil Change to Assess Recovery Potential

Lawrence, G.B.[1], Shortle, W.C.[2], K.T. Smith[2], Roy, K.M.[3] and David, M.B.[4]

Levels of acidic deposition have generally decreased over the past several decades in the northeastern U.S., but so too has the effectiveness of acid-neutralization processes as soils have become depleted of available calcium. As a result, chemical recovery from acidification has been marginal in many of the affected lakes and streams in the Northeast. Furthermore, the recovery in surface waters that has occurred may have resulted from neutralization processes that occur in deep flow paths through till that underlie watersheds with calcium-depleted soils. In this situation, high-flows can still lead to episodic acidification of streams and lakes with short residence times, and terrestrial vegetation is subjected to aluminum mobilization and calcium depletion.

Recent work in western Adirondack watersheds has shown that stream-water values of the chemical index BCS in were found to be negative (indicating mobilization of toxic inorganic Al) if base saturation of the upper B horizon was less than 12%. Base saturation values estimated from high-flow stream chemistry data from the Western Adirondack Stream Survey conducted in 2003-2005, ranged from 6% to 12% in 111 of 188 watersheds. Base saturation of these soils is therefore too low to prevent mobilization of toxic Al in most of these watersheds at the current deposition levels.

Assessments of recovery potential from acidification need to extend beyond surface water chemistry, but little information is available on the capacity of Ca depleted soils for recovery, or the rate at which this could occur. Retrospective soil studies, although rare, have shown that repeated sampling of soil over time can provide valuable information on soil change. Resampling of soils in 2003 at 6 sites in New York and New England that had been previously sampled and archived in 1992-1993 provided information on how these soils changed during a decade of declining deposition. Only one of 5 sites showed indications of recovery from acidification in the upper B horizon. However, in the Oa horizon, the Ca to Al ratio and base saturation increased at 5 of 6 sites and the $CaCl_2$ extractable pH increased at 4 of 6 sites. These results, in addition to a previously identified link between Oa horizon chemistry and stream water neutralization, suggest that processes in the forest floor may play an important role in the recovery of these catchments.

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TECHNICAL SESSION 4: **THE DEVELOPMENT AND APPLICATION OF CRITICAL LOADS OF SULFUR AND NITROGEN (PART II)**

Session Chair: Rich Pouyat, USDA Forest Service

Critical Loads for Protection of Aquatic Resources in the Blue Ridge, Ridge and Valley, and Appalachian Plateau Ecoregions of Virginia and West Virginia

T.J. Sullivan[1], B.J. Cosby[2] and T.C. McDonnell[1]

Streams found throughout the Blue Ridge, Ridge and Valley, and Appalachian Plateau ecoregions in Virginia and West Virginia are among the most acid-sensitive and acid-impacted aquatic ecosystems in the United States. Atmospheric sulfur (S) and nitrogen (N) deposition are relatively high; base cation supplies in soils, which could serve to buffer atmospherically deposited acidity, are limited in many small upland watersheds. Such acid-sensitive and acid-impacted aquatic resources in this region are especially numerous in Shenandoah National Park, Class I wilderness areas, and other National Forest lands. We modeled critical loads of atmospheric deposition to protect and restore stream resources to varying levels of protection, using a combination of the Model of Acidification of Groundwater in Catchments (MAGIC) and the Steady State Water Chemistry (SSWC) model. MAGIC was used to calculate effective weathering at 92 intensively studied watersheds. Estimates of weathering were then extrapolated to the regional landscape using empirical relationships with measured stream water chemistry at 533 sites together with spatial data on watershed lithology, soil characteristics, and watershed morphometry. Critical loads and exceedences were calculated with the SSWC model using extrapolated estimates of effective weathering from MAGIC, regional estimates of atmospheric deposition and runoff, and estimated base cation uptake by forest vegetation from USDA Forest Inventory and Analysis (FIA) data.

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Maryland Critical Loads and the Maryland Biological Stream Survey

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The State of Maryland initiated a number of studies in the 1980s as a response to the potential effects of acidic deposition on water quality and biotic resources. A brief history of these early studies on acidic deposition is described, as well as results from the Maryland Critical Loads Study (1992). Following the critical loads analyses, a number of other statewide programs were initiated including the Maryland Biological Stream Survey (MBSS) in 1993. Initially, the MBSS focused on an assessment of acidic deposition on biological resources in non-tidal wadeable streams (1st, 2nd and 3rd order), as well as determining the condition of stream biotic resources. In addition, the MBSS program (with three multi-year rounds) eventually expanded to analyzing stressors, to compiling biodiversity inventories, to prioritizing areas for protection and restoration, and to documenting changes in biological resources (temporal component).

Based on the first MBSS round (1995-1997), an estimated 28% of Maryland stream km are acidic or acid-sensitive, including about 2% acidic, 4% highly sensitive, and 22% sensitive to acidification. An estimated 38% of stream km are acidic or acid-sensitive (3% acidic, 8% highly sensitive and 27% sensitive) based on results from the second MBSS round (2000-2004). The presence of acidic or acid-sensitive streams correlated with poor watershed buffering capacity; stream biotic resources responded to acidic stressors. With the addition of state-wide sentinel sites in acid sensitive regions, especially western Maryland, long term biotic responses to acidic deposition will be monitored in the MBSS program.

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Adapting CMAQ Deposition Fields for Critical Loads Analyses

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A complete deposition budget, wet plus dry, is needed for critical loads analyses. It is desirable for the budget to be as accurate as possible. An air quality model can provide dry deposition estimates that have the advantage of including all species depositing and having complete spatial coverage, although not resolving well complex terrain. However, the error in the modeled precipitation amounts used by an air quality model is deemed unacceptably high. While there are errors in the emissions inventories driving the air quality models, monitoring sites are sparse and interpolation of these data can miss significant emissions that exist. Thus, it is would be an improvement if the wet deposition from the air quality model could be made more accurate and these could be combined with the model's dry deposition to support critical loads analyses. To meet this objective we developed an approach for post processing CMAQ predictions of wet deposition to reduce the model errors. The approach involves correcting the CMAQ annual precipitation amounts with PRISM (Parameter-elevations Regressions on Independent Slopes Model) annual data, which has national coverage, is based on 24-hour coop station data and accounts for orographic effects. The precipitation correction is followed by a bias correction for NO_3 and NH_4 deposition based on NADP data. Precipitation-corrected SO_4 does not need a bias correction, suggesting that the model can do well when the emissions are well known. The bias correction is developed separately for the intermountain west together with the plains and for the eastern US. No bias is developed for the west coast because NADP data are believed to miss important orographic effects there. We present the approach applied to 2002 CMAQ simulations and show that wet deposition error is significantly reduced for SO_4 and NO_3 and show the residual error across space for all species. We then show the results of a sensitivity analysis to demonstrate that changing wet deposition has an acceptably small effect on dry deposition, allowing us to add the dry deposition to the adjusted wet deposition for support of critical loads analyses. We have supplied critical loads scientists the adjusted CMAQ data, with national US coverage at 36-km and eastern half coverage at 12-km resolution. We conclude by presenting some hypotheses regarding the identified biases and briefly discuss future directions.

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Critical Loads as a Policy Tool: Highlights of the NOx/SOx Secondary National Ambient Air Quality Standard Review

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The U.S. Environmental Protection Agency (EPA) is currently conducting a joint review of the existing secondary (welfare-based) National Ambient Air Quality Standards (NAAQS) for oxides of nitrogen (NOx) and sulfur (SOx). EPA is jointly assessing the science, risks, and policies relevant to protecting the public welfare associated with nitrogen and sulfur due to both their atmospheric interactions and ecological effects. As discussed in the Clean Air Act (CAA), the purpose of a secondary NAAQS is to "protect the public welfare from any known or anticipated adverse effects associated with the presence of such air pollutants in the ambient air". This review has focused on the ecological effects due to ambient air concentrations of NOx and SOx as they relate to atmospheric deposition of nitrogen and sulfur: aquatic and terrestrial acidification and aquatic and terrestrial nutrient enrichment. Atmospheric deposition is the link between ambient concentrations and these ecological effects. Spatial fields of deposition were created by using wet deposition measurements from the National Atmospheric Deposition Program (NADP) National Trends Network and dry deposition estimates from the Community Multiscale Air Quality (CMAQ) model for the year 2002. These data were used in all the ecological analyses.

For the ecological endpoint of acidification, we have used a critical loads approach to assess whether adverse effects are occurring under current atmospheric loadings of nitrogen and sulfur. For aquatic acidification, the results indicated that 28-48% modeled lakes in the Adirondacks exceed their critical load for ANC ranging from 20-100 µeq/L. These data were scaled up to 1842 lakes in the region, indicating that 13-51% of the regional lake population exceeded critical loads for ANC ranging from 20-100 µeq/L. A similar analysis showed that 72-92% of the modeled streams in the Shenandoahs exceed their critical loads for ANC ranging from 20-100 µeq/L. For terrestrial acidification, the results indicated that 3-75% of sugar maple plots (n=4992 plots in 24 states) and 3-36% of red spruce plots (n=763 plots in 8 states) exceed their critical load for Bc:Al ranging from 0,6 to 10. An update on the status of the review will include highlights from the Risk and Exposure Assessment, policy implications, and the science-policy issues anticipated for the next review.

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TECHNICAL SESSION 5:   **ATMOSPHERIC MERCURY MEASUREMENT AND ASSESSMENT IN THE NORTHEAST**

Session Chair: David Schmeltz, U.S. Environmental Protection Agency

Sources and Regional Transport of Mercury to the Northeast: Insights from Air Observations at VT99

Eric K. Miller[1], Rich Poirot[2], Jamie Shanley[3] and Mim Pendelton[4]

At VT99 GEM concentrations range from 0.81 to 5.58 ng/m^3, averaging 1.45 ng/m^3. RGM concentrations range from 0 to 132.5 pg/m^3, averaging 3.56 pg/m^3. HGP ranges from 0 to 121 pg/m^3, averaging 11.50 pg/m^3. The concentrations of all three species are dependent on meteorological conditions but in different ways for RGM and HGP than for GEM. There are significant differences in concentrations based on surface wetness state (dry, moist, or wet), time of year, time of day, and in response to different atmospheric conditions. Of particular note are the correlation of RGM concentrations with relative humidity, the correlation of HGP concentrations with water-vapor mixing ratio, and the tendency for GEM concentrations to rise after first insolation of a moist surface at dawn or after precipitation. The dependence of RGM concentrations on RH may reflect the tendency for that species to be readily scavenged by moist aerosols at moderate RH. The dependence of HGP on the water vapor mixing ratio may relate to HGP source regions and accompanying seasonal variations in water vapor.

The concentrations of the three mercury species exhibit strong seasonal patterns that are slightly out of phase with each other. GEM concentrations peak in winter and spring with an early fall minimum, HGP concentrations peak in late winter and RGM concentrations peak in spring. The wintertime peak in HGP may be due, in part, to increased local combustion for home heating. However, trajectory analysis also indicates major out-of-region sources contribute to the observed HGP signal. The spring peak in RGM is likely due to a combination of factors including favored trajectories over major EGU RGM sources and relatively low atmospheric moisture levels at a time when leaves are off of trees along the favored trajectories. As soon as leaves emerge in late spring and early summer, the surface area for dry-deposition removal along the transport pathway increases by a factor of 3 to 4. Atmospheric moisture and relative humidity increase as well, allowing more scavenging by particles and ultimately cloud and rain droplets.

RGM and HGP concentrations exhibited two distinct temporal patterns that we interpret as driven by either 1) atmospheric mixing processes in conjunction with the balance between deposition and formation reactions and 2) regional transport episodes. The relatively long and continuous record of high-temporal resolution measurements at VT99 permits unique analysis opportunities for understanding the atmospheric chemistry and regional transport of mercury.

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Atmospheric Mercury (Hg) Concentrations in New York: A Comparison between Urban and Rural Areas

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Speciated atmospheric Hg concentrations are being measured using two Tekran mercury speciation systems in Rochester (urban) and Huntington Forest (HF) (rural) in New York state. Since 2007, the average concentrations ± standard deviation (S.D.) (range) of GEM, RGM, and PBM at the Rochester site were 1.6 ± 0.4 (0.9 to 16.4) ng m^{-3}, 5.3 ± 10.7 (< detection limit (DL) to 178) pg m^{-3}, and 11.0 ± 14.7 (< DL to 204) pg m^{-3}, respectively. The average concentrations ± S.D. (range) of GEM, RGM, and PBM at the HF site were 1.4 ± 0.3 (0.5 to 3.0) ng m^{-3}, 1.1 ± 2.7 (< DL to 86.7) pg m^{-3}, and 3.7 ± 7.5 (< DL to 297) pg m^{-3}, respectively. The seasonal mean concentrations of GEM were highest in winter at both sites although the GEM concentrations at the Rochester site were more constant than at the HF site. The mean concentration of RGM was highest and most variable in spring at Rochester whereas the RGM concentration was highest and most variable in winter season at HF. The PBM concentrations were highest and most variable in winter at both the Rochester and HFt sites. Diurnal variations in RGM concentrations with a maximum during the daytime and minimum during nighttime were observed at both sites. However, during warm seasons regular patterns of maximum GEM in the mid afternoon and minimum GEM at night were observed at the HF site while maximum GEM during the night and minimum GEM in the mid afternoon were observed at Rochester. Diurnal variations of PBM were not clearly observed at either site. For 12 high concentration events, GEM and CO concentrations were positively correlated (r^2>0.54-0.84; p<0.001) for the Rochester site for periods between three to eight days. During the events RGM and SO$_2$ were also positively correlated (r^2=0.39-0.76; p<0.001) except two events (r^2=0.14; p<0.001 and r^2=0.02; p<0.001). Overall ozone concentrations were positively correlated with RGM concentrations at both the Rochester and HF sites (r_s=0.342, p<0.001; r_s=0.325, p<0.001, respectively). Hybrid receptor modeling suggests sources of GEM, RGM and PBM were different but consistent with current emissions inventories.

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Atmospheric Mercury Monitoring in Canada

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and Jennifer Graydon[2]

Atmospheric mercury measurements have been conducted at several Canadian sites to support Environment Canada's mercury science program. These measurements have been done at sites of the Canadian Air and Precipitation Monitoring Network (CAPMoN) as well as in the vicinity of industrial facilities. Gaseous mercury, mercury in precipitation and speciated mercury are being measured. Efforts are underway to coordinate the Canadian program with the NADP-MDN Mercury Strategy. This presentation will outline the objectives of the monitoring project in the context of the Canadian mercury science program; discuss the on-going activities and present preliminary results of atmospheric mercury.

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Atmospheric Deposition of Mercury and Its Impact on Aquatic Ecosystems Draining Forested Watersheds in Pennsylvania

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Mercury emissions to the atmosphere from coal-fired power plants and other sources such as waste incineration can be deposited to the landscape in precipitation and in dry fallout. Some mercury reaches nearby streams through direct deposition or subsurface flow processes where it can accumulate in sediments and biota. Pennsylvania is one of the leading states in terms of total mercury emissions from all sources, and receives among the highest levels of wet mercury deposition of any location in the northeastern USA. Human exposure to mercury occurs primarily through fish consumption, and currently fish eating advisories due to mercury contamination have been posted for over 877 stream miles and 28 lakes across Pennsylvania. Mercury levels in stream water are believed to be a key indicator for concentrations of mercury available for uptake by biological organisms. We measured total mercury in precipitation at 9 locations across Pennsylvania from which we present variation in mercury deposition and initial assessments of factors related to patterns and trends. Further, we collected baseline data on mercury in streams draining 40 forested watersheds throughout the state, spanning gradients of atmospheric deposition, climate and geology. These watersheds are minimally disturbed (e.g., no direct impacts of agriculture, urbanization, or mining, and no point sources of Hg). Total and methyl mercury concentrations were measured in stream water under base-flow conditions, and total mercury was measured in stream-bed sediments, stream-bed mosses, and in fish tissue from brook trout. The highest mercury concentrations were found in mosses and sediments, suggesting their potential utility as indicators for understanding long term watershed responses. Mercury concentrations in fish samples are very low with respect to human health concerns. However, mercury levels in fish samples suggest potential ecosystem level concerns in some of the watersheds, with concentrations in fish approaching the US Fish and Wildlife Service advisories for birds and wildlife that eat fish. We comment on the relevance of our results to policy considerations in the state, and make recommendations for further monitoring and assessment of the effects of mercury deposition in Pennsylvania and the northeast.

TECHNICAL SESSION 6: **AGRICULTURAL EMISSIONS AND ECOSYSTEM EFFECTS**

Session Chair: Beth Boyer, Pennsylvania State University

A Process-based Soil Ammonia Emission Model for Agricultural Soils

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Emission of ammonia from fertilized agricultural soils is estimated to account for 35% of all agricultural NH3 emissions (2002 NEI), but few advances have been proposed with regard to process-based modeling of these emissions since early 2000. Current emission estimates rely on historic annual fertilizer sales reports and crop acreages and, although CMAQ v4.7 offers an option to consider the bi-directional flux of ammonia, it still relies heavily on fixed parameter values. These approaches may be sufficient for retrospective analyses, they lack the flexibility to respond to land use or climate changes needed to assess ecosystem exposure to nitrogen and sulfur deposition.

This presentation describes the development and preliminary evaluation of a more process-based, yet operationally practical approach for estimating bi-directional soil ammonia flux from a monitored agricultural field study site at Lillington, NC. While the application of this approach, when combined with modified canopy flux parameterizations results in more accurate temporally resolved flux estimates, it requires additional agricultural management information that is not currently required for routine ammonia emission processing. We propose to develop this information from a national implementation of the USDA Environmental Integrated Climate (EPIC) model. This combination of CMAQ with improved bi-directional ammonia flux and EPIC farm management scenarios will facilitate the exploration of the potential response of air quality and atmospheric nitrogen loadings to ecosystems in response to regional changes in land use, land cover, farm management and climate.

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Mechanism of Ammonia Loss in Swine Effluent

Sang Ryong Lee[1], Wayne P. Robarge[1*] and John T. Walker[2]

Swine animal feeding operations (AFOs) are sources of various gases [ammonia (NH_3), hydrogen sulfide (H_2S), carbon dioxide (CO_2), volatile organic compounds (VOCs)], and fine particulate matter. A key for understanding NH_3 emission in swine waste effluent has been suggested by the equilibrium equation:

$$NH_4^+ + OH^- \rightleftarrows NH_3 + H_2O, K_b = 1.8 \times 10^{-5}$$
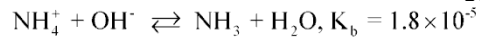
Gaseous emissions from simple aqueous systems are typically controlled by temperature, pH, wind speed, total dissolved concentration of the chemical species of interest (e.g. $NH_4 + NH_3$ = TAN), and the Henry's law coefficient. Using a simple flow-through Teflon-lined chamber (0.3m × 0.2m × 0.15m), we have compared emissions of NH_3 from swine barn and lagoon effluent (finisher facilities, eastern North Carolina) to pure solutions of $(NH_4)_2SO_4$ under conditions of identical pH, temperature and TAN. Wind speed in the chamber is < 0.05 m sec^{-1}. All treatments exhibit the expected response in emissions with changes in temperature and pH. However, NH_3 emissions from the barn liquid are 5 times those from pure solutions of $(NH_4)_2SO_4$ (figure 1).
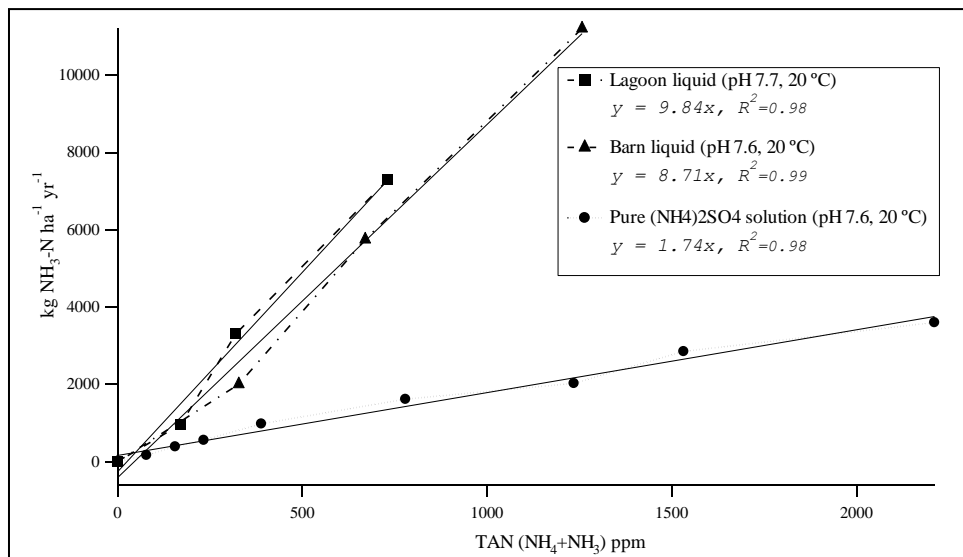
Figure 1. Ammonia flux from swine lagoon and barn liquid compared to an ammonium sulfate solution.

The large difference in emissions between solutions of equivalent TAN suggests the possibility of a synergistic mechanism that is enhancing NH_3 emissions. Little is known about the interactions of other gases, i.e. NH_3-VOCs which contribute to further loss of NH_3 in swine AFOs. This presentation will propose an alternative NH_3 volatilization mechanism in swine waste effluent. Concurrent measurements as part of the National Air Emissions Monitoring Study (NAEMS) document the emissions of CO_2, H_2S and VOCs (primarily acetic, propionic and butyric acids) at levels that are comparable to observed NH_3 emissions. Controlled experiments are underway to investigate further the potential for enhanced emissions of NH_3 due to the concurrent release of other volatile species. If successful, this work will be extended to determine the potential for other synergistic reactions that influence gaseous emissions across the air-liquid interface of swine manure effluent.

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Quality Assurance and Monitoring Results of the NADP's Passive Ammonia Network

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Ammonia is increasingly recognized as an important atmospheric pollutant as concentrations of oxides of sulfur and oxides of nitrogen change in the atmosphere. Ammonia is a principle component of $PM_{2.5}$ as well as a being a significant source of nitrogen deposition to sensitive ecosystems. Sources of gaseous ammonia include fertilizer applied to crop lands, human and domesticated animal waste including hogs, cows and poultry and industrial chemical manufacturing. Ammonia reacts in the atmosphere to form fine particulate matter ($PM_{2.5}$) via reactions with sulfuric and nitric acid. Until recently, long-term national ammonia concentration measurements have been overlooked. A national ammonia monitoring network is needed to characterize temporal and spatial trends, validate air quality models, calculate deposition fluxes, assess attempts to mitigate the eutrophication of sensitive ecosystems and meet the $PM_{2.5}$ NAAQS criteria.

The proposed NADP Ammonia Monitoring Network (AMoN) is comprised of triplicate passive ammonia monitoring samplers located at over 20 sites across the United States. Passive samplers are useful for long-term monitoring as they can be sampled weekly or biweekly following NADP sampling schedules, and they do not require pumps, electricity, computers or data loggers. AMoN has been routinely collecting samples since the fall of 2007, and the current data set consists of approximately 850 weekly records. Samplers are replaced every two weeks and sent to the Illinois State Water Survey's (ISWS) Central Analytical Laboratory (CAL) for analysis. More information on the AMoN is available at http://nadp.sws.uiuc.edu/nh3net/

Results from a multi-week statistical inter-comparison study using Radiello and Adapted Low-cost Passive High Absorption (ALPHA) samplers were used to confirm the selection of the Radiello passive sampler for network use. During the study, three sets of triplicate ALPHA and Radiello passive samplers were collocated with duplicate annular URG denuders as a reference method to quantify precision, accuracy and bias of the samplers at two sites: Bondville, IL and Cherokee Nation, OK. The precision between the triplicate passive samplers was evaluated against the denuder precision at the two sites. Results from the study showed both passive samplers had high precision values which were comparable to the denuders. To determine if spatial variability affected the precision of the samplers, three sets of triplicate Radiello and triplicate ALPHA samplers were deployed at three additional sites: Connecticut Hill, NY, Palo Duro, TX and Research Triangle Park, NC. Overall precision, accuracy, bias and cost were taken into consideration when recommending a passive sampler for AMoN.

Agricultural Ammonia Emissions and Ammonium Concentrations Associated with Precipitation in the Southeast United States

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The conversion of ammonia gas (NH_3) into ammonium ion (NH_4^+) is a fundamental process that is of great environmental significance. Excessive amounts of NH_4^+ can lead to acidification of soils and other pollution problems. An agricultural ammonia emissions inventory for the Southeast United States (Alabama, Florida, Georgia, Kentucky, North Carolina, South Carolina, Mississippi, and Tennessee) was developed using data from the United States Department of Agriculture 2002 Census and published ammonia emission factors for agricultural and anthropogenic sources. Moreover, temporal and spatial variations in ammonia (NH_3) emissions and ammonium (NH_4^+) concentrations associated with aerosols and volume-weighted NH_4^+ concentration in precipitation are investigated over the period 1990–1998 in the southeast United States. These variations were analyzed using an NH_3 emissions inventory developed for the southeast United States and ambient NH_4^+ data from the various Clean Air Status and Trends Network (CASTNet) and the National Atmospheric Deposition Program/National Trends Network (NADP/NTN). Results show that natural log-transformed annual NH_4^+ concentration associated with aerosols increases with natural log-transformed annual NH_3 emission density within the same county ($R^2 = 0.86$, $p < 0.0001$, N = 12). Natural log-transformed annual volume-weighted average NH_4^+ concentration in precipitation shows only a very weak positive correlation with natural log-transformed annual NH_3 emission densities within the corresponding county ($R^2 = 0.12$, $p = 0.04$, N = 29). Investigation into wet NH_4^+ concentration in precipitation consistently yielded temperature as a statistically significant ($p < 0.05$) parameter at individual sites. Positive trends in NH_4^+ concentration in precipitation were evident at NADP sites NC35, Sampson County, North Carolina (0.2–0.48 mg L^{-1}) and KY35, Rowan County, Kentucky (0.2–0.35 mg L^{-1}) over the period 1990–1998.

Multi-Air Pollutant Impacts on Forage Yields: A Case Study of Alfalfa Responses in West Central Alberta, Canada

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Under ambient conditions, the dynamics of multi-air pollutant exposures and chronic crop (yield) responses are stochastic by their nature. However, virtually all our knowledge of that subject is based on univariate studies in artificial field exposures. To address the consequent major limitation in our understanding, during 1998-2002, alfalfa yield responses to multiple gaseous air pollutants and climate parameters was examined under real world conditions using a cropping system as practiced by the local farmers. Ambient concentrations of sulfur and nitrogen dioxides at the study sites (emissions from oil and natural gas production) did not violate the National Ambient Air Quality Standards or Objectives in the US or in Canada. However, during 2002, one-hour average ozone levels exceeded 80 ppb (~twice the so-called current global background). Combining data from all study sites, years and the two harvests/year, 60% of the yearly alfalfa yields from harvest # 1 and 30% from # 2 were higher than their median value (+17 to +118%), while 40% from harvest # 1 and 70% from # 2 had yields lower than the median (-15 to -83%). Based on air quality and climatology, a multi-variant, growth season time series empirical forecasting model was applied and it correctly predicted 88% and 92% respectively of the time when alfalfa yields would be "low" or high. A global statistical model ("low" and "high" yield data combined) identified air quality (ozone + sulfur dioxide + oxides of nitrogen) as a major factor influencing alfalfa yields. The model could explain 68 to 76% of the variation in the combined yields, but only 43 to 57% in low alfalfa yields. Possible reasons for that appear to be the complex interactions resulting from, (1) low to moderate variations in air pollution concentrations, (2) significant genetic variability in the crop cultivar, (3) nutrient availability, (4) diseases and insects and (5) crop-weed competition. Air quality (ozone + sulfur dioxide + oxides of nitrogen) influenced ~50% of the accounted variation in all of the combined alfalfa yields with ozone accounting for one-half of it. The remaining 50% was due to variations in the climate and due to parameters that were not quantified (e.g., insect infestation). In summary, the results show the critical need for multi-variant ambient studies, as opposed to the continued reliance on univariate controlled exposure experiments and incomplete definition of the crop response surface. Currently the air quality-climate-forage model is being extended to other crops.

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TECHNICAL SESSION 7:   EVALUATING TRENDS FOR AIR CONCENTRATION, DEPOSITION, AQUATIC AND TERRESTRIAL EFFECTS

Session Chairs: Kathleen Weathers (invited), Cary Institute of Ecosystems Studies

Tom Butler, Syracuse University and Cary Institute of Ecosystems Studies

Recent Evidence of Biological Recovery from Acidification in the Adirondacks (NY, USA): A Paleolimnological Investigation of Big Moose Lake Using Diatoms, Chrysophytes, and Cladocera

Kristina M. A. Arseneau[1], Charles T. Driscoll[2], Lindsay M. Brager[1,3], Karen A. Ross[1,4] and Brian F. Cumming[1]

The Adirondack region of New York (USA) has been significantly impacted by acid deposition. Since the implementation of the Clean Air Act Amendments, the area has shown improvements in water chemistry. However, little work has been done to assess biological recovery in the region. Assessing biological recovery is often difficult due to a lack of long-term monitoring data but paleolimnology can overcome this problem. Paleolimnology uses the physical and biological characteristics of lake sediments to infer lake histories. Biological proxies such as diatoms, chrysophytes, and cladocera can be correlated to environmental variables like pH and temperature. By quantifying changes in these proxies overtime, paleolimnologists can assess changes in the aquatic environment. Big Moose Lake is an intensively studied, acidified drainage lake located in the south-western part of Adirondack Park. Water chemistry measurements taken approximately once a month since 1982 show that the lake's current pH is approaching its pre-industrial diatom-inferred pH of 5.8. The goal of this investigation was to see if biological recovery has followed chemical recovery in Big Moose Lake. Changes in the lake's chrysophyte, diatom and cladocera fossil assemblages were analyzed from ca. 1760-present in a 34-cm isotopically dated sediment core. An analysis of similarities (ANOSIM) was used to examine shifts in species composition in the three species groups between two recent time periods: period 1 (1982-1992; mean pH=5.0) and period 2 (1997-2007; mean pH=5.4). ANOSIM showed a significant shift in species composition between periods 1 and 2 for diatoms and chrysophytes but not for cladocera. Both algal groups showed a recent shift from acid-tolerant to acid-sensitive species. However, the changes in diatom species composition were small, suggesting that the diatoms remain relatively unresponsive to increases in pH. Recovery is further advanced in the chrysophytes but a recent (ca. 1995) increase in the species *Synura echinulata* suggests that the group is not returning to its pre-disturbance state, likely due to climate warming. Cladocera remain unresponsive to increasing pH and several local/regional factors may be preventing their recovery (i.e. predation, calcium depletion, climate warming). This study demonstrates that biological recovery is underway in the Adirondacks but that recovered assemblages may not return to their pre-industrial state due to other environmental factors.

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Nitrogen Deposition Increases Tree Carbon Storage and Shifts Species' Competitive Balance

R. Quinn Thomas[1*], Charles D. Canham[2], Kathleen C. Weathers[2] and Christine L. Goodale[1]

Human activities have greatly accelerated emissions of both CO_2 and reactive nitrogen (N) to the atmosphere. Because N availability often limits forest productivity, it has long been expected that anthropogenic N deposition could stimulate forest carbon (C) sequestration. However, spatially extensive evidence of deposition-induced stimulation of forest growth has been lacking, and quantitative estimates from models and plot-level studies are controversial. Here we use forest inventory data and N deposition; estimated using the National Atmospheric Deposition Program and Clean Air Status and Trends Network, to show that N deposition has affected tree growth, survival, and C storage across the northeastern and north-central USA during the 1980s and 1990s, with varying consequences for both growth and mortality of different tree species. Of the region's 24 most common tree species, 11 increased and 3 decreased growth over the range of observed total (wet + dry) inorganic N deposition (3-11 kg ha^{-1} yr^{-1}). Nitrogen deposition enhanced growth for all tree species with arbuscular mycorrhizal associations, and induced the largest growth enhancement in species with the highest background growth rates. Aboveground biomass increment increased by 56 (40-78) kg C per kg N deposition, amounting to a 36 (27-46) % enhancement over pre-industrial conditions. Extrapolating to the globe, we estimate a N-induced tree C sink of 0.29 (0.20-0.40) Pg C yr^{-1}.

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Interactions of Climate Change with Acidic Deposition in a Forest Watershed over the 21st Century Using a Dynamic Biogeochemical Model (PnET-BGC)

Afshin Pourmokhtarian[1]*, Charles T. Driscoll[1]; John L. Campbell[2] and Katharine Hayhoe[3]

Climate is an important regulator of the hydrology and biogeochemistry of forest watersheds. The ecological responses to climate change have been assessed by observational, gradient, laboratory and field studies; however, models are the only practical approach to investigate how future changes in climate are likely to interact with other drivers of global change such as atmospheric deposition. Biogeochemical watershed models are an important tool to help to understand the long-term effects of climate change on ecosystems. In this study, we are using a biogeochemical model (PnET-BGC) coupled with long-term measurements to evaluate the effects of potential future changes in temperature, precipitation, solar radiation, atmospheric deposition and atmospheric CO_2 on pools and fluxes of major elements at the Huntington Forest (HF) in New York. Future emissions scenarios were developed from monthly output from three atmosphere-ocean general circulation models (AOGCMs; HadCM3, PCM, GFDL) in conjunction with potential lower and upper bounds of projected atmospheric CO_2 (550 and 970 ppm by 2099, respectively). We also evaluated the interaction of climate change with changes in acidic deposition. Estimates of atmospheric deposition are based on a "business-as-usual" deposition scenario. We compared the results of the "business as usual" scenario with two additional scenarios, which consider additional moderate and aggressive emission controls on sulfate and nitrate.

AOGCM results over the 21st century indicate an average increase in temperature ranging from 1.9 to 7.0°C with simultaneous increases in precipitation ranging from 5.0 to 22.3% above the long term mean (1970-1999). Long-term measurements and watershed modeling results show a significant shift in hydrology with earlier spring discharge (snowmelt), greater evapotranspiration and longer growing season (due to CO_2 fertilization), and later snowpack development. Model results also show an increase in NO_3^- leaching over the second half of the century due to increases in net mineralization and nitrification. The extent of this response is dependent on the fertilization effect that increasing atmospheric CO_2 has on forest vegetation. The watershed responses of other major elements such as SO_4^{2-} and Ca^{2+}, and chemical characteristics such as pH and ANC varied based on future climate and deposition scenarios. Model predictions showed that equivalent decreases in sulfate deposition were twice as effective as decreases in nitrate on recovery of soil and streamwater chemistry. Model projections also suggest marked decreases in soil exchangeable calcium, magnesium and potassium with simultaneous decline in soil base saturation and Ca/Al ratio over the next century.

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A National Assessment of the Ecological Effects of Nitrogen and Sulfur Oxides

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Publically released in December 2008, the Integrated Science Assessment (ISA) for Oxides of Nitrogen and Sulfur (NOx and SOx)-Ecological Criteria is the scientific foundation for the review of the secondary National Ambient Air Quality Standards (NAAQS) for NOx and SOx. Over 3400 scientific publications, newly available since the last assessments of NOx and SOx (1993 and 1982, respectively), were reviewed. The key conclusions of the 2008 ISA were that acidification (due to NOx, NHx and SOx) and nitrogen enrichment (due to NOx and NHx) continue to occur in ecosystems across the U.S. under current loads of atmospheric deposition.

Assessment of the atmospheric sciences showed that the highest deposition levels of N and S in the U.S were 21 kg S/ha/yr and 9 kg N/ha/yr in the states of Ohio and Indiana, as reported by routine monitoring networks (2004-2006). However, national-scale networks that routinely monitor N deposition are inadequate to characterize the full range of reduced and oxidized forms of N deposition and the substantial regional heterogeneity across the U.S. Model-predicted values for N deposition are greater than 20 kg N/ha/yr in some regions of the Adirondacks and are greater than 32 kg N/ha/yr in a region of S. California.

Assessment of the ecological sciences indicated that the effects of acidifying deposition on ecosystems have been well studied over the past several decades, leading to the identification of vulnerable regions and the development of robust ecological models used for predicting soil and surface water acidification. Chemical and biological indicators of acidification were identified and threshold values discussed. In contrast to acidification, a broadly applicable and well-tested predictive model of the ecological effects of N deposition is not available. However, there is substantial empirical information for specific ecosystems and endpoints. Chemical and biological indicators of N enrichment were identified and values for critical loads were discussed. Publications typically did not include data on reduced vs. oxidized N, thus causality determinations were made on the effects of total N deposition. Additional ecological effects included mercury methylation caused by sulfate deposition and direct phytotoxic effects of gas-phase NOx and SOx. Few publications on ecosystem services and valuation associated with NOx and SOx air pollution are available. These were summarized and considered in terms of the categories outlined by the Millennium Ecosystem Assessment.

The conclusions of the NOx and SOx ISA serve as the scientific basis for decisions to retain or revise the NOx and SOx Secondary NAAQS.

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Trends in Cloud and Rain Water Chemistry from 1984-2007 on Mount Washington, NH (1,534 M)

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The Appalachian Mountain Club (AMC), with cooperation from the US National Forest and Institute of Ecosystem Studies, has sampled June – August montane rain and cloud events on Mt. Washington, NH since 1984. The Lakes of the Clouds (LOC) sampling site is located at 1,540 m asl, 1.6 km SW of the summit of Mount Washington, NH (44° 16'N, 71° 18'W, 1,914 m ASL), and adjacent to two designated Class I areas (Great Gulf and Presidential Dry River Wildernesses). The AMC/WPI cloud water collector used excludes rain from the cloud water sampled. Rain water was collected with an open funnel. Rain and cloud samples were analyzed in the field and lab for pH. Major cation and anions were analyzed for a subset of samples from 1984-1989, no analysis from 1990-1994, and for all samples from 1995-2007. Cloud volume data are insufficient across the historical dataset to volume weight cloud chemistry values; volume weighting rain water chemistry is possible. Some data gaps exist across the temporal record due to staffing and/or funding restrictions.

An initial comparison of non-volume weighted cloud and rain water event sample concentrations for pre (H ion: 1984-1994, sulfate ion: 1984-1989) and post (1995-2004) full implementation of the 1990 Clean Air Act Amendments (CAAA) show significantly lower hydrogen ion concentrations for the later time period (non-parametric Mann Whitney U tests $p<0.001$). Pre and post CAAA trends in cloud and rain water sulfate concentrations were weaker ($p= 0.08$ and >0.1 respectively). The absence of sulfate samples from 1990-1994 may contribute to the lack of significant differences in pre- and post CAAA implementation. We will present an update of this analysis through 2007 and include wet and dry chemistry reported from the nearby (55 km SW from LOC) but much lower (250m asl) USFS Hubbard Brook Experimental Forest's NADP and CASTNET sampling site, understanding that we used event samples while NADP and CASTNET used weekly samples. In addition, we will present comparisons of concurrent rain and cloud water sample chemistry, relationships of hydrogen ion with major anion concentrations in rain and cloud water, and the relationship of cloud hydrogen ion concentration with sampling period average wind speed and temperature.

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POSTER SESSION:

IN ALPHABETICAL ORDER BY AUTHOR

Liquid Water Content and Chemical Composition in Clouds at Whiteface Mountain, NY

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The objective of this study was to assess the relationship between acidity of clouds and cloud physical parameters at a high elevation site, Whiteface Mountain, in the Adirondack Park, NY. Prior studies at Mt. Brocken /Harz in Germany indicated that ionic composition of clouds is predominantly determined by the liquid water content. Utilizing more than a decade long (1994 to 2006) record of cloud water chemistry at Whiteface we investigated if such a relationship also holds for the Adirondacks, as well changes in the measured acidity over this period.

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Impacts of Chronic Low Level Nitrogen Deposition along a Roadside Deposition Gradient

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Despite large reductions in the emission rates of individual vehicles, mobile source NO_x emissions have increased by 33% since the clean air act amendments of 1970, and are the single largest source of nitrogen (N) emissions in the US. A portion of these emissions are deposited adjacent to roads. In order to assess the contribution of these sources to local N budgets on Cape Cod, we use methods similar to Lovett et al (2000) in which bulk and through-fall precipitation collectors were placed at 10, 50,100, and 150 meters away from a moderately heavy traveled road of ~18,800 vehicles day^{-1}, as well as a third transect of through-fall collectors adjacent to a road less clearing (power line right of way) to control for edge effects. Increased deposition was not due solely to an edge effect. Deposition along roadside edges was higher than along non-road edges. These gradients were short, less than 150 meters, and steep, with most of the elevated deposition occurring within the first 10-50 meters. Deposition near the road (10 meters) was 1.5-2 x that of areas farther away (150 meters) from the road. This increased deposition was likely due to near-source deposition of mobile source emissions, and correlated well with data from passive samplers. The percent of TDN in throughfall that is NH_4^+ decreased with distance from the road. This deposition has likely been occurring for decades causing changes in decomposition (-15%), leaching (~2x), forest floor C:N (-5.3 units), and pH (- 0.41 units) in sites near the road compared to sites farther away. When near source deposition is taken into account deposition estimates for a small watershed are 10.5-12.5 %.

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Regional Impacts of Reduced NOx Emissions on Ozone Concentrations in the Eastern USA: Positive Results from the NOx Budget Trading Program (NBP)

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We have used statistical random coefficient models to quantify the relation between changing ozone season (May-September) NOx emissions and ozone concentrations at sites in the eastern US for the period 1997 to 2007. The models produced from these analyses show highly significant relationships ($p < 0.001$) between NOx emissions and warm season max 8-hr ozone concentrations.   For the eastern US as a whole, ozone levels have declined by 5 to 6 ppb, a 10% decline in ozone concentrations over the entire region. The Mid-Atlantic and Southeast regions show the greatest declines with a 6 to 7 ppb drop or 12% decline in ozone concentration. The Midwest region has an ozone decline of 5 to 5.5 ppb, a 9% to 10% decline. The Northeast region shows the smallest impact from NBP regulation with a decline of 4.5 ppb, an 8.5% decrease in ozone concentration.

The random coefficient models were extended to separate urban and rural sites. For the Eastern US as a whole, the behavior of rural and urban sites are statistically different from each other ($p < 0.05$). Greater declines in ozone concentrations have occurred at the rural sites, which show a 7 ppb (12%) decline, while urban sites show a 5 ppb (8%) decline between pre- and post-NBP implementation periods. The greater declines at rural sites, except for the Mid-Atlantic region, may be explained by the fact that stationary source emissions which are dispersed more regionally, are likely to have a larger impact on rural sites because these sites are less impacted by other NOx sources. Urban sites may be more impacted by local transportation sources which have not been regulated to the same extent as stationary source NOx emissions.

The proposed Clean Air Interstate Rule (CAIR) is designed to further reduce power plant pollutant emissions, including a 2 million ton (61%) reduction in NOx stationary source emissions from 2003 levels. The NOx reductions due to CAIR will lead to further ozone declines in all regions, but the future declines will not be as great as those already achieved by the NBP and other stationary source reductions. Over ½ of the 61% decline from 2003 NOx emission levels were already achieved by the period 2004 to 2007. Reduced stationary source emissions have been effective in reducing maximum 8-hr ozone levels, and CAIR implementation will continue that pattern. However significant future reductions in ozone levels should also focus on vehicle emissions as well as stationary sources.

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Responses of Epiphytic Lichens to Atmospheric Reactive Nitrogen – Development of the Critical Level Approach for the Western United States

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Atmospheric reactive nitrogen (N_r), including nitrogen oxides (NO_x), nitric acid vapor (HNO_3), and ammonia (NH_3), can have direct phytotoxic effects on vegetation at highly elevated ambient concentrations. Elevated levels of N_r species also lead to increased nitrogen (N) deposition that influences growth and health of forest and other ecosystems. Direct phytotoxic effects of N_r on vascular plants are quite rare and occur only at very high ambient concentrations. In contrast, long-term exposures to elevated N_r and resulting N deposition are common and may result in serious ecological changes, such as promotion of growth of the nitrophyllous vascular plants at the expense of the oligotrophic ones and shifts in ecosystem species composition. Because of their direct uptake of nutrient from the atmosphere, epiphytic lichens proved to be highly sensitive to elevated N deposition which has been demonstrated by shifts from N-sensitive lichens to the dominance by N-tolerant and nitorphyllous species. Such responses have been described in several terrestrial ecosystems in the western US and have been used as a tool for determining critical loads of N deposition for protection of these ecosystems. In our approach we link changes in the epiphytic lichen communities directly to ambient concentrations of the main drivers of elevated N deposition, NH_3 and HNO_3. Statistical models that relate changes in the occurrence of the acidophyllous vs. nitrophyllous species to ambient concentrations of NH_3 and HNO_3 have been developed. These models have been used for evaluation of critical levels of these pollutants for the mixed conifer forests of the south-western Sierra Nevada in California. Similar efforts are also taking place in the mixed conifer forests of the San Bernardino Mountains of southern California and boreal forests in the Athabasca Oil Sands Region in Alberta, Canada.

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Atmospheric Concentrations and Sources of Mercury to Western Maryland

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Since June 2005, we have been measuring the atmospheric concentrations of gaseous elemental mercury (GEM), reactive gaseous mercury (RGM) and particulate mercury (Hg_p) in western Maryland. In this poster, we will present some of the important highlights our atmospheric mercury speciation data. For example, hourly averaged GEM concentrations ranged from 0.52 to 2.8 ng m^{-3}, with an overall average of 1.45 $\pm$ 0.01 ng m^{-3}. GEM exhibited statistically significant seasonal and diurnal variations. Seasonally averaged GEM concentrations ranged from 1.35 to 1.59 ng m^{-3}. Summer (1.35 $\pm$ 0.02) and fall (1.39 $\pm$ 0.01 ng m^{-3}) had significantly ($p<0.05$) lower average GEM concentrations than winter (1.53 $\pm$ 0.04) and spring (1.59 $\pm$ 0.02). There were statistically significant ($p<0.05$) variations in the hourly averaged GEM concentrations in the summer. Lowest hourly averaged GEM concentrations occurred between 3:00 AM (1.17 $\pm$ 0.04 ng m^{-3}) and 6:00 AM (1.21 $\pm$ 0.03 ng m^{-3}). From 6:00 AM to 9:00 AM, the hourly averaged GEM concentrations increased at a rate of 0.09 ng m^{-3} hr^{-1} until reaching the maximum value of 1.45 $\pm$ 0.02 ng m^{-3} at 9:00 AM. From 9:00 AM until 5:00 PM, the GEM concentrations were relatively constant, ranging between 1.41 and 1.45 ng m^{-3}. Starting around 5:00 PM, the GEM concentrations slowly decreased until around 3:00 AM. Between 3:00 AM and 6:00 AM, the GEM concentrations were relatively stable at concentrations between 1.17 and 1.20 ng m^{-3}. RGM concentrations ranged from below detection limits (BDL) to 119.3 pg m^{-3}, with an overall average of 10.3 pg m^{-3}. RGM exhibited strong seasonal variations with the greatest average concentration in spring (16.1 pg m^{-3}), intermediate in summer and fall (9 pg m^{-3}) and lowest in winter (6.8 pg m^{-3}). In the summer and spring, RGM concentrations were statistically greater in the day than at night. Average particulate mercury Hg_p concentrations ranged from BDL to 37.8 pg m^{-3}, with an average of 5.1 pg m^{-3}. Hg_p exhibited strong seasonal variation with greatest concentrations in winter and fall and lowest concentrations in the other seasons. Hg_p did not exhibit diurnal variations in any season. Back trajectory analyses using NOAA HYSPLIT suggested that mercury sources west and northwest of our monitoring station are the likely sources of RGM and Hg_p.

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Mercury Trends in Fish from Streams and Lakes in the United States, 1969 - 2005

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A national compilation of fish-mercury concentration data from state and federal monitoring programs was used to analyze trends in mercury (Hg) concentrations in fish from streams and lakes across the U.S. Trends were analyzed by site and by state on samples of the same fish species and tissue type, using similar fish lengths. Trends were evaluated over 2 time periods, 1969 – 1987, and 1988-2005. In addition, the most recent fish data (1995 – 2005) was compared to concurrent wet Hg deposition data from the Mercury Deposition Network (MDN). Downward Hg trends in fish from data collected between 1969-1987 outweighed upward trends by 6:1. Downward Hg trends in fish during the 1970's and 1980's are consistent with decreases in atmospheric Hg deposition inferred from many records of sediment, ice, and peat cores. The Southeastern U.S. consistently had more upward trends than other regions of the country both in site trends (1969-1987) and statewide trends (1988-2005). Upward Hg trends in fish from the Southeastern U.S. is supported by MDN wet deposition increases in the region and may be attributed to a greater influence of global atmospheric emissions in the Southeastern U.S. Overall, statewide fish data (1988-2005 and 1996–2005) did not have significant Hg trends (52 and 62 percent respectively). A lack of Hg trends in fish in the more recent data was consistent with the lack of trends in Hg wet deposition at MDN sites and relatively constant global emissions over the same time period. Although few significant trends were observed in the more recent Hg data in fish, it is anticipated that Hg concentrations in fish will decrease with decreases in atmospheric Hg deposition, however, the magnitude and timing of the response is uncertain.

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Responses of a Watershed Manipulated By Calcium Silicate at a Northern Hardwood Forest Ecosystem: Mass Balance and Landscape Position

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In spite of decreases in atmospheric sulfate (SO_4^{2-}) deposition, stream pH in watershed 1 (W1: 11.8 ha) at the Hubbard Brook Experimental Forest (HBEF) in New Hampshire (NH) had remained acidic. W1 was experimentally treated by a calcium silicate ($CaSiO_3$; wollastonite) addition in October of 1999 to assess the role of calcium (Ca) and silica (Si) supply in the structure and function of base poor forest ecosystems. In this study, we discuss landscape position and mass balances of Ca and Si in soil water and stream water to determine how much wollastonite is retained and lost from the ecosystem in response to the watershed application.

A long-term sampling program was initiated to evaluate longitudinal patterns of watershed response to the wollastonite treatment. Soil water and stream water samples within sub-watersheds were collected monthly prior to and after treatment to investigate changes in soil, soil water and stream chemistry. $CaSiO_3$ addition significantly increased Ca and Si fluxes in both organic soil solution and stream water at all elevations following the treatment. The magnitude of changes in fluxes decreased with increasing soil depth, since much of Ca and Si derived from the dissolution of the wollastonite addition remained in upper soil horizons during the study period. Approximately 5.3% of the added Ca and 20.3% of the added Si was exported from the high elevation spruce-fir-white birch (SFB) zone, 4.7% and 14.8% from the high-elevation hardwood (HH) zone, 4.9% and 15.3% from the low-elevation hardwood (LH) zone, and 5.2% and 18.4% from the whole watershed (W1) over the six year study period. These removals suggest that 94.7% of the added Ca and 79.2% of the added Si at SFB, 95.3% and 85.2% at HH, 95.1% and 84.7% at LH, and 94.8% and 81.6% for all W1 was retained. The SFB zone showed somewhat greater export of Ca and Si than the HH and LH zones due to its shallow soil depth and greater soil water content.

Wet Mercury Deposition at Two Urban Sites in New York

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Since January 2008 the New York State Department of Environmental Conservation has been collecting wet mercury deposition at two urban MDN sites, Rochester and New York City. The purpose of these measurements is to monitor baseline concentations and deposition of mercury prior to planned state and national emission reduction programs. In this study we examine the variation of wet mercury deposition on a seasonal basis, as well as compare deposition at these urban locations to three more rural MDN sites in New York – Huntington Wildlife, Biscuit Brook, and West Point. Since all of these sites are collocated with acid deposition monitors, we also investigate any correlation and co-variation with wet SO_4 deposition at these sites.

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Exploring the Spatial Association between Environmental Methylmercury and Atmospheric Deposition at Varying Geographic Scales

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Over the past few decades, researchers have explored the relationship between concentrations of the neurotoxin methylmercury and sources of mercury emissions to the atmosphere with little success. More recently, researchers have begun to examine the spatial relationship between environmental methylmercury and ecosystem factors known to enhance the formation of methylmercury. Using comprehensive fish tissue data from the State of Ohio Cooperative Fish Tissue Monitoring Program and atmospheric deposition data from the National Atmospheric Deposition Program's National Trends Network, this study attempts to explore the strength of spatial associations between these datasets at varying scales. Statistical methodologies were employed using analytical tools in ArcGIS, including radius of influence and distance weighted averaging. Associations were identified that address uncertainties when comparing local, regional, and global factors of environmental methylmercury formation. The results of this study imply that methylmercury investigations may be scale dependent.

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2009 Measurements of Atmospheric Mercury Species in Atlantic Canada at Kejimkujik National Park (NS01)

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Environment Canada has recently began measuring the concentrations of three gaseous Hg species – gaseous elemental mercury (GEM), reactive gaseous mercury (RGM), particulate (P-Hg) fine fraction (<2.5 µm) at a remote rural site in Nova Scotia (Canada). In January of 2009, an integrated Tekran 1130/1135 sampling and analysis unit was setup at the Canadian Atmospheric Precipitation Monitoring Network (CAPMoN) site in Kejimkujik National Park. This mercury speciation sampling is funded by the Clean Air Regulatory Agenda (CARA) to increase our understanding of the contribution of dry deposition to total deposition of atmosphere mercury in Canada. In addition to RGM and P-Hg, ongoing 5 minute sampling of total gaseous mercury (TGM) is monitored as well as the weekly collection of mercury in precipitation samples as part of the Mercury Deposition Network (MDN). This site is one of the Environment Canada CARA Hg "super sites" established for long-term measurements of atmospheric constituents and is one of the sites in the National Atmospheric Deposition Network (AMnet). Adjacent to the Tekran 1130/1135 sampling system, a Davis Instruments weather station collected meteorological data (MET) along with leaf wetness. This poster will illustrate mercury speciation data and also note any trends observed with the MET or air quality data collected from the Kejimkujik site.

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Determination of Total Dissolved Nitrogen (TDN) in Wet Deposition Samples Preserved During Collection and Post Collection

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Concentrations of ammonium and nitrate, the dissolved components of nitrogen, are routinely determined in wet deposition samples analyzed by the National Atmospheric Deposition Program/Central Analytical Laboratory (NADP/CAL). To quantify the contribution of all nitrogen species, the U.S. EPA has provided funding to the NADP/CAL to analyze total dissolved nitrogen (TDN) in select NADP National Trends Network (NTN) and Atmospheric Integrated Research Monitoring Network (AIRMoN) samples. This data set will provide additional information on spatio-temporal patterns of nitrogen in deposition, and determine the feasibility of operating a national-scale network to measure TDN.

There is evidence in the literature that organic fractions of nitrogen are unstable and sample preservation must be considered when evaluating the total nitrogen concentration in wet deposition. A collocated sampler study was conducted by the CAL at its monitoring site located at Bondville, IL during summer 2009 (June 1 – August 31). The purpose of this study was to compare total, organic, and inorganic nitrogen measurements for weekly NTN samples, daily AIRMoN samples, and daily samples from a third chilled collector. Preliminary data indicate that the AIRMoN and field-chilled samples have higher total nitrogen concentrations than NTN samples.

Two additional sample preservation techniques were evaluated on samples with adequate volume. Select NTN and AIRMoN samples from Bondville were acidified to pH < 2.0 using sulfuric acid and some samples were frozen post-collection. This poster will present a comparison of the nitrogen species concentrations in the NTN, AIRMoN, and field-chilled samples as well as a comparison of sample preservation methods (field-chilled, acidified, and frozen). Quality assurance data will also be presented to quantify method detection limits, analytical reproducibility, and analytical bias.

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Productivity of the Balsam Fir Boreal Forest in 2100: Experimental Interactions of Climate Change and Nitrogen Deposition

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Most recent simulations of the future climate from the Canadian Regional Climate Model for the eastern boreal forest of Canada suggest an average annual temperature increase of 3 °C by 2050 whereas precipitations should increase by 5 to 20%. Such changes will certainly have a major impact on the growth of the boreal forest. But climate is not the only important factor: nitrogen is also a major growth-limiting factor in such biome. In fact, more and more studies show that the response of plants to climate change is strongly influenced by the availability of inorganic nitrogen, although this aspect is largely ignored in today's predictive growth models.

The principal objective of this project is to identify the parameters that influence tree growth in boreal biomes by integrating, within the same study, an experimental manipulation of the climate (precipitations, soil temperature and growth season length) and nitrogen additions directly on the tree canopies.

The study site is located in a typical balsam fir forest near the calibrated watershed of the Lake Laflamme, Québec (Canada). The addition of artificial precipitations, enriched with nitrate-15 and ammonia-15, are carried out by means of independent water nozzles set up above each tree. Heating cables and thermocouples are buried under each tree, laid out in concentric circles on a radius of two meters.

To account for the effects of the experimental treatments, the measurement protocol consists in a continuous monitoring of stem diameter variations, analysis of wood cells formation using microcarots extracted weekly, measures of seasonal nutrient availability in the soil using adsorbing membranes, measures of soil and wood water content as well as analysis of leaf chemistry.

Preliminary results will be presented, with the intention of better quantifying the fine climate-growth relationships for balsam fir. This research will lead to the development of a quantitative model of the impact of climatic changes brought to the nitrogen cycle of the boreal forests following modifications in concentration of dissolved inorganic nitrogen in precipitations and to changes in the rate of mineralisation of the organic nitrogen in the soil. Moreover, a sound understanding of the cambial response of balsam fir species to the future climate will also be extremely useful for improving predictive power of forest dynamic models which for now do not take into account soil warming and more globally the effects of the climate change on the nitrogen cycle.

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More than Monitoring: Extending NADP and CASTNET across Landscapes

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NADP and CASTNET data have been useful for years for monitoring deposition to specific locations across the country and over time. More recent efforts have sought to spatially extend this information across the landscape to locations where the fund and time expensive monitoring is not feasible. We have used NADP and CASTNET data in various ways and locations in the attempt to characterize deposition across the landscape of the US and North America. Combined with other monitoring networks (such as CAPMON), other methods of estimating deposition (such as the CMAQ model and throughfall measurement), and spatially explicit data (such as precipitation models, elevation, and land cover data), these monitoring data are critical for understanding how substances are deposited on the landscape, both functionally and spatially. This information can then be applied to concepts such as critical loads and ecosystem budgets and processes.

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Utility of Isotopic Techniques for Partitioning No$_x$ Sources Contributing to Landscape Nitrogen Deposition

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Dry deposition is a major component of total atmospheric nitrogen deposition and thus an important source of bioavailable nitrogen to ecosystems. However, relative to wet deposition, less is known regarding the sources and spatial variability of dry deposition. This is in part due to difficulty in measuring dry deposition and associated deposition velocities. Passive sampling techniques offer potential for improving our understanding of the spatial distribution and sources of gaseous and aerosol N species, referred to here as dry deposition. We present dual nitrate isotopes (δ^{15}N and δ^{18}O) in actively collected dry and wet deposition across the high deposition region of Ohio, New York, and Pennsylvania. We also present results from initial tests to examine the efficacy of using passive nitric acid collectors as a collection medium for isotopic analysis at a site in New York. Further, we present new measurements of δ^{15}N in stack gases from a coal-fired power plant. Isotopes in actively collected dry deposition, including particulate nitrate and gaseous nitric acid, are compared with those in wet nitrate deposition and surrounding NO$_x$ emission sources.

δ^{15}N values in dry and wet fractions are highest at the westernmost sites and lowest at the easternmost sites, and stationary source NO$_x$ emissions (e.g., power plants and incinerators) appear to be the primary control on δ^{15}N spatial variability. In contrast, δ^{18}O values show a less consistent spatial pattern in dry deposition. Both δ^{15}N and δ^{18}O show strong seasonality, with higher values in winter than summer. Seasonal variations in stationary source NO$_x$ emissions appear to be the most likely explanation for seasonal variations in δ^{15}N, whereas seasonal variations in air temperature and solar radiation indicate variable chemical oxidation pathways control δ^{18}O patterns. Additionally, we demonstrate the utility of passive samplers for collecting the nitric acid (HNO$_3$) component of dry deposition suitable for isotopic analysis. We observe slight differences in δ^{15}N-HNO$_3$ values between simultaneous samples collected actively and passively (0.6‰). However, we observe a larger offset in δ^{18}O values between actively and passively collected samples; the causes for this offset warrant further investigation. Nonetheless, passive sample collection represents a significant cost savings over active sampling techniques and will allow a more extensive understanding of patterns of dry deposition and associated insights to nitrogen sources across landscapes.

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Assessing the Use of NH$_3$ Isotopic Composition Collected by Passive Samplers to Indicate Regional NH$_3$ Emission Sources

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Given the growing concern regarding the increasing NH$_4^+$ deposition rates in both wet and dry deposition across the U.S., there is heightened interest in improving our understanding of NH$_3$ emission sources, the processes controlling the formation of NH$_4^+$ aerosols subject to long-range transport, and ultimately the deposition of NH$_3$ products in wet and dry deposition. As a result of this growing concern, the NADP and CASTNET programs are collaborating on a new monitoring program, the "Ammonia Monitoring Network (AMoN)." In collaboration with this initiative, our research aims to assess the utility of adding δ^{15}N-NH$_3$ measurements to the monitoring protocol. Beginning in July of 2009, ALPHA passive samplers equipped with phosphorous acid-coated filters were deployed at multiple NADP sites to collect NH$_3$ emissions for isotopic analysis. Sites were chosen based on their proximity to NH$_3$ emission sources including concentrated livestock operations, power plants, urban areas and intensive rowcrop operations. As part of this effort, we are also characterizing the isotopic composition of major NH$_3$ emission sources including livestock waste, fossil fuel combustion, and fertilizer. These source isotope compositions will be used to construct mixing models for each site to characterize the relative contribution of individual NH$_3$ sources to gaseous NH$_3$ concentrations.   To aid mixing model formulations, δ^{15}N-NH$_3$ values will be compared with monthly NH$_3$ emission estimates from local and regional emission sources and ongoing NH$_3$ concentration measurements at individual sites.   δ^{15}N-NH$_3$ values will also be examined for temporal variations, as well as correlations with NH$_3$ concentrations, temperature, and wind/speed direction. The results from this work will constitute an annual record of monthly δ^{15}N-NH$_3$ values recorded at multiple monitoring sites throughout the U.S. characterized by a range of NH$_3$ concentrations and associated emission sources.

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Baseline Measurements of Ambient Concentrations of Elemental, Reactive Gaseous and Particle-Bound Mercury at Two Urban Locations in New York

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Since late August 2008, the New York State Department of Environmental Conservation has been monitoring ambient levels of elemental mercury (Hg^0), reactive gaseous mercury (RGM), and particle-bound mercury (PBM) in Rochester and New York City using full speciation Tekran systems. These data will eventually be included in the MDN mercury initiative, a national collaborative effort to investigate spatial and temporal trends in ambient concentrations and deposition of mercury. Here we present preliminary findings of this monitoring effort, including diurnal and seasonal variations, analysis of co-pollutants such as O_3 and SO_2, and lessons learned. The Rochester site is collocated with a Tekran unit operated by Clarkson University, and results from this collocation effort are also presented. We also examine several high pollution episodes and high RGM events over this period, using wind roses and back trajectory analysis.

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Mercury in Throughfall and Litterfall Inputs and Stream Export in the Great Smoky Mountains National Park 2007 - 2009

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Several major mercury input and export pathways were sampled at three elevations in the Great Smoky Mountain National Park (GSMNP) between April and October during both 2007 and 2009. Throughfall (TF) which is precipitation that reaches the forest floor after falling through and interacting with the forest canopy and litterfall (LF) which are pieces and fragments of leaves, twigs, bark etc. that fall to the forest floor are two pathways which comprise the bulk of the mercury that reaches the forest floor and ultimately enters nutrient cycling pathways that bring mercury into various trophic levels of the forest ecosystem and eventually to aquatic ecosystems. In a discussion of the causal factors of increased mercury in the Tennessee River Valley and the Northern hemisphere (Joslin, 1994) identified the major inputs to water bodies and the transformational factors that either result in sequestration or higher concentrations of mercury in aquatic environments. Interestingly, Joslin identified Fontana Lake, which is bordered by the GSMNP, and other similar high elevation lakes in the Tennessee Valley as being potentially vulnerable to future increases in mercury levels in fish. This vulnerability was suggested to be attributable to the relatively low acid neutralizing capacity (ANC) and low nutrient levels of lake water which affect within-lake mechanisms that lessen the rate of mercury loss through volatilization and may increase mercury methylation. Mercury and its cycling within various environmental components are of concern to TVA because of the potential for adverse human health impacts in sensitive populations resulting from the presence of methylmercury in fish.

Mercury emissions from coal-fired power plants, particularly those in Asia, together with other various worldwide sources are primary contributors of mercury to the environment. It is thought that regional high elevation sites are potentially affected more than low elevation sites. This study is designed to generate some initial data that may provide some basic understanding of mercury movement within the terrestrial ecosystem of the GSMNP. Sampling was initiated in April 2007 and expanded and focused on primary mercury inputs and exports in 2008 and 2009. Reported here are the results from 2007 through current 2009 collection period.

This study is being carried out at three sites; two high elevation sites - Clingmans Dome (CD) at 6643 ft and Noland Divide (ND) at 5578 ft and a low elevation site - Noland Creek (NC) at 1945 ft. The CD and ND sites are coniferous forest composed of primarily fir (*Abies fraseri*) at the CD site and spruce (*Picea rubens*)

Radiello™ Type Passive Samplers versus ALPHA Type Passive Samplers

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Efforts to quantify and measure ammonia in the atmosphere are continuing within the NADP program. Currently 19 sites throughout the USA and Canada deploy passive devices that are impregnated with phosphoric acid and capture ambient ammonia gas. The NADP program is evaluating differences between passive ammonia devices at five of its 19 sites. ALPHA (Adapted low-cost Passive High Absorption) devices are being compared with Radiello™ devices. Both types of samplers work on diffusion theory, where ammonia is absorbed as ammonium ion by the interior cartridge.

Radiello™ cartridges are made of microporous polyethylene coated with phosphoric acid. Radiello™ cartridges are available with two types of diffusive bodies, one that is white in color and the other that is blue.

The cartridges loaded into the ALPHA devices must be impregnated with phosphoric acid at the Central Analytical Laboratory (CAL).

The passive samplers, once loaded with impregnated cartridges, have been deployed side-by-side in the field at five sites. After returning to the CAL, cartridges are removed, the ammonia is extracted in deionized water using sonication, and the extracts are analyzed within 24 hours by Flow Injection Analysis. The purpose of this study is to compare the precision, repeatability and reliability of two types of passive samplers. We should also determine whether there is a statistically significant effect between white- and blue-colored Radiello™ diffusive bodies.

Linked Micromap Plots for Evaluating Trends in Multi-Pollutant Deposition

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The National Atmospheric Deposition Program (NADP) traditionally provides multi-pollutant data summaries as color choropleth maps. Linked Micromap (LM) plots, however, provide an alternate arrangement to displaying such statistical information that avoids some of the restrictions of choropleth maps. LM plots were first introduced at the Joint Statistical Meetings 1996 in Chicago. Since then, they have been used for various applications. Interactive, Web-based versions of micromaps are also available on-line. Similar to the micromaps accessible on Web sites, micromaps compiled for NADP data interpretation consist of three to four columns: The first (leftmost) column shows a series of small maps. Different sub-regions (here the states of the US) are highlighted on each map. The next column shows the identifiers of the sub-regions (here the state names). Typically, one or two columns follow with statistical data (here different air pollutants such as NO_3 and NH_4). All columns are sorted according to one of these data columns, say NO_3. The columns are linked by color so that the same color is used to highlight a state, the state name, and the color used in the statistical columns representing this state. Then, the top map highlights the five states with the highest NO_3 values; the second to top map highlights the five states with the next highest NO_3 values, and so on. By highlighting a few states in a particular map, strong geographical relationships were detected. Moreover, by emphasizing a median state, it becomes possible to easily identify a subset of states with similar NO_3 concentrations and to determine whether these states form a geographic pattern. For NO_3 (in 2004), such patterns were spotted: There is a band of states with high NO_3 values stretching from the Southwest (Arizona) to the Northeast (New Hampshire). On the other hand, the Northwest and the Gulf Coast form additional strong geographic patterns. Additional data columns (here NH_4) show the associations between statistical variables and immediately highlight geographic outliers. New Jersey, although having the maximum NO_3 value, only had a very low NH_4 value in 2004.

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Quantitative Assessment of Bromide Ion Measurements in NTN Samples by Ion Chromatography

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Bromide is released into the environment via natural and anthropogenic processes. Brominated compounds are used in the production of polymers to increase the fire resistance of a wide variety of products. Methyl bromide is used as a fumigant for a variety of fruits and vegetables and can be applied to soils before plant growth. It can be applied post harvest for some food processing applications. Methyl bromide is classified as an ozone-depleting substance and its use is strictly regulated and monitored by the U.S EPA.

Ethylene dibromide (EDB) was also used as a fumigant until 1984 when it was banned for soil and grain use by the EPA because of its extreme toxicity to human health. Ethylene dibromide is currently used in the treatment of felled logs for bark beetles and termites, and control of wax moths in beehives. EDB can migrate to groundwater supplies, leading to human health concerns (http://www.epa.gov/OGWDW/contaminants/dw_contamfs/ethylene.html).

The Central Analytical Laboratory (CAL) for the National Atmospheric Deposition Program/National Trends Network (NADP/CAL) measures chloride, nitrate, and sulfate by Ion Chromatography (IC) The CAL has investigated the analysis of bromide as an anion measurement by IC in NADP/NTN samples.

The estimated MDL 0.006 ppm was determined by measuring the CAL's lowest calibration standard. As part of bromide ion method development, the CAL measured bromide concentrations in weekly supply blank samples (NADP collection buckets, lids, buckets, bags, etc.) The results from these samples were used to determine background levels of bromide present in the CAL's supplies. The CAL measured bromide in all of the NADP/NTN samples processed throughout summer and will highlight samples or areas that test positive for bromide.

Speciated Mercury Measurements in Rochester New York: Concentrations and Sources

Jiaoyan Huang[1], Hyun-Deok Choi[1], Philip K. Hopke[2] and Thomas M. Holsen[1]

A Tekran mercury (Hg) speciation system (Models 1130, 1135, and 2537) has been operated at an urban site (Rochester, New York) since Dec 2007. Ozone (O_3), sulfur dioxide (SO_2), carbon monoxide (CO), and $PM_{2.5}$ and meteorological data including temperature (Temp), barometric pressure (BP), relative humidity (RH), wind direction (WD), wind speed (WS), and precipitation (precip) are also being measured. These data were examined using principle component analysis (PCA) to identify mercury sources for this site. A melting factor was also included to account for Hg release from melting snow.

PCA of 3886 observations identified 8 factors. Melting snow was a source of Hg^0 during both winters. Conversion of Hg^0 to RGM in the presence of O_3 was found to be important in spring and summer 2008, and spring 2009. A factor in which RGM concentrations increased simultaneously with SO_2 when the winds came from northwest where local coal fired utilities are located was also found. A factor characterized as a combustion source based on the relationship among Hg^0, RGM, and CO was found to be important for most seasons. Conditional probability function (CPF) analysis found the factors were associated with different wind directions and suggests that the three species of mercury often come from different directions. Seasonal Hg^0 concentrations in winter 2007 and spring 2008 were significantly higher than the following seasons when Hg^0 concentrations were relatively constant. These differences may be attributed to the closing of the Russell coal fired power plant, located to the northwest of site in spring 2008.

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Monitoring Hydrogen Sulfide Concentrations in a Farrowing Room at a Sow Farm in Eastern North Carolina

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Large-scale swine production facilities are known emission sources of ammonia (NH_3) and hydrogen sulfide (H_2S). Presented are the results of monitoring H_2S concentrations in a farrowing room at a sow gestation/farrowing farm (~2500 hog permitted capacity) in eastern North Carolina. This farm is one of two swine sites in North Carolina being monitored by the National Air Emission Monitoring Study (NAEMS). Piglets are produced throughout the year in farrowing rooms (20 sows; ~ 240 piglets) where piglets are born and raised during a period of 21 – 28 days. The farrowing rooms have solid walls and are ventilated with three mechanical fans (2 46-cm and 1 61-cm fans). Fresh air enters the room through ceiling baffles along the entire length of the sidewalls. Target temperature range for the farrowing rooms is 26-28°C. Solid and liquid waste accumulates in two shallow pits (~48 cm from floor to bottom of pit) in the room that are flushed and filled with anaerobic lagoon water twice during the 21 – 28 day growth period. As expected, the H_2S concentration of exhaust air measured ~70 cm from the Stage 1 fan was dependent on the total ventilation rate for the farrowing room. However, we also observed an increase in the gas concentrations of H_2S between flushing events of the pits, and a substantial short-term increase in H_2S during actual drainage of the pits (which lasts ~ 10 minutes). During this short period, H_2S concentrations could reach 30 times average observed concentrations in the room, depending on season of the year (colder periods yielding higher peaks in measured H_2S concentrations). Other gases (NH_3 and carbon dioxide) did not exhibit this phenomenon, suggesting that the high measured H_2S concentrations are related to the physical disturbance of the pit liquid. H_2S concentrations were lowest when the pits were filled with fresh anaerobic lagoon liquid. We did not observe these elevated levels of H_2S during flushing of the pits in the breeding/gestation and gestation barns also located at this facility. We continue to investigate this phenomenon to identify the unique characteristics of the farrowing room that result in the elevated concentrations of H_2S.

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National Air Emissions Monitoring Study (NAEMS) Sow Site NC4B:Observations of Farm Operation and Management

Jihoon Kang*[1], Wayne P. Robarge[1], Sang R. Lee[1], Albert Heber[2], Erin Cortus[3], Lilong Chai[2], Kaiyang Wang[4] and Jiqin Ni[2]

The NAEMS provides a unique opportunity to continuously observe individual animal confined feeding operations over long periods. Information is presented on the operation and management of a representative sow gestation and farrowing farm (~ 2500 hogs permitted capacity) in eastern North Carolina. Approximately 2200 pigs are on site in three barns: breeding/gestation (~900), gestation (~900), and farrowing (~320; 16 rooms; 20 sows/room). Sows weigh ~140 to 230 kg and farrow an average of 10 - 13 piglets/sow. Piglets grow to 6.4 kg from a birth weight of 1.2 kg in 21 days; 700 to 900 piglets are shipped weekly. A single feed formulation (~ 2.2% N) is provided once daily to pregnant sows. Lactating sows are fed a 3.3% N diet 4x daily. All three barns are force ventilated. Default duty cycle is 10 min. for stage 1 fans, till overridden by the difference between internal and exterior temperature. As internal temperatures increase, various combinations of fans turn on and off changing the total volume of air exiting the barns. Air is pulled into the farrowing rooms via controlled baffles distributed along the sidewalls (2 46-cm and 1 61-cm variable-speed fans). The breeding/gestation barn uses end wall exhaust fans (122-cm dia., 12 total) that draw air through evaporative cooling pads in the center. The gestation barn uses conventional tunnel-ventilation (8 122-cm dia. fans) with adjustable end wall curtain. The breeding/gestation and gestation barns do not have side baffles, but during the "winter" ventilation configuration, the sidewalls are dropped to allow a 1-inch gap for entry of additional fresh air along the length of the barns. Waste is handled through shallow pits (3 pits per breeding and gestation barns, 2 per farrowing room; ~48 cm from animal floor to bottom of the pit). The pit is drained (pull-plug) every 7 – 10 days, then flushed and filled with liquid from the anaerobic lagoon. Pit sludge depth varies along the length of the barn and undoubtedly with age. Presence of sludge in the pits over half the length of the breeding and gestation barns represents a potential source of ammonia and hydrogen sulfide emissions in excess of that from fresh urine and fecal matter and weekly renewal of lagoon liquid. The supplemental information gathered by the NAEMS project will facilitate the development of process-based models to describe gaseous emissions from animal confined feeding operations.

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The E-gage Transition

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As the NADP transitions into its next 30 years the adoption of electronic/digital raingages (egages) has not been without its challenges. The NADP program office has worked tirelessly to facilitate this transition and has now passed on a share of the technical support to the CAL and the HAL. The tools used to provide this support have evolved and are used daily to help validate and invalidate weekly samples.   Once sites become comfortable their new equipment they tend to have very little trouble. The first 3-4 weeks with the new equipment can be quite challenging but this can be improved. A few of the common problems and their solutions will be exhibited. An update of egage deployment by site and agency will also be exhibited.

Do the Competitions among Calcium, Aluminum and Hydrogen Ion for Organic Binding Sites Determine Soil pH and Aluminum Solubility in Adirondack Forest Soils?

Wei Li[1]*, Chris E. Johnson[1] and April M. Melvin[2]

Long-term acid deposition has resulted in a decrease of soil pH, the depletion of labile calcium (Ca) and the mobilization of aluminum (Al) in Adirondack forest ecosystems. In acidic soils, the labile Al^{3+} is highly toxic to most organisms, affects the growth of plants, and can displace base cations (such as Ca^{2+}, Mg^{2+}, K^+, Na^+) on the exchange sites of soil organic matter (SOM). Liming is generally applied to mitigate the soil acidity and to improve the soil base status. After liming, the acid cations (Al^{3+}, H^+) may be neutralized by base cations (Ca^{2+}), and the soil pH may be improved, suggesting that the competition between Ca^{2+} and Al^{3+} binding on SOM is the key process controlling soil pH and Al solubility. However, some researchers have noted that the fraction of exchangeable base cations and Al to cation exchange capacity (CEC) might present a strong correlation with soil pH, and it has been suggested that Al^{3+} might act as a base cation. Furthermore, researchers have hypothesized that the composition of hydrogen ions (H^+) and Al^{3+} adsorbed to the SOM determines the soil pH and Al solubility.

The goal of this project is to explore the relationships between Al^{3+}, Ca^{2+} and H^+ bound to the organic exchange sites of SOM, and to improve understanding of the key acid-base processes determining the soil pH and Al solubility in the acidic forest ecosystem. We have conducted experiments to determine the acid-base chemistry of thirty-six samples from three horizons (Oe, Oa and mineral) of two limed subcatchments (II and IV) and two control subcatchments (III and V) at the Woods Lake watershed in the Adirondack Region. Our study indicated that the soil pH and the base saturation (the ratio of exchangeable base cations to CEC) have experienced a large increase in organic horizons of treatment sites comparing reference sites, and the soil Al concentrations are opposite. The model of cation exchange reactions among H^+, Al^{3+} and Ca^{2+} and the pH-dependent solubility of Al hydroxide should be both considered while determining soil pH and Al solubility. The cation exchange reaction works more effectively for Oa horizon than for Oe and mineral horizons. Later on, we will optimize the WinHumicV model by using the batch titration data of reference samples and calculate equilibrium concentrations of cations in solution with changing soil Al and Ca concentrations. The model simulation results will be used to compare the liming effects of the treated subcatchments with the measured results, and furthermore test the relationships between Al^{3+}, Ca^{2+} and H^+ on organic binding sites.

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Atmospheric Mercury Measurements in the Gulf of Mexico and Mid-Atlantic: Trends in Concentrations and Estimated Deposition

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We present results from two sites established to monitor mercury species and ancillary trace gases in the atmosphere: a rural site at the Grand Bay National Estuarine Research Reserve (NERR) in Moss Point, MS, and a suburban site on the campus of the Beltsville Agricultural Research Center (BARC) in Beltsville, MD. The measured atmospheric mercury concentrations at the sites (elemental Hg(0), reactive gaseous mercury, and fine particulate mercury) will be summarized, and will be interpreted using ancillary measurements of primary (CO, NO/NO_Y, SO_2) and secondary (O_3) trace gases at each site; prevailing meteorology; and back trajectory analysis. Trends of air concentrations and estimated and measured deposition patterns will be evaluated. Plans for a 2010 field intensive, designed to study the role of halogens in the conversion of Hg(0) to more soluble species, will be presented.

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Estimating the Importance of Near-Source Deposition of Nitrogen from Vehicle Emissions along Roadside Gradients

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Recent evidence suggests that total nitrogen deposition in urban and suburban areas can be substantially higher than estimated using data from national monitoring stations, which are located purposefully away from such areas, and which do not measure dry deposition of some important gaseous components. We are using passive samplers to estimate near-source dry deposition of the primary nitrogen gases (NOx, NH_3) associated with vehicle emissions. At our primary study site on Cape Cod, MA, we examined summertime patterns of nitrogen pollution and estimated deposition along 5 to 150 meter gradients away from two roads (16,000 to 20,000 vehicles/day average), using gas concentration measurements and literature-based depositional velocities. Gaseous nitrogen deposition is highest near the road and falls exponentially with distance, decreasing 60 to 80% over 20 meters. Concurrent measurements of nitrogen in bulk (open field) and through-fall collectors were made along the same gradient, and the patterns of nitrogen concentration correlate well with the passive sampler data (see abstract and oral presentation by N. Bettez et al.). Our results suggest that vehicle traffic is likely a significant source of nitrogen deposition to high-traffic, suburban coastal areas. We estimate that within 50 meters of the road, gaseous dry nitrogen deposition may represent half of total nitrogen deposition at these sites, with two thirds as NH_3, and one third as oxidized nitrogen. We have recently begun making air concentration measurements and gaseous dry deposition estimates for NH_3 in two urban areas in New York State (New York City, Binghamton); preliminary data may be presented.

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Isotopic Investigation of Reactive Nitrogen Deposition along a Highway Road Gradient

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Though it is well understood that mobile emissions on highways create "hotspots" of air pollution, there is limited understanding of the effects of these emissions on the surrounding environment and human health. Because vehicle emissions constitute about half of Eastern U.S. NO_x emissions, it is critical to identify the fate and impact of automobile emissions on near-road ecosystems. Previous studies have indicated that nitrogen emissions from automobiles are deposited locally, in the form of particulates and aerosols in dry deposition. Unlike emissions from more regional air pollution sources (e.g., smoke stacks) dry deposition from vehicles can deposit within 10's to 100's of meters from roadways. This spatial pattern of concentrated nitrogen deposition has important implications for near-road environments. For example, storm water infrastructure likely channels near-road deposition directly into surface waters. In addition, excess nitrogen can have adverse affects on near-road plant communities; studies have documented defoliation and changes in community structure due to nitrogen pollution near roadways.

This study uses stable isotopes of nitrogen in plant tissue and dry nitrogen deposition to examine the extent of nitrogen deposition along a gradient perpendicular to a major highway. The gradient spanned 400 meters perpendicular to a heavily trafficked section (33,000 cars and trucks per day) of I-76 in Rector, Pennsylvania. Passive samplers were deployed monthly for five months at six sites along the gradient to collect dry deposition of three N species: NH_3, HNO_3 and NO_2. The passive samplers were analyzed for concentration and isotopic composition. Additionally, we used two types of grasses (*Agrostis perennans* and *Panicum virgatum*) as biomonitors to examine the relative sources of nitrogen to plant tissue along the road gradient. The plants were grown in pots with similar potting soil, deployed along the gradient, and sampled once a month for five months for isotopic analysis.

Initial results indicate that concentrations of the three N species were significantly higher within 20 meters of the road. Furthermore, we expect that isotopic signatures of the dry deposition and plant tissue will reflect an automobile source near the highway, and a biogenic source at the far end of the gradient.

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Analysis of Critical Loads and Exceedance with Respect to Projected 2018 Sulfur and Nitrogen Deposition in the Northeastern US

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Determination of pollutant critical loads provides an ecosystem-based reference point for assessment of the magnitude of future deposition reduction goals and a target against which progress in deposition reductions can be evaluated. Considerable prior research and analysis has been conducted in the area of atmospheric deposition, ecosystem impacts, and critical loads of major pollutants in the Northeastern US. Despite extensive prior research, resource managers and policy makers have not yet had the benefit of integrated assessments of aquatic and terrestrial critical loads.

We have identified and mapped specific forested and aquatic ecosystems most sensitive to continued S and N deposition in New York and New England under the anticipated atmospheric conditions in 2018 at full implementation of current state and federal emission control programs. Steady-state terrestrial critical loads were developed using the previously established NEG/ECP regional assessment protocols. Steady-state aquatic critical loads were developed for subset of well-characterized northeastern surface waters using a modified form of the SSWC model employing an empirical correction DOC. Critical loads for all remaining surface waters were estimated using transfer functions developed between the well-characterized subset and watershed parameters developed via the terrestrial critical loads modeling.

Our analysis of critical load exceedance used Community Multiscale Air-Quality Model (CMAQ) results generated by NESCAUM as part of a recent Mid-Atlantic/Northeast Visibility Union (MANE-VU) modeling exercise. Air and precipitation concentration changes derived from the CMAQ results on a 12-km grid were be used in conjunction with Ecosystems Research Group, Ltd.'s High-Resolution Deposition Model (30-meter grid) to estimate deposition on a scale appropriate for critical loads assessment in the complex terrain of the Northeastern United States.

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Characterization of Nitrogen and Sulfur Deposition in and near Selected Sensitive Ecosystems for the NOx/SOx Secondary NAAQS Review

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The U.S. Environmental Protection Agency (EPA) is currently conducting a joint review of the existing secondary (welfare-based) National Ambient Air Quality Standards (NAAQS) for oxides of nitrogen (NOx) and sulfur (SOx). EPA is jointly assessing the science, risks, and policies relevant to protecting the public welfare associated with nitrogen and sulfur due to both their atmospheric interactions and ecological effects. This review used a case study analysis approach to address aquatic and terrestrial effects associated with ambient air concentrations of NOx and SOx as they relate to atmospheric deposition in areas known to be sensitive to acidification and nutrient enrichment. The air quality analyses for this review encompass the current emissions sources of nitrogen and sulfur, as well as atmospheric concentrations, estimates of deposition of total nitrogen, policy-relevant background, and non-ambient loadings of nitrogen and sulfur to ecosystems. Annual total emissions for 2002 from the National Emissions Inventory (NEI) were used to characterize the magnitude and spatial patterns in emissions of NO_x, NH_3, and SO_2 nationwide. Air quality model predictions are taken from applications of the Community Multiscale Air Quality (CMAQ) model. CMAQ was used to simulate concentrations and deposition for 2002 using meteorology and emissions.

Atmospheric deposition is the link between ambient concentrations and ecological effects. Spatial fields of deposition were created by using wet deposition measurements from the National Atmospheric Deposition Program (NADP) National Trends Network and dry deposition estimates from the Community Multiscale Air Quality (CMAQ) model for the year 2002. The spatial patterns of total nitrogen deposition reflect the combination of the deposition from the reduced and oxidized nitrogen components. The case study analyses examined the magnitude of nitrogen and sulfur deposition in sensitive areas, as well as the relative contributions of oxidized vs reduced forms of nitrogen. Overall, nitrogen deposition varied among the case study areas, and was higher in the East (ranging from 8-15 kg N/ha-yr) than the West (ranging from 3-11 kg N/ha-yr). Sulfur deposition also varied among the case study areas and was greater in the East (7-24 kg S/ha-yr) than the West (~2 kg S/ha-yr or less). Year-to year variation ranged from 1-3 kg/ha yr or less between 2002 and 2005 for both pollutants, with larger differences in the Kane Experimental Forest (PA) for sulfur. This analysis indicated that 2002 was generally representative of current levels of deposition for both pollutants, and was consistent with trends associated with 24 NADP/CASTNet sites in the East.

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Mercury in Indiana Watersheds

Martin Risch

Mercury-monitoring data, mercury-source inventories, precipitation data, streamflow data, and landscape characteristics were evaluated to understand the factors that influence the levels of mercury in the water and fish in Indiana watersheds. The watersheds studied were defined by a network of monitoring stations for mercury in streams and include most of the state.

Mercury concentrations in streams, annual stream mercury loads, and mercury concentrations in fish-tissue samples from the watersheds were examined graphically, statistically, and with factor analysis to identify geographic differences and the highest levels of mercury. Four factors were evaluated to explain the degree of differences in watershed mercury.

One, annual atmospheric mercury wet-deposition loads were estimated for the watersheds with National Atmospheric Deposition Program-Mercury Deposition Network concentrations and National Weather Service Cooperative Observer precipitation data. Stream mercury loads were positively correlated with atmospheric mercury loads. A few watersheds had stream mercury loads that were higher than the atmospheric mercury loads, but atmospheric loads typically were higher than stream mercury loads in most watersheds. The study found that sources other than mercury wet deposition could influence mercury levels in some watersheds.

Two, stationary sources of mercury emissions and annual mercury emissions were totaled for each watershed. Mercury concentrations in streams were positively correlated with the number of stationary sources and annual emissions. The study found that local and regional emissions could influence mercury levels in some watersheds.

Three, mercury was shown to present in wastewater discharges of 64 publicly owned treatment works sampled in Indiana. Mercury concentrations in streams were positively correlated with the number of permitted wastewater outfalls in a watershed, including the number of facilities with discharge capacities greater than one million gallons per day. The study found that mercury in wastewater discharges could influence mercury levels in some watersheds.

Four, surface areas and the percentages of each watershed area in various land-cover types were compiled for the watersheds. Multiple lines of evidence indicated that high mercury concentrations and high mercury stream loads in a watershed in central Indiana corresponded with a 12.6 percent urban land cover, one of the highest in the study. The urban land cover included 20 stationary sources of mercury emissions and 400 permitted wastewater outfalls, both among the highest in the study. In addition, evidence indicated that high mercury concentrations in a watershed in southern Indiana corresponded with 40 percent forest land cover, the highest in the study. Atmospheric mercury accumulation and dry deposition in the forest potentially contributed mercury to the watershed.

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National Air Emissions Monitoring Study (NAEMS) Finisher Hog Site NC3B: Observations of Farm Operation and Management

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The NAEMS provides a unique opportunity to continuously observe individual animal confined feeding operations over long periods of time (~ 2 years). Information is presented on the operation and management of a representative swine finisher farm (7200 head permitted capacity; 9 barns) in eastern North Carolina. Animal numbers in the three tested barns (880 capacity) being monitored ranged from ~700 to ~830 hogs/barn for each 20 week growth cycle. Death rates are low (< 2 head/barn/week). Growth rate varies within the population, with an initial grade out of 110 – 120 kg hogs at 16 wks (~185 hogs). A second grade out typically occurs between 17 – 19 wks, prior to final "runout" at 20 wks (~ 500 hogs). Five different feed formulations available on demand are used each cycle. Percent total nitrogen content of these formulations ranges from 2.2 to 3.5% N. Total feed consumed is over 180,000 kg per barn per 20 wk growth cycle. The barns are tunnel-ventilated (3 122-cm dia. and 2 91-cm dia. fans), but also contain baffles above the side-curtain walls that work in combination with the end wall curtain to ensure a well-mixed and uniform environment for the hogs. Default duty cycle is 10 min. for the stage 1 fan (91-cm dia.), till overridden by the difference between internal and exterior temperatures. As internal temperatures increase, various combinations of fans turn on and off changing the total volume of air exiting the barn. At the final fan stage, all fans are operating and the end wall curtain is fully lowered. Waste generated by the hogs is handled through a shallow pit (~48 cm from animal floor to bottom of the pit). The pit is drained (pull-plug) once per week and then flushed and filled with liquid from the nearby anaerobic lagoon. Sludge depth within the pit varies the length of the barn (2.5 to 12.5 cm) and undoubtedly with age, complicating attempts to quantify a nitrogen balance. TAN content and pH of pit liquid is sometimes higher (~ 1800 mg TAN/L; pH 7.6) than that found in the primary lagoon, depending on season of the year. Presence of a surface crust on the pit liquid will complicate modeling the air-water exchange of gases. The supplemental information gathered by the NAEMS project will facilitate the development of process-based models to describe gaseous emissions from animal confined feeding operations.

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Kicking the Bucket in Illinois

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The NADP's Central Analytical Laboratory (CAL) pulls six National Trends Network (NTN) and Atmospheric Integrated Research Monitoring Network (AIRMoN) buckets at random after cleaning each week to check for residual contamination. If these "clean" buckets are determined to still be dirty (i.e., have concentrations outside set control limits), they are rewashed and rechecked. However, a sample size of six buckets represents only two percent of the total buckets washed each week and distributed to NTN & AIRMoN sites.

The IL11 Bucket Study was designed to follow all buckets used at the IL11 site for both NTN and AIRMoN for an entire year. The study addressed these questions: Do some buckets need multiple cleanings to be certified clean? Does sample concentration influence bucket cleanliness after washing? Is there a limited life expectancy for the buckets after which they are difficult or impossible to clean effectively?

At the start of the study, new buckets were clean with all analyte-of-interest concentrations below detection limit. No bucket was sent back into the field unless all analytes were below detection limit. The number of times a bucket needed to be washed, the relationship between the bucket's cleanliness and the concentrations of analytes in the samples, and the concentration of the analytes found in "cleaned" buckets is discussed.

Sub-grid Dry Deposition Estimates from the Community Multiscale Air Quality Model (CMAQ)

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Atmospheric deposition is an important contributor to total ecosystem loadings of pollutants such as sulfur and nitrogen. Quantification of the deposition is often challenging as direct measurements of dry deposition are seldom available for individual ecosystems. Monitoring networks provide point estimates of deposition, but spatial interpolation of the values to other sites is not appropriate. CMAQ, a regional scale air quality models is capable of providing the needed estimates of deposition at all sites within the modeling domain. However, CMAQ currently only calculates a single deposition velocity per grid cell for each chemical.

Dry deposition velocity varies with underlying vegetation type due to differences in leaf area index, canopy height, and plant characteristics such as minimum stomatal resistance. The deposition velocity calculation for CMAQ is a combination of processes modeled in the land-surface component of the meteorological model and the chemical transport model. Since CMAQ is a grid-based model, the influences of the different land covers that comprise a grid cell are averaged in the meteorological model for use in the land-surface model. These grid-average values are carried forth from the meteorological model to the chemical transport model where chemical specific deposition velocity calculations are done. Ecological applications require information regarding the amount of deposition to subgrid land cover types. To be able to provide this information without requiring modification of the meteorological model, an approach has been implemented in CMAQ that disaggregates these grid-average values within CMAQ to allow output of dry deposition estimates for each land cover type within a grid in a manner consistent with meteorological model flux calculations. These land cover specific deposition estimates can then be used in studies such as critical loads analyses. Comparisons between the grid-average values of deposition flux and the land cover specific fluxes are presented.

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MERGANSER - A Geospatial Model to Predict Fish Mercury in New England Lakes

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Neil Kamman[6], Susy King[7], Eric Miller[8], Richard Moore[4], Diane Nacci[9], Alison Simcox[10],
Dick Smith[11] and Kate Williams[2]

All six New England states have issued health advisories for fish consumption in specific water bodies because of mercury contamination. But how does one assess the human and ecosystem exposure risk to methylmercury in lakes that are not monitored? MERGANSER (MERcury Geo-spatial AssessmeNtS for the New England Region) is a project designed to predict fish Hg (and loon Hg) in lakes based on watershed features, local mercury deposition estimates, and other parameters for which region-wide coverages can be readily generated. MERGANSER is constructed for the 4425 lakes in New England larger than 8 ha using fish Hg measurements from 811 sites spanning the period 1996-2006 and modeled Hg deposition for 2002. By restricting consideration to this ten-year period we minimize the complication of trends. We have developed a fish Hg index normalized to body length and fish species, and will also create a loon Hg index. MERGANSER uses an empirical multiple regression approach to identify the features and factors associated with the fish Hg index. Many parameters are relatively time invariant, such as areal extent of total wetland and various wetland types, wetland in contact with lakeshore, critical load exceedance (a proxy for pH), and topographic features,.. Other parameters are dynamic, such as mercury deposition, population, and land cover types. MERGANSER allows prediction of fish Hg in unmonitored lakes for present conditions, and it will suggest the magnitude and direction of fish Hg change with changes in dynamic predictors such as land use and other factors. Most notably, within the model uncertainty, MERGANSER will also quantify the sensitivity of fish Hg (and loon Hg) to changes in atmospheric Hg deposition. We anticipate that the MERGANSER approach will have broad transferability to other regions.

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The NADP North American Atmospheric Mercury Initiative

Tim Sharac[1], David Gay[2], David Schmeltz[1], Mark Olson[3] and Eric Prestbo[4]

The National Atmospheric Deposition Program launched a new initiative to monitor atmospheric mercury monitoring stations across North America. The NADP initiative is a collaborative effort involving many federal, state, and tribal agencies, academic researchers, and industry partners. The network envisioned will monitor, summarize, and report on concentrations of atmospheric mercury species (elemental, gaseous oxidized, and particulate-bound) from automated, continuous measuring systems; concentrations of total mercury in precipitation; and meteorological measurements. Currently 20 sites are participating to provide high-resolution, high-quality atmospheric data.

Datasets generated from this effort will be used to support many objectives, including estimating mercury dry deposition, assessing mercury source/receptor relationships, evaluating atmospheric models, and determining long-term trends. Future work will focus on continued development of a quality assurance program (enhancing data reduction, improving both the data management SOP and the field SOP, etc.) and providing data on the web.

We will also continue to reach out to a broad cross-section of agencies and institutions to coordinate mercury monitoring activities, building on current efforts and encouraging new collaborative partnerships. The presentation will summarize the status of the initiative including the structure for participation, standardization of methods, quality assurance, site locations, site liaison results, and data handling.

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Developing Critical Loads for Atmospheric Deposition of Nitrogen to High Alpine Lakes in the Pacific Northwest: Preliminary Results

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Excessive nitrogen from atmospheric deposition can be an important component of eutrophication in some aquatic ecosystems. Nitrogen limitation of alpine lakes makes these ecosystems especially sensitive to additional inputs of atmospheric nitrogen because they have adapted to an oligotrophic environment and may have less capacity to use additional inputs. Previous work at Rocky Mountain (ROMO) National Park in Colorado indicated that nitrogen deposition at levels greater than 1.5 kg/ha-yr was sufficient to alter trophic state in high alpine lakes. In Washington State, long term National Atmospheric Deposition Program (NADP) monitoring at low elevation (< ~1,500 feet) has shown deposition amounts around the 1.5 kg/ha-yr effects level determined for ROMO. However, deposition data for higher elevations in Washington is lacking. It is hypothesized that at higher elevations, greater amounts of precipitation leads to greater nitrogen deposition when compared to low elevation NADP sites. The U.S. Geological Survey (USGS) initiated a study with the National Park Service to address this question and work to develop critical loads for the Pacific Northwest. Similar to ROMO, our approach to develop a critical load for nitrogen deposition is based on shifts in sediment diatoms at 12 lakes in Mount Rainier, North Cascades, and Olympic National Parks. Sites were located at elevations higher than 4,000 feet with minimal forest cover to increase the potential nitrogen deposition to these lakes. Historical data from the sites showed that surface water was low in nitrogen and phosphorus indicating that the lakes are oligotrophic and potentially susceptible to increases in these nutrients. The DIN:TP ratio of surface water, an indicator of nutrient limitation for phytoplankton, ranged from 0.2 to 12.8 across all sites. Olympic National Park was the only park that showed consistently low DIN:TP ratios and evidence of nitrogen limitation. During summer 2008, bulk nitrogen deposition was determined using ion exchange resin collectors and are currently being analyzed. Five collectors were installed at each lake, and rainwater was collected in a collapsible bag attached to the outlet of the resin column at three of the five collectors. Precipitation volumes were variable within and across the three parks indicating the heterogeneity in precipitation in this region. During summer 2009, a sediment core from each lake will be collected for diatom analysis and dated to identify if and when shifts to nitrophilic species occur. This presentation will outline preliminary data collected to date and discuss work planned for the final field season in 2010.

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Examination of Different Approaches to Estimating Ammonia Emissions from Poultry Operations

John Sherwell[1], Anand Yegnan[2], Surya Ramaswamy[2] and Mark Garrison[2]

Anthropogenic emissions of ammonia (NH3) have the potential to contribute to nutrient loading in sensitive estuaries and coastal waters such as the Chesapeake Bay, both directly and indirectly since NH3 can combine in the atmosphere with nitrates (NO3) that are formed from the emissions of nitrogen oxides (NOx) from power plant and other combustion sources to form particulate nitrate. Particulate nitrate, in turn, makes up a significant part of the airborne nitrogen load to the Bay through deposition processes. NH3 can also combine (preferentially) with sulfates to form ammonium sulfate (NH4)2SO4. The aerosols formed in this manner can play a significant role in ambient concentrations of fine particulate matter (PM2.5). This paper provides a critical look at different emissions estimation techniques for NH3 from poultry operations, particularly in the area surrounding the Chesapeake Bay, and at the range of emissions predicted by different techniques. Estimates that are not representative of actual non-point source NH3 emissions could significantly affect our understanding of these atmospheric transformations, and significantly affect our ability to estimate atmospheric contribution to nitrogen loading and PM2.5 concentrations. The paper summarizes the findings and points to the need to better understand emissions from these types of sources.

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Status of Mercury Monitoring in Maryland

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There is a state-wide fish consumption advisory for all fresh water impoundments in Maryland. These advisories are linked to the inputs of mercury by atmospheric deposition. The links between the fish tissue burden of methyl mercury and the precursor inputs of mainly inorganic forms from the atmosphere is complex. The State is seeking cost effective monitoring programs that can add to the state of science in understanding the biogeochemistry of mercury and also provide tools to understand the trends in target species as local and national mercury controls are implemented. Comprehensive mercury control requirements at coal-fired electricity generating units in the state was recently passed. In addition comprehensive federal rules are anticipated. Establishing current baselines of deposition and mercury in selected target species will allow the efficacy of emission controls efforts to be assessed. This poster will describe four programs currently being implemented to address these objectives. These are:

- Ambient air and wet deposition monitoring,
- Soil flux and dry deposition measurements including the use of surrogate surfaces,
- Young-of-the-year surveys, and
- Instrumented watershed studies.

The status of the programs and data highlights will be discussed.

Linkage between an Advanced Air Quality Model and a Mechanistic Watershed Model

Krish Vijayaraghavan[1*], Joel Herr[2*], Shu-Yun Chen[1], Eladio M. Knipping[3] and Robert Goldstein[3]

Historically the air quality modeling and watershed modeling communities have tended to operate in distinct spheres. However, in cases where water quality and subsequent ecosystem impairment is due, in part, to atmospheric deposition, it is useful to directly link the effect of atmospheric sources to water quality. Also, air monitoring data required by watershed models are often sparse. These two issues are addressed in this work wherein we describe the development of a software linkage between an air quality model and a watershed model: (1) AMSTERDAM (the Advanced Modeling System for Transport, Emissions, Reactions and Deposition of Atmospheric Matter) and (2) WARMF (the Watershed Analysis Risk Management Framework). AMSTERDAM is a state-of-the-science 3-D multi-pollutant air quality model derived from EPA's Community Multiscale Air Quality model (CMAQ). WARMF is an advanced model and decision support system for watershed planning and Total Maximum Daily Load (TMDL) analysis. Results from this multi-media framework are presented to compare the effect of measured and modeled meteorology and dry and wet deposition of gaseous and particulate sulfur and nitrogen species on flow rates and aqueous concentrations of these species in the Catawba River Watershed in North and South Carolina.

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Relevance of the Plume-in-Grid Treatment of Point Sources to the Modeling of Atmospheric Mercury

Krish Vijayaraghavan [1*], Prakash Karamchandani [1], Rochelle Balmori [1] and Leonard Levin[2]

AMSTERDAM (the Advanced Modeling System for Transport, Emissions, Reactions and Deposition of Atmospheric Matter) is a multi-pollutant model derived from EPA's Community Multiscale Air Quality model (CMAQ) and offers sophisticated treatments of ozone, PM and mercury processes. The model includes a state-of-the-science analysis of the atmospheric dynamics and chemistry of mercury and other species in plumes from elevated point sources. This paper presents the application of this plume-in-grid model to simulate the wet and dry deposition of mercury species over the United States during a month in 2002. AMSTERDAM is applied here over a domain that covers the central and eastern United States and has a horizontal grid resolution of 12 km with 19 vertical levels extending up to the tropopause. Model performance is evaluated by comparison of simulated wet deposition of mercury with 2002 wet deposition data from the Mercury Deposition Network (MDN) in the National Atmospheric Deposition Program (NADP). The importance of using an explicit treatment of the plumes from 158 large coal-fired power plants in the United States on local and regional mercury deposition is presented.

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Impacts of Nitrogen and Sulfur Deposition on the Growth of Red Spruce and Sugar Maple in the United States

Jennifer N. Phelan[1], Paramita Sinha[1], Van Houtven George[1], Deerhake Marion[1], Randall G. Waite[2*], Anne W. Rea[2] and Ginger M. Tennant[2]

Nitrogen (N) and sulfur (S) deposition in forest systems can have positive or negative impacts on tree growth. The growth of many forests is limited by N availability, and therefore N and S deposition may stimulate growth. However, N and S additions can sometimes be greater than that required by trees and negatively impact tree health. In cases where N and S deposition exceeds the critical acid load of a site, tree health and growth may be reduced directly and indirectly due to soil nutrient imbalances caused by leaching of base cations from the soil. To determine the relationship between N and S deposition and tree growth, analyses comparing the growth of sugar maple and red spruce and critical load exceedances (positive and negative) were conducted. Sugar maple and red spruce were selected as the test species because both have been shown to experience decline in areas of high N and S deposition. Critical loads were calculated using the simple mass balance model and three different levels of protection to tree health (Bc/Al soil solution ratio = 0.6, 1.2 and 10.0), and were compared against 2002 N and S deposition to estimate critical load exceedance. Annual tree growth estimates for sugar maple and red spruce were obtained from the U.S. Forest Service Forest Inventory and Analysis (FIA) database. Multivariate regression analyses were conducted using a quadratic functional form to test for an inverted U-shaped relationship between tree growth and critical load exceedance.

Although none of coefficients for the quadratic curve were significant at the $p=0.05$ level, the estimated parameters for both species suggested an inverted U-shaped relationship between tree growth and critical load exceedance. In addition, the data revealed that the highest protection level critical load (Bc/Al=10.0) best described the relationship between N and S deposition and the growth of sugar maple and red spruce. Considering the implications of the results across the ranges of the two species, tree health may have been compromised in at least 80% of plots in 13 of the 24 states where sugar maple is found and in 100% of plots in 5 of the 8 states where red spruce grows. These results suggest that the health of sugar maple and red spruce may be compromised in multiple locations throughout their natural ranges.

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Submicron Particle Number Fluxes and Size Distributions above a Loblolly Pine Forest in the Southeast U.S.

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Representative parameterizations of particle dry deposition are required for accurate air quality model prediction of particulate matter concentrations. While several models of size-specific particle deposition velocity are available, observations vary significantly across vegetation types within size categories. Additional data are needed to further test and refine these models for surface types and chemical environments not previously characterized. We present bulk particle number fluxes measured above a Loblolly pine canopy (Forest-Atmosphere Carbon Transfer and Storage site, Chapel Hill, NC) using the eddy covariance technique. Size-specific deposition velocities for particles between 20 and 70 nm aerodynamic diameter (D_p) are inferred by combining bulk number fluxes (3 nm – 3 µm D_p) and particle size distributions (10 – 400 nm). Particle number concentrations and size distributions are controlled by primary emissions from local mobile sources and nucleation events. Particle number fluxes are largely controlled by turbulent mixing and deposition velocities are within the range of values observed over other forests. Deposition velocity and particle size vary inversely between 20 – 70 nm D_p, indicating the importance of the boundary layer resistance (R_b), particularly for the smallest particles at low friction velocities.

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NADP Measurement Confidence Intervals for Critical Load Contingency Planning

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Accounting for the variability inherent in National Atmospheric Deposition Program (NADP) measurements is important for prudent implementation of critical load contingency plans. The overall variability of NADP measurements is used to compute confidence limits for annual wet-deposition estimates, which provide confirmation of whether annual wet-deposition loads are increasing or decreasing from year to year.

The U.S. Geological Survey, Water Resources Discipline, Branch of Quality Systems (USGS) operates a Co-located Sampler Program to estimate the overall variability of NADP measurements. For more than 17 years this program has been an integral part of the external quality assurance project for NADP. Co-located samplers are defined by the USGS program as two sets of identical wet/dry precipitation collectors and precipitation depth gages located at the same site within 5 to 30 meters of each other. Replicate weekly precipitation samples and depth measurements were obtained from 47 co-located NADP National Trends Network sites during 1989-2006. These data were compiled to estimate annual dissolved wet-deposition of selected constituents for each of the paired sites.

Average relative standard deviations of annual wet-deposition measurements for nitrate plus ammonium as nitrogen (N), sulfate, and hydrogen ion were calculated from the co-located program replicate data. These data were used to compute statistical confidence intervals. The confidence intervals broaden as concentration increases. For example, the 90% confidence interval for annual N wet-deposition is 1.7 to 2.4 kilograms per hectare (kg/ha) for a measurement of 2 kg/ha. For a measurement of 4 kg/ha, the confidence interval is 3.4 to 4.8 kg/ha. In other words, one can discern between 2 kg/ha and 1.7 kg/ha with 90% confidence.

The confidence intervals can be used by natural resources managers to determine whether observed changes in annual wet-deposition should trigger contingency plans to control atmospheric emissions sources. In addition, they may be used to decide whether the atmospheric wet-deposition is proceeding along a path toward the critical load.

Developing the Critical Loads for the Acidification of Some Lake- Watersheds in the Adirondack Region of New York

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Critical loads are a useful tool to guide emission control strategies that will lead to the recovery of ecosystems in response to decreases in atmospheric deposition. In an ongoing study, we are developing critical loads and target loads of acidity for lake-watersheds in Adirondack region of New York. We examined the response of lake-watersheds to a range of future scenarios of decreases in atmospheric nitrate and sulfate deposition. The projects involves examining critical and target loads for 20 lake-watersheds. For this presentation we present results for Constable Pond, a chronically acidic, thin till drainage lake and Arbutus Lake, a moderate ANC, medium till drainage lake as case studies. The project was conducted with the dynamic watershed model PnET-BGC. We ran the model under different scenarios of combinations of decreases in atmospheric nitrate and sulfate deposition ranging from 0% to 100% that was ramped down from 2008 to 2020 and remained constant thereafter until steady-state was attained. Critical loads were determined from steady-state values, while target loads were determined for various years approaching steady-state. Model calculations suggest that Adirondack lake-watersheds have become sensitive to ongoing inputs of acidic deposition due to the long-term loss of exchangeable base cations in soil from historical acidic deposition. As a result the ANC and soil %base saturation (BS) of the lake-watersheds following decreases in acidic deposition never reach values that occurred prior to the Industrial Revolution (before the onset of acidic deposition). The target and critical loads of Adirondack lakes greatly depend on rates of base cation supply, and the resulting initial ANC and soil base status. Our results show that recovery of lake ANC and soil %BS is accomplished most effectively by equivalent decreases in sulfate deposition compared to nitrate deposition. As part of this study we also examine aquatic and forest biological indicators of acidification stress.

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NTN Map and Site Listings

National Atmospheric Deposition Program
National Trends Network

Map of the United States (with insets for Alaska, Puerto Rico, and the Virgin Islands) showing National Trends Network monitoring sites labeled by state and site number.

Virgin Islands
VI 01

Puerto Rico
PR 20

Alaska
AK
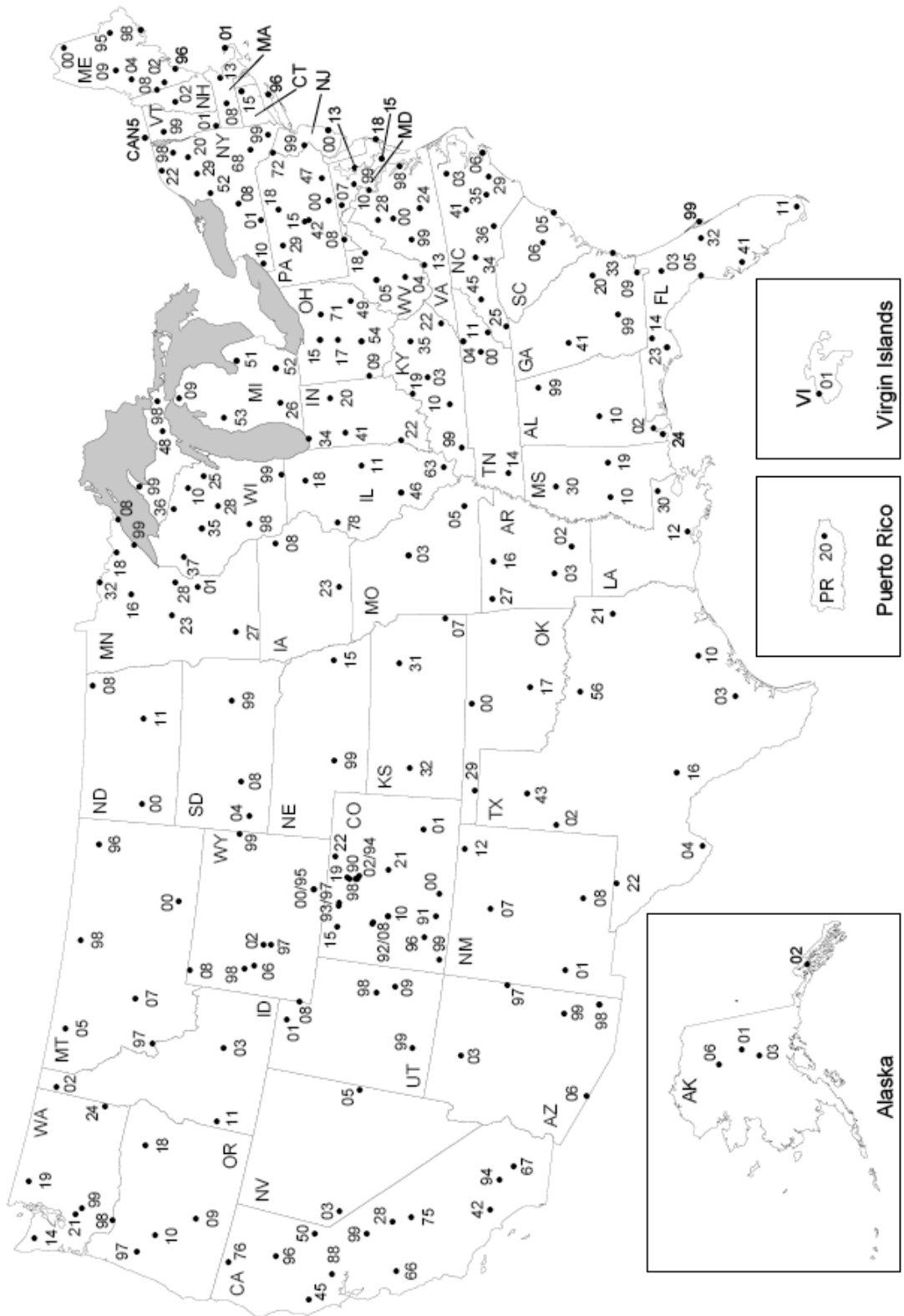
National Atmospheric Deposition Program/National Trends Network Sites
July 31, 2009

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Alabama				
AL02	Delta Elementary	MDN	Mobile Bay Nat'l Estuary Prog & Dauphin Island Sea Lab	06/01
AL10	Black Belt Research & Extension Center		US Geological Survey	08/83
AL24	Bay Road	MDN	Mobile Bay Nat'l Estuary Prog & Dauphin Island Sea Lab	05/01
AL99	Sand Mountain Research & Extension Center		Tennessee Valley Authority	10/84
Alaska				
AK01	Poker Creek		USDA Forest Service	12/92
AK02	Juneau		USDA Forest Service/University of Alaska Southeast	06/04
AK03	Denali NP - Mount McKinley		National Park Service - Air Resources Division	06/80
AK06	Gates of the Artic NP - Bettles		National Park Service - Air Resources Division	11/08
Arizona				
AZ03	Grand Canyon NP - Hopi Point		National Park Service - Air Resources Division	08/81
AZ06	Organ Pipe Cactus NM		National Park Service - Air Resources Division	04/80
AZ97	Petrified Forest NP-Rainbow Forest		National Park Service - Air Resources Division	12/02
AZ98	Chiricahua		US Environmental Protection Agency-CAMD	02/99
AZ99	Oliver Knoll		US Geological Survey	08/81
Arkansas				
AR02	Warren 2WSW		US Geological Survey	05/82
AR03	Caddo Valley		US Geological Survey	12/83
AR16	Buffalo NR - Buffalo Point		National Park Service - Air Resources Division	07/82
AR27	Fayetteville		US Geological Survey	04/80
California				
CA28	Kings River Experimental Watershed		USDA Forest Service/Pacific Southwest Research Station	04/07
CA42	Tanbark Flat		USDA Forest Service	01/82
CA45	Hopland		US Geological Survey	10/79
CA50	Sagehen Creek		US Geological Survey	11/01
CA66	Pinnacles NM - Bear Valley		National Park Service - Air Resources Division	11/99
CA67	Joshua Tree NP - Black Rock		National Park Service - Air Resources Division	09/00
CA75	Sequoia NP - Giant Forest	MDN	National Park Service - Air Resources Division	07/80
CA76	Montague		US Geological Survey	06/85
CA88	Davis		US Geological Survey	09/78
CA94	Converse Flats	MDN	Big Bear Municipal Water District	05/06
CA96	Lassen Volcanic NP - Manzanita Lake		National Park Service - Air Resources Division	06/00
CA99	Yosemite NP - Hodgdon Meadow		National Park Service - Air Resources Division	12/81
Colorado				
CO00	Alamosa		US Geological Survey	04/80
CO01	Las Animas Fish Hatchery		US Geological Survey	10/83
CO02	Niwot Saddle		NSF-Institute of Artic & Alpine Research/University of CO	06/84
CO08	Four Mile Park		US Environmental Protection Agency-CAMD	12/87
CO10	Gothic		US Environmental Protection Agency-CAMD	02/99
CO15	Sand Spring		Bureau of Land Management	03/79
CO19	Rocky Mountain NP - Beaver Meadows		National Park Service - Air Resources Division	05/80
CO21	Manitou		USDA Forest Service	10/78
CO22	Pawnee		NSF-Shortgrass Steppe LTER/Colorado State University	05/79
CO90	Niwot Ridge-Southeast		NSF-Institute of Artic & Alpine Research/University of CO	01/06

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
CO91	Wolf Creek Pass		USDA Forest Service	05/92
CO92	Sunlight Peak		US Environmental Protection Agency-CAMD	01/88
CO93	Buffalo Pass - Dry Lake		USDA Forest Service	10/86
CO94	Sugarloaf		US Environmental Protection Agency-CAMD	11/86
CO96	Molas Pass		USDA Forest Service	07/86
CO97	Buffalo Pass - Summit Lake	MDN	USDA Forest Service	02/84
CO98	Rocky Mountain NP - Loch Vale		USGS/Colorado State University	08/83
CO99	Mesa Verde NP - Chapin Mesa	MDN	US Geological Survey	04/81
Connecticut				
CT15	Abington		US Environmental Protection Agency-CAMD	01/99
Florida				
FL03	Bradford Forest		St John's River Water Management District	10/78
FL05	Chassahowitzka NWR	MDN	US Fish & Wildlife Service - Air Quality Branch	08/96
FL11	Everglades NP - Research Center	MDN	National Park Service - Air Resources Division	06/80
FL14	Quincy		US Geological Survey	03/84
FL23	Sumatra		US Environmental Protection Agency-CAMD	01/99
FL32	Orlando		Seminole County Public Works Department	12/05
FL41	Verna Well Field		US Geological Survey	08/83
FL99	Kennedy Space Center		NASA/Dynamac Corporation	08/83
Georgia				
GA09	Okefenokee NWR	MDN	US Fish & Wildlife Service - Air Quality Branch	06/97
GA20	Bellville		US Environmental Protection Agency-CAMD	04/83
GA33	Sapelo Island	MDN	NSF/UGA, NOAA-NERR, & GA Dept of Natural Resources	11/02
GA41	Georgia Station		SAES-University of Georgia	10/78
GA99	Chula		US Geological Survey	02/94
Idaho				
ID02	Priest River Experimental Forest		USDA Forest Service	12/02
ID03	Craters of the Moon NM	MDN	National Park Service - Air Resources Division	08/80
ID11	Reynolds Creek		US Geological Survey	11/83
Illinois				
IL11	Bondville	AIRMoN/MDN	US Environmental Protection Agency-CAMD	02/79
IL18	Shabbona		SAES-University of Illinois	05/81
IL46	Alhambra		US Environmental Protection Agency-CAMD	01/99
IL63	Dixon Springs Agricultural Center		SAES-University of Illinois	01/79
IL78	Monmouth		US Geological Survey	01/85
Indiana				
IN20	Roush Lake	MDN	US Geological Survey	08/83
IN22	Southwest-Purdue Agricultural Center		US Geological Survey	09/84
IN34	Indiana Dunes NL	MDN	National Park Service - Air Resources Division	07/80
IN41	Agronomy Center for Research and Extension		SAES-Purdue University	07/82
Iowa				
IA08	Big Springs Fish Hatchery		US Geological Survey	08/84
IA23	McNay Memorial Research Center		US Geological Survey	09/84

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Kansas				
KS07	Farlington Fish Hatchery		US Geological Survey	03/84
KS31	Konza Prairie		SAES-Kansas State University	08/82
KS32	Lake Scott State Park	MDN	US Geological Survey	03/84
Kentucky				
KY03	Mackville		US Geological Survey	11/83
KY10	Mammoth Cave NP-Houchin Meadow	MDN	National Park Service - Air Resources Division	08/02
KY19	Seneca Park		US Geological Survey	10/03
KY22	Lilley Cornett Woods		NOAA-Air Resources Lab	09/83
KY35	Clark State Fish Hatchery		US Geological Survey	08/83
KY99	Mulberry Flats		TVA/Murray State University	12/94
Louisiana				
LA12	Iberia Research Station		US Geological Survey	11/82
LA30	Southeast Research Station		US Geological Survey	01/83
Maine				
ME00	Caribou	MDN	NOAA-Air Resources Lab	04/80
ME02	Bridgton	MDN	EPA/Maine Dept of Environmental Protection	09/80
ME04	Carrabassett Valley		US Environmental Protection Agency-CAMD	03/02
ME08	Gilead		US Geological Survey	09/99
ME09	Greenville Station	MDN	EPA/Maine Dept of Environmental Protection	11/79
ME96	Casco Bay - Wolfe's Neck Farm	MDN	EPA/Maine Dept of Environmental Protection	01/98
ME98	Acadia NP - McFarland Hill	MDN	National Park Service - Air Resources Division	11/81
Maryland				
MD07	Catoctin Mountain Park		National Park Service - Air Resources Division	05/03
MD08	Piney Reservoir	MDN	MD DNR/University of Maryland-Appalachian Lab	06/04
MD13	Wye		SAES-University of Maryland	03/83
MD15	Smith Island		NOAA-Air Resources Lab	06/04
MD18	Assateague Island NS - Woodcock		Maryland Department of Natural Resources	09/00
MD99	Beltsville	MDN	Maryland Department of Natural Resources	06/04
Massachusetts				
MA01	North Atlantic Coastal Lab	MDN	National Park Service - Air Resources Division	12/81
MA08	Quabbin Reservoir		Northeast States for Coordinated Air Use Management	03/82
MA13	East		Northeast States for Coordinated Air Use Management	02/82
Michigan				
MI09	Douglas Lake		SAES-Michigan State University	07/79
MI26	Kellogg Biological Station		SAES-Michigan State University	06/79
MI48	Seney NWR - Headquarters	MDN	US Fish & Wildlife Service - Air Quality Branch	11/00
MI51	Unionville		US Environmental Protection Agency-CAMD	01/99
MI52	Ann Arbor		US Environmental Protection Agency-CAMD	01/99
MI53	Wellston		USDA Forest Service	10/78
MI98	Raco		US Environmental Protection Agency-CAMD	05/84
MI99	Chassell		National Park Service - Air Resources Division	02/83
Minnesota				
MN01	Cedar Creek		Minnesota Pollution Control Agency	12/96
MN08	Hovland		Minnesota Pollution Control Agency	12/96
MN16	Marcell Experimental Forest	MDN	USDA Forest Service	07/78
MN18	Fernberg	MDN	US Environmental Protection Agency-CAMD	11/80

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
MN23	Camp Ripley	MDN	US Geological Survey	10/83
MN27	Lamberton	MDN	Minnesota Pollution Control Agency	01/79
MN28	Grindstone Lake		Minnesota Pollution Control Agency	12/96
MN32	Voyageurs NP - Sullivan Bay		National Park Service - Air Resources Division	05/00
MN99	Wolf Ridge		Minnesota Pollution Control Agency	12/96
Mississippi				
MS10	Clinton		US Geological Survey	07/84
MS19	Newton		NOAA-Air Resources Lab	11/86
MS30	Coffeeville		Tennessee Valley Authority	07/84
Missouri				
MO03	Ashland Wildlife Area		US Geological Survey	10/81
MO05	University Forest		US Geological Survey	10/81
Montana				
MT00	Little Bighorn Battlefield NM		US Geological Survey	07/84
MT05	Glacier NP - Fire Weather Station	MDN	National Park Service - Air Resources Division	06/80
MT07	Clancy		US Geological Survey	01/84
MT96	Poplar River		EPA/Fort Peck Tribes	12/99
MT97	Lost Trail Pass		USDA Forest Service	09/90
MT98	Havre - Northern Agricultural Research Center		US Geological Survey	07/85
Nebraska				
NE15	Mead	MDN	SAES-University of Nebraska	07/78
NE99	North Platte Agricultural Experiment Station		US Geological Survey	09/85
Nevada				
NV03	Smith Valley		US Geological Survey	08/85
NV05	Great Basin NP - Lehman Caves		National Park Service - Air Resources Division	01/85
New Hampshire				
NH02	Hubbard Brook		USDA Forest Service	07/78
New Jersey				
NJ00	Edwin B Forsythe NWR		US Fish & Wildlife Service - Air Quality Branch	10/98
NJ99	Washington Crossing		US Environmental Protection Agency	08/81
New Mexico				
NM01	Gila Cliff Dwellings NM		New Mexico Environment Department - AQB	07/85
NM07	Bandelier NM		DOE-Los Alamos National Lab/National Park Service	06/82
NM08	Mayhill		US Geological Survey	01/84
NM12	Capulin Volcano NM		New Mexico Environment Department - AQB	11/84
New York				
NY01	Alfred		US Geological Survey	08/04
NY08	Aurora Research Farm		USDA/Cornell University	04/79
NY10	Chautauqua		US Geological Survey	06/80
NY20	Huntington Wildlife	MDN	EPA/SUNY-College of Environmental Science & Forestry	10/78
NY22	Akwesasne Mohawk - Fort Covington		US Environmental Protection Agency - CAMD	08/99
NY29	Moss Lake		US Geological Survey	07/03
NY52	Bennett Bridge		EPA/State University of New York-Oswego	06/80
NY68	Biscuit Brook	MDN	US Geological Survey	10/83
NY96	Cedar Beach, Southold		EPA/Suffolk Dept of Health Service-Peconic Estuary Program	11/03
NY98	Whiteface Mountain		US Geological Survey	07/84
NY99	West Point	MDN	US Geological Survey	09/83

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
North Carolina				
NC03	Lewiston		North Carolina State University	10/78
NC06	Beaufort		US Environmental Protection Agency-CAMD	01/99
NC25	Coweeta		USDA Forest Service	07/78
NC29	Hofmann Forest		North Carolina State University	07/02
NC34	Piedmont Research Station		North Carolina State University	10/78
NC35	Clinton Crops Research Station		North Carolina State University	10/78
NC36	Jordan Creek		US Geological Survey	10/83
NC41	Finley Farms		North Carolina State University	10/78
NC45	Mount Mitchell		North Carolina State University	11/85
North Dakota				
ND00	Theodore Roosevelt NP-Painted Canyon		National Park Service-Air Resources Division	01/01
ND08	Icelandic State Park		US Geological Survey	10/83
ND11	Woodworth		US Geological Survey	11/83
Ohio				
OH09	Oxford		US Geological Survey	08/84
OH15	Lykens		US Environmental Protection Agency-CAMD	01/99
OH17	Delaware		USDA Forest Service	10/78
OH49	Caldwell		US Geological Survey	09/78
OH54	Deer Creek State Park		US Environmental Protection Agency-CAMD	01/99
OH71	Wooster		US Geological Survey	09/78
Oklahoma				
OK00	Salt Plains NWR		US Geological Survey	12/83
OK17	Great Plains Apiaries		NOAA-Air Resources Lab	03/83
OK29	Goodwell Research Station		US Geological Survey	01/85
Oregon				
OR09	Silver Lake Ranger Station		US Geological Survey	08/83
OR10	H J Andrews Experimental Forest	MDN	USDA Forest Service	05/80
OR18	Starkey Experimental Forest		US Geological Survey	03/84
OR97	Hyslop Farm		US Environmental Protection Agency-CAMD	04/83
Pennsylvania				
PA00	Arendtsville	MDN	US Environmental Protection Agency-CAMD	01/99
PA15	Penn State	AIRMoN	NOAA-Air Resources Lab	06/83
PA18	Young Woman's Creek		US Geological Survey	04/99
PA29	Kane Experimental Forest		USDA Forest Service	07/78
PA42	Leading Ridge		SAES-Pennsylvania State University	04/79
PA47	Millersville	MDN	Pennsylvania Department of Environmental Protection/PSU	11/02
PA72	Milford	MDN	USDA Forest Service	12/83
Puerto Rico				
PR20	El Verde		USDA Forest Service	02/85
South Carolina				
SC05	Cape Romain NWR	MDN	US Fish & Wildlife Service - Air Quality Branch	11/00
SC06	Santee NWR		US Geological Survey	07/84

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
South Dakota				
SD04	Wind Cave National Park-Elk Mountain		National Park Service - Air Resources Division	11/02
SD08	Cottonwood		NOAA-Air Resources Lab	10/83
SD99	Huron Well Field		US Geological Survey	11/83
Tennessee				
TN00	Walker Branch Watershed	AIRMoN	DOE/Oak Ridge National Lab/Lockheed-Martin	03/80
TN04	Speedwell		US Environmental Protection Agency-CAMD	01/99
TN11	Great Smoky Mountain NP - Elkmont	MDN	National Park Service - Air Resources Division	08/80
TN14	Hatchie NWR		Tennessee Valley Authority	10/84
Texas				
TX02	Muleshoe NWR		US Geological Survey	06/85
TX03	Beeville		NOAA-Air Resources Lab	02/84
TX04	Big Bend NP - K-Bar		National Park Service - Air Resources Division	04/80
TX10	Attwater Prairie Chicken NWR		US Geological Survey	07/84
TX16	Sonora		US Geological Survey	06/84
TX21	Longview	MDN	Texas Commission on Environmental Quality	06/82
TX22	Guadalupe Mountains NP-Frijole Ranger Stn		US Geological Survey	06/84
TX43	Cañónceta		Texas A&M University/Texas Agrilife Research	07/07
TX56	LBJ National Grasslands		US Geological Survey	09/83
Utah				
UT01	Logan		US Geological Survey	12/83
UT08	Murphy Ridge		BP Amoco	03/86
UT09	Canyonlands NP - Island in the Sky		National Park Service - Air Resources Division	11/97
UT98	Green River		US Geological Survey	04/85
UT99	Bryce Canyon NP - Repeater Hill		National Park Service - Air Resources Division	01/85
Vermont				
VT01	Bennington		US Geological Survey	04/81
VT99	Underhill	AIRMoN/MDN	US Geological Survey	06/84
Virgin Islands				
VI01	Virgin Islands NP - Lind Point		National Park Service - Air Resources Division	04/98
Virginia				
VA00	Charlottesville		US Geological Survey	10/84
VA13	Horton's Station		Tennessee Valley Authority	07/78
VA24	Prince Edward		US Environmental Protection Agency-CAMD	01/99
VA28	Shenandoah NP - Big Meadows	MDN	National Park Service - Air Resources Division	05/81
VA98	Harcum	MDN	Virginia Department of Environmental Quality	08/04
VA99	Natural Bridge Station		Virginia Department of Environmental Quality	07/02
Washington				
WA14	Olympic NP - Hoh Ranger Station		National Park Service - Air Resources Division	05/80
WA19	North Cascades NP-Marblemount Ranger Stn		US Geological Survey	02/84
WA21	La Grande		US Environmental Protection Agency-CAMD	04/84
WA24	Palouse Conservation Farm		US Geological Survey	08/85
WA98	Columbia River Gorge		USDA Forest Service - Pacific Northwest Region	05/02
WA99	Mount Rainier NP - Tahoma Woods		National Park Service - Air Resources Division	10/99

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
West Virginia				
WV04	Babcock State Park		US Geological Survey	09/83
WV05	Cedar Creek State Park		US Environmental Protection Agency-CAMD	01/99
WV18	Parsons		USDA Forest Service	07/78
Wisconsin				
WI10	Potawatomi	MDN	EPA/Forest County Potawatomi Community	06/05
WI25	Suring		Wisconsin Department of Natural Resources	01/85
WI28	Lake Dubay		Wisconsin Department of Natural Resources	06/82
WI35	Perkinstown		US Environmental Protection Agency-CAMD	01/99
WI36	Trout Lake	MDN	Wisconsin Department of Natural Resources	01/80
WI37	Spooner		Wisconsin Department of Natural Resources	06/80
WI98	Wildcat Mountain		Wisconsin Department of Natural Resources	08/89
WI99	Lake Geneva	MDN	Wisconsin Department of Natural Resources	06/84
Wyoming				
WY00	Snowy Range		USDA Forest Service	04/86
WY02	Sinks Canyon		Bureau of Land Management	08/84
WY06	Pinedale		Bureau of Land Management	01/82
WY08	Yellowstone NP - Tower Falls	MDN	National Park Service - Air Resources Division	06/80
WY95	Brooklyn Lake		USDA Forest Service	09/92
WY97	South Pass City		USDA Forest Service/Bridger Teton NF	04/85
WY98	Gypsum Creek		USDA Forest Service/Bridger Teton NF	12/84
WY99	Newcastle		Bureau of Land Management	08/81
Canada				
CAN5	Frelighsburg		US Geological Survey	10/01

131

AIRMON MAP AND SITE LISTINGS

National Atmospheric Deposition Program
Atmospheric Integrated Research Monitoring Network
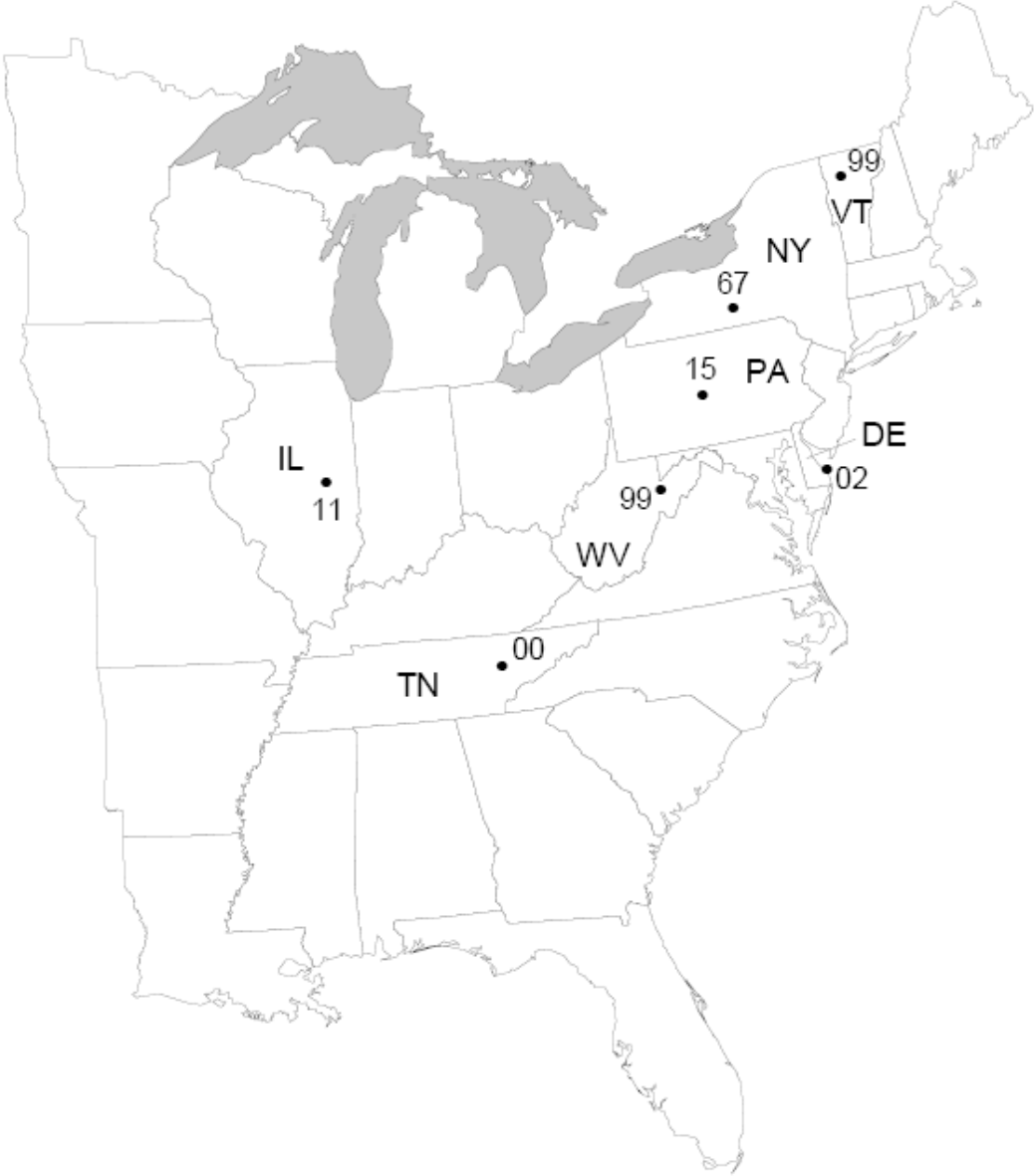
NADP/Atmospheric Integrated Research Monitoring Network Sites

July 31, 2009

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

MDN MAP AND SITE LISTINGS

National Atmospheric Deposition Program/Mercury Deposition Network Sites
July 31, 2009

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Alabama				
AL02	Delta Elementary	NTN	Mobile Bay National Estuary Prog & Dauphin Island Sea Lab	06/01
AL03	Centreville		Southern Company/Atmospheric Research and Analysis, Inc	06/00
AL24	Bay Road	NTN	Mobile Bay National Estuary Prog & Dauphin Island Sea Lab	05/01
Alaska				
AK06	Gates of the Artic NP - Bettles	NTN	National Park Service - Air Resources Division	11/08
AK98	Kodiak		State of Alaska Department of Environmental Conservation	09/07
Arizona				
AZ02	Sycamore Canyon		Arizona Department of Environmental Quality/EPA	02/06
California				
CA20	Yurok Tribe-Requa		Electric Power Research Institute	08/06
CA75	Sequoia NP-Giant Forest	NTN	National Park Service - Air Resources Division	07/03
CA94	Converse Flats	NTN	Big Bear Municipal Water District	04/06
Colorado				
CO96	Molas Pass	NTN	USDA Forest Service	06/09
CO97	Buffalo Pass - Summit Lake	NTN	USDA Forest Service	09/98
CO99	Mesa Verde NP-Chapin Mesa	NTN	National Park Service - Air Resources Division	12/01
Florida				
FL05	Chassahowitzka NWR	NTN	US Fish & Wildlife Service - Air Quality Branch	07/97
FL11	Everglades NP - Research Center	NTN	South Florida Water Management District	03/96
FL34	Everglades Nutrient Removal Project		South Florida Water Management District	07/97
FL97	Everglades - W estern Broward County		South Florida Water Management District	11/06
Georgia				
GA09	Okefenokee NWR	NTN	US Fish & Wildlife Service - Air Quality Branch	07/97
GA33	Sapelo Island	NTN	Georgia Department of Natural Resources /Sapelo Island NERR	07/07
GA40	Yorkville		Southern Company/Atmospheric Research and Analysis, Inc	06/00
Idaho				
ID03	Craters of the Moon NM	NTN	Idaho Department of Environmental Quality	10/06
ID98	Deer Flats		Idaho Department of Environmental Quality	03/08
ID99	McCall		Idaho Department of Environmental Quality	11/07
Illinois				
IL11	Bondville	AIRMoN/NTN	Illinois State Water Survey/NADP	01/99
Indiana				
IN20	Roush Lake	NTN	Indiana Department of Environmental Management/USGS	10/00
IN21	Clifty Falls State Park		Indiana Department of Environmental Management/USGS	01/01
IN26	Fort Harrison State Park		Indiana Department of Environmental Management/USGS	04/03
IN28	Bloomington		Indiana Department of Environmental Management/USGS	12/00
IN34	Indiana Dunes NL	NTN	Indiana Department of Environmental Management/USGS	10/00
Kansas				
KS03	Reserve		Kansas Department of Health and Environment	01/08
KS04	West Mineral		Kansas Department of Health and Environment	10/08
KS05	Coffey County Lake		Kansas Department of Health and Environment	12/08
KS24	Glen Elder State Park		Kansas Department of Health and Environment	05/08
KS32	Lake Scott State Park	NTN	Kansas Department of Health and Environment	06/08
KS99	Cimarron National Grassland		US Forest Service - Cimarron National Grassland	12/08

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Kentucky				
KY10	Mammoth Cave NP-Houchin Meadow	NTN	National Park Service - Air Resources Division	08/02
Louisiana				
LA05	Lake Charles		Louisiana Department of Environmental Quality	10/98
LA10	Chase		Louisiana Department of Environmental Quality	10/98
LA23	Alexandria		Louisiana Department of Environmental Quality	02/01
LA28	Hammond		Louisiana Department of Environmental Quality	10/98
Maine				
ME00	Caribou	NTN	University of Maine	05/07
ME02	Bridgton	NTN	Maine Department of Environmental Protection/EPA	06/97
ME04	Carrabassett Valley	NTN	US Environmental Protection Agency-CAMD	02/09
ME09	Greenville Station	NTN	Maine Department of Environmental Protection/EPA	09/96
ME96	Casco Bay - Wolfe's Neck Farm	NTN	Maine Department of Environmental Protection/EPA	01/98
ME98	Acadia NP - McFarland Hill	NTN	Maine Dept of Environmental Protection/NPS-Acadia NP/EPA	03/96
Maryland				
MD00	Smithsonian Environmental Res Ctr		MD DNR/Smithsonian Environmental Research Center	12/06
MD08	Piney Reservoir	NTN	MD DNR/University of Maryland-Appalachian Lab	06/04
MD99	Beltsville	NTN	Maryland Department of Natural Resources	06/04
Massachusetts				
MA01	North Atlantic Coastal Lab	NTN	NPS - Cape Cod National Seashore	07/03
Michigan				
MI48	Seney NWR - Headquarters	NTN	US Fish & Wildlife Service-Air Quality Branch	11/03
Minnesota				
MN16	Marcell Experimental Forest	NTN	USDA Forest Service-North Central Research Station & MNPCA	02/96
MN18	Fernberg	NTN	Minnesota Pollution Control Agency	03/96
MN23	Camp Ripley	NTN	Minnesota Pollution Control Agency	07/96
MN27	Lamberton	NTN	Minnesota Pollution Control Agency	07/96
MN98	Blaine		Minnesota Pollution Control Agency	02/08
Mississippi				
MS22	Oak Grove		Southern Company/Atmospheric Research and Analysis, Inc	06/00
Missouri				
MO46	Mingo NWR		Missouri Department of Natural Resources /EPA	03/02
Montana				
MT05	Glacier NP - Fire Weather Station	NTN	National Park Service - Air Resources Division	10/03
Nebraska				
NE15	Mead	NTN	Nebraska Department of Environmental Quality	06/07
NE99	North Platte Agricultural Experiment Station	NTN	US Geological Survey	10/08
Nevada				
NV02	Lesperance Ranch		Nevada Dept of Conservation & Natural Resources/Frontier Geosciences, In	01/03
NV99	Gibb's Ranch		Nevada Dept of Conservation & Natural Resources/Frontier Geosciences, In	02/03
New Jersey				
NJ30	New Brunswick		US Geological Survey	01/06
New Mexico				
NM97	Valles Caldera National Preserver		Pueblo of Jemez Tribe	03/09
NM98	Navajo Lake		New Mexico Environment Department-Air Quality Bureau	04/09

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
New York				
NY06	Bronx		New York Department of Environmental Conservation	01/08
NY20	Huntington Wildlife	NTN	Syracuse University /EPA	12/99
NY43	Rochester		New York Department of Environmental Conservation	01/08
NY68	Biscuit Brook	NTN	US Geological Survey	03/04
NY99	West Point	NTN	US Dept of Education/John Jay College-City University of New York	10/06
North Carolina				
NC08	Waccamaw State Park		North Carolina Dept of Environment & Natural Resources	02/96
NC42	Pettigrew State Park		North Carolina Dept of Environment & Natural Resources	02/96
Ohio				
OH02	Athens Super Site		Ohio University/EPA	12/04
Oklahoma				
OK01	McGee Creek		Oklahoma Department of Environmental Quality	10/06
OK04	Lake Murray		Oklahoma Department of Environmental Quality	10/07
OK06	Wichita Mountains NWR		Oklahoma Department of Environmental Quality	11/07
OK31	Copan		Oklahoma Department of Environmental Quality	10/06
OK99	Stilwell	NTN	Cherokee Nation/EPA	04/03
Pennsylvania				
PA00	Arendtsville	NTN	PA Dept of Environmental Protection/Penn State University	11/00
PA13	Allegheny Portage Railroad NHS		PA Dept of Environmental Protection/Penn State University	01/97
PA30	Erie		PA Dept of Environmental Protection/Penn State University	06/00
PA47	Millersville	NTN	PA Dept of Environmental Protection/Penn State University	11/02
PA52	Little Pine State Park		PA Dept of Environmental Protection/Penn State University	07/07
PA60	Valley Forge		PA Dept of Environmental Protection/Penn State University	11/99
PA72	Milford	NTN	PA Dept of Environmental Protection/Penn State University	09/00
PA90	Hills Creek State Park		PA Dept of Environmental Protection/Penn State University	01/97
South Carolina				
SC03	Savannah River		Savannah River Nuclear Solutions	01/01
SC05	Cape Romaine NWR	NTN	US Fish & Wildlife Service - Air Quality Branch	03/04
SC19	Congaree Swamp		South Carolina Dept of Health & Environmental Control	03/96
South Dakota				
SD18	Eagle Butte		Cheyenne River Sioux Tribe/EPA	03/07
Tennessee				
TN11	Great Smoky Mountains NP-Elkmont	NTN	National Park Service - Air Resources Division	01/02
Texas				
TX21	Longview	NTN	Texas Commission on Environmental Quality	03/96
Utah				
UT97	Salt Lake City		Utah Departent of Environmental Quality	05/07
Vermont				
VT99	Underhill	AIRMoN/NTN	NOAA/Univ of VT-Rubinstein School of Envirn & Natural Resources	07/04
Virginia				
VA28	Shenandoah NP-Big Meadows	NTN	National Park Service - Air Resources Division	10/02
VA98	Harcum	NTN	Virginia Department of Environmental Quality	12/04
Washington				
WA03	Makah National Fish Hatchery		Washington State Department of Ecology	03/07
WA18	Seattle - NOAA		Illinois State Water Survey & Frontier Geosciences Inc	03/96

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
West Virginia				
WV99	Canaan Valley Institute	AIRMoN	NOAA - Air Resources Lab	06/07
Wisconsin				
WI08	Brule River		Wisconsin Department of Natural Resources	03/96
WI10	Potawatomi	NTN	Forest County Potawatomi Community/EPA	06/05
WI22	Milwaukee		Wisconsin Department of Natural Resources	10/02
WI31	Devils Lake		Wisconsin Department of Natural Resources	01/01
WI32	Middle Village		Menominee Indian Tribe/EPA	01/02
WI36	Trout Lake	NTN	Wisconsin Department of Natural Resources	03/96
WI99	Lake Geneva	NTN	Wisconsin Department of Natural Resources	01/97
Wyoming				
WY08	Yellowstone NP-Tower Falls	NTN	Wyoming Department of Environmental Quality	10/04
CANADA				
Alberta				
AB13	Henry Kroeger		ATCO Power	09/04
AB14	Genesee		Jacques Whitford Axys Ltd.	07/06
Newfoundland				
NF09	Cormak		Environment Canada	05/00
Nova Scotia				
NS01	Kejimkujik NP		Environment Canada	07/96
Ontario				
ON07	Egbert		Environment Canada	03/00
ON99	Egbert Forest		Environment Canada	04/09
Saskatchewan				
SK12	Bratt's Lake BSRN		Environment Canada	05/01

PROCEEDING NOTES

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