Hubbard Brook Experimental Forest, 2015 (Photo by: Mariel Carr) Attribution: Science History Institute [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons.

2018 Scientific Symposium and Fall Meeting

40 Years of Monitoring Atmospheric Deposition: Historical Legacy and Looking Ahead to the Future

November 5 – 9, 2018
Albany, NY

National Atmospheric
Deposition Program

NADP Proceedings 2018-2019

NADP 2018
Technical Committee Meeting

November 5 – 9, 2018
Albany, New York

Scientific Symposium Chair
Dr. Doug Burns
U.S. Geological Survey

PROCEEDINGS

Conference Schedule

Monday, November 5, 2018	
Registration	9:00 AM – 5:00 PM
TDEP Subcommittee meeting	1:00 PM – 5:00 PM
AMSC (Aeroallergen Monitoring Science Committee)	1:00 PM – 3:00 PM
Break	3:00 PM
CLAD Working Group	3:00 PM – 5:00 PM
Tuesday, November 6, 2018	
Registration	7:30 AM – 6:00 PM
Continental Breakfast	7:30 AM – 8:30 AM
Joint Subcommittee Meeting	8:30 AM – 10:00 AM
Break	10:00 AM
NOS/CLAD/EROS Subcommittee Meetings	10:00 AM – 12:00 PM
Lunch (on your own)	12:00 PM – 1:30 PM
Joint Subcommittee Meeting	1:30 PM – 2:30 PM
Break	2:30 PM – 3:00 PM
Executive Committee Meeting	3:00 PM - 6:00 PM
Wednesday, November 7, 2018	
Registration	7:30 AM – 5:15 PM
Continental Breakfast	7:30 AM – 8:00 AM
Welcome, Introductions and Overview	8:00 AM – 8:30 AM
Annual State of the NADP Report	8:30 AM – 9:00 AM
Keynote Address – Gene Likens, PhD	9:00 AM – 10:00 AM
Break	10:00 AM – 10:20 AM
Session #1 (6 speakers) **Atmospheric Deposition – Spatial and Temporal Patterns**	10:20 AM – 12:20 PM
Lunch (on your own)	12:20 PM – 1:35 PM
Session #2 (5 speakers) **Urban Deposition and Critical Loads**	1:35 PM – 3:15 PM
Break	3:15 PM – 3:35 PM
Session #3 (5 speakers) **Atmospheric Mercury Deposition**	3:35 PM – 5:15 PM
Break	5:15 PM – 6:30 PM
Poster Reception (Hudson Ballroom)	6:30 PM – 8:30 PM
Thursday, November 8, 2018	
Registration	7:30 AM – 4:30 PM
Continental Breakfast	7:30 AM – 8:00 AM
Opening Remarks, Announcements and Overview	8:00 AM – 8:10 AM
Session #4 (5 speakers) **Mercury in Ecosystems**	8:10 AM – 9:50 AM
Break	9:50 AM – 10:10 AM
Session #5 – Part 1 (6 speakers) **Ecosystem Effects, Recovery and the Future**	10:10 AM – 12:10 PM
Lunch (on your own)	12:10 PM – 1:30 PM
Session #5 – Part 2 (2 speakers) **Ecosystem Effects, Recovery and the Future** **Session #6** – Part 1 (3 speakers) **Atmospheric Deposition – Total and Reduced Nitrogen**	1:30 PM – 3:10 PM
Break	3:10 PM – 3:30 PM
Session #6 – Part 2 (3 speakers) **Atmospheric Deposition – Total and Reduced Nitrogen**	3:30 PM – 4:30 PM
Meeting Adjourn	4:30 PM
Friday, Nov 9, 2018	
Optional Field Trip - Mohonk Lake and Surrounding Area	8:00 AM – 4:00 PM

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Acknowledgements

The NADP Program Office would like to thank the following people and sponsors for their additional support of the 2018 Scientific Symposium and Fall Meeting:

- Dr. Doug Burns, Symposium Chair
- NADP Executive Committee
- New York State Energy Research & Development Authority (NYSERDA)
- Lisa Volk
- Dr. David Gay

In addition, we thank everyone who submitted abstracts for sharing their research. The use of NADP data by researchers and policymakers is what has made NADP successful for the past 40 years and will continue to do so for many years to come.

Agenda

NADP Scientific Symposium and Fall Meeting
Hilton Hotel, Albany, NY
November 5 - 9, 2018

Monday, November 5, 2018

		Room Location
9:00 AM – 5:00 PM	Registration	East Gallery C
1:00 PM – 5:00 PM	TDEP	Governor C
1:00 PM – 3:00 PM	AMSC	Anteroom
3:00 PM	Break	
3:00 PM – 5:00 PM	CLAD	Hudson Ballroom

Tuesday, November 6, 2018

7:30 AM – 6:00 PM	Registration	East Gallery C
7:30 AM – 8:30 AM	Continental Breakfast	
8:30 AM – 10:00 AM	Joint Subcommittee Meeting	Hudson Ballroom
10:00 AM	Break	
10:00 AM – 12:00 PM	Subcommittee Meetings	
	Network Operations	Governor C
	Ecological Response and Outreach	Capital AB
	Critical Loads	Governor D
12:00 PM – 1:30 PM	Lunch on your own	
1:30 PM – 2:30 PM	Joint Subcommittee Meeting	Hudson Ballroom
2:30 PM – 3:00 PM	Break	
3:00 PM – 6:00 PM	Executive Committee Meeting	Governor C

Wednesday, November 7, 2018		**Room Location**
7:30 AM – 5:15 PM	Registration	East Gallery C
7:30 AM – 8:00 AM	Continental Breakfast	
8:00 AM – 8:30 AM	**Welcome, Introductions**, **Overview of Meeting Agenda** Doug Burns – NADP Vice Chair, Symposium Chair U.S. Geological Survey Tamara Blett – NADP Chair National Park Service	Governor A
8:30 AM – 9:00 AM	**Annual State of the NADP Report** Jamie Schauer –Wisconsin State Laboratory of Hygiene Director and NADP Principal Investigator Michael Olson – NADP Program Coordinator	
9:00 AM – 10:00 AM	**Keynote Address:** **Long-term Monitoring: Environmental Insights from NADP and Hubbard Brook Pertaining to Acid Rain** Gene Likens, PhD (see abstract and biography, page 10) Founder and President Emeritus, Cary Institute of Ecosystem Studies, Millbrook, NY Distinguished Research Professor and Special Advisor to the President on Environmental Affairs, University of Connecticut	
10:00 AM – 10:20 AM	Break	
Technical Session 1:	**Atmospheric Deposition – Spatial and Temporal Patterns** Session Chair: John Walker, U.S. Environmental Protection Agency	
10:20 AM – 10:40 AM	**Linking Improvements in Sulfur Dioxide Emissions to Decreasing Sulfate Deposition by Combining Satellite and Surface Observations with Trajectory Analysis** Fedkin Nikita, University of Maryland-College Park	
10:40 AM – 11:00 AM	**Quantifying Inter-Regional Atmospheric Nitrogen Deposition to U.S. Hydrologic Regions** Kristina Wagstrom, University of Connecticut	
11:00 AM – 11:20 AM	**Spatial and Temporal Patterns of Atmospheric Deposition in USA** Habibollah Fakhraei, Syracuse University	
11:20 AM – 11:40 AM	**Background of Atmospheric Deposition in Mexico Studies and Actual Challenges** Rodolfo Sosa Echeverría, Universidad Nacional Autonoma de México (UNAM)	

Wednesday, November 7, 2018

Room Location
Governor A

11:40 AM – 12:00 PM	**Atmospheric Deposition of Reactive Nitrogen and Trace Species in South Asia** Umesh Kulshrestha, Jawaharlal Nehru University
12:00 PM – 12:20 PM	**A Reassessment of Bromide Levels in NADP/NTN Precipitation Samples** Martin Shafer, University of Wisconsin-Madison/Wisconsin State Laboratory of Hygiene
12:20 PM – 1:35 PM	Lunch on your own
Technical Session 2:	**Urban Deposition and Critical Loads** Session Chair: Chris Clark, U.S. Environmental Protection Agency
1:35 PM – 1:55 PM	**Patterns and Controls on Atmospheric Nitrogen, Phosphorus, and Carbon Deposition in Urban Environments** Pamela Templer, Boston University
1:55 PM – 2:15 PM	**Enhancing Wet-Deposition Maps with Urban Data: Preliminary Results from the Network for Urban Atmospheric Nitrogen Chemistry** Gregory Wetherbee, U.S. Geological Survey
2:15 PM – 2:35 PM	**History of Critical Loads in North America** Tamara Blett, National Park Service
2:35 PM – 2:55 PM	**Exceedance of Lichen-based Critical Loads of Atmospheric Deposition: Why Would a Manager Care?** Linda Geiser, USDA-Forest Service
2:55 PM – 3:15 PM	**Past, Present and Future of Critical Loads ─ European Perspective** Maximilian Posch, International Institute for Applied Systems Analysis (IIASA)
3:15 PM – 3:35 PM	Break
Technical Session 3:	**Atmospheric Mercury Deposition** Session Chair: Karen Murray, U.S. Geological Survey
3:35 PM – 3:55 PM	**Gaseous Deposition of Atmospheric Elemental Mercury in Ecosystems - What We Know and What is Missing** Daniel Obrist, University of Massachusetts, Lowell
3:55 PM – 4:15 PM	**Investigation of Atmospheric Chemistry of Gaseous Oxidized Mercury at a Coastal Site in Atlantic Canada** Irene Cheng, Environment and Climate Change Canada

Wednesday, November 7, 2018		**Room Location**
		Governor A
4:15 PM – 4:35 PM	**Mercury Wet Deposition Differences by Precipitation Type at One Remote Island Site in Northwest Pacific and Two Sites in Northern Taiwan in 2010-2015** Guey-Rong Sheu, National Central University	
4:35 PM – 4:55 PM	**Is it Possible to Accurately Measure Ambient Air Mercury at the Low Parts Per Quadrillion Level Using Passive Samplers?** Eric Prestbo, Tekran Instruments	
4:55 PM - 5:15 PM	**Wet and Dry Deposition of Total Mercury and Methylmercury at an Unpolluted Site in Puerto Rico** James Shanley, U.S. Geological Survey	

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6:30 PM – 8:30 PM	**Poster Session and Reception**	Hudson Ballroom

Atmospheric Deposition of Metals and Polycyclic Aromatic Hydrocarbons (PAH) in the Canadian Oil Sands Region
M.A. Bari, W.B. Kindzierski

Synthesizing and Communicating Ecosystem Responses to Air Pollution for Federal Resource Management
Michael Bell, Linda Pardo, Chris Clark, Linda Geiser, Jason Lynch and Bill Jackson

Temporal and Spatial Trends of Atmospheric Deposition in Maryland and Comparison to Observations of Atmospheric Pollutants in the Chesapeake Bay Watershed
Sarah Benish, Phil Stratton, Allison Ring, Gina Mazzuca and Xinrong Ren

Total Sulphur Deposition Downwind of an Aluminum Smelter in the Kitimat Valley, British Columbia
Dane Blanchard and Julian Aherne

Long Term Atmospheric Monitoring in New York State: From Mountaintop to New York City
Richard Brandt, James Schwab, Brian Crandall, Matt Ninneman, Hesham Hassan, Paul Casson, Dirk Felton and Oliver Rattigan

Spatial Assessment of Total Mercury Concentrations on Baffin Island, Nunavut
Rachel Brown, Tanner Liang, Phaedra Cowden, Julian Aherne and Holger Hintelmann

A Review of 2008 - 2017: Data in the Adirondacks with Recommendations for Future Monitoring Options
Amanda Carpenter, Oliver Rattigan and Dirk Felton

An Intercomparison of Several Collocated Rain Gauges at Whiteface Mountain Field Station
Paul Casson, Scott McKim, Rich Brandt, Jim Schwab, Brian Frei and Justin Minder

Measurements and Modelling of Atmospheric Deposition in Canada: Acidifying Pollutants, Base Cations and Polycyclic Aromatic Compounds
Irene Cheng, Leiming Zhang, Deyong Wen, Zhiyong Wu, Xin Qiu, Fuquan Yang and Tom Harner

A Specific Ultraviolet Absorbance Pilot Project in Adirondack Mountain Lakes and Streams
Kevin Civerolo, Karen Roy, Philip Snyder and Gregory Lawrence

AMoN Readiness Verification Plan Ammonia Field Inter-comparison
Camille Danielson, Martin Shafer, Jesse Wouters and Chris Worley

The Anthropogenic Impact on Precipitation Quality
Courtney Davis, Charles Driscoll, Mario Montesdeoca and Dimitar Todorov

Brook Trout Restoration and Monitoring of the Adirondack Ecosystem: Bringing Additional Value to the NYSDEC Stocking and Liming Program
James Dukett, Phil Snyder, Matt Kelting and Sue Capone

Ethanol Concentrations in Wet Deposition Collected at the Atmospheric Integrated Research Monitoring Network Sites
J. David Felix and Bipin Sharma

Investigating Gaseous Atmospheric Mercury Exchange in a Forest Ecosystem with a Gradient-based Micrometeorology Approach
Dean Howard, Timothy Richards, J. William Munger and Daniel Obrist

A New Online Continuous Relaxed Eddy Accumulation Flux System Coupled with Ion Chromatographs
Amy Hrdina, Alexander Moravek, Elizabeth Patte and Jennifer G. Murphy

Wet Atmospheric Deposition and Stream Water Chemistry at the Glacier Lakes Ecosystem Experiments Site (GLEES), Southeastern Wyoming, USA, 1989-2018
John Korfmacher and Kathleen A. Dwire

Monitoring Cloud Water Chemistry (including Organics) at Whiteface Mountain
Christopher Lawrence, Paul Casson, Richard Brandt, Elizabeth Yerger, Hunter Favreau, Dan Kelting, James Schwab and Sara Lance

Transitioning a Major National Monitoring Program: Transition Strategy, Current Status and Future Plans
Amy Mager, Camille Danielson, Chris Worley and Martin Shafer

Isotopic Investigation of Redox Effects on Nitrate Partitioning in a Forest Soil
Ariel Mollhagen

A Decadal Change in Mercury in Upland Irish Lakes
Sarah Nelson, Julian Aherne and Holger Hintelmann

Variations of Wet Deposition of Mercury Across Eastern North America
Raheem Outlaw, Ronnie Blakeney, Nallah Muhammad, Precious Hairston, Jacorey Patterson and Godfrey Uzochukwu

Total Reduced Nitrogen (NHx) Measurement Methods for Implementation in Long-Term Monitoring Networks
Melissa Puchalski, John T. Walker, Xi Chen, Christopher Rogers, Ralph Baumgardner, Kevin Mishoe, Gregory Beachley, Joann Rice, Bret Schichtel and Katherine Barry

Atmospheric Deposition of Microfibers
Brett Roblin and Julian Aherne

The Clean Air Status and Trends Network (CASTNET): A Versatile Platform for Evolving Deposition Science and Other Air Quality Monitoring Research
Christopher Rogers, Melissa Puchalski, Selma Isil and Marcus Stewart

Evaluation and Intercomparison of Modeled Atmospheric Deposition over North America and Europe - An Overview of Phase 4 of the Air Quality Model Evaluation International Initiative
Donna Schwede, Johannes Bieser, Olivia Clifton, Jason Ducker, Lisa Emberson, Johannes Flemming, Stefano Galmarini, Christian Hogrefe, Christopher Holmes, Paul Makar, Martijn Schaap and Sam Silva

Broader Proficiencies of the WSLH: Enhancing and Building NADP Network Capabilities and Collaborations
Martin Shafer, Mike Olson, Mark Olson, Chris Worley and James Schauer

Tekran 2537 A, B, X Intercomparison Study
Timothy Sharac, Mark Olson, David Grande, Mark Rhodes, Sandy Steffen, Rob Tordon and Eric Prestbo

Long-term Changes in Soil and Stream Chemistry across an Acid Deposition Gradient in the Northeastern United States
Jason Siemion, Michael R. McHale, Gregory B. Lawrence, Douglas A. Burns and Michael R. Antidormi

Advancements in NADP Field Equipment and Site Liaison Support
Richard Tanabe, Mark Olson and Robert Larson

A National Survey of Total Gaseous Mercury Stable Isotope Composition
Michael Tate, Ryan Lepak, Sarah Janssen, David Krabbenhoft, Martin Risch, David Gay, John DeWild and Jacob Ogorek

Atmospheric Depositions Introduce Anomalies in Modeled Estimates of Dissolved Organic Carbon Export from Terrestrial to Aquatic Ecosystems in the United States from 1981-2010
Xinyuan Wei and Daniel J. Hayes

Comparison of Accuracy, Variability and Relative Bias for Two Central Analytical Laboratories for the National Atmospheric Deposition Program
Gregory Wetherbee, Camille Danielson, Martin Shafer, Sybil Anderson, Nina Gartman, Chris Worley and Amy Mager

It's Raining Plastic
Gregory Wetherbee, Austin Baldwin and James Ranville

NADP Sample Processing at the WSLH: Conventional Strategies and New Approaches
Kirsten Widmayer, Amy Mager and Chris Worley

Investigating Different Strategies to Reduce Costs, Enhance Sampler Integrity, and Improve the Extraction Process, in the Ammonia Monitoring Network (AMoN)
Jesse Wouters, Chris Worley, Camille Danielson and Martin Shafer

Thursday, November 8, 2018		**Room Location**
7:30 AM – 4:30 PM	Registration	East Gallery C
7:30 AM – 8:00 AM	Continental Breakfast	
8:00 AM – 8:10 AM	**Opening Remarks, Announcements, and Overview of Day 2** Doug Burns – NADP Vice Chair, Symposium Chair U.S. Geological Survey	Governor A
Technical Session 4:	**Mercury in Ecosystems** Session Chair: Eric Prestbo, Tekran Instruments	
8:10 AM – 8:30 AM	**Factors Influencing Mercury Concentrations in Fish from Streams in the Northeastern United States** Karen Riva-Murray, U.S. Geological Survey	
8:30 AM – 8:50 AM	**Chemical and Physical Controls on Mercury Source Signatures in Stream Fish from the Northeastern United States** Sarah Janssen, U.S. Geological Survey	
8:50 AM – 9:10 AM	**Mercury in Fish from National Parks - Concentrations, Sources, and Ecological Risk** Colleen Flanagan Pritz, National Park Service-Air Resources Division	
9:10 AM – 9:30 AM	**Increase in Lake Champlain Fish Mercury Linked to Elevated Sediment Loading from Hurricane Irene** Mark Swinton, Rensselaer Polytechnic Institute	
9:30 AM – 9:50 AM	**The Dragonfly Mercury Project: Biosentinel Mercury Concentrations and Landscape Drivers across U.S. National Parks** Megan Hess, Program in Ecology and Environmental Sciences, University of Maine	
9:50 AM – 10:10 AM	Break	
Technical Session 5:	**Ecosystem Effects, Recovery, and the Future** Session Chair: Linda Geiser, USDA-Forest Service	
10:10 AM – 10:30 AM	**25 Years of Whole-Watershed Experimental N Additions in a Forested Maine Watershed** Ivan Fernandez, University of Maine	
10:30 AM – 10:50 AM	**Differential Vulnerability of 348 Herbaceous Species to Atmospheric Deposition of Nitrogen and Sulfur across the Contiguous U.S.** Christopher Clark, U.S. Environmental Protection Agency	

Thursday, November 8, 2018

Room Location
Governor A

10:50 AM – 11:10 AM	**Assessing Risk to Forest Ecosystems from Nitrogen and Sulfur Deposition across the Continental U.S.** Linda Pardo, USDA-Forest Service
11:10 AM – 11:30 AM	**A Clean Air Act Success: Indicators of Recovery in Fish Assemblages and Water Quality from Acidified Streams of the Catskill and Adirondack Mountains, New York** Barry Baldigo, U.S. Geological Survey
11:30 AM – 11:50 AM	**Do Watershed and In-Stream Liming Accelerate Recovery of Macroinvertebrate Communities in Acidified Tributaries to an Adirondack Lake?** Scott George, U.S. Geological Survey
11:50 AM – 12:10 PM	**Soil-Calcium Depletion Extends Increasing Trends of Dissolved Organic Carbon in Adirondack Streams** Gregory Lawrence, U.S. Geological Survey
12:10 PM – 1:30 PM	Lunch on your own
1:30 PM – 1:50 PM	**Recent and Potential Future Changes in the Chemistry of Surface Waters of the Adirondack Region of New York in Response to Decreases in Atmospheric Deposition** Charles Driscoll, Syracuse University
1:50 PM – 2:10 PM	**The Responses of Stream Ecosystems to Future Scenarios of Atmospheric Deposition Derived from Changing Land Use-related Emission and Projected Future Meteorological Conditions** Shuai Shao, Syracuse University
Technical Session 6:	**Atmospheric Deposition - Total and Reduced Nitrogen** Session Chair: Donna Schwede, U.S. Environmental Protection Agency
2:10 PM – 2:30 PM	**Measuring Surface-Atmosphere Exchange of Ammonia over a Corn Field Using the Eddy Covariance Method** Saumya Singh, Department of Chemistry, University of Toronto
2:30 PM – 2:50 PM	**Measurements of Ammonia Emission and Deposition in Adjacent Natural Ecosystems** Mark Zondlo, Princeton University

Thursday, November 8, 2018

Room Location
Governor A

2:50 PM – 3:10 PM	**Potential Contribution of the Satellite Observations for Improving Atmospheric Deposition Estimates** Mark Shephard, Environment and Climate Change Canada
3:10 PM – 3:30 PM	Break
3:30 PM – 3:50 PM	**Loch Vale, CO Wet Reactive Nitrogen Deposition Long Term Trends and Uncertainty** Bret Schichtel, National Park Service-Air Resources Division
3:50 PM – 4:10 PM	**Assessing Uncertainty in Total Reactive Nitrogen Deposition Estimates for North American Critical Load Applications** John Walker, U.S. Environmental Protection Agency
4:10 PM – 4:30 PM	**Trends in Reactive Nitrogen at Rocky Mountain National Park by Transport Direction** Kristi Gebhart, National Park Service

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Friday, November 9, 2018

8:00 AM – 4:00 PM **Optional Field Trip - Mohonk Lake and Surrounding Landscape**
(Departs from hotel at 8:00 AM and returns to hotel at 4:00 PM)

During the field trip you will see Mohonk Lake and hear the history of acid rain effects on the glacial lakes of the Shawangunk Mountains. We will visit the NOAA weather station near the lake that began measurements in 1896. The group will also visit the Dan Smiley Research Center and see the precipitation collector he developed in the 1970s that is still in operation today. Later, time will be available to hike some of the nearby trails and to observe this unique and stunning landscape.

Keynote Speaker – Dr. Gene E. Likens

Dr. Gene Likens received a Ph.D. in zoology from the University of Wisconsin in 1962. He served on the faculty of Dartmouth College from 1963-69 and at Cornell University from 1969-83.

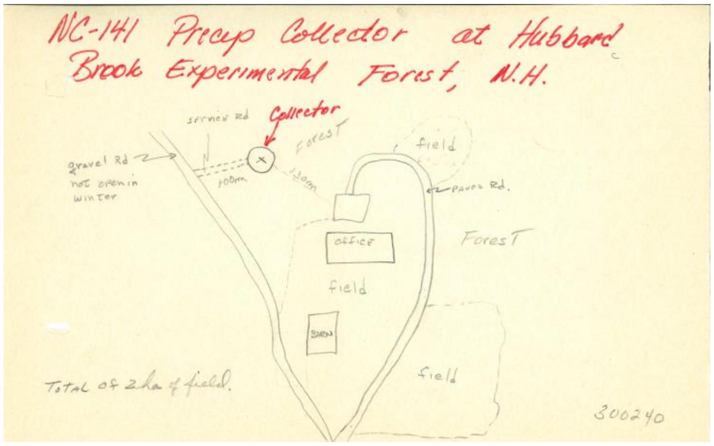
Dr. Likens is founder and President Emeritus of the Cary Institute of Ecosystem Studies, Millbrook, NY. Currently, he serves as Distinguished Research Professor and Special Advisor to the President on Environmental Affairs at the University of Connecticut.

Dr. Likens' research focuses on the ecology and biogeochemistry of forest and aquatic ecosystems, primarily through long-term studies at the Hubbard Brook Experimental Forest in New Hampshire. He co-founded the Hubbard Brook Ecosystem Study in 1963, which has informed understanding of the links between ecosystem function and land-use practices. He and his colleagues were the first scientists to discover and document acid rain in North America and its links to fossil fuel combustion. His findings have influenced politicians and policy makers, motivated scientific studies, and increased public awareness of human-accelerated environmental change. He has received many awards and honors including election to the National Academy of Science in 1981, and the 2001 National Medal of Science.

Dr. Likens has authored more than 600 papers, reports, and books that include studies of limnology, acid rain and its ecological effects, human influence on water quality, and the ecological effects of forest management, among others. He has been a long-time proponent of the value of environmental monitoring, including the activities of NADP.

Keynote Talk Title: Long-term Monitoring: Environmental Insights from NADP and Hubbard Brook pertaining to Acid Rain

Abstract: High quality, long-term scientific data offer unique insights into how atmospheric chemistry affects human-accelerated environmental change. Data from Hubbard Brook and NADP provide two special examples regarding long-term changes in atmospheric deposition. Acid rain was discovered in North America at Hubbard Brook in 1963. Chemical records at Hubbard Brook now have been hindcasted to 1900 to provide context for the 55-year measurement period. The NADP, celebrating 40 years of successful operations, provided critical temporal, and especially, spatial data for the acid rain debates in the 1980s. Long-term data from these programs were important in passing the 1990 Clean Air Act Amendments.



Original drawing for NADP site application. Included in NADP archival site files.

2018 NADP Site Operator Awards

35 Year Award

Site Code	Operator Name	Site Name	Funding Agency	Wet Start
MD13 - NTN	Michael Newell	Wye	University of Maryland-State Agricultural Experiment Station	3/8/1983

30 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Wet Start
MT07 - NTN	Kent Dodge	Clancy	U.S. Geological Survey	1/24/1984
TX16 - NTN	Robert Moen	Sonora	U.S. Geological Survey	6/26/1984

25 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Wet Start
PA15 - AIRMoN	Robert Ziegler	Penn State	National Oceanic and Atmospheric Administration - Air Resources Laboratory	10/6/1992
PA15 - NTN	Robert Ziegler	Penn State	National Oceanic and Atmospheric Administration - Air Resources Laboratory and Pennsylvania Game Commission	6/7/1983
PA42 - NTN	Kevin Horner	Leading Ridge	Pennsylvania State University-State Agricultural Experiment Station	4/25/1979

20 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Wet Start
NC36 - NTN	Paul Anderson	Jordan Creek	U.S. Geological Survey	10/18/1983
NM08 - NTN	Linda Madron	Mayhill	U.S. Geological Survey	1/24/1984

15 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Wet Start
MI51 - NTN	Denise Dickson	Unionville	U.S. Environmental Protection Agency - Clean Air Markets	1/26/1999
MS19 - NTN	Grace Norman	Newton	National Oceanic and Atmospheric Administration - Air Resources Laboratory	11/11/1986
NY20 - MDN	Charlotte Demers	Huntington Wildlife	New York State Energy Research & Development Authority and U.S. Environmental Protection Agency	12/10/1999
TX56 - NTN	Dale Burks	L.B.J. National Grasslands	U.S. Geological Survey	9/20/1983
WI31 - MDN	Alexander Nyhus	Devil's Lake	Wisconsin Department of Natural Resources	1/11/2001
WY00 - NTN	John Korfmacher	Snowy Range	U.S. Forest Service	4/22/1986
WY95 - NTN	John Korfmacher	Brooklyn Lake	U.S. Forest Service	9/22/1992

10 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Wet Start
AZ99 - NTN	Janice Goodman	Oliver Knoll	U.S. Geological Survey	8/25/1981
KS24 - MDN	Lisa Silby	Glen Elder State Park	Kansas Department of Health and Environment	5/27/2008
KS32 - MDN	Curt Sauer	Lake Scott State Park	Kansas Department of Health and Environment	6/10/2008
MD08 - AMNet	Mark Castro	Piney Reservoir	State of Maryland	1/1/2008
MI48 - NTN	Jim Patton	Seney National Wildlife Refuge-Headquarters	U.S. Fish and Wildlife Service-Air Quality Branch	11/28/2000
MI96 - AMoN	Matt Nowak	Detroit	U.S. Environmental Protection Agency - Clean Air Markets	10/29/2007
MN27 - MDN	Lee Klossner	Lamberton	Minnesota Pollution Control Agency	7/2/1996
ND08 - NTN	Janna Robinson	Icelandic State Park	U.S. Geological Survey	10/25/1983
NM98 - AMoN	Joe Cotie	Navajo Lake	U.S. Environmental Protection Agency - Clean Air Markets	1/11/2008
NM99 - AMoN	Joe Cotie	Farmington	U.S. Environmental Protection Agency - Clean Air Markets	1/9/2008
NY06 - MDN	Sergio Fleishaker	Bronx	New York State Department of Environmental Conservation	1/9/2008

10 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Wet Start
NY43 - MDN	Tom Everts	Rochester	New York State Energy Research & Development Authority	1/8/2008
NY67 - AMoN	Tom Butler	Ithaca	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007
OH02 - AMoN	Gary Conley	Athens Super Site	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007
OK99 - AMNet	Larry Scrapper	Stillwell	Cherokee Nation	10/20/2008
SD08 - NTN	David Gay	Cottonwood	U.S. Geological Survey	10/11/1983
WI10 - NTN	Joe Cebe	Potawatomi	Forest County Potawatomi Community	6/7/2005
WY06 - NTN	Ted Porwoll	Pinedale	U.S. Bureau of Land Management	1/26/1982
WY08 - NTN	John Klaptosky	Yellowstone National Park-Tower Falls	Wyoming Department of Environmental Quality	6/5/1980

5 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Wet Start
AK98 - MDN	Stephen Bodnar	Kodiak	State of Alaska Department of Environmental Conservation	9/18/2007
BC22 - NTN	Jim Young	Haul Road Station	Rio Tinto	9/19/2012
BC23 - NTN	Jim Young	Lakelse Lake	Rio Tinto	3/20/2013
CO21 – NTN	Steven Alton	Manitou	U.S. Forest Service	10/17/1978
CO96 - MDN	Bob Brantlinger	Molas Pass	U.S. Bureau of Land Management	6/30/2009
CO96 - NTN	Bob Brantlinger	Molas Pass	U.S. Forest Service	7/29/1986
ID03 - NTN	Douglass Owen	Craters of the Moon National Monument	National Park Service-Air Resources Division	8/22/1980
MD08 - MDN	Ben Brown	Piney Reservoir	Maryland Department of Natural Resources and University of Maryland - Appalachian Laboratory	6/29/2004
ME94 - NTN	Martin Dana	Indian Township	Passamaquoddy Tribe and U.S. Environmental Protection Agency	10/3/2013
ME96 - MDN	Liza Woodward	Casco Bay-Wolfe's Neck Farm	Maine Department of Environmental Protection and U.S. Environmental Protection Agency	1/6/1998

5 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Wet Start
ME96 - NTN	Liza Woodward	Casco Bay-Wolfe's Neck Farm	Maine Department of Environmental Protection and U.S. Environmental Protection Agency	1/6/1998
MN18 - AMoN	James B. Anderson	Fernberg	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007
MN18 - MDN	James B. Anderson	Fernberg	Minnesota Pollution Control Agency	3/5/1996
MN18 - NTN	James B. Anderson	Fernberg	U.S. Environmental Protection Agency - Clean Air Markets	11/18/1980
MN32 - NTN	Bryce Olson	Voyageurs National Park-Sullivan Bay	National Park Service-Air Resources Division	5/30/2000
MS12 - AMNet	Ronald Cole	Grand Bay NERR	National Oceanic and Atmospheric Administration	9/29/2006
NC45 - NTN	Alexander Dreyer	Mt. Mitchell	North Carolina State University and U.S. Environmental Protection Agency - Clean Air Markets	11/26/1985
NS01 - AMoN	Margo DeLong	Kejimkujik National Park	Environment Canada	10/8/2013
NY06 - NTN	Sergio Fleishaker	Bronx	New York State Department of Environmental Conservation	1/22/2013
NY28 - NTN	Erik Cortright	Piseco Lake	New York State Energy Research & Development Authority	12/31/2012
NY43 - NTN	Tom Everts	Rochester	New York State Energy Research & Development Authority	4/30/2013
NY92 - NTN	Jim Wolfe	Amherst	New York State Energy Research & Development Authority	10/29/2013
NY94 - AMoN	Ken Eckhardt	Nick's Lake	U.S. Environmental Protection Agency - Clean Air Markets	11/20/2012
NY96 - MDN	Andrew Seal	Cedar Beach-Southold	New York State Energy Research & Development Authority	9/24/2013
NY98 - AMoN	Paul Casson	Whiteface Mountain	U.S. Environmental Protection Agency - Clean Air Markets	11/20/2012
OH02 - AMNet	Alex Burke	Athens Super Site	Ohio EPA	1/1/2007
OK00 - NTN	Robert Kildow	Salt Plains National Wildlife Refuge	U.S. Geological Survey	12/13/1983
PA18 - MDN	Kevin Horner	Young Woman's Creek	Pennsylvania State University	10/22/2013
TX04 - NTN	Jeff Bennett	Big Bend National Park - K-Bar	National Park Service-Air Resources Division	4/10/1980
TX43 - AMoN	Brent Auvermann	Cañónceta	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007

5 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Wet Start
VA24 - AMoN	Gene Brooks	Prince Edward	U.S. Environmental Protection Agency - Clean Air Markets	3/1/2011
VT99 - AMoN	Miriam Pendleton	Underhill	U.S. Environmental Protection Agency - Clean Air Markets	11/20/2012
WY26 - MDN	Steve Renner	Roundtop Mountain	Wyoming Department of Environmental Quality	12/20/2011
WY97 - NTN	Steve Renner	South Pass City	Bridger-Teton National Forest	4/30/1985

Abstracts

Technical Session 1: **Atmospheric Deposition – Spatial and Temporal Patterns**
Session Chair: John Walker, U.S. Environmental Protection Agency

Linking Improvements in Sulfur Dioxide Emissions to Decreasing Sulfate Deposition by Combining Satellite and Surface Observations with Trajectory Analysis

Fedkin Nikita[1] , Can Li[2], Russell R. Dickerson[3], Nick Krotkov[4] and Timothy Canty[5]

Sulfur dioxide (SO_2), a criteria pollutant, and sulfate (SO_4^{2-}) deposition are major environmental concerns and both have been on the decline in the Eastern U.S. for more than two decades. We combined satellite column SO_2 data from the Ozone Monitoring Instrument (OMI), and SO_4^{2-} wet deposition data from the NADP (National Atmospheric Deposition Program) to investigate the temporal and spatial relationship between the downward trends in SO_2 emissions and sulfate deposition over the eastern U.S. from 2005 to 2015. To establish a relationship between SO_2 emission sources and receptor sites, we conducted a Potential Source Contribution Function (PSCF) analysis based on HYSPLIT back trajectories for five selected Air Quality System (AQS) sites - (Hackney, OH, Akron, OH, South Fayette, PA, Wilmington, DE, and Beltsville, MD). Back trajectories were run for three summers (JJA) and three winters (DJF) and used to generate seasonal climatology PSCFs for each site. The OMI SO_2 and interpolated NADP sulfate deposition trends were normalized and overlapped with the PSCF, to identify the areas that had the highest contribution to the observed deposition trend. The results suggest that emission reductions along the Ohio River Valley have led to decreases in sulfate deposition at Hackney, Akron and South Fayette. Emission reductions in southeast PA have resulted in improvements in sulfate deposition at Wilmington, DE, while for Beltsville, reductions from both the Ohio River Valley and nearby have had an impact on sulfate deposition. For Beltsville, sources closer than 300 km from the site contribute roughly 56% and 82% of the observed deposition trends in winter and summer respectively, reflecting seasonal changes in transport pattern as well as faster SO_2 oxidation in summer. The results also suggest that emissions and deposition are linked through not only the location of sources relative to the observing sites, but also the weather patterns characteristic to the region, as evidenced by differences in winter and summer contributions. The methodology developed in this study is applicable to other regions with significant trends and can be used to estimate the potential benefits of emission reduction in those areas.

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Quantifying Inter-Regional Atmospheric Nitrogen Deposition to U.S. Hydrologic Regions

Kristina Wagstrom[1] , Michael Crowl[2], Xuanwen Chen[3] and Carmen Lamancusa[4]

Increasing anthropogenic emissions of nitrogen released into the atmosphere contributes to water eutrophication. In this study we quantified seasonal dry and wet deposition of major nitrogen-containing species, including ammonia (NH_3), nitric acid (HNO_3), nitrogen oxides (NOx), particulate ammonium (PNH_4) and particulate nitrate (PNO_3) onto hydrologic regions in the contiguous United States. We used a regional chemical transport model, the Comprehensive Air Quality Model with eXtension (CAMx) to obtain deposition information in the contiguous United States.

Our results show that gaseous species dominant dry deposited mass. Ammonia (NH_3), nitric acid (HNO_3), and nitrogen dioxide (NO_2) each contribute 40% to 60%, 20% to 40%, and approximately 10% of the total nitrogen dry deposition, respectively. For wet deposition the major contributors are nitric acid (HNO_3) and particulate ammonium (PNH_4). HNO_3 contributes 40%-60% of the total nitrogen wet deposited mass, PNH_4 20%-40%, and NH_3 and particulate nitrate (PNO_3) together about 10%. Spring and summer consistently receive the more deposited nitrogen than fall or winter for both wet and dry deposition. The maximum deposition of spring is over twice that of fall due to more frequent rainfall, which removes the nitrogen-containing species from the atmosphere increasing the loading to hydrologic regions. Increased vegetation in spring and summer increases dry deposition.

Over the different hydrologic regions, the annual mass of nitrogen deposited through dry deposition ranges from around 110 to 910 kgN/km^2, over twice that of wet deposition, which ranges from about 40 to 390 kgN/km^2. The Eastern United States, including Ohio, Mid Atlantic, Great Lakes, Upper Mississippi, Lower Mississippi, Tennessee, and New England hydrologic regions alongside the California, Texas-Gulf, and Arkansas-White-Red hydrologic regions receive the most deposition during the year. These spatial trends exist because nitrogen sources are mainly vehicular emissions, power plants, and fertilizer use and these hydrologic regions are highly populated.

In addition, we have estimated the amount of deposited nitrogen from outside each region to provide additional insight into the regional sources of nitrogen in each hydrologic region. We will conclude with a discussion about which regions contribute disproportionately to nitrogen deposition and which regions are disproportionately impacted by nitrogen emissions.

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Spatial and Temporal Patterns of Atmospheric Deposition in USA

Habibollah Fakhraei[1] and Charles T. Driscoll[2]

Atmospheric deposition of sulfur and nitrogen compounds (known as acid deposition) has diversely impacted the forest and aquatic ecosystems in North America, Europe, and Asia. In the United States, following the implementation of the Clean Air Act and the subsequent rules, there has been a marked decline in emissions of acidifying compounds (SO_2 and NO_x) resulting in a concomitant decrease in the concentrations of sulfate (SO_4^{2-}) and nitrate (NO_3^-) in atmospheric deposition in the eastern United States. Studies indicate that concentrations of SO_4^{2-} and NO_3^- in precipitation at monitoring sites in Northeast were correlated with national emissions of SO_2 and NO_x, respectively. Having historical time series of national emissions, the SO_2 - SO_4^{2-} and NO_x - NO_3^- relationships can be used to hindcast the time series of historical depositions. The accuracy of the hindcasted historical depositions depends on how strongly the current national emissions are related to the current monitored depositions. In this study, we generated an algorithm to develop regression model between national emissions of SO_2 and NO_x and concentrations of SO_4^{2-} and NO_3^- in precipitation at each individual 263 National Atmospheric Deposition Program (NADP) sites throughout the US. We visualized the spatial patterns of correlation coefficients between emissions and deposition concentrations for all NADP sites in the continental US. The time series of reconstructed historical atmospheric deposition can be used as an important input to ecosystem effects models. In the second phase of this study, we evaluated the spatial pattern of dry to wet deposition ratios throughout the US. Currently the CASTNET program provides an estimate of atmospheric dry deposition for about 100 sites throughout the US by using modeled dry deposition velocity and the measured air quality concentrations. As the monitoring stations of dry and wet depositions are distributed at different locations, we used an algorithm to calculate dry to wet ratio for the paired stations with the closest distance. We computed dry to wet ratios for all major cations and anions and visualized the spatial patterns of these ratios for the entire US sites.

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Background of Atmospheric Deposition in Mexico Studies and Actual Challenges.

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In this research, the background of the studies carried out in Mexico on the subject of atmospheric deposition was integrated. 195 publications were reviewed, including articles, reports, technical reports and theses. The first studies on acid rain in Mexico City began in the 80's between the National Meteorological Service and the National University of Mexico (UNAM). The case of Mexico City is an example of collaboration between the government and the academic sectors, with joint evaluation of atmospheric deposition since 2002.

It was found that the acidity of rainwater increased from North to South in Mexico City, taking into account the spatial variability of the pH and the influence of meteorology. Therefore, to solve this problem, other aspects should be considered, such as the dispersion, transport, deposition and concentration of acid rain precursors, as well as the reaction mechanisms.

The results of the investigations carried out in Mexico on wet atmospheric deposition have shown the presence of the acid rain phenomenon at the different studied sites, with the exception of Monterrey, Nuevo León and Calakmul, Campeche, where higher weighted pH values to 5.6 were recorded. The potential problem of deterioration in sites of natural and cultural interest continues, due to acid pH on the coast of the Gulf of Mexico and in the Southeast of the country.

An indicator of the reduction of emissions of acid rain precursors is the SO_4^{2-} / NO_3^- ratio, which it was applied during the realization of this study. Comparing the chemical composition of rainwater in the Gulf of Mexico region with stations located in the United States from Texas to Florida is instructive. The State of Veracruz site reported the high values of the SO_4^{2-} / NO_3^- ratio (a value of 4.9 was registered for 2015), which demonstrates the high contribution of sulfur compounds in the atmospheric deposition and the need to control the emissions of the main sources of SO_2 in Mexico.

There is a SO_4^{2-} / NO_3^- ratio of 1.5 at Mexico City, at almost all the stations. However, it is interesting to mention that at the beginning of the 80's s this ratio was four, coinciding with the value currently registered actually in the Gulf of Mexico region.

It is necessary to create links with different institutions for jointly and permanently to promote the operation of a National Atmospheric Deposition Network in Mexico, as well as to strengthen collaboration at an international level. In the last years, collaboration between UNAM and NADP has started and is growing.

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Atmospheric Deposition of Reactive Nitrogen and Trace Species in South Asia

Umesh Kulshrestha[1]

The rapid increase in the use of synthetic fertilizers and fossil fuel energy has resulted in the massive perturbance in the N, C, S and P cycles in the atmosphere. The global rate of anthropogenic N fixation is seen exceeding the natural rate of N fixation. There has been a very significant rise in the global N budget during the past century. Asia is also following such trends. Around 26.8% of the global NO_x emissions and 39.4% of the global NH_3 emissions are contributed by Asia. In South Asia also, the emissions and depositions of Nr species are increasing which have multiple environmental and socio-economic consequences. The Indo-Gangetic region has been reported with high deposition of NH_4 and NO_3 due to very high population density and the related activities. Wet deposition of NO_3 has been increased many folds in urban areas during the past two decades due to increasing fuel emissions. According to reports, the rural sites have higher deposition fluxes of NH_3 as compared to the urban sites due to increased agricultural and other related activities which contribute ammonia. This might lead to Eutrophication in future, However, calcium rich atmospheric dust has been a buffering agent controlling the acidification in the region. Since the emission trend of Nr is still upward, there is a need to investigate their depositions and their consequences in South Asia through a measurement network. The new comprehensive measurements need to focus on identifying Nr sources, their transport, gaseous-aerosols phase abundance of Nr species, the role of meteorology in their transformations, regional atmospheric chemistry, in particular, the role of atmospheric dust and the QA/QC of data. The outcome will further help in the integrated assessment of the possible impacts of atmospheric deposition of reactive nitrogen and other trace species on crop systems, water bodies, vegetation, forests, air quality and human health etc. in the region.

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A Reassessment of Bromide Levels in NADP/NTN Precipitation Samples

Martin Shafer[1] , Chris A Worley[2] and Camille G. Danielson[3]

Bromide was added to the NADP analyte list in 2009 and monitoring of Br levels in NTN and AIRMoN samples continues to date (2018). However, routine measurement of bromide by Ion Chromatography (IC) is challenging and to date nearly 80% of the precipitation samples examined exhibit bromide levels below IC quantification limits (<3-4 µg/L). Prompted by some recent precipitation measurements of bromide that were hard to reconcile geographically or geochemically, the CAL at WSLH initiated a critical evaluation of the NADP bromide IC methods to define the veracity of the bromide data.

A selection of 32 recent NTN samples with IC-measured bromide levels ranging from below detection to over 150 µg/L, were re-evaluated for bromine concentrations using magnetic-sector ICPMS at both Br isotopes (79 and 81). The SF-ICPMS method provides greatly enhanced detection (LOD of 0.05 µg/L) AND specificity. The SF-ICPMS data indicated only very low levels (3.0 ± 1.9 µg/L) of Br, suggesting that the IC data were biased and subject to an interfering species. The most likely candidates for interference under the conditions of the anion-IC run are organic acids and of the common organic acids, oxalate was the most likely species. We have measured oxalate in precipitation and snow samples at levels exceeding the apparent bromide concentrations and the published literature documents levels of oxalate in precipitation in the range of 1-50 µg/L. We confirmed the problem by running both oxalate standards and NTN samples spiked with oxalate and demonstrated that oxalate and Br have nearly identical retention times under the conditions of the NADP IC protocol used by the CAL at both WSLH and ISWS - thus oxalate would be miss-quantified as Br. We then initiated a method development program to identify IC run conditions that would enable baseline separation of oxalate and Br, but not compromise the chromatography of the primary NADP analytes (Cl, nitrate, sulfate). Though still a work in progress, we are now able to isolate bromide from oxalate and preliminary data indicate only low (essentially below LOD) levels of bromide with oxalate accounting for nearly all of the "apparent" Br measured with the old method.

We will be reexamining a large number of NTN samples where bromide was detected by the standard NADP protocol, using the new IC method that enables separation of Br and oxalate. The outcomes of this study and additional SF-ICPMS measurements will be presented.

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Patterns and Controls on Atmospheric Nitrogen, Phosphorus, and Carbon Deposition in Urban Environments

Pamela Templer[1] , Lucy Hutyra[2] and Stephen Decina[3]

The 1990 Clean Air Act Amendments led to declining rates of atmospheric nitrogen deposition in the northeastern U.S., but urban areas remain as hot spots with rates significantly above nearby rural sites. Small amounts of nitrogen deposition can serve as fertilizer, stimulating plant growth. However, high rates of nitrogen deposition can lead to a series of negative consequences, including reductions in plant species diversity, acidification of soils and waterways, and harmful effects on human health. Compared to rates of inorganic nitrogen deposition, less is known about rates of organic nitrogen, phosphorous, and carbon deposition in urban ecosystems. These fluxes are important to understand as more than half of the world's population lives in cities and this number is expected to rise over the coming decades.

We measured nitrogen, carbon, and phosphorus in bulk deposition and throughfall at multiple sites throughout the greater Boston area, including two urban NADP National Trends Network (NTN) sites. We find that rates of atmospheric nitrogen deposition are on average twice as high as nearby rural areas, but vary more than threefold within the greater Boston area. Organic nitrogen makes up approximately one third of bulk and throughfall nitrogen inputs and ammonium makes up about 70% of total inorganic nitrogen deposition. Rates of ammonium and total inorganic N deposition are strongly correlated with on-road emissions of nitrogen oxides and distance to roads, suggesting a significant source of ammonia emissions from urban vehicles. However, we find enhanced rates of throughfall nitrogen in late spring, suggesting either a local source from dry deposition or biogenic processes within the canopy.

Comparing throughfall to bulk deposition, we find that the urban tree canopy enhances growing season inputs of nitrogen, phosphorus, and carbon to urban ecosystems, likely due to a combination of the capture of dry deposition on canopy surfaces, canopy processes, and production of biological matter. With Boston's tree canopy covering approximately 26% of the city, inputs from throughfall roughly double the amount of nitrogen and triple the amount of phosphorus inputs to the ground surface compared to bulk deposition across the City of Boston.

The results of our work demonstrate that atmospheric deposition of nitrogen, phosphorus, and carbon can be both high and variable within an urban area and highlight the need for more measurements of both dry deposition and biogenic fluxes in tree canopies across urban areas.

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Enhancing Wet-Deposition Maps with Urban Data: Preliminary Results from the Network for Urban Atmospheric Nitrogen Chemistry

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For forty years, the National Atmospheric Deposition Program (NADP) has emphasized monitoring at sites where the chemical composition of precipitation is expected to be regionally representative and not influenced by specific emission sources, which are ubiquitous in urban areas. Data from NADP sites designated as urban-influenced are omitted from inclusion in the spatial interpolation processes used to prepare some NADP mapping products to prevent excessive urban influence on surrounding areas. However, the converse is also true, whereby data from regionally representative sites is not representative of urban wet deposition. One of the objectives of the Network for Urban Atmospheric Nitrogen Chemistry (NUANC) is to evaluate the appropriate radius of influence of urban wet-deposition data for NADP's interpolated maps and other products.

The NUANC consists of 5 NADP National Trends Network (NTN) sites specifically installed to collect urban wet-deposition data across the Denver, CO metropolitan area. These 5 sites are aligned in a southeast to northwest transect. In addition, three more NTN sites are included to extend the transect. These 3 sites are in the foothills and mountains of the Front Range, terminating with the Loch Vale site in Rocky Mountain National Park. Weekly samples were analyzed for a suite of constituents, including nitrate and ammonium concentrations, which are used to calculate weekly and annual precipitation-weighted inorganic reactive nitrogen (Nr) concentrations and deposition for each site. The NUANC annual deposition results were included with data from regionally representative sites to create interpolated wet-deposition maps.

Maps with and without the NUANC data were compared. Inclusion of the NUANC data in the wet-deposition maps resulted in a 50 percent increase in estimated Nr wet deposition in the Denver – Boulder urban corridor compared to maps that used only regionally representative data. Not only is the spatial representation of Nr wet-deposition improved, but the NUANC data also allows for more representative estimation of the potential Nr loading to the South Platte River watershed. Assuming an annual runoff coefficient of 0.1, at least 10 percent of the Nr load in the South Platte River was from atmospheric deposition during 2017.

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History of Critical Loads in North America

Tamara Blett[1] and Richard Haeuber[2]

The history of critical loads in North America could be described as a large group scavenger hunt, where many dedicated scientists, land managers and environmental specialists sought to discover multiple pathways which could be used to determine "how much deposition is too much" for sensitive ecosystems. Critical loads are valuable because they can be used in policy and management contexts to determine whether current policies and programs are protecting ecosystems from harm or damage or, if the loading threshold has been reached, to assist in developing goals and strategies for recovery.

These investigations and explorations began in earnest in North America in the 1990s, following the European models, and were largely centered on ozone in the US, and on acidification of surface waters and soils in Canada. The U.S. research on critical loads began in a relatively uncoordinated fashion through multiple efforts affiliated with many different agencies and universities. This resulted in a variety of different methods, some overlap and duplication of effort, and an insufficient linkage between research and policy needs.

In the early 2000s, critical loads in North America began to gain momentum as federal agencies and the research community held several workshops to coordinate and plan research, modeling, monitoring and policy efforts. These workshops determined that items needed in the critical loads scavenger hunt could span a vast portfolio of pollutants (nitrogen, sulfur, ozone, mercury); pathways and mechanisms (airborne, soil and water mediated, direct environmental uptake by plants), synergistic effects such as acidification from both nitrogen and sulfur; and ecological receptors sensitive to air pollutants (e.g., certain species of fish and other aquatic biota, lichen, plants, trees, and soil microorganisms).

In 2006, the critical loads research community gathered at the NADP annual meeting to consider a coordinated multi-stakeholder effort to advance critical loads science in the U.S. Ultimately, Critical Loads Atmospheric Deposition (CLAD) was formed as NADP's first science subcommittee to provide a forum for information sharing, coordination and planning between North American agencies, groups and individuals interested in critical loads development and use. CLAD has worked successfully for over 12 years to systematically prioritize and implement critical loads research and projects, an important task given the immense complexity involved in all the facets of critical loads development. In the early days of CLAD, easier problems were tackled (such as using simple surface water models to predict changes in water chemistry at levels harming fish), later moving successively towards building more complex models (such as tens of thousands of data points representing the impacts of deposition on lichen, tree and herb species); and building comprehensive critical loads data bases and interactive web-based tools. Critical loads data is now increasingly being used to support regulatory development (Nox/Sox secondary standards), resource management decisions (FS and NPS land management and park planning), and stakeholder collaboration (e.g., government-business centered on agricultural emissions) forums. Critical loads has also been instrumental in making over 1000 scientific linkages between air pollutant deposition and ecosystem services such as clean water, healthy fisheries, timber, fiber, grazing, traditional medicine, and the enjoyment of nature. The field of critical loads will continue to evolve and build upon new in

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Exceedance of Lichen-based Critical Loads of Atmospheric Deposition: Why Would a Manager Care?

Linda Geiser[1] , Peter Nelson[2], Mike Bell[3], Linda Pardo[4], Chris Clark[5] and Jason Lynch[6]

Lichens are widely recognized for their relative sensitivity to air pollution compared to plants. As a corollary, lichen-based critical loads of atmospheric deposition have been touted as protective of the broader terrestrial flora. Lichens are less well known for their ecological roles. But, in fact, the roles they play are broadly exemplary of the many ecosystem functions and services provided by other forest and rangeland vegetation. Thus, lichen responses to air pollution can be used to illustrate the risks, from a land manager's perspective, of exceeding terrestrial critical loads of atmospheric deposition. Here, we use lichen species known or likely to occur in Superior National Forest in a case study to show how species level air pollution responses can be used to assess risks from deposition on biological diversity, extirpation of rare species, and the ecological functions and services provided by those species.

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Past, Present and Future of Critical Loads ─ European Perspective

Maximilian Posch[1] and Julian Aherne[2]

The idea of a critical load (CL), i.e., a deposition limit that would protect sensitive ecosystems in the long run, was first suggested by Canadian scientists during the early 1980s. The concept was taken over and further developed in Scandinavia during the mid-80s and by the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) towards the end of the 1980s. Critical loads were subsequently adopted by the CLRTAP as a tool to inform and guide negotiations on emission reduction protocols. At this time a Task Force on Modelling & Mapping, together with a Coordination Centre for Effects (CCE), was also set up under the CLRTAP, with the mandate to compile, maintain and update CL models and databases. Models and methods were documented in a so-called Mapping Manual, which was/is regularly updated and functions as a guideline for a country's National Focal Centre (NFC) to determine internationally compatible CL data for use under the CLRTAP. The negotiations of the Second Sulphur Protocol (1994) marked the first use of CLs, and only five years later the Gothenburg Protocol was signed, following negotiations supported by both CLs for acidification and eutrophication. Updated CLs were used in the revision of the Gothenburg Protocol (2012); further, the European Union (EU) adopted CLs in their negotiations of the latest National Emission Ceilings (NEC) Directive. More recently, the Convention has supported and promoted the development of CLs of sulphur (S) and nitrogen (N) that have biodiversity as an endpoint, given the increasing importance of biological diversity (and the potential impacts from air pollution) . This presentation will give an overview of these various stages in the CL development, and also compare it to developments outside Europe, taking Canada as an example.

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Gaseous Deposition of Atmospheric Elemental Mercury in Ecosystems – What We Know and What is Missing

Daniel Obrist[1] , Dean Howard[2], Martin Jiskra[3], Tanvir Khan[4], Yannick Agnan[5] and Judith Perlinger[6]

Atmospheric Hg, emitted from anthropogenic sources as well as natural sources, deposits via various wet and dry deposition processes. We now understand that the dominant source of Hg in many terrestrial ecosystems is from atmospheric elemental Hg(0) deposition taken up by vegetation and transferred to soils when plants die off or shed leaves (also termed “litterfall”). Here, we discuss recent evidence that Hg(0) dominates as a source to ecosystems, including stable Hg isotopes measurements, direct flux characterization of Hg(0) in the field, proxy measurements such as litterfall deposition and observational and modeling evidence of atmospheric Hg(0) dynamics.

First, we show evidence based on litterfall deposition that has been used to estimate dry Hg deposition in forests. We also discuss limitations of using litterfall as a proxy to estimate Hg(0) deposition, including that it fails to capture deposition of woody tissues, contains both Hg(0) and oxidized Hg(II), does not consider re-emissions of Hg(0) via photochemical processes, and does not account for additional Hg(0) deposition such as direct uptake in soils and under snow. Second, we provide evidence based on stable Hg isotope studies that now show that Hg(0) accounts for 57-94% of Hg in soils of central North American forests, 71% in Alaskan tundra soils, 79% in central European peat soils, and 90% in boreal forest soils in Northern Sweden. Third, we provide evidence that a strong global vegetation Hg(0) sink induces pronounced seasonal variability and diurnal variation of atmospheric Hg(0) concentrations, in particular summertime atmospheric Hg(0) minima at remote sites. Fourth, we provide evidence that provides based on annual measurement series of direct Hg(0) deposition measurements from three ecosystems using micrometeorological measurements and provide preliminary data from a temperate forest in the Eastern United States using flux-gradient measurements. Finally, we provide an overview on how to best integrate Hg(0) deposition into global and regional chemical transport models and show how currently employed resistance-in-series approaches perform against field measurements. For the future, we suggest to deploy direct micrometeorological flux methods across a series of ecosystems to address the critical lack of temporal and spatial data on Hg(0) exchange across ecosystems and to provide direct Hg(0) deposition datasets from remote ecosystems to allow parameterizations of Hg(0) deposition in models against field observations.

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Investigation of Atmospheric Chemistry of Gaseous Oxidized Mercury at a Coastal Site in Atlantic Canada

Irene Cheng[1] , Leiming Zhang[2], Huiting Mao[3], Zhuyun Ye[4], Robert Keenan[5] and Rob Tordon[6]

Atmospheric mercury chemistry is an integral part of the environmental cycling of mercury; however the understanding of the chemical reaction mechanisms and kinetics remains incomplete. Atmospheric chemistry drives the cycling of mercury by converting gaseous elemental mercury (GEM) to speciated mercury, including gaseous oxidized mercury (GOM) and particle-bound mercury (PBM), which enters terrestrial and aquatic ecosystems through atmospheric deposition. In this study, a box model containing the most up-to-date gaseous and aqueous chemical reactions involving mercury, bromine, chlorine, iodine, and ozone was used to simulate the formation and dry deposition of GOM at the Kejimkujik National Park, Nova Scotia, Canada. The measurements available as initial input to the box model included GEM, O_3, NO_2, solar radiation, and temperature. The modeled results were evaluated through comparisons with GOM measurements at this site. For selected dry, clear sky days from 2009 to 2016, the mean and standard deviation of the GOM concentration was 1.3 ± 2.0 pg m^{-3} in the observed data and 1.8 ± 1.5 pg m^{-3} in the modeled results. The model was able to reproduce not only the observed GOM concentrations, but also the spring/summer variation and land/marine differences in GOM. The normalized mean bias of the model was +42% for GOM and -94% for PBM, indicating that the model overestimated the observed GOM and significantly underestimated the observed PBM. The model-measurement discrepancies in PBM suggest that gas-particle partitioning may not be accurately represented given a lack of particle size-resolved PBM data and uncertainties in the aqueous chemistry. PBM could also be originating from natural sources that have not been included in the box model. Thus, we find that the box model is most suitable for simulating GOM. Based on the GOM species from the model output, GOM was predominantly formed by GEM oxidation by O_3 and OH (74%), H_2O_2 (17%), Br with NO_2 in the second reaction step (6%), BrO (2%) and other oxidants (<1%). Future work will include a detailed comparison of model and measurement differences by stratifying the data into different seasons and transport patterns to examine how these factors affect atmospheric mercury oxidation.

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Mercury Wet Deposition Differences by Precipitation Type at One Remote Island Site in Northwest Pacific and Two Sites in Northern Taiwan in 2010-2015

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A nation-wide wet Hg deposition monitoring network, consisting of 11 sampling sites in Taiwan and a remote island site in subtropical Northwest Pacific Ocean, was established to collect weekly rainwater samples for total Hg analysis since 2009. Recent studies indicate that Hg wet deposition is influenced by precipitation type, usually higher Hg concentrations and/or depositions associate with thunderstorms. Using 6 years (2010-2015) of wet Hg deposition measurements at a remote island site (Pengjiayu) in Northwest Pacific Ocean and 2 sites (Anbu and Taipei) in northern Taiwan, we explored and reported here the effect of precipitation type on wet Hg deposition. Taipei is an urban site and Anbu is a mountain site inside a national park near the city of Taipei. Six-year volume-weighted mean (VWM) concentrations of rainwater Hg were 7.77, 10.01 and 10.60 ng/L at Pengjiayu, Mt. Bamboo and Taipei, respectively. Average annual wet deposition fluxes were 11.89, 41.24, and 26.03 μg/m^2/yr, respectively. Much higher wet Hg deposition flux at Anbu was because of much higher rainfall depth (4549 mm) compared to Pengjiayu (1662 mm) and Taipei (2369 mm). Wet deposition events were classified into 7 precipitation types, including frontal system in spring (FS), circulation associates with high pressure in spring (HS), Pacific high pressure in summer (PH), typhoon (TP), low pressure in southern China or the South China Sea (LS), frontal system in fall and winter (FA), and northeast monsoon flow (NE). Because of notable surface heating under summer PH conditions, precipitation systems usually form locally as a result of strong convection. The highest VWM concentrations of rainwater Hg were found to associate with the PH precipitation type at all the sites, with values of 18.35, 16.34, and 17.39 ng/L at Pengjiayu, Anbu and Taipei, respectively. This is possibly due to the scavenging of gaseous oxidized Hg (GOM) from above the mixing layer by convective precipitation in summer.

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Is it Possible to Accurately Measure Ambient Air Mercury at the Low Parts Per Quadrillion Level Using Passive Samplers?

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Ambient air background levels of gaseous mercury are routinely observed below 150 parts per quadrillion (ppqv), or in typical units, 1.3 ng/m^3. It is now taken for granted that measurements at this level are routine using the automated, continuous, CVAFS-based, Tekran 2537X Gaseous Mercury Air Monitor and associated speciation modules. At these levels, which are one thousand and one million times lower than typical ambient NO_x and O_3, respectively, it is not surprising that maintaining continuous and accurate automated gaseous air mercury measurements can be more challenging and costly than anticipated. While high-resolution, automated air mercury speciation measurements have and still are demonstratively valuable for leaps forward in knowledge about air mercury cycling, and the links to wet and dry deposition, the Minimata Convention on Mercury has created an opening for low-tech, lower cost and more widespread ambient air mercury monitoring to compliment the current global instrument-based networks. At the low ppqv level, a low-tech, low-cost ambient air mercury monitoring method has a number of hurdles to overcome and demands trade-offs in sensitivity and resolution. Enter the U. of Toronto team of Wania, McLagan and Mitchell who have developed a passive gaseous air mercury method for highly accurate and precise air mercury determinations at the ppqv level. The science and methodology of MerPAS (Mercury Passive Air Monitor) will be presented, including the key results from calibration and performance studies in comparison to automated electronic monitors. Additionally, the analysis methodology and unique challenges will be presented in brief. MerPAS applicability is not confined to ambient air monitoring. For example MerPAS is useful for source area monitoring studies, which may help with Minimata compliance. An example of a MerPAS national or global network design will be presented.

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Wet and Dry Deposition of Total Mercury and Methylmercury at an Unpolluted Site in Puerto Rico

James Shanley[1] , Martin Risch[2], Robert Brunette[3], Willam H. McDowell[4] and Grizelle Gonzales[5]

Wet deposition of mercury (Hg) at an unpolluted site in windward northeastern Puerto Rico is comparable to the highest levels in the continental USA. Here we update the existing seven-year record after three years of measurements at a relocated station, provide estimates of dry Hg deposition based on throughfall and litterfall, and quantify methylmercury (MeHg) in wet and dry deposition. In 2006-2007 (the most complete record), annual wet Hg deposition averaged 27.9 µg m^{-2}. High wet Hg deposition is attributed to scouring of global pool Hg from the upper free troposphere by rain near the tops of high convective clouds, as well as high rainfall amounts (2855 mm y^{-1}). In 2014, after years of incomplete record due to logistical difficulties, the station relocated 11 km west to a NADP site in August 2014. The new station has less rainfall due to its lower elevation (360 vs. 480 m). The measurement period included a significant drought in 2015, and the devastating hurricanes of September 2017, which shut down the station for several weeks. Wet Hg deposition was 15.9 µg m^{-2} with 2034 mm rainfall in 2015, and 30.9 µg m^{-2} with 3347 mm rainfall in 2016. Weighted average Hg concentration decreased slightly from 9.8 ng L^{-1} at the original site to 8.7 ng L^{-1} at the new site. Preliminary wet and dry deposition measurements did not overlap well in time and space, but suggest that dry Hg deposition is a major fraction of the total. For calendar year 2014, litterfall Hg deposition (representing primarily dry deposition of Hg^0) at the NADP site was 38.0 µg m^{-2}. Throughfall Hg deposition (representing primarily dry deposition of Hg^{2+}) for 9 months of overlapping measurements at the original site in 2006-2007 was 54% greater than wet Hg deposition. The percentage total Hg as MeHg was 0.06 % in rainfall, 0.56% in throughfall, and 0.31% in litterfall. Combined, these measurements suggest that dry Hg deposition is considerably greater than wet (similar to findings in temperate forests) and that relative input of (or conversion to) MeHg in the forest canopy is considerably less than published values.

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Technical Session 4: **Mercury in Ecosystems**

Session Chair: Eric Prestbo, Tekran Instruments

Factors Influencing Mercury Concentrations in Fish from Streams in the Northeastern United States

Karen Riva-Murray[1] , Peter C. Van Metre[2] and James F. Coles[3]

Fish-tissue mercury (Hg) concentrations frequently exceed human health advisory levels and wildlife guidelines in surface water throughout the northeastern United States. However, most assessments of fish Hg concentrations have been conducted on lakes, and little is known about the spatial distribution of stream fish Hg concentrations across the region. The Northeast Stream Quality Assessment (NESQA), a multi-stressor study of wadable streams across eight northeastern states, provided an opportunity to address these issues. Specific objectives were to document stream-fish Hg concentrations in relation to guidelines for human and wildlife health, and to advance the understanding of Hg bioaccumulation in streams by describing relations between fish Hg concentration patterns and biological, chemical, and physical factors measured during the NESQA. Streams were located in urban, agricultural, and forested watersheds in eight states, and represented a range of Hg source conditions, methylation potentials, and food web characteristics. Total Hg concentration (THg, assumed to be primarily methylmercury [MeHg]) was analyzed in fish specimens collected from 90 streams. Small-bodied, mid-trophic, invertivorous fishes were collected from nearly every site, and were processed as single-species composites of whole specimens. Game fish samples were collected from 54 of the sites, and were processed as individual skinless fillets. Fish and periphyton samples also were analyzed for nitrogen stable isotopes ($\delta^{15}N$) to provide estimates of base-adjusted trophic position (i.e., by adjusting fish $\delta^{15}N$ for differences among sites in base nitrogen signature) and for carbon stable isotopes ($\delta^{13}C$), an indicator of dietary carbon source. Fish Hg concentrations will be compared with human-health and wildlife-health guideline levels, and will be analyzed in relation to stream physical data (e.g., stage, temperature), water quality data (e.g., pH and dissolved organic carbon, sulfate, THg, and MeHg concentrations), bed sediment THg, landscape characteristics, and biological data (e.g., trophic position, size, and feeding ecology) to determine factors affecting mercury bioaccumulation in stream-resident fish across the northeastern United States.

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Chemical and Physical Controls on Mercury Source Signatures in Stream Fish from the Northeastern United States

Sarah Janssen[1] , Karen Riva-Murray[2], Peter C. Van Metre[3] and David P. Krabbenhoft[4]

Streams in the northeastern US receive mercury (Hg) from direct and indirect atmospheric deposition, as well as current and (or) historic point source contamination / discharges, which, together, contribute to high concentrations in fish throughout the region. Mercury stable isotope ratios were used to identify Hg sources to fish and bed sediments in 23 small streams spanning a wide range in water-quality characteristics and land use, ranging from largely undeveloped, forest-dominated to dense urban with current or historical industrial land use. Median mass-dependent isotopes (δ^{202}Hg) in prey and game fish differed among three land-use defined groups of sites. Median δ^{202}Hg values were relatively depleted (-0.95 and -0.83 ‰, respectively) in the forested group, intermediate (-0.61 and -0.58‰, respectively) in the residential group, and relatively enriched (-0.37 and -0.25 ‰, respectively) in the industrial group. A principal components analysis of environmental variables produced a synthetic urban-intensity gradient of increasing chloride, nitrogen, phosphorous, and total mercury concentrations in stream water, total mercury concentrations in bed sediments, and watershed road density. Prey fish and game fish δ^{202}Hg were strongly correlated to site scores along this urban-intensity gradient (ρ= 0.87, $p<0.0001$ and ρ= 0.79, $p < 0.0001$, respectively), indicating that Hg source signatures from the landscape are preserved in fish. In contrast, neither prey fish nor game fish Δ^{199}Hg (an indicator of photochemistry) were significantly correlated with the urban-intensity gradient, but Δ^{199}Hg in bed sediment was strongly correlated (ρ= 0.89, $p < 0.0001$) with this environmental gradient. This indicates that photochemical tracers in sediment are unique to the source of Hg whereas those in fish record more recent water column processes, such as water column demethylation. Using measurements of physical and chemical parameters of stream ecosystems coupled to Hg isotope ratio measurements allows for the identification of Hg source portfolios in fish tissue that can be used to probe Hg bioaccumulation over a wide range of ecosystems.

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Mercury in Fish from National Parks – Concentrations, Sources, and Ecological Risk

Colleen Flanagan Pritz[1] , Collin Eagles-Smith[2], David Krabbenhoft[3], Sarah Janssen[4], James Willacker[5],
Kerensa King[6] and Alan Ellsworth[7]

Mercury (Hg) emissions to the atmosphere can transport at global scales and subsequently deposit anywhere, including pristine national parks. As Hg accumulates in the ecosystem it can be toxic to natural resources the National Park Service is mandated to protect. Possible deleterious effects include reduced foraging efficiency and reproductive success of wildlife, and the issuance of fish consumption advisories to protect human health. But since Hg is a naturally occurring element it can often be challenging to distinguish how much arrives from anthropogenic sources. Therefore, we measured Hg in more than 3,900 fish from 239 remote lakes and rivers (spanning 51 fish species and 56 national parks in 33 states), analyzed composite samples for Hg isotopic signatures to assess sources, and compared eastern fish Hg concentrations to health benchmarks.

Preliminary findings suggest that across all parks, sites, and species, fish Hg concentrations ranged from 7.3 to 2,663 ng/g ww with a mean of 149.6 ng/g ww. Fish Hg levels varied greatly both among and within parks, suggesting that patterns of Hg risk are driven by processes occurring at site specific, local, and continental scales. Measurements of d^{202}Hg, D^{199}Hg, and D^{200}Hg have been shown to be effective indicators of Hg source, photo-chemical processing, and atmospheric transport, respectively. Preliminary data indicate that the atmospheric tracer D^{200}Hg was observed in most sites, but to a lesser extent in the east, suggesting regional Hg sources that have not undergone long range atmospheric transport. Western sites show enhanced D^{199}Hg likely tied to precipitation inputs and increased photochemical processing, whereas, lower D^{199}Hg and tightly clustered d^{202}Hg data from the eastern sites suggests a different Hg input pathway, likely dry deposition driven by regional Hg emitters. These trends are clearer when constrained to a single fish species. Preliminary results also indicate that Hg concentrations were below EPA's fish tissue criterion for safe human consumption in 81% of the fish sampled. However, Hg levels in individual fish at some sites from 21 of 35 eastern national parks exceeded the human health criterion. Mercury concentrations in at least one individual exceeded the most conservative fish toxicity benchmark at 45% of all sites, and the most sensitive health benchmark for fish-eating birds at 76% of all sites. Much of the mercury found in these mainly remote areas is likely the result of air pollution from outside the parks. Future targeted research and monitoring across park habitats would help identify patterns of Hg distribution across the landscape and facilitate informed management decisions aimed at reducing the ecological risk posed by Hg contamination in sensitive ecosystems.

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Increase in Lake Champlain Fish Mercury Linked to Elevated Sediment Loading from Hurricane Irene

Mark Swinton[1] and Sandra Nierzwicki-Bauer[2]

Routine monitoring of Lake Champlain fish showed a steady decrease in mercury between the late 1980s and 2011 associated with stricter emission regulations. However, the most recent study, 2016-2017, revealed that mercury has significantly increased in smallmouth bass and yellow perch. Between 2011 and 2016-2017 mercury in smallmouth bass increased by 27% in 14” specimens, while mercury in yellow perch increased by 32% in 7” specimens. Factors known to influence biotic mercury (atmospheric deposition, temperature, primary production and pH) can not account for recent increases, however sediment loading is a likely contributor. Sediment loading to Lake Champlain in 2011 was ~4-fold greater than the average annual load with Hurricane Irene responsible for loading almost an entire year’s worth of sediment in a single day. The increased loading and subsequent rise in fish mercury is reminiscent of the METALLICUS study that showed spiked mercury accounted for ~25% of the mercury in young-of-the-year yellow perch three years after the initial application. Although mercury concentrations have risen in Lake Champlain, the trends did vary by lake segment, the most notable in Malletts Bay where fish mercury continued to decline. Causeways severely restrict water exchange in Malletts Bay and result in seasonal hypoxia/anoxia, both of which may be linked to the continued decrease in fish mercury. Obtaining a better understanding of the factors affecting the mercury cycle in a future with more extreme events will help improve resource management to ensure human and wildlife health.

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The Dragonfly Mercury Project: Biosentinel Mercury Concentrations and Landscape Drivers across U.S. National Parks

Megan Hess[1] , Sarah Nelson[2], Collin Eagles-Smith[3], Colleen Flanagan Pritz[4] and James Willacker[5]

The Dragonfly Mercury Project spans nearly every state in the US, and represents samples collected across over 100 diverse national parks. Since 2009, parks have sampled dragonfly nymphs for total mercury (Hg) analyses, often coupled with water and sediment quality metrics to determine: (1) baseline Hg concentrations in national parks prior to large-scale implementation of national and international mercury emission controls; and, (2) how vulnerability food web Hg accumulation varies among habitats and with landcover characteristics. Dragonfly nymphs are useful biosentinels for Hg spatial patterns because they inhabit many freshwater habitats, are relatively sedentary, and as predators, contain almost all of their Hg as MeHg. As of 2017, a total of 127 freshwater lakes, ponds, wetlands, streams, and river sites have been sampled across 34 national parks. Preliminary results indicate that the mean (± SE) THg concentration in dragonfly nymphs was 141.1 ± 2.5 ppb dry weight (dw). We observed 76fold variation between the sites with the greatest (>1000 ppb, dw) and least (~20 ppb, dw) THg concentrations across parks, and up to 44-fold variation among sites within a single park. These preliminary findings highlight the importance of spatial variability at the scale of individual water bodies. By linking dragonfly THg concentrations with data on water and sediment Hg, water chemistry, and watershed characteristics, the DMP will provide valuable insights into the drivers of, and potential vulnerability to, MeHg bioaccumulation in the NPS's aquatic resources. Although benchmarks that define how these dragonfly Hg concentrations translate to risk for the animals that consume them are still in development, our early analyses suggest that dragonfly larvae with Hg concentrations less than about 315 ppb, dw are likely to be in the lowest risk category. This proposed benchmark reflects potential toxicological risk to fish and wildlife based upon a combination of published effects thresholds and trophic enrichment factor estimates; further interpretation requires site-specific information on foodweb structure and community composition that is rarely available. The DMP is implemented within each park via engagement of citizen scientists, sparking public interest in biodiversity and participatory science, as well as communicating key messages about air quality and mercury risk. Since 2009, over 3,705 citizens have participated in the project, providing the scientist team with 8,769 dragonfly samples and making the research possible across this broad spatial scale.

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Technical Session 5: **Ecosystem Effects, Recovery, and the Future**
Session Chair: Linda Geiser, USDA-Forest Service

25 Years of Whole-Watershed Experimental N Additions in a Forested Maine Watershed

Ivan Fernandez[1] , Kaizad Patel[2], Marie-Cecile Gruselle[3], Stephen A. Norton[4], Sarah J. Nelson[5] and Aaron Weiskittel[6]

Chronic elevated nitrogen (N) deposition has altered the N status of temperate forest ecosystems in North America, with implications for forest productivity, nutrient transformations, ecosystem nutrient retention, and surface water chemistry. The Bear Brook Watershed in Maine (BBWM) is a paired whole watershed manipulation experiment focused on the effects of N and sulfur (S) deposition on ecosystem function. N was added bimonthly as $(NH_4)_2SO_4$ to one watershed (West Bear) from 1989 to 2016. Research at the site has studied the evolution of ecosystem response to both treatments and ambient changes in the chemical and physical climate over time, Here, we synthesize results from three decades of research on streams, soils, and vegetation for both the reference and treated watersheds. While N leaching and export increased almost immediately in West Bear when treatments began, labile soil N (ammonium, NH_4^+-N and nitrate, NO_3^--N) did not increase in West Bear until the fifth year of treatment. Labile N became increasingly available in West Bear over time, and after 25 years of treatment, West Bear soils had 10X more extractable NH_4^+-N and 100X more extractable NO_3^--N than the reference watershed soils. Stream exports of N from the reference watershed declined by 95% from 1990 to 2016 to approximately 0.05 kg ha^{-1} yr^{-1}, consistent with declines in ambient N deposition. In comparison, exports from West Bear were approximately 5 kg ha^{-1} yr^{-1} and remained constant. Forest vegetation contained 1.3X the N in the treated watershed compared to the reference, attributable to increased forest growth and tissue N concentrations as a result of the treatments. Despite multi-decadal N additions to the treated watershed, forest vegetation still was mining soil N stocks to meet annual increment demand. The study demonstrates how long-term ecosystem research is essential to define changing N dynamics on decadal timescales and how these patterns of N dynamics continue to evolve over time.

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Differential Vulnerability of 348 Herbaceous Species to Atmospheric Deposition of Nitrogen and Sulfur across the Contiguous U.S.

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Atmospheric nitrogen (N) and sulfur (S) pollution increased greatly across industrialized temperate regions during much of the 20th century. Despite significant declines in recent decades, N and S deposition continue to negatively affect the distribution of many plant species. We used presence/absence data from >14,000 survey sites across the contiguous US to determine how regional variation in N and S deposition affects the distribution of 348 herbaceous species. We found that 53% of species assessed were negatively affected by N and/or S deposition somewhere in the contiguous US. Species-level critical loads of N deposition, above which detection probability declined, varied widely between species (means from 2.9 to 17.6 kg N ha-1 yr-1) and within species (average range of 8 kg N ha-1 yr-1). Wide within species variation urges caution when using any single threshold for a species and was due to interactions with S deposition and soil pH which influenced local critical loads. Critical loads for 30 (N) and 139 (S) species could not be quantified as they were lower than the minimum deposition experienced. Approximately 17% and 54% of species were experiencing detrimental levels of deposition over more than half their occurrences for N and S, respectively. Although more species increased than decreased with N deposition, increasers were more likely to be introduced species, and high value natives tended to be more vulnerable. We developed predictive equations relating vulnerability from N deposition to simple traits like leaf magnesium and nitrogen concentrations, suggesting that these results may be generalized to species with trait information. These results can inform ecological theory, as well as the protection of natural communities through air quality policies.

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Assessing Risk to Forest Ecosystems from Nitrogen and Sulfur Deposition across the Continental U.S.

Linda Pardo[1] , Kevin J. Horn[2], Christopher M. Clark[3], R. Quinn Thomas[4], Robert Sabo[5], Jeremy Ash[6], Michael D. Bell[7], Justin Coughlin[8] and Jennifer James[9]

The consequences of atmospheric nitrogen and sulfur deposition continue to affect the growth and survival of trees in forest ecosystems across the US. We found that the majority of the 94 tree species we evaluated had detrimental responses to N and or S deposition. Based on analysis of US Forest Service Forest Inventory and Analysis (FIA) data and US-EPA CMAQ model deposition estimates, we set critical loads for N and S deposition for 73 tree species in the conterminous United States. Growth and survival estimates were made from repeated measurements of more than 1.4 million individual trees measured between 2000 and 2016.

We examine tree CLs and exceedances for example ecosystem types in the eastern and western US to demonstrate how resource managers could use this information to assess *likely impacts from atmospheric N and S deposition under various management scenarios.*

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A Clean Air Act Success: Indicators of Recovery in Fish Assemblages and Water Quality from Acidified Streams of the Catskill and Adirondack Mountains, New York

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Decades of acidic deposition adversely affected aquatic ecosystems across eastern North America, with particular severe impacts noted in mountainous regions of New York State. The 1990 Clean Air Act Amendments (CAAA) reduced acid deposition and acidity of many poorly-buffered lakes in the Adirondacks, but had little effect on streams due to their dynamic hydro-geochemical regimes. Significant temporal trends and improvements in stream chemistry and biology did not become apparent until only recently. Water chemistry and discharge from six streams (1991-2017), and fish data from dozens of quantitative surveys (1979-2017) were assessed to ascertain the effects of the CAAA on acid-base chemistry and fish assemblages in acidified Adirondack and Catskill Mountain streams. Concentrations of sulfate and inorganic Al decreased, whereas pH and acid neutralizing capacity increased significantly in many previously acidified streams between 1991 and 2017. Inorganic Al concentrations decreased to, or below, an acute toxicity threshold of 2.0 µmol/L in several severely acidified streams and reached a chronic toxicity threshold of 1.0 µmol/L in some moderately acidified streams. Except for streams with barriers, total density and biomass of fish communities (and brook trout populations), and total community richness increased in de-acidifying streams between the early 1990s and present. These findings indicate that the chemistry and biology of many streams in acid-sensitive regions of New York are beginning to recover in response to the 1990 CAAA.

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Do Watershed and In-Stream Liming Accelerate Recovery of Macroinvertebrate Communities in Acidified Tributaries to an Adirondack Lake?

Scott George[1] , Barry P. Baldigo[2], Gregory B. Lawrence[3] and Randall L. Fuller[4]

Liming techniques are being explored as tools to accelerate the recovery of aquatic biota from decades of acid deposition in many regions. The preservation or restoration of native sportfish populations has typically been the impetus for liming programs, and as such, less attention has been given to its effects on other biological assemblages such as macroinvertebrates. Furthermore, the effects of various lime application strategies such as in-stream and watershed applications are not well understood. In 2012, a program was initiated using in-stream and aerial (whole-watershed) liming to improve water quality and Brook Trout (*Salvelinus fontinalis*) recruitment in three acidified tributaries of a high-elevation Adirondack lake in New York. Concurrently, macroinvertebrates were sampled annually between 2013 and 2016 at 3 treated sites and 3 untreated reference sites to assess the effects of each liming technique on this community. Despite increases in pH and acid neutralizing capacity and decreases in inorganic aluminum in all three limed streams, neither liming technique improved the condition of macroinvertebrate communities. The watershed application caused a brief decrease in the density of macroinvertebrates and increase in the proportion of sensitive taxa. These changes were driven primarily by a one-year 71 percent reduction of the acid-tolerant *Leuctra* stoneflies and likely represent an initial chemistry shock from the lime application rather than a recovery response. The in-stream applications appeared to reduce the density of macroinvertebrates, particularly in one stream where undissolved lime coated the natural substrate. The close proximity of our study sites to the in-stream application points (50 and 1230 m) may partly explain these negative effects. Our results are consistent with those from prior studies which indicate that in-stream liming often fails to restore macroinvertebrate communities to a pre-acidification condition, especially at distances within 1.5 km downstream of the lime application point. The inability of either liming technique to improve the condition of macroinvertebrate communities may be partly explained by the persistence of acidic episodes in all three streams. This suggests that in order to be effective, liming programs should attempt to eliminate even temporary episodes of unsuitable water chemistry rather than just meeting minimal criteria most of the time. Because watershed liming produced a more stable water chemistry regime than in-stream liming, this technique may have greater future potential to eliminate toxic episodes and accelerate the recovery of acid-impacted macroinvertebrate communities.

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Soil-Calcium Depletion Extends Increasing Trends of Dissolved Organic Carbon in Adirondack Streams

Gregory Lawrence[1]

Increasing trends of dissolved organic carbon (DOC) in surface waters have been documented in northern Europe and North America where these waters are being influenced by acid deposition recovery. Lower S deposition and associated acidity can increase the solubility of organic carbon by decreasing the charge density of soluble organic matter and lowering the ionic strength of soil solutions as atmospheric deposition becomes more dilute. With several decades of declining S deposition, the focus has been on the effect of decreased acidity in moving DOC concentrations toward levels that naturally occurred before acid deposition. However, despite S deposition approaching levels estimated for the early 1900s, increasing DOC has continued. These ongoing increases in DOC are of ecological significance because (1) the associated organic acidity suppresses pH and ANC increases from lower acid deposition, (2) increased DOC alters the thermal properties and mixing of lakes, and (3) nutrient relationships of surface waters are likely to be altered.

To improve our understanding of the mechanisms controlling trends in surface water DOC concentrations, stream chemistry data were collected from over 50 streams (stratified random selection of streams from severe to no acidification) in the western Adirondack region of New York. Data collected in 2004/05 were compared by season (spring snowmelt, August base flow) with data collected in the same manner from the same streams in 2014/15. Data collected from high elevation streams (> 860 m sampling elevation) were also collected during late summer base flow in 2010 and spring snowmelt in 2011. From 2004/05 to 2014/15, pH averaged for all streams increased in August, but decreased during snowmelt, whereas concentrations of DOC decreased during the summer and increased during snowmelt. These results are the opposite of what would be expected if acidity was the primary factor controlling DOC trends. However, comparison of snowmelt data from these two sampling periods did show that higher DOC coincided with lower ionic strength in 2014/15, which suggests that ionic strength was controlling DOC concentrations. High elevation stream chemistry also showed that even though concentrations of strong acid anions (SO_4, NO_3, and Cl) were lower during snowmelt than summer, pH was also lower during snowmelt because of acute dilution of base cations. The driver of increasing trends in DOC concentrations appear to be shifting from decreases in acid inputs to decreases in ionic strength, which is dependent on the base saturation of soils as well as S inputs.

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Recent and Potential Future Changes in the Chemistry of Surface Waters of the Adirondack Region of New York in Response to Decreases in Atmospheric Deposition

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Historical acid deposition has contributed to the acidification of soil and surface waters in acid-sensitive regions of the U.S. Over past several decades, however, controls on sulfur dioxide and nitrogen oxide emissions in the U.S. have reversed this process, resulting in decreases in acid deposition that have led to decreases in sulfate and nitrate concentrations and increases in the acid neutralizing capacity (ANC) in surface waters of acid-sensitive regions like the Adirondacks of New York. Concentrations of dissolved organic carbon (DOC) in surface waters have also increased in response to decreasing acid deposition. As recovery from acid deposition proceeds, changing climate is also becoming an important potential driver of changes in surface water chemistry. We present an analysis of long-term observations of lake chemistry in the Adirondacks in response to decreases in acid deposition. This analysis is complemented by the application of the watershed biogeochemical model, PnET-BGC, to an intensive study site in the Adirondacks, Buck Creek, to examine future decreases in acid deposition coupled with projected changes in meteorological conditions. PnET-BGC has been modified to include an algorithm that depicts changes in the mobility of DOM (dissolved organic matter) with changes in soil acid-base chemistry. Analysis of chemical trends in Adirondack lakes show ongoing decreases in sulfate, nitrate, calcium and inorganic monomeric aluminum, and increases in ANC. Coincident with lake recovery from acid deposition are marked, but spatially variable increases in DOC concentrations. The supply of DOM provides naturally occurring organic acids that offset increases in ANC. Results show mean lake DOC concentrations and changes in lake DOC concentrations increase with increases in watershed to lake surface area ratio and decreases in lake hydraulic residence time. The PnET-BGC modeling of Buck Creek is consistent with ongoing lake trends. Likely future decreases in acid deposition are projected to continue to decrease stream sulfate and nitrate concentrations and increase ANC, but recovery of soil percent base saturation will be delayed. Model simulations also examine effects of DOM mobility and changing climate on recovery of soil and surface waters.

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The Responses of Stream Ecosystems to Future Scenarios of Atmospheric Deposition Derived from Changing Land Use-related Emission and Projected Future Meteorological Conditions

Shuai Shao[1] , Charles Driscoll[2], Huizhong Shen[3], Yilin Chen[4] and Armistead G. Russell[5]

While SO_2 and NO_x emissions from energy, industrial and mobile sources have been reduced significantly by traditional regulations, land use-related emissions are playing a more dominant role in affecting surface water acidification through deposition. Development of land use and climate-based policies to improve both air and water quality requires comprehensive assessments of future deposition and meteorological conditions and its associated impacts on water quality, especially in sensitive regions (National Parks and other Class I regions). In this study, we applied the watershed biogeochemical model, PnET-BGC, to evaluate the responses of stream water chemistry to the future changes in atmospheric deposition and meteorological conditions in the Great Smoky Mountains National Park and the Adirondack region of New York in eastern US. The future atmospheric deposition scenarios were developed by using CMAQ model simulations of future (2050) scenarios with and without considering land use-related emission changes in various sectors (agriculture, biogenic and forest fire emissions). The future climate scenarios were extracted and downscaled from 18 global climate models from the Coupled Model Inter-comparison Project Phase 5 (CMIP5). Our simulation results will show that the difference in stream water chemistry in response to two future deposition scenarios (with and without land use-related emission change) and the comparison of stream water chemistry in response to multiple projected meteorological conditions. Model simulations will examine the effects of changing climate and land use-related emission on recovery of stream waters.

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Technical Session 6: **Atmospheric Deposition - Total and Reduced Nitrogen**
Session Chair: Donna Schwede, U.S. Environmental Protection Agency

Measuring Surface-Atmosphere Exchange of Ammonia over a Corn Field Using the Eddy Covariance Method

Saumya Singh[1] , Alex Moravek[2], Elizabeth Pattey[3], Amy Hrdina[4], Thoodora Li[5], Luc Pelletier[6], Stuart Admiral[7] and Jennifer G Murphy[8]

Atmospheric ammonia (NH_3) is an important precursor of fine particulate matter in the atmosphere, adversely affecting air quality, climate and biodiversity. Ammonia originates mostly from agricultural sources, including N synthetic and organic fertilization. It is important to quantify NH_3 exchange of crops to better understand the conditions favouring ammonia volatilization/deposition in response to fertilizer application and crop growth. However, NH_3 fluxes are challenging to measure because NH_3 is easily adsorbed and desorbed from most surfaces. The study presents the direct eddy covariance (EC) NH_3 fluxes measured over the 2017 and 2018 growing seasons from a urea-fertilized corn field located in Ottawa, Canada. A flux tower was equipped with a 3-D sonic anemometer (CSAT3; Campbell Scientific, UT) and a fast time-response Quantum Cascade Tunable Infrared Differential Absorption Spectrometer (QC-TILDAS; Aerodyne Research, MA) for NH_3 measurements. The second year had a rainfall deficit while the first year had unusual rainfall surplus. During the 2017 growing season, NH_3 emission reached up to 500 ng m^{-2} s^{-1} within the first week following urea application as the urea hydrolysis occurred quickly due to significant rain within this period. As the canopy started growing, the NH_3 emissions decreased and at the end of the growing season deposition of NH_3dominated. In 2018, there was little evidence of NH_3 emission immediately following fertilizer application, but sustained emissions occurred following a rainfall event two weeks later. The results from both years highlight the importance of measuring fluxes over long periods to capture the bi-directional exchanges of NH_3 and evaluate the contribution of NH_3 fluxes to the annual nitrogen budget.

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Measurements of Ammonia Emission and Deposition in Adjacent Natural Ecosystems

Mark Zondlo[1] , Xuehui Guo[2], Da Pan[3], John Walker[4] and Ryan Daly[5]

Ammonia (NH_3) is the most abundant alkaline gas in the atmosphere and a precursor to ammonium (NH_4^+) aerosols. NH_3 and NH_4^+ also deposit to ecosystems, degrading the environment through eutrophication of surface waters and soil acidification. Agricultural activities dominate anthropogenic NH_3emissions, but significant uncertainties exist on the fate of these emissions further downwind. NH_3 deposition is poorly constrained by observations, in part due to the measurement challenges of gas phase NH_3 itself. To this end, we developed and deployed two laser-based open-path NH_3 sensors over a natural grassland and adjacent deciduous forest canopy at Duke Forest, North Carolina from August to November 2017 to examine NH_3 fluxes in adjacent natural ecosystems. While the site location is relatively clean with respect to local NH_3 emissions, southeasterly winds place it downwind of the intense agricultural emissions in eastern North Carolina. The sensors were mounted on a 44-m tall tower over the forest canopy and on a 2-m tower over the grassland. A MARGA gradient system and NH_x denuders were also available at the site for intercomparison. The forest and grassland sensors demonstrated 10 Hz precision of 0.17 and 0.30 ppbv, respectively. NH_3 fluxes were calculated from the 10 Hz concentration and three-dimensional wind velocity using the eddy covariance method. Preliminary results suggest net deposition of NH_3 onto the forest canopy and weak net emission from the grassland. Mean NH_3 fluxes of -9.2 ng/m^2/s and 1.4 ng/m^2/s were measured by the forest and the grassland systems over the entire campaign. Diurnal profiles of NH_3 at the forest and the grassland showed both highest deposition and highest emission during the midday. Smaller peaks of fluxes were also observed in the late afternoon. Ongoing analyses examine the potential biogeochemical and micrometeorological drivers of differences in fluxes between the two ecosystems and relationships between fluxes and trajectories of air passing over the upwind agricultural areas. Our results point to variability of NH_3 fluxes among natural ecosystems as an important sub-grid process and source of uncertainty in chemical transport models used for deposition assessments.

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Potential Contribution of the Satellite Observations for Improving Atmospheric Deposition Estimates

Mark Shephard[1] , Shailesh K. Kharol[2], Enrico Dammers[3], Karen E. Cady-Pereria[4], Cristen Adams[5],
Cynthia H. Whaley[6], Chris A. McLinden[7], Christopher E. Sioris[8] and Debora Griffin[9]

The spatial coverage provided by current satellites provides the opportunity to enhance our knowledge of atmospheric deposition through the fusion of the satellite observations with ground-based observations and air quality models. Presented is a brief description of the recent Cross-Track Infrared Sounder (CrIS) satellite observations of ammonia (NH_3) (Shephard and Cady-Pereira, (2015)), and their initial evaluation against available ground-based observations (e.g. AMoN, NAPS, Fourier Transform Infrared (FTIR)). Also provided are examples of how the CrIS NH_3 observations can be used for air quality model evaluation, and deriving emission estimates from large point sources and forest fires. Furthermore, we present recent results from an atmospheric deposition application combining CrIS and Ozone Monitoring Instrument (OMI) satellite observations with modelled deposition velocities to derive atmospheric dry deposition of reactive nitrogen from short-lived nitrogen species of ammonia and nitrogen dioxide (NO_2) (Kharol et al., 2018). Some key findings from this application are that: (i) satellite estimates of NH_3 and NO_2 dry deposition indicate that the NH_3 dominates over most regions across the North America during the warm season, and (ii) locations at northern latitudes affected by forest fires tend to have 2–3 times more dry deposition of ammonia relative to the local background. The same approach was applied to derive the atmospheric dry deposition of sulphur from sulphur dioxide (SO_2) using OMI observations. We will also briefly discuss the increased capabilities of recently launched (e.g. TropOMI) and future satellites (e.g. TEMPO).

Kharol, S. K., M. W. Shephard, C. A. McLinden, L. Zhang, C. E. Sioris, J. M. O'Brien, R. Vet, K. E. Cady-Pereira, E. Hare, J. Siemons, and N. A. Krotkov, Dry deposition of reactive nitrogen from satellite observations of ammonia and nitrogen dioxide over North America, *Geophysical Research Letters*, 45, 1157-1166, https://doi.org/10.1002/2017GL075832, 2018.

Shephard**,** M.W. and K.E. Cady-Pereira, Cross-track Infrared Sounder (CrIS) Satellite Observations of Tropospheric Ammonia, *Atmos. Meas. Tech.,* 8, 1323–1336, doi:10.5194/amt-8-1323-2015, 2015.

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Loch Vale, CO Wet Reactive Nitrogen Deposition Long Term Trends and Uncertainty

Bret Schichtel[1] , Kristi Morris[2], Kristi Gebhart[3], Jim Cheatham[4], John Vimont[5] and Robert Larson[6]

Excess reactive nitrogen (N_r) deposition is occurring in Rocky Mountain National Park (RMNP) and impacting its sensitive ecosystems. To address this issue, the National Park Service, State of Colorado, and Environmental Protection Agency are collaborating through a joint Memorandum of Understanding (MOU) with the goal to reduce N_r deposition to levels below the critical load over 25 years. Progress towards this goal is tracked using five-year averages of annual wet inorganic nitrogen deposition (IN) measured at the Loch Vale NADP site. These five year annual IN deposition rates are compared to a glidepath, which is a linear reduction from 2006 levels (3.1 kg/ha/yr) to 1.5 kg IN/ha/yr in 2032. Loch Vale is a remote high alpine location that is challenging to operate and service particularly during large snow events in winter and spring. When the equipment fails or operators are prevented from getting to the site within the allotted time frame, samples are invalidated by NADP. This often leads to large fractions of the annual precipitation, at times more than 40%, to have associated invalid IN concentrations which are not used to calculate annual averages. To calculate the annual IN deposition, NADP protocol is to replace missing samples with the precipitation-weighted annual average concentration derived from valid samples. This process does not account for seasonal variations in the IN concentrations in addition to the inverse relationship between concentration and precipitation amounts. This can lead to large errors that can bias the annual averages, trends in these averages, and the tracking of progress towards the critical load. In this work, we present a new method for imputing missing IN data with values that better account for the seasonal interdependence of wet deposition concentrations and precipitation depth. In addition, a Monte Carlo analysis was conducted to evaluate various data imputation methods and the relationship between missing data and uncertainty. Confidence intervals on the Loch Vale annual wet IN deposition rates that account for the variable fraction of invalidated data interannual variability are presented. The influence of these uncertainties on the long-term trends of IN wet deposition at Loch Vale is also explored.

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Assessing Uncertainty in Total Reactive Nitrogen Deposition Estimates for North American Critical Load Applications

John Walker[1] , Michael Bell[2], Donna Schwede[3], Amanda Cole[4], Greg Beachley[5],
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Critical loads are used to quantify the amount of atmospheric deposition (load) that can be tolerated by ecosystems without significant harm or change occurring. Determination of the amount of deposition to the ecosystem in excess of the critical load (i.e. "exceedance") requires an estimate of total deposition, which is typically derived from gridded chemical transport models (CTMs) or a combination of measurements and CTM output. Because the critical load exceedance is a metric used to inform policy decisions, uncertainty estimates for both the critical load and the exceedance itself are required. However, estimates of uncertainty are not currently available for the reactive nitrogen (Nr) total deposition estimates most commonly used for North American ecosystem assessments.

Uncertainty in measured deposition results from analytical uncertainty in the measurements themselves, from the completeness of the suite of species analyzed with respect to the significant forms of nitrogen that impact the deposition budget, and from 'scaling-up' measurements from field to ecosystem. Aspects of uncertainty in deposition budgets derived from CTMs or measurement-model fusion approaches include completeness of deposition budgets, uncertainties in input emissions and meteorology, representation of chemical reactions, deposition algorithms, fusion procedures, and spatial averaging of sub-grid processes.

In this presentation, we explore the state of the science with respect to these and other sources of uncertainty in total Nr deposition budgets used for North American critical loads assessments and propose future research activities to address the underlying knowledge and data gaps.

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Trends in Reactive Nitrogen at Rocky Mountain National Park by Transport Direction

Kristi Gebhart[1] , Bret Schictel[2], Kristi Morris[3], Jim Cheatham[4], John Vimont[5] and Robert Larson[6]

Excess reactive nitrogen deposition at Rocky Mountain National Park (RMNP) impacts sensitive ecosystems there, especially at high altitudes. For this reason, the National Park Service, State of Colorado and U.S. Environmental Protection Agency have collaborated through a Memorandum of Understanding to work toward reducing impacts in the park. Progress is tracked using five-year rolling averages of annual wet inorganic nitrogen deposition measured at the Loch Vale (CO98) NADP wet deposition sampler. When a trend is seen in either concentrations or deposition, it can be difficult to know the reason for it. We would like to know if trends are due to meteorological factors such as changes in precipitation or transport directions or if they are due to changes in emissions. While mesoscale chemical transport models could theoretically be used for this task, in practice they are too expensive to run for decades. An alternative tool using back trajectories is being developed for this purpose.

Initial analysis is with data from Loch Vale (CO98) and Beaver Meadows (CO19), both in RMNP. Hysplit back trajectories were calculated hourly for 1980-2017 from a near surface height and an elevated height that is nearer to cloud level. The positions of the trajectories, or endpoints, are determined for each hour for one and two days back in time. Then the number of endpoints in each of four upwind areas, eastern Colorado, western Colorado, eastern U.S., and western U.S., were tallied and time matched with the weekly NADP observations. NADP daily precipitation was used to screen out days with no precipitation at the measurement site. Concentrations and deposition can then be weighted by the fractions of endpoints in each of the four upwind regions, allowing a transport direction- weighted trend to be calculated. Because there are seasonal differences in both precipitation and transport direction at both sites, trends can be calculated for individual seasons as well as full years. If the technique proves useful, smaller, more numerous source regions could be used. Preliminary results will be presented at the meeting.

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Posters

Atmospheric Deposition of Metals and Polycyclic Aromatic Hydrocarbons (PAH) in the Canadian Oil Sands Region

M.A. Bari [1,2], W.B. Kindzierski[2]

Atmospheric deposition processes are potentially important pathways for trace metals and polycyclic aromatic hydrocarbons (PAH) inputs to the landscape in the Athabasca Oil Sands Region (AOSR) in northeastern Alberta, Canada. A pilot study was carried out during winter 2012 to characterize the magnitude and extent of deposition of selected metals and PAH in the AOSR. A cost-effective bulk (open face vessel) deposition collection system was used which allows for continuous collection of wet and dry forms of atmospheric pollutants. Monthly samples were collected for the period January–March 2012 at four sampling sites along a north-south alignment in the Athabasca valley near (< 20 km) and distant (>45 km) to oil sands development. For quality assurance, triplicate sampling was performed at one distant site. Samples were analyzed for 36 metals, ultra-low mercury, and 25 PAH (including alkylated, and parent PAH).

A consistent deposition pattern was observed between sampling sites for important trace metals (As, Ni, Cr, V) and PAH classes (alkylated, and carcinogenic PAHs), conforming to expected behavior — decreasing with distance from emission sources. Much smaller amounts of metals and PAH deposition were observed at distant sites compared to near development sites. Median uncertainties in deposition measurements of metals and both PAH classes were 26% and within ±15%, respectively. This suggests that the bulk deposition sampling method offers a potential alternative approach to obtain future direct measures of metals and PAH deposition at remote areas and/or locations without access to power.

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Synthesizing and Communicating Ecosystem Responses to Air Pollution for Federal Resource Management

Michael Bell[1] , Linda Pardo[2], Chris Clark[3], Linda Geiser[4], Jason Lynch[5] and Bill Jackson[6]

Lichen, herbaceous plants, trees, and aquatic systems can develop negative responses to atmospheric pollution once deposition thresholds are exceeded. The threshold at which a negative change begins to occur is known as a critical load and each ecosystem component has a unique critical load value based on their sensitivity. While the relationship between pollution and ecosystem change is clear, the application of critical load science to land management can be challenging when each critical loads within an area of interest is different. Here we integrated all relevant critical load data within two federal land management areas to communicate the risks to their ecosystems to change at current and future deposition levels. Agencies manage a broad range of resources impacted by disturbance and changing gradients, therefore it is imperative to be clear about the risk of impact, the amount of change expected, and where the change is expected to occur.

We evaluated critical loads of nitrogen deposition for herbaceous species (richness decline), tree species (growth and survival decline), and lichen species (detectability), and critical loads of sulfur deposition for aquatic systems (decreased ANC and fish species richness decline). We calculated the exceedance of each critical load based on the average nitrogen and sulfur deposition from 2014-2016 modeled using the NADP Total Deposition Model. Exceedances and responses to deposition were presented to land managers as graphs, maps, and tables. Exceedance values were identified as valid indicators for managers, but we not actionable without showing expected impact to the system. Critical load exceedances that could be tied to predetermined management priorities were more relevant to managers; e.g. the loss of basal area of harvestable tree species. Ecosystem components that are not directly connected to a resource priority, linking the change to downstream effects was useful for communication; e.g. the loss of forage lichen impact deer and rodent communities. Tying responses to management priorities allowed managers to not only justify action, but allowed them to integrate the new data into preexisting management plans.

Disclaimer: Views expressed are the authors' and not views or polices of the U.S.EPA.

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Temporal and Spatial Trends of Atmospheric Deposition in Maryland and Comparison to Observations of Atmospheric Pollutants in the Chesapeake Bay Watershed

Sarah Benish[1] , Phil Stratton[2], Allison Ring[3], Gina Mazzuca[4] and Xinrong Ren[5]

Due to the proximity of heavily polluted urban areas, such as Baltimore, MD and Washington, D.C., the Chesapeake Bay receives an unusually large amount of atmospheric pollutants through deposition. Estimates from the Maryland Department of Natural Resources have found about 27% of nitrogen delivered to the Chesapeake Bay is from the atmosphere. These estimates include direct deposition to the bay's surface as well as runoff to the watershed. Understanding and quantifying the long-term trends of nitrogen, sulfur, and mercury atmospheric deposition in Maryland is important due to the adverse effects these pollutants have on the local environment. We will assess 40 years atmospheric deposition trends of nitrogen and sulfur in three Maryland locations: Beltsville, located outside of the Washington, D.C. area; Smithsonian Environmental Research Center, situated south of Annapolis, MD near the Bay; and Piney Reservoir in northwestern Maryland. Preliminary results from 2000-2015 show the total nitrogen deposition in Beltsville has decreased by about 50% from 22.72 kg N/ha to 13.76 kg N/ha. Maryland and Mid-Atlantic stations will be compared with national trends of atmospheric pollutants, including mercury, sulfates, and nitrates, to assess relative changes at the local, regional, and national levels. We will use the Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program to compare results from the atmospheric deposition monitors with Mid-Atlantic streams data of nitrate and sulfate to understand how atmospheric and water trends are linked. Additionally, the EPA Continuous Emission Monitoring System will explicate trends in sulfur dioxide and Nox ($NO+NO_2$) from local and upwind power plants. This study will show how atmospheric deposition of pollutants such as sulfates, nitrates, and mercury have decreased over the past several decades in Maryland. Linking these trends to additional datasets will help deepen the understanding between emission reductions from local and upwind regions and the level of nitrates and sulfates present in watersheds, demonstrating improvements to the health of the Chesapeake Bay.

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Total Sulphur Deposition Downwind of an Aluminium Smelter in the Kitimat Valley, British Columbia

Dane Blanchard[1] and Julian Aherne[2]

Recent modernisation of an aluminum smelting facility in Kitimat, British Columbia, has resulted in a permitted increase in sulphur dioxide (SO_2) emissions from 27 to 42 tonnes per day. Prior to modernisation, a broad environmental assessment to identify potential impacts focused on modelled atmospheric dispersion and deposition of sulphur (S) throughout the Kitimat region. One major limitation of this investigation was the lack of observational data to evaluate modelled atmospheric S along the smelter's predominant emission plume. In lieu of this knowledge gap, a network of passive and active air samplers was deployed along the Kitimat Valley to evaluate atmospheric dispersion, conversion, and total S deposition during 2017-2018. The network consisted of ion-exchange-resin columns to capture wet deposition, passive-diffusive samplers to capture ambient SO_2 air concentrations, and portable active samplers equipped with two-stage filterpacks capable of measuring ambient SO_2 and particulate sulphate (pSO_4^{2-}). Estimated annual wet S deposition ranged from 14.0 – 1.4 kg S/ha/yr with distance from the smelter (~40 km) and exhibited a non-linear decline (logarithmic decline; $R^2 = 0.70$) with increased distance. Ambient SO_2 ranged from 10.26–0.76 µg/m^3 during the June–October 2017 sampling period and similarly displayed decreasing concentration away from the emissions source. Average pSO_4^{2-} varied between seasonal exposures, ranging from 0.134, 0.088, 0.184, and 0.255 µg/m^3 during June and October 2017, and February and June 2018 respectively. The highest concentrations of pSO_4^{2-} were observed within the plume path further down-wind from the emissions source.

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Long Term Atmospheric Monitoring in New York State: From Mountaintop to New York City

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Long term records of trace gas atmospheric constituents (O_3, NO, NO_2, NO_Y, SO_2, CO), aerosol mass (PM2.5), and standard meteorological parameters have been collected by the Atmospheric Sciences Research Center (ASRC) of the University of Albany at two rural sites in New York State. In the Adirondack Park at 1483 m elevation, the Whiteface Mountain Observatory on Whiteface summit (44.37°N 73.90°W) is near the 850 mb pressure level where long range transport of trace gasses from regional sources dominates. Pinnacle State Park near the Pennsylvania boarder in western New York hosts ASRC's other rural site, Pinnacle Field Station (42.09°N 77.21°W) on the Allegheny Plateau at 504 m elevation. In addition to these ASRC sites, Queens College hosts an urban site (40.74°N 73.82°W) in a partnership with New York's Department of Environmental Conservation and ASRC located in Queens, New York City less than a kilometer south of the Long Island Expressway. This suite of sites provides a rich data set that reveals long-term trends in trace gas and aerosol concentrations and is being used to examine current issues in atmospheric chemistry.

All trace gases have been continuously monitored at these three sites for 17 years or more. SO_2 at all three stations display a monotonic decrease of up to 90% reflecting policy driven emission controls. Oxides of nitrogen, both NO_X and NO_Y, are also decreasing over this time period although not as rapidly as SO_2 as their wider range of sources is more difficult to address with policy. CO at these three sites is trending downward with Whiteface reaching the lowest annual average of about 100 ppbv. Ozone is more complicated, with Whiteface seeing a modest decrease, Pinnacle remaining steady and Queens College experiencing an increase during 2001-2011 but remaining lower than both the rural sites. Work is underway to quantify summertime ozone production efficiency (OPE) at the rural sites where very low NO_x (<0.5 ppbv) sets the stage for OPE > 10 ppb/ppb at Pinnacle and >15 ppb/ppb at Whiteface. PM2.5 measured at the three sites shows significant decreasing trends in total mass and in the major chemical components (SO_4, NO_3, NH_4 and TC).

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Spatial Assessment of Total Mercury Concentrations on Baffin Island, Nunavut

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The long-range transport of atmospheric elemental mercury (Hg) has caused great concern in the Arctic owing to its ability to bioaccumulate and biomagnify in flora and fauna. Specifically, this poses a risk to northern communities, due to their reliance on traditional foods. One of the most common components of the Arctic landscape, are lakes and ponds, which are recognized as 'sentinels of change' owing to their ability to reflect internal and external (catchment) processes. Quantifying, the level of Hg in Arctic lake catchments will further our understanding regarding its fate, and the potential for human exposure. This study assessed the concentrations of total mercury (THg) in surface waters (n=80), moss (*Hylocomium splendens*; n=43) and surface (0–10 cm) soil (n=40) and surface sediment (n=25) samples in lake catchments around Iqaluit, Pond Inlet and Auyuittuq National Park along Pangnirtung Pass. The highest concentration of THg in surface waters (9.3 ng L^{-1}) was observed in Pond Inlet, while the lowest concentrations were observed in Iqaluit (1.9 ng L^{-1}). A similar pattern was observed in moss 49.4–86.0 ng g^{-1} (Iqaluit–Pond Inlet). In contrast, higher concentrations were observed in surface soil in Iqaluit (27.4 ng g^{-1}) compared with Pond Inlet (12.4 ng g^{-1}).

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A Review of 2008 – 2017 SO_2 Data in the Adirondacks with Recommendations for Future Monitoring Options

Amanda Carpenter[1] , Oliver Rattigan[2] and Dirk Felton[3]

New York State collects hourly SO_2 data at four locations in the Adirondacks as part of the monitoring network established after the NYS Acid Deposition Control Act was signed in 1984. The three plus decades of SO_2 data have shown consistent declines in concentration well correlated with reductions in emissions both within and upwind of New York State. One recent result of this decrease is that the continuous monitoring method is now inadequate in rural areas. Continuous SO_2 analyzers were designed to produce data that can be compared to the higher concentrations relevant for the NAAQS. Features such as auto zeroing were not implemented for these instruments and EPA regulations do not permit post adjusting data to remove signal drift.

We will present data trends and spatial and temporal comparisons including diurnal profiles of the hourly SO_2 data. We will also compare the integrated hourly data to the weekly CASTNET data collected at NYSDEC monitoring sites. Lastly, we will attempt to determine if the continuous data or the integrated CASTNET data can better meet the needs of the air quality data user community in the future.

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An Intercomparison of Several Collocated Rain Gauges at Whiteface Mountain Field Station

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The accuracy of a variety of rain gauges was evaluated at the University at Albany, Atmospheric Sciences Research Center's (ASRC) Whiteface Mountain Lodge, which hosts a National Atmospheric Deposition Program (NADP) site that is collocated with a New York State MESONET site and New York State Department of Environmental Conservation (DEC) / ASRC atmospheric monitoring site. During the period May 2017 through July 2017 daily precipitation data was collected. Five precipitation gauges were compared: an NADP installed OTT Pluvio^{2}L weighing-bucket rain gauge with single Alter shield windscreen, NYS Mesonet OTT Pluvio^{2}L weighing-bucket rain gauge with double Alter shield windscreen, University at Albany, Department of Atmospheric and Environmental Sciences OTT Parsivel^2 Distrometer, The National Weather Service's COOP observer High Sierra Electronics 8" non-recording rain gauge, and the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) 4" rain gauge.

During the three month period the NADP gauge measured a total rain accumulation 19.09 inches while the NYS Mesonet gauge reported 18.63 inches, a 2.5% difference. All other gauges had data gaps so total 3 month precipitation was not available. Historical mean NADP precipitation at this site for this three month period is 9.67 inches, 2017 was twice the mean. Comparison of the four gauges making direct measurements (COOP, CoCoRaHS, NYS Mesonet, and NADP) show remarkable consistency with differences generally below 5%. However, the Parsivel disdrometer had a high bias of 20% - 30% throughout the measurement period, suggesting that while it is useful for precipitation rate and drop size distributions, integrated volume is not sufficiently accurate for monitoring precipitation amounts.

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Measurements and Modelling of Atmospheric Deposition in Canada: Acidifying Pollutants, Base Cations and Polycyclic Aromatic Compounds

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We highlight some of the research at Environment and Climate Change Canada (ECCC) on atmospheric pollutant deposition in Canada. The Canadian Atmospheric Precipitation Monitoring Network (CAPMoN) of ECCC has been measuring daily wet deposition of acidifying pollutants and base cations since 1983. These measurements are necessary for monitoring the spatial and temporal trends in acid rain, evaluating environmental policies as part of the Canada-U.S. Air Quality Agreement, and studying the acidification of ecosystems. Wet deposition of inorganic ions including Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, NH_4^{+}, Cl^{-}, NO_3^{-}, and SO_4^{2-} measured between 1984 and 2011 were analyzed at 31 sites in Canada. Annual wet deposition fluxes (kg ha^{-1} a^{-1}) ranged from 0.08-3.6 for Ca^{2+}, 0.02-1.6 for Mg^{2+}, 0.01-0.7 for K^{+}, 0.03-12.0 for Na^{+}, 0.1-6.4 for NH_4^{+}, 0.06-23 for Cl^{-}, 0.4-27 for NO_3^{-}, and 0.5-33 for SO_4^{2-}. Most of the sites observed statistically significant decreases in the annual NO_3^{-} and SO_4^{2-} wet deposition at a rate of 0.07-1.0 kg ha^{-1} a^{-1} over the 1984-2011 period. The rate of decline in annual SO_4^{2-} wet deposition was particularly larger at southern Canadian sites likely because of decreasing SO_2 emissions leading to lower sulfur air concentrations. In contrast, there were no significant temporal trends in base cations and NH_4^{+}. In terms of acid rain, pH levels in precipitation were lower in southern and eastern Canada than western Canada. Our analysis indicates that precipitation has become less acidic over time.

In addition to acidifying pollutants, the atmospheric deposition of 43 polycyclic aromatic compounds (PACs) was estimated in the oil sands region of Alberta, Canada and surrounding communities. PACs, which include routinely-monitored polycyclic aromatic hydrocarbons (PAHs) and other lesser known compounds, are a concern in this region because these pollutants are typically emitted from crude oil production and biomass burning and are known for their carcinogenic effects. Our model results estimates the annual total deposition of PACs in 2011 ranged from 55 to 175,000 µg m^{-2} a^{-1}. The highest deposition fluxes were found over the surface mining area and at a few sites in the in-situ production region. The contributions from wet and dry deposition were 64% and 36%, respectively. Alkylated PAHs were the dominant PACs in deposition and the fluxes for these compounds were higher over a larger area than parent PAHs. The deposition estimates provide insight into wildlife exposure to PACs and supplement gaps in deposition monitoring in this remote region.

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A Specific Ultraviolet Absorbance Pilot Project in Adirondack Mountain Lakes and Streams

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Specific ultraviolet absorbance at 254 nm ($SUVA_{254}$) has been proposed to be an indicator of mercury (Hg) methylation potential in aquatic ecosystems, and there have been numerous efforts to measure $SUVA_{254}$ in streams in different watersheds of the US. In the Adirondack Mountain region of northern New York, long-term monitoring has primarily focused on lakes, and to date there have been few if any measurements of $SUVA_{254}$ in lakes in this region. From August 2013 through July 2015, the New York State Department of Environmental Conservation (NYSDEC) and Adirondack Lakes Survey Corporation (ALSC) measured $SUVA_{254}$ in >1800 lake and stream samples. Here we describe the complete pilot data set, which includes routine acid/base chemical parameters and Hg concentrations in select Adirondack surface waters. These data can be made available upon request.

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AMoN Readiness Verification Plan Ammonia Field Inter-comparison

Camille Danielson[1] , Martin Shafer[2], Jesse Wouters[3] and Chris Worley[4]

A key component of the Readiness Verification Plan (RVP) prepared by the NADP Quality Assurance Advisory Group (QAAG) was to implement an AMoN comparison study between ICAL (Illinois State Water Survey) and WCAL (Wisconsin State Laboratory of Hygiene). The study incorporated collocated (ICAL and WCAL) passive ammonia samplers following the NADP-dedicated sampling and analysis protocols.

As specified in the RVP, Radiello® passive ammonia samplers were prepared at ICAL and WCAL and sent to 11 AMoN sites. Each AMoN site received 3 samplers from both WCAL and ICAL consisting of replicate samplers ("A" and "B") and an un-deployed travel blank. Samplers were deployed following standard AMoN protocols and shipped back to their respective laboratories. All Radiello® cores from the samplers and the travel blanks were extracted and analyzed for ammonium. Measurements of ammonium (mg/L) were converted to ammonia air concentration ($\mu g/m^3$) based on sampler deployment time, extract volume, and published Radiello® core sampling rates.

A wide range of site concentrations were included in the study, with the average ammonia results ranging from 0.29 $\mu g/m^3$ at WA99 to 14.8 $\mu g/m^3$ at UT01. The analysis results produced by both labs were nearly identical.

A and B replicate averages were compared between each lab resulting in a median percent difference of -6.1% with respect to I-CAL. In comparison, ICAL triplicates for 2016 had a median RSD of 4.3%. The median WCAL field replicate (A and B) RPD was 1.9%.

Median travel blank concentrations were very similar for I-CAL and W-CAL with median RPD of -4.1% with respect to ICAL. Travel blanks from ICAL ranged from 0.06 to 0.22 $\mu g/m^3$ while WCAL travel blanks ranged from 0.07 to 0.23 $\mu g/m^3$. These are all well below the flagging criteria of 0.399 $\mu g/m^3$. The median travel blank concentration for both ICAL and WCAL data sets was 0.12 $\mu g/m^3$. This is just slightly higher than the ICAL median travel blank concentration from 2016 of 0.094 $\mu g/m^3$.

Overall, there was exceptional agreement between ICAL and WCAL results indicating supplies and procedures were equivalent.

Another RVP requirement involved an assessment of the AMoN supplies/facilities. This was assessed in association with the collocated study by analyzing quality control blanks from the preparation/extraction period including: cores, sonicator water, sampler jars, assembled samplers, preparation room, preparation hood and extraction hood. Although lab construction was not complete and the primary ammonia hoods were not in place at the time, the majority of the quality control samples met the RVP goals.

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The Anthropogenic Impact on Precipitation Quality

Courtney Davis[1] , Charles Driscoll[2], Mario Montesdeoca[3] and Dimitar Todorov[4]

Atmospheric deposition can be an important input and can affect the structure and function of watersheds and water bodies. Many studies have been conducted on atmospheric deposition, but have largely focused on rural areas, leaving much unknown about urban deposition. In this research, we assess deposition patterns of urban Syracuse NY and compare observations with a rural reference site in Skaneateles NY. Some lakes in the region suffer from legacy mercury pollution while others have recently endured harmful algal blooms which can be caused by excessive nutrient loadings. These issues make analytes such as total phosphorus (TP), total nitrogen (TN) and total mercury (THg) of interest in Central NY. To assess the impacts of atmospheric deposition, samples are collected utilizing both wet-only and bulk precipitation collectors at each location following each significant precipitation event (>0.2 in) and are measured for 25 analytes, including TN, TP and THg. Concentrations are coupled with precipitation quantities for each event to determine the loading of analytes. For most analytes, the concentrations are greater at the urban than the rural site. In both the urban and rural locations, the concentrations of TN, TP, and THg are typically greater in bulk than wet-only deposition, with bulk TP much greater than wet-only suggesting the importance of dust. Concentrations of THg are higher during the growing season, while TP and TN are higher during the non-growing season. Orthophosphate is a small fraction of TP (< 2%), while NH_4^+ is the major form of TN (46-70%) with significant fractions of NO_3^- (30-40%) and organic N (0-20%). Concentrations of TP in wet-only and bulk deposition are higher at the urban site (300-400 µg P/L) than the rural area (20-100 µg P/L), but both are elevated compared with local surface waters (4-25 µg P/L). At the rural site, TP peaks in the spring and is correlated with TN and potassium, suggesting fertilizer or manure application as a source. At the urban site, TP is elevated and correlated with chloride suggesting a relation with the use of road deicers. These results indicate that urban and rural deposition patterns can be influenced by very different sources many of which are anthropogenic in origin.

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Brook Trout Restoration and Monitoring of the Adirondack Ecosystem

Bringing Additional Value to the NYSDEC Stocking and Liming Program

James Dukett[1] , Phil Snyder[2], Matt Kelting[3] and Sue Capone[4]

The Adirondack Lakes Survey Corporation (ALSC) and Adirondack Long-Term Monitoring (ALTM) cooperators have provided key scientific results to New York State and Federal policy makers regarding atmospheric pollutants from emissions. The efforts of the ALSC and ALTM cooperators have helped show a marked recovery from acid deposition within the Adirondack Park. The ALSC is continuing ALTM efforts and is also working with the New York State Department of Environmental Conservation (NYSDEC) on additional brook trout restoration efforts.

As the Adirondacks recover from decades of acid deposition, the opportunity may now exist to restore brook populations to many historical waters. For brook trout recovery efforts to be successful, fisheries managers need to be provided with key metrics to ensure that appropriate waters are selected for reintroduction. The suitable acid-base chemistry of a given water should represent a dynamic that allows survival, growth, and ultimately reproduction of the fishery. Additional chemical analysis by the ALSC may also help NYSDEC identify natural spawning waters. This analysis could result in future significant cost savings to the NYSDEC. This poster will show current efforts by the ALSC to help NYSDEC with key brook trout restoration efforts in the Adirondack Pak that is recovering from acid deposition.

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Ethanol Concentrations in Wet Deposition Collected at the Atmospheric Integrated Research Monitoring Network Sites

J. David Felix[1] and Bipin Sharma[2]

US ethanol fuel consumption has increased exponentially over the last two decades as part of a movement to reduce greenhouse gas emissions and become more fuel independent. US annual renewable fuel production is ~17 billion gallons and is targeted to increase to 36 billion by 2022 according to the renewable fuel standard. Regardless of the technology or feedstock used to produce renewable fuel, the primary end product will be ethanol. Increasing ethanol production and consumption will increase ethanol emissions, thus increasing aldehyde, peroxyacetyl nitrate and tropospheric ozone concentrations. Despite this potential for ethanol to affect air quality, there have been few studies monitoring ambient ethanol concentrations in the US.

To characterize temporal and spatial variations of atmospheric ethanol concentrations in the Eastern US, we have been collaborating with the five Atmospheric Integrated Research Monitoring Network (AIRMoN) sites since February 2018 to measure ethanol concentrations in event-based rain samples. To date, samples from all sites have a simple average ethanol concentration of 437 nM with a range of below detection limit (< 19 nM) to 4160 nM (n = 116). PA15 and IL11 sites have high average concentrations, 937 and 505 nM respectively, and are located downwind of ethanol production facilities. TN00, WV99, NY67 sites are located in rural areas absent significant anthropogenic ethanol sources (e.g. dense vehicles traffic and ethanol plants) and this is reflected by lower average concentrations, 321, 361, 340 nM respectively. This project is ongoing and ethanol concentrations will be investigated for correlation with a variety of rainwater components (e.g. Mg^{2+}, Ca^{2+}, K^+, Na^+, NH_4^+, NO_3^-, Cl^-, SO_4^{2-}, PO_4^{3-}, pH) that will be used to infer similar source and transport. In addition, air mass back trajectories will be created using the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT) for each individual rain event in order to investigate emission source regions.

As the US prepares to significantly increase renewable fuel production in the next four years, this project will provide a current atmospheric ethanol concentration baseline, which is vital when determining how future emissions are affecting atmospheric composition. The wet deposition data will be combined with our previous US concentration data to create a more robust inventory to model US ethanol wet deposition flux. The ultimate goal of this research is to provide air quality modelers, climate scientists and policy-makers with empirical data of how increasing ethanol fuel consumption will affect ethanol concentrations in the atmosphere.

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Investigating Gaseous Atmospheric Mercury Exchange in a Forest Ecosystem with a Gradient-Based Micrometeorology Approach

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Deposition of atmospheric mercury to vegetated terrestrial ecosystems is now understood to be a significant sink, and recent monitoring and isotopic data have suggested that dry deposition of gaseous elemental mercury (GEM) represents the majority of this atmosphere—surface exchange. Until recently, uptake of atmospheric mercury has been monitored using wet deposition and litterfall mass balance techniques, however these have been shown to not take into account all mercury deposition pathways and are not able to resolve the bi-directional nature of mercury air—surface exchange.

Micrometeorological methods provide a direct, non-intrusive method of observing fluxes of many trace gas species, and the instrumentation and logistic networks necessary to measure greenhouse gas fluxes have already been deployed across the developed world in large monitoring networks. Technological limitations currently exclude the application of direct eddy covariance techniques to resolving GEM fluxes, as it is not possible to measure GEM concentrations at the same timescales as the transporting turbulent structures. Relaxed eddy accumulation methods have shown successes in resolving GEM fluxes, however these methods are technically cumbersome, requiring complicated instrumentation and specialised expertise, thus limiting their applicability in large-scale monitoring networks.

Gradient-based methods instead relax some theoretical assumptions of turbulent exchange in order to retain technical simplicity in measurement of trace gas fluxes. These methods have successfully been deployed over short vegetation (grassland) environments, however applying these methods to forest ecosystems requires measuring the flux at the forest canopy as well as at the forest floor, thus excluding current gradient GEM sampling methods. We present here a technically simple method of resolving time-averaged GEM gradients at multiple levels within a forest canopy, thereby allowing calculation of forest floor and forest canopy fluxes. This system utilises commercially-available instrumentation and requires relatively little technical expertise, thereby making it ideal for deployment within pre-existing monitoring networks. We present here also preliminary data testing this system in a temperate deciduous forest during the summer growing season, and its abilities and limitations in measuring forest ecosystem fluxes. We propose that this system is currently ready for deployment within existing ecosystem exchange networks, and will provide essential data required for understanding an important aspect of the global mercury cycle.

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A New Online Continuous Relaxed Eddy Accumulation Flux System Coupled with Ion Chromatographs

Amy Hrdina[1] , Alexander Moravek[2], Elizabeth Pattey[3] and Jennifer G. Murphy[4]

A relaxed eddy accumulation flux measuring system coupled with ion chromatographs (REA-IC) was developed and optimized to capture the flux of ammonia and other water-soluble gases. The instrument assembly is based on the ambient ion monitoring ion chromatographs (AIM-IC) adapted following previous work in the group. The REA-IC system uses wet parallel plate denuders to capture water-soluble gases, namely NH_3, HNO_3, HONO, HCl, and SO_2 followed by automated IC analysis every hour. The system is designed to have a continuous gas flow by operating the conditional sampling between ambient air and a clear air source. The fast-response valves of the conditional sampling, located on the clean air stream, are controlled according to vertical wind direction to separate updrafts and downdrafts. Accurate flux measurements using this technique require excellent precision between the respective reservoirs. Our preliminary estimates based on REA simulations that are informed by eddy covariance NH_3 fluxes over maize crops following fertilization show maximum fluxes of ~50 umol m^{-2} h^{-1} leads to a concentration difference of less than 30% between the two reservoirs, emphasizing the need for high measurement precision. Preliminary lab tests showed a relative precision of ~10 % for NH_3 and HONO concentrations measured in both up and downdraft reservoirs, with SO_2 concentrations being close to the detection limit that precision was impeded. Normalization based on a lithium bromide (LiBr) internal standard made an improvement on the precision. The use of LiBr also facilitates diagnosis of the instrumentation and background influence of the denuder assemblies. The REA-IC system was deployed in a corn field (Ottawa, ON) with its inlet close to a sonic anemometer (CSAT-3, CSI, Logan, UT), which was connected to a data acquisition and control flux measuring system developed by Agriculture and Agri-Foods Canada. The REA sample software controlled the fast-response valves and processed the standard deviation of the vertical wind speed and the REA coefficient using water vapor as a surrogate. The hourly ammonia fluxes were calculated using the REA technique as the concentration difference between up- and downdraft reservoirs. The performance of the REA-IC measuring system will be presented. The ability to resolve NH_3 fluxes can help assess the utility of different agricultural management practices.

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Wet Atmospheric Deposition and Stream Water Chemistry at the Glacier Lakes Ecosystem Experiments Site (GLEES), Southeastern Wyoming, USA, 1989-2018

John Korfmacher[1] and Kathleen A. Dwire[2]

NTN Site WY00 was established adjacent to a high-elevation lake in Wyoming's Snowy Range in 1986, and seasonal lake and stream water chemistry data collection was initiated at this location in 1989. Both data collection efforts have continued to the present, and analyses of long-term trends are now possible. As part of a larger project to assess water chemistry trends in remote, high-elevation lakes across the central Rocky Mountains, we present data from a site (GLEES) that is intended to serve as a reference watershed relatively free of pollution impacts. Weekly and bi-weekly water samples from the lake outlet were analyzed for concentrations of anions, cations, pH, ANC and conductivity and compared to reported precipitation chemistry values from WY00. Preliminary analyses indicate that analyte concentrations in lake water samples were not closely correlated to that observed from precipitation samples. Additional analyses (including deposition values and estimation of analyte fluxes) are ongoing.

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Monitoring Cloud Water Chemistry (including Organics) at Whiteface Mountain

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Whiteface Mountain (WFM) in the Northern Upstate New York has an important history in cloud water chemistry observations. Most of that chemistry research has focused on inorganic ions, pertaining to large scale deposition in the Adirondack Mountains and throughout the country. Clouds and aerosols are tied together and play important roles in climate and atmospheric chemistry, but significant uncertainty remains about aerosol-cloud interactions. Aerosols play an important role in the formation of clouds by acting as condensation nuclei. Clouds, in turn, play an important role in the removal of aerosols by wet deposition. Clouds can also play important roles in the composition of aerosols, allowing for aqueous phase chemistry to occur, thereby changing the aerosol upon subsequent evaporation of cloud droplets. While the inorganic chemistry of clouds and aerosols is relatively well understood, the chemistry of organic constituents, which make up a majority of both fine aerosol and cloud water mass loadings in the modern day, is much more complex and requires further study.

This poster is a summary of work that has been done in the summer of 2018 to utilize and expand upon a system to monitor cloud water composition at WFM. Our work continues the longterm measurement of inorganic ions dating back to 1994, as well as measurements of total dissolved organic carbon, which began in 2009. In addition, routine measurement of select organic acids have begun, as these chemical constituents have been shown to make up the largest percentage of any single type of organic molecule found in cloud water. A filtration system was installed to remove microbes in the cloud water that could potentially change the chemical composition over time prior to chemical analysis. Tests of the system and preliminary results from the cloud water collected during 2018 are highlighted.

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Transitioning a Major National Monitoring Program: Transition Strategy, Current Status and Future Plans

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In September, 2017 a request for proposals was sent out to identify a new location for the National Atmospheric Deposition Program (NADP) Program Office (PO) and Central Analytical Laboratory (CAL). On December 1, 2017 the Wisconsin State Laboratory of Hygiene (WSLH/WCAL) was officially notified that the PO/CAL was moving to Wisconsin. A few (crazy) months later, the PO was transferred on March 1st, 2018 and on June 1st, 2018, all services related to supplies and sample analysis for the NTN, AIRMoN and AMoN networks were fully transitioned to WSLH. This presentation will provide an overview of our transition strategy, implementation highlights, and systems put in place to ensure acceptable performance of the CAL. We established three primary goals for the transition period (a) maintain continuity of operation, (b) produce comparable high-quality data, and © ensure that the transition was as non-disruptive as possible. Several visits were made to the existing CAL in Illinois (ICAL) to observe the facilities and processes. Space was identified and remodeled at two WSLH facilities to accommodate supply preparation, sample receiving and analysis. Supplies, equipment and NADP-dedicated analytical instruments were purchased. Though the analytical capabilities for NADP analytes already existed at the WSLH, the unique nature of the NADP program was best served by a dedicated infrastructure within the WSLH. This included porting the databases/LIMS from ICAL to WCAL. Extensive communication with ICAL and all network sites was done to clarify transition plans. A Readiness Verification Plan (RVP) was established by NADP's Quality Assurance Advisory Group (QAAG) to assess the analytical variability between ICAL, WCAL and other labs. The NADP audit team also visited WSLH to evaluate WCAL's systems. NADP-specific quality assurance practices were established and critical supply cleaning protocols were validated. Currently, processes are running smoothly, twelve staff have been hired and trained, and the RVP has been completed and is awaiting QAAG approval. Data are being produced and reviewed and will be published to the PO in September. We are now beginning the process of critically examining procedures in order to find improvements. We are exploring changes such as packaging of AMoN samplers, refining MDL determinations, improving quantification of bromide, creating an archive library and extensive cross-training of the analysts. We are also endeavoring to effectively document all of our procedures and QA practices. We will continue to investigate how we can further the NADP mission given the extensive capabilities available at WSLH.

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Isotopic Investigation of Redox Effects on Nitrate Partitioning in a Forest Soil

Ariel Mollhagen[1]

Though the U.S. and Canada have seen a decrease in nitrate (NO_3) deposition since the 1990s, deposition of this and other reactive nitrogen (N) species is still far higher than a century ago. The fate of this N determines the potential effects on forest ecosystems. Past studies have shown that the majority of deposited N that is retained in forest ecosystems is held in soil and litter on a 1-2 year timescale. Few studies have linked N-partitioning in forest soils with oxic status and activity of other redox active species (such as iron (Fe) and manganese (Mn)). This study examines the fate of a ^{15}N-NO_3 tracer in a lab-scale soil slurry experiment, probing N transformation as a function of depth (4 horizons differing in physical and chemical properties) and oxic status (oxic and suboxic). Of particular interest are the coupled interactions of N, Fe, Mn, and organic matter.

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A Decadal Change in Mercury in Upland Irish Lakes

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While mercury is a naturally occurring element, concentrations found in the atmosphere, surface waters and soils have increased as a result of human activities. Once in the environment, bacteria can convert elemental mercury into methylmercury, which can bioaccumulate and biomagnify in organisms. Methylmercury can cause significant impacts to human health, most notably causing harm to the nervous, digestive and immune systems. During the last decade there have been efforts to minimize anthropogenic sources of mercury. In 2013, the Minamata Convention on Mercury was adopted: a global treaty to protect human health and the environment from anthropogenic emissions of mercury.

A survey of 56 upland lake catchments in Ireland was conducted during summer 2017 to assess decadal changes in mercury. Water (n=56), soil (n=28), and sediment (n=24) samples were collected and analyzed for concentrations of total mercury (THg), and other chemical characteristics, including organic matter. The upland lakes are situated along the Western Irish coast, and are primarily influenced by long range transport and atmospheric deposition of pollutants rather than local emissions. Average THg (± SD) were 6.0 ng/L ± 4.1, 236.4 ng/g ± 93.3, and 51.5 ng/g ± 50.2 for water, soil and sediment respectively. Total Hg concentrations in water had the strongest relationship with SUVA-320, and THg in soil and sediment had a significant relationship with organic matter. Total Hg concentrations were statistically higher during the 2017 survey in comparison to a previous survey conducted in 2008.

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Variations of Wet Deposition of Mercury Across Eastern North America

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North Carolina Agricultural and Technical State University (N.C. A&T) is managing and operating NC 17 (one Mercury Deposition Network, MDN and one National Trends Network, NTN) in concordance with guidelines and procedures of the National Atmospheric Deposition Program (NADP) technical manual.

Mercury Deposition Network (MDN) provides a national database of weekly concentrations of total mercury in precipitation and the seasonal and annual flux of total mercury associated with wet deposition. National Trends Network (NTN) provides a national database of weekly information on precipitation chemistry. The NTN is the only network providing a long-term record of precipitation chemistry across the United States.

Investigation of wet deposition of mercury in eastern North America using weekly observations from Mercury Deposition Network (MDN) stations that are located along the 80° west longitude line is in progress. These N-S stations include ON07, PA30, PA21, PA37, NC17, NC26, SC19, SC03, GA33, FL34, FL95, FL97, and FL11. Preliminary data on variations of wet deposition of mercury across the N-S stations for selected periods will be presented. The monitoring of pollutants flow into the ecosystem (NADP data) provides information about the effects of wet deposition on human populations, ecosystems and agricultural systems.

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Total Reduced Nitrogen (NHx) Measurement Methods for Implementation in Long-Term Monitoring Networks

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Reductions in oxidized nitrogen and sulfur emissions have resulted in a shift in atmospheric chemistry and the need to reassess the primary species contributing to PM formation and total deposition. Reduced nitrogen (NHx) has replaced oxidized nitrogen as the dominate nitrogen compound in the atmosphere, contributing more than 50% in most areas and the contribution is expected to continue increasing. EPA is considering NHx in the secondary NAAQS review for the ecological effects of NOx/SOx/PM. Currently, monitoring networks across the U.S. provide ambient measurements of oxidized and reduced nitrogen species using different measurement methods and varying time-scales, but NHx ($NH_3 + NH_4^+$) is not measured routinely in any of the national networks. The Chemical Speciation Network (CSN) measures ambient NH_4^+ concentrations on a nylon filter following a MgO-coated denuder at more than 160 urban sites throughout the U.S using a MetOne SASS/Super SASS. The Interagency Monitoring of Protected Visual Environments network (IMPROVE) compliments the CSN, providing comparable $PM_{2.5}$ speciation data collected using the PM2.5 sampler with 4 channels at more than 100 sites located in rural areas including National Parks and Class I areas. IMPROVE does not currently measure NHx. The Clean Air Status and Trends Network (CASTNET) measures weekly concentrations of NH_4^+ using a Teflon filter and most CASTNET sites are co-located with NADP's Ammonia Monitoring Network (AMoN).

In this study EPA, in partnership with the National Park Service, deployed acid-impregnated filters in the Super SASS and IMPROVE PM sampler in Gainesville, FL and Duke Forest, NC for 6-months in 2017 to assess whether this modification could be implemented across the networks to measure NHx at more than 200 locations throughout the US. The Super SASS and PM samplers were co-located with CASTNET and AMoN, as well as URG annular denuder systems (ADS) as the reference method. Bias, calculated as the median difference between the ADS versus the Super SASS and ADS versus the PM sampler, was -0.03 and 0.09, respectively, at Duke Forest and -0.17 and -0.14, respectively, at Gainesville. NHx concentrations at both sites were below 2 $\mu g\ m^{-3}$ with low variability throughout the sample period.

Results from the 2017 study showed unexpected breakthrough on the ADS with high capture of NH_3 on the backup denuder. Further analysis of the filters was performed to determine the cation/anion ratio and additional testing of the URG ADS system was performed at the AIRS site on the EPA RTP, NC campus.

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Atmospheric Deposition of Microfibers

Brett Roblin[1] and Julian Aherne[2]

Plastics particles < 5 mm long called microplastics, have been found throughout marine, freshwater and terrestrial systems. There is growing concern of their environmental impacts given that they can absorb organic pollutants and trace metals. While our understanding of the sources and transport of microplastics has increased during the last decade, there have been limited studies on microplastics in atmospheric deposition. In this study, rainfall was collected from four 'background' precipitation chemistry stations under the EMEP network from June 2017 to May 2018. Daily rainfall samples were bulked by calendar month and analyzed for microfibers. Samples were vacuum filtered on to GF/C Whatman filters and microfibers were identified and counted using a stereomicroscope. Pictures each of microfibers were taken and measured using image processing software. A subsample of microplastics were further analyzed using Raman spectroscopy to identify the type of plastics. Annual deposition ranged from 16 to 29 microfibers per litre, resulting in a deposition of 64.5 to 102.0 microplastics/m^2/day. The average microfibre length was 1.28 mm, resulting in a deposition of 37.6 m of microplastics/m^2. Atmospheric deposition is an important vector for the transport of microfibres into remote locations.

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The Clean Air Status and Trends Network (CASTNET): A Versatile Platform for Evolving Deposition Science and Other Air Quality Monitoring Research

Christopher Rogers[1] , Melissa Puchalski[2], Selma Isil[3] and Marcus Stewart[4]

CASTNET is a long-term environmental monitoring network with 96 sites located throughout the United States and Canada. CASTNET is managed and operated by the U.S. Environmental Protection Agency (EPA) in cooperation with the National Park Service (NPS); Bureau of Land Management, Wyoming State Office (BLM); and other federal, state, and local partners (www.epa.gov/castnet) including six Native American tribes that operate CASTNET sites on tribal lands. The network was established under the 1991 Clean Air Act Amendments to assess the trends in acidic deposition due to emission reduction programs. CASTNET measures ambient concentrations of sulfur and nitrogen species as well as rural ozone concentrations. Results are used to report on geographic patterns and temporal trends in acidic pollutants and deposition. CASTNET is the only network in the United States that provides a consistent, long-term data record of acidic dry deposition fluxes.

CASTNET complements the National Atmospheric Deposition Program's (NADP's) National Trends Network (NTN). The NTN is considered the nation's primary source of wet deposition data. Nearly all CASTNET sites are co-located with or near an NTN site. Together, the CASTNET and NADP/NTN programs provide data necessary to estimate long-term temporal and spatial trends in total deposition (dry and wet) as well as ecosystem health. In recent years, the NADP Total Deposition Science Committee (TDEP) developed a hybrid method which combines the NADP and CASTNET measurements with model output from the Community Multi-Scale Air Quality (CMAQ) model to provide continuous spatial and temporal estimates of total deposition. CMAQ output includes estimates of non-measured nitrogen pollutants and improves understanding of the complicated processes that factor into dry deposition. The maps produced by this hybrid method are being used to identify areas where more monitoring data are needed to help evaluate and refine model outputs.

Many CASTNET sites are also co-located with the NADP's AIRMoN, AMoN, MDN, and AMNet networks. CASTNET also collaborates with the EPA's National Core monitoring network (Ncore) and the Interagency Monitoring of Protected Visual Environments (IMPROVE). EPA, NPS, and BLM have deployed more than 65 NADP Ammonia Monitoring Network (AMoN) sites at CASTNET sites. AMoN sites measure biweekly concentrations of ambient ammonia (NH_3). Results from CMAQ estimated that NH_3 accounts for an additional 10 to 40% of the total nitrogen deposition budget.

For increased flexibility in siting and lower operating costs, CASTNET developed a small-footprint monitoring station that does not require a temperature-controlled shelter. These sites can be operated using alternative power sources (wind/solar). During 2018, 12 CASTNET small-footprint sites, including 3 off-grid, alternate power sites, were operated. Three of the CASTNET sites operated on tribal lands utilize the small-footprint station. The availability of the small footprint design makes it more affordable for monitoring agencies, universities, and others to join the CASTNET network in areas of the country where CMAQ has identified the need for additional monitoring.

With more than 90 monitoring locations available, CASTNET also offers the infrastructure and platform for further collaboration with other networks, organizations, and research partners. CASTNET sites and existing data products present the opportunity for ground truthing of satellite observations, co-location with short-term high resolution monitoring technologies, and additional long-term flux measurements.

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Evaluation and Intercomparison of Modeled Atmospheric Deposition over North America and Europe – An Overview of Phase 4 of the Air Quality Model Evaluation International Initiative

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This poster will present an overview of work planned under Phase 4 of the Air Quality Model Evaluation International Initiative (AQMEII). Since its inception in 2009, AQMEII has brought together a total of 37 modeling groups from 17 countries in North America and Europe to conduct coordinated research projects and model inter-comparison exercises aimed at advancing model evaluation practices and informing model development. The focus of Phase 4 is on assessing the ability of regional-scale air quality models to simulate dry and wet deposition of trace gases and aerosols. The poster will present the design of the coordinated model simulations, describe the common emission and boundary condition datasets to be used by all modeling groups, summarize the observational datasets to be used for model evaluation over North America and Europe, and discuss the data infrastructure aspect of the activity. Furthermore, we provide a description of planned analysis methods aimed at quantifying the impact of different process-level deposition algorithms and parameterizations on modeled deposition fields. Finally, we present a roadmap for how output fields generated by AQMEII Phase 4 participants could potentially be used in measurement-model fusion approaches for generating total deposition maps and in ecosystem impact assessment studies.

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Broader Proficiencies of the WSLH: Enhancing and Building NADP Network Capabilities and Collaborations

Martin Shafer[1] , Mike Olson[2], Mark Olson[3], Chris Worley[4] and James Schauer[5]

With the transition of the NADP PO & CAL to the WSLH, new opportunities for outreach and research within the broad purview of NADP are presented. While the WSLH is foremost dedicated to the core principals and components of NADP, the siting at the WSLH, a unique laboratory with immense analytical and intellectual capabilities, itself closely coupled to the UW School of Medicine & Public Health (and the larger University community), provides the environment for tremendous new opportunities.

Within the current sampling and analytical model, there is a need for expanded data interpretation, systems analysis, and importantly new data products that directly support the NADP stakeholders. Additional emphasis should be placed on integration of faculty and graduate student research within NADP and promote journal publications that provide visibility and expansion of network partnerships.

Given the broad-spectrum of analytical tools and capabilities at the WSLH, new analytes can be added to the NADP network samples with very minimal start-up investment. In-house expertise will ensure that data quality for new and innovative protocols meets the high standards that NADP stakeholders expect. The analyte menu of existing analytical platforms can be readily expanded [e.g. transition metals to ICP-OES; organic acids to IC]. The WSLH maintains long-standing world-renowned capabilities in trace element [ICP-MS] quantification and speciation, and more recently in high-precision stable isotope analysis (MC-ICP-MS], powerful tools that can be applied to source apportionment and atmospheric processing questions. With a large complement of GC/MS & LC/MS/MS platforms, methods are in place for a most "traditional" and emerging organic species and contaminants. We have already begun the process of evaluating NADP sampling protocols for integration of PFAS measurements. With expertise in black carbon measurement and data interpretation/use, advanced capabilities for molecular testing, microscopic analysis, and radiochemistry, many new avenues of research could be explored. The WSLH maintains close ties with researchers/programs involved in human biomonitoring, and working to couple NADP products to biomonitoring will be pursued.

Opportunities exist and must be followed-up for outreach and partnering with UW-Madison researchers as well as the community of scientists across the country. Building these connections will also engage the public and build the base for long-term viability of the NADP programs.

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Tekran 2537 A, B, X Intercomparison Study

Timothy Sharac[1] , Mark Olson[2], David Grande[3], Mark Rhodes[4], Sandy Steffen[5], Rob Tordon[6]
and Eric Prestbo[7]

This poster describes the testing that was performed both internal and external to National Atmospheric Deposition Program's Atmospheric Mercury Network (AMNet), presents results from that testing, and evaluates the Tekran Instruments Corporation ("Tekran") mercury analyzer model 2537X with regard to: target specifications, field testing, controlled testing, and usability as required for network use. In addition to Tekran 2537X test results, additional results from collocated performance tests in this study also include earlier models of Tekran's ambient mercury analyzer (i.e., model A and model B) for completeness. The performance tests include two separate bench tests performed at the AMNet site liaison's laboratory in Mount Horeb, Wisconsin, collocated measurements at the AMNet site in Horicon Marsh, Wisconsin (WI07), collocated measurements from two Canadian Atmospheric Mercury Measurement Network (CAMNet) monitoring sites, and in-house performance results supplied at Tekran's headquarters in Toronto, Ontario.

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Long-term Changes in Soil and Stream Chemistry across an Acid Deposition Gradient in the Northeastern United States

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Declines in acidic deposition across Europe and North America have led to decreases in surface water acidity and signs of chemical recovery of soils from acidification. To better understand the link between recovery of soils and surface waters, chemical trends in precipitation, soils, and streamwater were investigated in three watersheds representing a depositional gradient from high to low across the northeastern United States. Significant declines in concentrations of H^+ (ranging from −1.2 to −2.74 microequivalents [meq] L^{-1} yr^{-1}), NO_3^- (ranging from −0.6 to −0.84 meq L^{-1} yr^{-1}), and SO_4^{2-} (ranging from −0.95 to −2.13 meq L^{-1} yr^{-1}) were detected in precipitation in the three watersheds during the period 1999 to 2013. Soil chemistry in the A horizon of the watershed with the greatest decrease in deposition showed significant decreases in exchangeable Al and increases in exchangeable bases. Soil chemistry did not significantly improve during the study in the other watersheds, and base saturation in the Oa and upper B horizons significantly declined in the watershed with the smallest decrease in deposition. Streamwater SO_4^{2-} concentrations significantly declined in all three streams (ranging from −2.01 to −2.87 meq $L^{-1}yr^{-1}$) and acid neutralizing capacity increased (ranging from 1.38 to 1.60 meq L^{-1} yr^{-1}) in the two streams with the greatest decreases in deposition. Recovery of soils has likely been limited by decades of acid deposition that have leached base cations from soils with base-poor parent material.

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Advancements in NADP Field Equipment and Site Liaison Support

Richard Tanabe[1] , Mark Olson[2] and Robert Larson[3]

With the move of the Program Office (PO) to the Wisconsin State Laboratory of Hygiene (WSLH) at the University of Wisconsin (UW) – Madison, it provided an opportunity to reassess the current field equipment technology and Site Liaison support tools beings used across the NADP networks.

The last significant modernization of equipment occurred 8-11 years ago with the introduction of the electronic gauges in 2007 and the NCON wet only deposition samplers in 2010. Among the planned changes are upgrades to the remaining Belfort sites with electronic gauges and a redesign of the Remote Monitoring Module (RMM). The Program Office continues to investigate other options for wet-only deposition collectors, among these are the Xancom Inc. collector modified from the recent Canadian Air and Precipitation Monitoring Network (CAPMoN) D400 collector and a prototype event collector as part of the UW College of Engineering, Mechanical Engineering Senior Design program.

Other improvements that will be presented are advances in data collection methods and tools for site operators to correct and resolve data acquisition related issues in a timely manner.

In 2016, the Executive Committee approved the move of the Network (NTN, AIRMoN and AMoN) Site Liaison's to the Program Office (PO). As of March 1st, 2018, the role of the site liaison has been re-evaluated at the WSLH Program Office. Some of the changes to the site support tools and role will be presented.

This poster will examine some of the challenges and successes of the reassessing network equipment and Site Liaison activities within the first year of operation at the WSLH.

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A National Survey of Total Gaseous Mercury Stable Isotope Composition

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With the 2011 promulgation of the Mercury and Air Toxics Standards by the U.S. Environmental Protection Agency, and the successful negotiation by United Nations Environment Programme of the Minamata Convention, global emissions of mercury (Hg) to the atmosphere from anthropogenic sources are expected to decline. Recent reports suggest regional gaseous Hg declines have already begun well before they were anticipated; however, providing independent evidence for the drivers of such declines is difficult. To address this challenge, the U.S. Geological Survey and the National Atmospheric Deposition program (NADP) have initiated a national-scale effort to establish a baseline of total gaseous mercury (TGM) and Hg stable isotopic compositions at 31 sites distributed across North America over a two-year period (March 2016 – May 2018). Collaboration with national scale air quality monitoring networks, such as the Mercury Deposition Network (MDN) and the Atmospheric Mercury Network (AMNet), has provided the backbone for linking the baseline measurements of TGM stable isotopic compositions to long-term wet Hg deposition and gaseous Hg monitoring. Approximately two thirds of the bulk air samplers were operated at MDN or AMNet sites. The network includes a highly diverse set of sites ranging from remote (e.g., Denali National Park, Alaska and Mauna Loa, Hawaii) to highly urbanized locations (e.g., Bronx, New York and Boston, Massachusetts). For all sites, the average odd isotope mass independent fractionation (MIF, D^{199}Hg), an indicator of photochemistry, was -0.20±0.07‰ and had a range of -0.43 to 0.01 ‰. Mass dependent fractionation (MDF, d^{202}Hg), the commonly used isotope ratio for source tracking, was generally positive with a mean value of 0.45±0.40‰, although intermittent negative MDF was also observed at some sites. Urban sites were consistently lighter in d^{202}Hg (0.34‰) compared to remote background sites (0.65‰), potentially indicating differences between emission sources. The site at Oak Ridge National Lab, near the contaminated Y12 plant, had a mean d^{202}Hg of -0.04±0.36‰, indicating an industrial Hg end member with very little odd MIF. Though regional differences in odd MIF and MDF were small, we observed a trend showing enrichment of d^{202}Hg in the northeastern United States, from the Ohio River Valley to remote sites in northern Maine and Nova Scotia, suggesting a shift from localized emission sources to globally transported Hg across this region. The long-term goal of this effort is to help provide a better understanding of regional trends in TGM isotopic composition and evaluate the success of new regulations.

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Atmospheric Depositions Introduce Anomalies in Modeled Estimates of Dissolved Organic Carbon Export from Terrestrial to Aquatic Ecosystems in the United States from 1981-2010

Xinyuan Wei[1] and Daniel J. Hayes[2]

In addition to the better-studied land-atmospheric carbon fluxes, the land-water transfer of carbon also directly affects terrestrial carbon sequestration. The export of dissolved organic carbon (DOC) through soils is an important process for the transport of carbon from terrestrial to aquatic ecosystems. Current studies show that two physical factors related to sorption dynamics and hydrology play dominant roles in regulating DOC loading. These processes have been represented in conceptual and numerical models, but the sorption dynamics driven by atmospheric depositions (e.g. heavy precipitation, nitrogen, and sulfur) are rarely represented. Heavy precipitation obviously increases the runoff, but the DOC concentration can also be changed in different soil layers as a result. Higher nitrogen loads may increase the intact phenolic compounds in the soil, which can decrease the soil adsorption ability and increase the DOC concentration with runoff. In addition, more DOC can be produced through active soil organic carbon decomposition processes, resulting in greater DOC loading. Furthermore, decreasing sulfur deposition accelerates the soil DOC solubility and decreases the soil adsorption ability, thus more DOC could be transported to aquatic ecosystems. In addition, soil organic carbon decomposition can be more active due to increasing soil acidity. In current Terrestrial Ecosystem Model (TEM, version 6), for example, the leaching quantity of DOC is estimated by the DOC concentration of the water yield. However, the sorption impact from atmospheric depositions is not simulated. Here, we synthesize current DOC estimation methods and improve the TEM6 model by developing the TEM6-DOC extension to allow it the ability to simulate the both of these key physical processes. We parameterized this extension with published field and experimental data, and estimated the terrestrial DOC loading of the Continental United States over the period of 1981-2010. We then studied the influence of each atmospheric deposition driver on land-water DOC loading through turning on different combinations of simulation experiments. Our results suggest that 1) during this period, the average annual DOC loading increased from 35.3 Tg C yr^{-1} (1981) to 64.5 Tg C yr^{-1} (2010); 2) Decreasing sulfur deposition played a more important role on DOC loading, which is greater than the influence from nitrogen deposition; 3) The runoff was the main driver of the interannual variation in DOC export; and 4) Heavy precipitation can greatly increase the total DOC loading, which was mostly exported from the forest floor, and has smaller influence on the deeper soil DOC loading.

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Comparison of Accuracy, Variability and Relative Bias for Two Central Analytical Laboratories for the National Atmospheric Deposition Program

Gregory Wetherbee[1] , Camille Danielson[2], Martin Shafer[3], Sybil Anderson[4], Nina Gartman[5], Chris Worley[6] and Amy Mager[7]

Implementation of new data-collection methods and systems, including changes in laboratories for the National Atmospheric Deposition Program (NADP) requires great care to prevent shifts in the analytical data, which could then be interpreted as real changes in the chemical composition of the atmosphere. In 2018, the NADP moved centralized support operations, including the Central Analytical Laboratory (CAL), from the University of Illinois (UI) to the University of Wisconsin (UW). This change in laboratory could potentially introduce biases into the chemical wet-deposition data for the National Trends Network (NTN – major ions, ammonia, bromide, and pH), the Atmospheric Integrated Research Monitoring Network (AIRMoN, same analytes as NTN plus orthophosphate), and Ammonia Monitoring Network (AMoN, ambient ammonia in air). The former CAL at UI (I-CAL) and the new laboratory at UW (W-CAL) collaborated with the U.S. Geological Survey's Precipitation Chemistry Quality Assurance Project (PCQA) to implement comparison studies to identify potential shifts in analytical data.

The PCQA supplied 30 natural matrix samples to I-CAL, W-CAL, and four additional volunteer laboratories to evaluate laboratory accuracy and precision. These samples were amended with bromide and phosphate to ensure detection. PCQA also used these solutions to created low-volume (2 – 69 mL) samples. Monthly PCQA interlaboratory-comparison program data were also evaluated to assess W-CAL performance. Additionally, 75 NTN samples were shared between I-CAL and W-CAL for assessment of relative bias. Results for the PCQA monthly samples, the additional 30 natural matrix spike samples, and the low-volume samples were compared to most probable (median) values (MPVs) for each test solution. Results from I-CAL and W-CAL for the 75 shared NTN samples were compared directly. Metrics for acceptance criteria based on current I-CAL quality-control protocols were prescribed in a Readiness Verification Plan (RVP) before the comparison studies began.

Results for monthly PCQA samples indicated acceptable precision and bias for both I-CAL and W-CAL per RVP metrics. Analyses of the shared 75 NTN samples indicate a slight positive bias for W-CAL data relative to I-CAL data for calcium, sodium, and potassium and a slight negative bias for ammonium, chloride, nitrate, specific conductance, and hydrogen ion. Median differences were small and of the same magnitude of analytical detection limits. No bias was observed for W-CAL data for magnesium, bromide, sulfate, and phosphate in the 75 NTN samples. Similar, biases in W-CAL results were observed for the 30 natural matrix spike samples.

Analysis of low-volume samples by W-CAL showed median relative percent biases ranging from: -13% to -1.1% for ammonium, -45% to -0.3% for nitrate, and -2.9% to 2.8% for sulfate. The largest negative relative percent biases were for the smallest sample volumes (2 – 6 mL) and for analytes at concentrations near analytical detection; primarily potassium, bromide, and orthophosphate.

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It’s Raining Plastic

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Atmospheric deposition samples were collected using the National Atmospheric Deposition Program / National Trends Network (NADP/NTN) at 6 sites in the Denver-Boulder urban corridor and 2 adjacent sites in the Colorado Front Range. Weekly wet-only atmospheric deposition samples collected at these sites during winter-summer of 2017 were filtered (0.45 micrometers, polyethersulfone) to obtain particulates washed from the atmosphere (washout). Plastics were identified on over 90 percent of the filters. The plastic materials are mostly fibers that are only visible with magnification (~40X). Fibers were present in a variety of colors; the most frequently observed color was blue followed by red > silver > purple > green > yellow > other colors. Plastic particles such as beads and shards were also observed with magnification. More plastic fibers were observed in samples from urban sites than from isolated, montane sites. However, frequent observation of plastic fibers in washout samples from the isolated Loch Vale site in Rocky Mountain National Park (elevation 3,159 meters) suggest that wet-deposition of plastic is ubiquitous and not just an urban condition.

The mass of plastic in even the most concentrated samples was not large enough to weigh or reliably estimate. Developing a routine capability to calculate plastic wet-deposition loads is not possible with current technology. Counting plastic fibers under a microscope and multiplying the counts by a mean mass per fiber might be possible, but it is tedious, expensive, and has large inherent error. A means to estimate the recovery of the plastic materials from the NADP samples is needed. However, saving the NADP filters for subsequent analysis would make a washout deposition network possible with very little added expense, and methods could be developed to more accurately estimate plastic loads using the NTN.

It is unclear how these plastic materials are accumulating and being assimilated in the environment and biota. Moreover, the potential effects of these materials on biota is not understood.

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NADP Sample Processing at the WSLH: Conventional Strategies and New Approaches

Kirsten Widmayer[1] , Amy Mager[2] and Chris Worley[3]

Current NADP sample processing at the Wisconsin State Laboratory of Hygiene (WCAL) integrates processes and procedures previously implemented by the Illinois State Water Survey (ICAL), while incorporating selected new and innovative approaches. Several modifications to the initial sample processing steps, which include sample receiving, data entry, pH and conductivity measurement, and sample filtration, have been implemented. The WCAL has initiated same day processing (pH and conductivity determination and filtration) upon sample receipt. Manual pH and conductivity procedures have been optimized and now only require a total of 10 mLs per sample. The Titrec Automated Electro-Chemistry Analyzer was upgraded and is being phased-in to replace both manual pH and conductivity measurements. Filtration methods have been simplified, including reducing low volume sample dilutions to 25 mLs, while still incorporating the filtration apparatus used by the ICAL. After extensive validation, modifications to certain supply preparation and shipping protocols have also been implemented. Further improvements in supply preparation and shipping are being explored.

After initial processing, samples are ready for analyte measurement. WCAL utilizes similar analytical platforms to ICAL. This includes the Agilent 5110 ICP-OES, two Lachat QuickChem 8500 Series 2 instruments and two Thermo Fisher/Dionex Integrion HPIC instruments. These analytical platforms are well established and are used by EPA, State, and NELAC accredited laboratories (including the WSLH). At this time WCAL has not modified any specific analytical chemistries. However, QA/QC practices have been modified in relation to instrument calibration, sample duplicates, filter and method blanks, and tier 1 level data review processes. WCAL is in the early stages of evaluating viable analytical options to improve detection limits, sample throughput, and expansion of the ICP-OES element menu. These alternatives include utilizing a 2 cm flow cell on the FIA systems, and exploring a concentrator and high sample output analytical columns on the IC.

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Investigating Different Strategies to Reduce Costs, Enhance Sampler Integrity, and Improve the Extraction Process, in the Ammonia Monitoring Network (AMoN)

Jesse Wouters[1] , Chris Worley[2], Camille Danielson[3] and Martin Shafer[4]

The Ammonia Monitoring Network (AMoN), associated with the National Atmospheric Deposition Program (NADP), is currently measuring ambient ammonia concentrations (NH_3) at over 100 sites throughout the United States and Canada. To accomplish this, a passive sampler consisting of a Radiello®adsorbent cartridge (microporous polyethylene impregnated with phosphoric acid) enclosed in a Radiello® diffusive body is shipped to each of the sites. The samplers are deployed for two weeks under a protective shelter, after which the sampler is returned to the NADP Central Analytical Laboratory (Wisconsin State Laboratory of Hygiene), where the adsorbed ammonia (ammonium – NH_4) is extracted from the cartridge and the concentration determined with flow-injection spectrophotometry. In this presentation we will present the outcomes of three separate studies designed to address the efficacy of proposed sampler shipping improvements and sampler extraction optimization.

Study 1: Currently, a glass jar (with lid) is used to protect the sampler from contamination and damage during shipping; however, movement of the sampler within the glass jar can compromise its' integrity and result in significant sampler attrition. This study investigated the use of plastic bags to ameliorate this issue; specifically, if placing the sampler inside a plastic bag will limit the motion of the sampler within the jar and thereby reduce damage. A comparison of damage rates during shipping of bagged samplers to those with no bags will be presented. We also investigated the potential for ammonia contamination from the bags.

Study 2: This study evaluated the use of Mylar and anti-static bags as viable alternatives to glass jars, which are expensive to ship due to their weight and may contribute to sampler breakage. Results from this study will be used to evaluate both barrier effectiveness to ambient ammonia and ammonia contamination issues.

Study 3: This study focused on optimization of the extraction protocol of ammonium from the adsorbent cartridge (core). The current procedure is to place the core into a Radiello® tube and fill with 10.0 mL of 18.2 MΩ-cm water. The tube is then sonicated for 20 minutes and placed in a refrigerator overnight. The next day, the core is removed from the tube and the solution analyzed for ammonium. This study investigated the influence of sonication time and duration of core exposure to the 18.2 MΩ-cm water on ammonium desorption from the core. The outcomes of this study may point to improvements in ammonium extraction efficiency and quality/reproducibility of the ammonia data.

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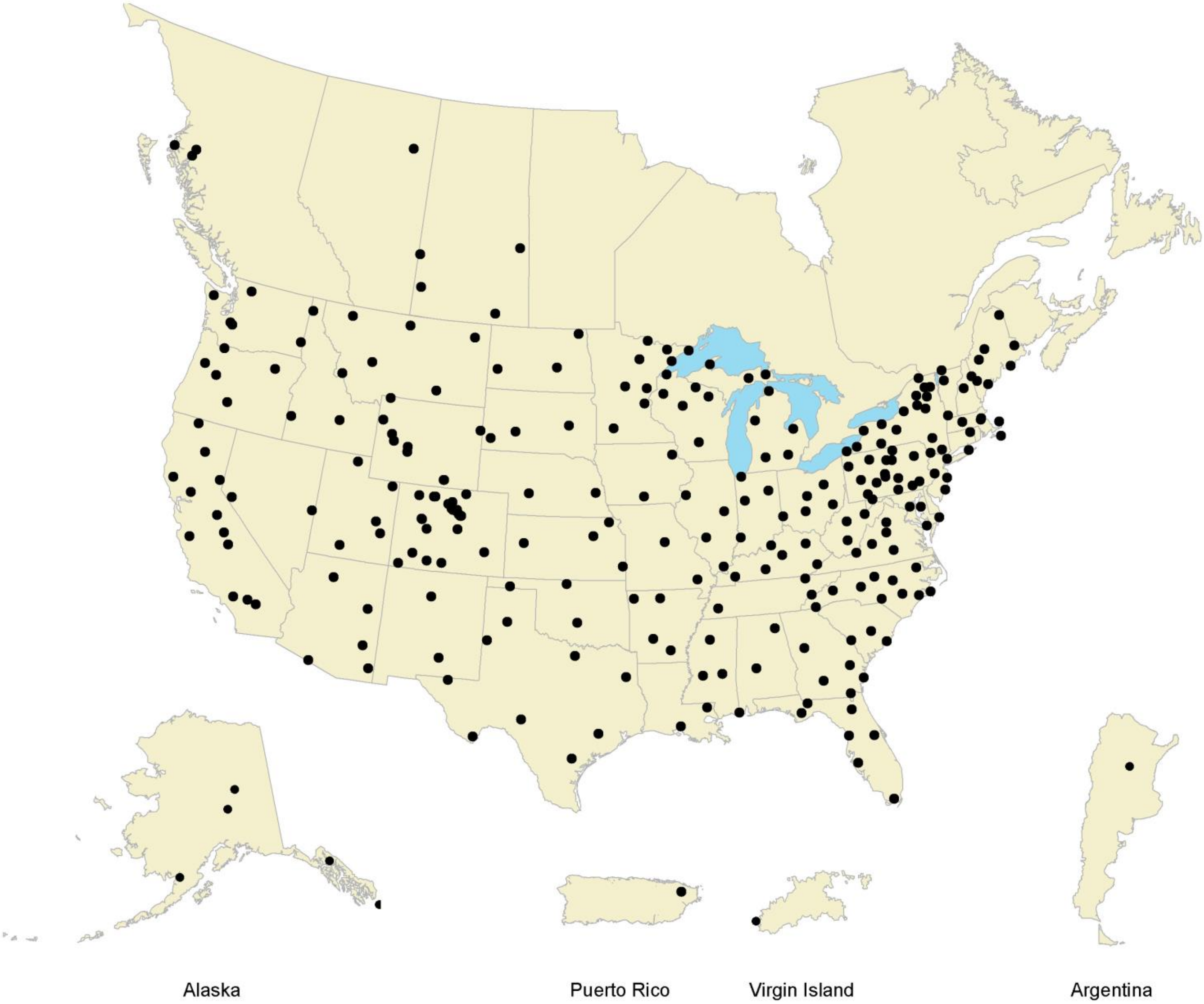
National Atmospheric Deposition Program

National Trends Network (NTN)



NTN

Site ID	Site Name	Site Sponsor	Start Date
AB32	Fort Mackay	Wood Buffalo Environmental Association	9/13/2016
AK01	Poker Creek	U.S. Forest Service	12/29/1992
AK02	Juneau	U.S. Forest Service	6/22/2004
AK03	Denali National Park-Mt. McKinley	NPS-Air Resources Division	6/17/1980
AK96	Toolik Field Station	University of Alaska Fairbanks	10/12/2017
AK97	Katmai National Park - King Salmon	NPS-Air Resources Division	11/2/2009
AL10	Black Belt Research & Extension Center	U.S. Geological Survey	8/31/1983
AL99	Sand Mountain Research & Extension Center	U.S. Environmental Protection Agency - Clean Air Markets	10/2/1984
AR02	Warren 2WSW	U.S. Geological Survey	5/25/1982
AR03	Caddo Valley	U.S. Geological Survey	12/30/1983
AR16	Buffalo National River-Buffalo Point	NPS-Air Resources Division	7/13/1982
AR27	Fayetteville	U.S. Geological Survey	5/13/1980
AZ03	Grand Canyon National Park-Hopi Point	NPS-Air Resources Division	8/11/1981
AZ06	Organ Pipe Cactus National Monument	NPS-Air Resources Division	4/15/1980
AZ97	Petrified Forest National Park-Rainbow Forest	NPS-Air Resources Division	12/3/2002
AZ98	Chiricahua	U.S. Environmental Protection Agency - Clean Air Markets	2/23/1999
AZ99	Oliver Knoll	U.S. Geological Survey	8/25/1981
BC22	Haul Road Station	Rio Tinto	9/19/2012
BC23	Lakelse Lake	Rio Tinto	3/20/2013
BC24	Port Edward	Prince Rupert Port Authority	1/15/2014
CA28	Kings River Experimental Watershed	USFS - Pacific Southwest Research Station	4/24/2007
CA42	Tanbark Flat	U.S. Forest Service	1/12/1982
CA45	Hopland	U.S. Geological Survey	10/3/1979
CA50	Sagehen Creek	U.S. Geological Survey	11/6/2001

NTN

Site ID	Site Name	Site Sponsor	Start Date
CA66	Pinnacles National Monument-Bear Valley	NPS-Air Resources Division	11/2/1999
CA67	Joshua Tree National Park-Black Rock	NPS-Air Resources Division	9/19/2000
CA75	Sequoia National Park-Giant Forest	NPS-Air Resources Division	7/8/1980
CA76	Montague	U.S. Geological Survey	6/25/1985
CA88	Davis	U.S. Geological Survey	9/4/1978
CA94	Converse Flats	U.S. Forest Service	5/9/2006
CA96	Lassen Volcanic National Park-Manzanita Lake	NPS-Air Resources Division	6/13/2000
CA99	Yosemite National Park-Hodgdon Meadow	NPS-Air Resources Division	12/8/1981
CAN5	Frelighsburg	U.S. Geological Survey	10/2/2001
CO00	Alamosa	U.S. Geological Survey	4/22/1980
CO01	Las Animas Fish Hatchery	U.S. Geological Survey	10/4/1983
CO02	Niwot Saddle	INSTAAR-University of Colorado/ National Science Foundation	6/5/1984
CO06	CAMP	City and County of Denver	1/10/2017
CO08	Four Mile Park	U.S. Environmental Protection Agency - Clean Air Markets	12/29/1987
CO09	Kawuneechee Meadow	U.S. Bureau of Land Management	7/10/2012
CO10	Gothic	U.S. Environmental Protection Agency - Clean Air Markets	2/2/1999
CO11	Arvada Gardens	U.S. Geological Survey	12/5/2016
CO15	Sand Spring	U.S. Bureau of Land Management	3/20/1979
CO19	Rocky Mountain National Park-Beaver Meadows	NPS-Air Resources Division	5/29/1980
CO21	Manitou	U.S. Forest Service	10/17/1978
CO22	Pawnee	Colorado Department of Public Health & Environment	5/22/1979
CO84	Betasso	U.S. Geological Survey	5/2/2017
CO85	Boulder	Colorado Department of Public Health & Environment	1/3/2017
CO86	Rocky Flats NWR	U.S. Fish and Wildlife Service	1/3/2017
CO87	National Jewish Hospital	Colorado Department of Public Health & Environment	1/10/2017
CO90	Niwot Ridge-Southeast	INSTAAR-University of Colorado	1/24/2006

NTN

Site ID	Site Name	Site Sponsor	Start Date
CO90	Niwot Ridge-Southeast	National Science Foundation	1/24/2006
CO91	Wolf Creek Pass	U.S. Forest Service	5/26/1992
CO92	Sunlight Peak	U.S. Environmental Protection Agency - Clean Air Markets	1/13/1988
CO93	Buffalo Pass - Dry Lake	U.S. Forest Service	10/14/1986
CO94	Sugarloaf	U.S. Environmental Protection Agency - Clean Air Markets	11/4/1986
CO96	Molas Pass	U.S. Forest Service	7/29/1986
CO97	Buffalo Pass - Summit Lake	U.S. Forest Service	2/7/1984
CO98	Rocky Mountain National Park-Loch Vale	U.S. Geological Survey - Biological Resources Division/ Colorado State University	8/16/1983
CO99	Mesa Verde National Park-Chapin Mesa	U.S. Geological Survey	4/28/1981
CT15	Abington	U.S. Environmental Protection Agency - Clean Air Markets	1/26/1999
FL03	Bradford Forest	U.S. Environmental Protection Agency - Clean Air Markets	10/10/1978
FL05	Chassahowitzka National Wildlife Refuge	USFWS-Air Quality Branch	8/27/1996
FL11	Everglades National Park-Research Center	NPS-Air Resources Division	6/17/1980
FL14	Quincy	U.S. Geological Survey	3/13/1984
FL23	Sumatra	U.S. Environmental Protection Agency - Clean Air Markets	1/26/1999
FL41	Verna Well Field	U.S. Geological Survey	8/25/1983
GA09	Okefenokee National Wildlife Refuge	USFWS-Air Quality Branch	6/3/1997
GA20	Bellville	U.S. Environmental Protection Agency - Clean Air Markets	4/26/1983
GA41	Georgia Station	University of Georgia-State Agricultural Experiment Station	10/3/1978
GA99	Chula	U.S. Geological Survey	2/10/1994
IA08	Big Springs Fish Hatchery	U.S. Geological Survey	8/14/1984
IA23	McNay Research Center	U.S. Geological Survey	9/11/1984
ID02	Priest River Experimental Forest	U.S. Forest Service	12/31/2002

NTN

Site ID	Site Name	Site Sponsor	Start Date
ID03	Craters of the Moon National Monument	NPS-Air Resources Division	8/22/1980
ID11	Reynolds Creek	U.S. Geological Survey	11/22/1983
IL11	Bondville	U.S. Environmental Protection Agency - Clean Air Markets	2/27/1979
IL46	Alhambra	U.S. Environmental Protection Agency - Clean Air Markets	1/26/1999
IL78	Monmouth	U.S. Geological Survey	1/8/1985
IN20	Roush Lake	U.S. Geological Survey	8/22/1983
IN22	Southwest Purdue Agriculture Center	U.S. Geological Survey	9/25/1984
IN34	Indiana Dunes National Lakeshore	NPS-Air Resources Division	7/15/1980
IN41	Agronomy Center for Research and Extension	Purdue University-State Agricultural Experiment Station	7/13/1982
KS07	Farlington Fish Hatchery	U.S. Geological Survey	3/27/1984
KS31	Konza Prairie	Kansas State University-State Agricultural Experiment Station	8/17/1982
KS32	Lake Scott State Park	U.S. Geological Survey	3/27/1984
KS97	Kickapoo Tribe - Powhattan	Kickapoo Tribe	10/13/2015
KY03	Mackville	U.S. Geological Survey	11/29/1983
KY10	Mammoth Cave National Park-Houchin Meadow	NPS-Air Resources Division	8/27/2002
KY19	Cannons Lane	U.S. Geological Survey	10/7/2003
KY22	Lilley Cornett Woods	U.S. Geological Survey	9/6/1983
KY35	Clark State Fish Hatchery	U.S. Geological Survey	8/30/1983
KY99	Mulberry Flat	Murray State University/ U.S. Forest Service	12/27/1994
LA12	Iberia Research Station	U.S. Geological Survey	11/16/1982
LA30	Southeast Research Station	U.S. Geological Survey	1/18/1983
MA01	North Atlantic Coastal Lab	NPS-Air Resources Division	12/15/1981
MA08	Quabbin Reservoir	Northeast States for Coordinated Air Use Management	3/5/1982
MA14	Nantucket	Nantucket Land Council, Inc.	3/4/2014

NTN

Site ID	Site Name	Site Sponsor	Start Date
MA22	Boston University	Boston University	6/16/2015
MA98	Arnold Arboretum	Boston University	2/9/2016
MD08	Piney Reservoir	Maryland Department of Natural Resources	6/29/2004
MD13	Wye	University of Maryland-State Agricultural Experiment Station	3/8/1983
MD15	Smith Island	National Oceanic and Atmospheric Administration - Air Resources Laboratory	6/1/2004
MD18	Assateague Island National Seashore-Woodcock	Maryland Department of Natural Resources	9/5/2000
MD99	Beltsville	Maryland Department of Natural Resources	6/1/2004
ME00	Caribou	U.S. Environmental Protection Agency/ Maine Department of Environmental Protection	4/14/1980
ME02	Bridgton	U.S. Environmental Protection Agency/ Maine Department of Environmental Protection	9/30/1980
ME04	Carrabassett Valley	U.S. Environmental Protection Agency - Clean Air Markets	3/12/2002
ME08	Gilead	U.S. Geological Survey	9/28/1999
ME09	Greenville Station	Maine Department of Environmental Protection/ Maine Department of Environmental Protection	11/20/1979
ME94	Indian Township	Passamaquoddy Tribe/ U.S. Environmental Protection Agency/	10/3/2013
ME96	Casco Bay-Wolfe’s Neck Farm	Maine Department of Environmental Protection/ U.S. Environmental Protection Agency	1/6/1998
ME98	Acadia National Park-McFarland Hill	NPS-Air Resources Division	11/10/1981
MI09	Douglas Lake	Michigan State University-State Agricultural Experiment Station	7/3/1979
MI26	Kellogg Biological Station	Michigan State University-State Agricultural Experiment Station	6/26/1979
MI48	Seney National Wildlife Refuge-Headquarters	USFWS-Air Quality Branch	11/28/2000
MI51	Unionville	U.S. Environmental Protection Agency - Clean Air Markets	1/26/1999
MI52	Ann Arbor	U.S. Environmental Protection Agency - Clean Air Markets	1/26/1999
MI53	Wellston	U.S. Forest Service	10/10/1978
MI99	Chassell	U.S. Forest Service	2/15/1983
MN01	Cedar Creek	Minnesota Pollution Control Agency	12/31/1996

NTN

Site ID	Site Name	Site Sponsor	Start Date
MN08	Hovland	Minnesota Pollution Control Agency	12/31/1996
MN16	Marcell Experimental Forest	U.S. Forest Service	7/6/1978
MN18	Fernberg	U.S. Environmental Protection Agency - Clean Air Markets	11/18/1980
MN23	Camp Ripley	U.S. Geological Survey	10/18/1983
MN27	Lamberton	Minnesota Pollution Control Agency	1/2/1979
MN28	Grindstone Lake	Minnesota Pollution Control Agency	12/31/1996
MN32	Voyageurs National Park-Sullivan Bay	NPS-Air Resources Division	5/30/2000
MN99	Wolf Ridge	Minnesota Pollution Control Agency	12/31/1996
MO03	Ashland Wildlife Area	U.S. Geological Survey	10/20/1981
MO05	University Forest	U.S. Geological Survey	10/27/1981
MS10	Clinton	U.S. Geological Survey	7/10/1984
MS12	Grand Bay NERR	National Oceanic and Atmospheric Administration - Air Resources Laboratory	3/9/2010
MS19	Newton	National Oceanic and Atmospheric Administration - Air Resources Laboratory	11/11/1986
MS30	Coffeeville	U.S. Forest Service	7/17/1984
MT00	Little Bighorn Battlefield National Monument	U.S. Geological Survey	7/13/1984
MT05	Glacier National Park-Fire Weather Station	NPS-Air Resources Division	6/3/1980
MT07	Clancy	U.S. Geological Survey	1/24/1984
MT96	Poplar River	Fort Peck Assiniboine & Sioux Tribes	12/21/1999
MT97	Lost Trail Pass	U.S. Forest Service	9/25/1990
MT98	Havre - Northern Agricultural Research Center	U.S. Geological Survey	7/30/1985
NC03	Lewiston	North Carolina State University	10/31/1978
NC06	Beaufort	U.S. Environmental Protection Agency - Clean Air Markets	1/26/1999
NC17	University Research Farm	U.S. Department of Energy	1/30/2015
NC25	Coweeta	U.S. Forest Service	7/5/1978
NC29	Hofmann Forest	North Carolina State University	7/2/2002
NC34	Piedmont Research Station	North Carolina State University	10/17/1978
NC35	Clinton Crops Research Station	North Carolina State University	10/24/1978
NC36	Jordan Creek	U.S. Geological Survey	10/18/1983

NTN

Site ID	Site Name	Site Sponsor	Start Date
NC41	Finley Farm	North Carolina State University	10/3/1978
NC45	Mt. Mitchell	U.S. Environmental Protection Agency - Clean Air Markets / North Carolina State University	11/26/1985
ND00	Theodore Roosevelt National Park-Painted Canyon	NPS-Air Resources Division	1/30/2001
ND08	Icelandic State Park	U.S. Geological Survey	10/25/1983
ND11	Woodworth	U.S. Geological Survey	11/29/1983
NE15	Mead	University of Nebraska-State Agricultural Experiment Station	7/25/1978
NE99	North Platte Agricultural Experiment Station	U.S. Geological Survey	9/24/1985
NH02	Hubbard Brook	U.S. Forest Service	7/25/1978
NJ00	Edwin B. Forsythe National Wildlife Refuge	USFWS-Air Quality Branch	10/13/1998
NJ39	Cattus Island County Park	U.S. Environmental Protection Agency - Clean Air Markets	12/4/2012
NJ99	Washington Crossing	U.S. Environmental Protection Agency - Clean Air Markets	8/4/1981
NM07	Bandelier National Monument	NPS-Air Resources Division	6/22/1982
NM08	Mayhill	U.S. Geological Survey	1/24/1984
NV03	Smith Valley	U.S. Geological Survey	8/7/1985
NV05	Great Basin National Park-Lehman Caves	NPS-Air Resources Division	1/15/1985
NY01	Alfred	U.S. Geological Survey	8/17/2004
NY06	Bronx	New York State Energy Research & Development Authority	1/22/2013
NY08	Aurora Research Farm	Cornell University	4/17/1979
NY10	Chautauqua	U.S. Geological Survey	6/10/1980
NY20	Huntington Wildlife	New York State Energy Research & Development Authority	10/31/1978
NY22	Akwesasne Mohawk-Fort Covington	U.S. Environmental Protection Agency - Clean Air Markets	8/18/1999
NY28	Piseco Lake	New York State Energy Research & Development Authority	12/31/2012

NTN

Site ID	Site Name	Site Sponsor	Start Date
NY43	Rochester	New York State Energy Research & Development Authority	4/30/2013
NY52	Bennett Bridge	U.S. Environmental Protection Agency - Clean Air Markets	6/10/1980
NY59	Wanakena	New York State Energy Research & Development Authority	1/2/2013
NY67	Ithaca	National Oceanic and Atmospheric Administration - Air Resources Laboratory	1/2/2018
NY68	Biscuit Brook	U.S. Geological Survey	10/11/1983
NY92	Amherst	New York State Energy Research & Development Authority	10/29/2013
NY93	Paul Smith's	New York State Energy Research & Development Authority	1/1/2013
NY94	Nick's Lake	New York State Energy Research & Development Authority	11/3/2015
NY96	Cedar Beach-Southold	U.S. Environmental Protection Agency/ County of Suffolk-Department of Health Services-Peconic Estuary Program	11/25/2003
NY98	Whiteface Mountain	U.S. Geological Survey	7/3/1984
NY99	West Point	U.S. Geological Survey	9/13/1983
OH09	Oxford	U.S. Geological Survey	8/14/1984
OH17	Delaware	U.S. Forest Service	10/3/1978
OH49	Caldwell	U.S. Geological Survey	9/26/1978
OH54	Deer Creek State Park	U.S. Environmental Protection Agency - Clean Air Markets	1/26/1999
OH71	Wooster	U.S. Geological Survey	9/26/1978
OK00	Salt Plains National Wildlife Refuge	U.S. Geological Survey	12/13/1983
OK17	Kessler Atmospheric and Ecological Field Station	National Oceanic and Atmospheric Administration - Air Resources Laboratory	3/29/1983
OK29	Goodwell Research Station	U.S. Geological Survey	1/8/1985
OR09	Silver Lake Ranger Station	U.S. Geological Survey	8/23/1983
OR10	H. J. Andrews Experimental Forest	U.S. Forest Service	5/13/1980
OR18	Starkey Experimental Forest	U.S. Geological Survey	3/6/1984
OR97	Hyslop Farm	U.S. Environmental Protection Agency - Clean Air Markets	4/26/1983
PA00	Arendtsville	U.S. Environmental Protection Agency - Clean Air Markets	1/26/1999

NTN

Site ID	Site Name	Site Sponsor	Start Date
PA13	Allegheny Portage Railroad National Historic Site	Pennsylvania Department of Environmental Protection/ Pennsylvania State University	7/26/2011
PA15	Penn State	National Oceanic and Atmospheric Administration - Air Resources Laboratory/ Pennsylvania Game Commission	6/7/1983
PA18	Young Woman's Creek	U.S. Geological Survey	4/20/1999
PA29	Kane Experimental Forest	U.S. Forest Service	7/18/1978
PA30	Erie	Pennsylvania State University/ Pennsylvania Department of Environmental Protection	7/27/2011
PA42	Leading Ridge	Pennsylvania State University-State Agricultural Experiment Station-	4/25/1979
PA72	Milford	U.S. Forest Service	12/27/1983
PA90	Hills Creek State Park	Pennsylvania Department of Environmental Protection/ Pennsylvania State University	7/26/2011
PR20	El Verde	U.S. Forest Service	2/12/1985
SC05	Cape Romain National Wildlife Refuge	USFWS-Air Quality Branch	11/21/2000
SC06	Santee National Wildlife Refuge	U.S. Geological Survey	7/19/1984
SD04	Wind Cave National Park-Elk Mountain	NPS-Air Resources Division	11/5/2002
SD08	Cottonwood	U.S. Geological Survey	10/11/1983
SD99	Huron Well Field	U.S. Geological Survey	11/29/1983
SK20	Cactus Lake	Saskatchewan Ministry of Environment	2/14/2012
SK21	Hudson Bay	Saskatchewan Ministry of Environment	4/30/2012
SK30	Weyburn	Saskatchewan Ministry of Environment	6/7/2016
SK31	Fox Valley	Saskatchewan Ministry of Environment	6/14/2016
TN04	Speedwell	U.S. Environmental Protection Agency - Clean Air Markets	1/26/1999
TN11	Great Smoky Mountains National Park-Elkmont	NPS-Air Resources Division	8/12/1980
TN14	Hatchie National Wildlife Refuge	U.S. Geological Survey	10/2/1984
TX02	Muleshoe National Wildlife Refuge	U.S. Geological Survey	6/18/1985
TX03	Beeville	U.S. Geological Survey	2/7/1984

NTN

Site ID	Site Name	Site Sponsor	Start Date
TX04	Big Bend National Park - K-Bar	NPS-Air Resources Division	4/10/1980
TX10	Attwater Prairie Chicken National Wildlife Refuge	U.S. Geological Survey	7/3/1984
TX16	Sonora	U.S. Geological Survey	6/26/1984
TX22	Guadalupe Mountains National Park Frijole Ranger Station	U.S. Geological Survey	6/5/1984
TX43	Cañónceta	U.S. Environmental Protection Agency - Clean Air Markets	7/24/2007
TX56	L.B.J. National Grasslands	U.S. Geological Survey	9/20/1983
UT01	Logan	U.S. Geological Survey	12/6/1983
UT09	Canyonlands National Park-Island in the Sky	NPS-Air Resources Division	11/11/1997
UT95	East McKee	U.S. Forest Service	12/5/2017
UT98	Green River	U.S. Geological Survey	4/25/1985
UT99	Bryce Canyon National Park-Repeater Hill	NPS-Air Resources Division	1/29/1985
VA00	Charlottesville	U.S. Geological Survey	10/2/1984
VA13	Horton's Station	U.S. Environmental Protection Agency - Clean Air Markets	7/25/1978
VA24	Prince Edward	U.S. Environmental Protection Agency - Clean Air Markets	1/26/1999
VA28	Shenandoah National Park-Big Meadows	NPS-Air Resources Division	5/12/1981
VA99	Natural Bridge Station	USFS - Air Program	7/2/2002
VI01	Virgin Islands National Park-Lind Point	NPS-Air Resources Division	4/14/1998
VT01	Bennington	U.S. Geological Survey	4/28/1981
VT99	Underhill	U.S. Geological Survey	6/12/1984
WA14	Olympic National Park-Hoh Ranger Station	NPS-Air Resources Division	5/20/1980
WA19	North Cascades National Park-Marblemount Ranger Station	U.S. Geological Survey	2/7/1984

NTN

Site ID	Site Name	Site Sponsor	Start Date
WA21	La Grande	U.S. Environmental Protection Agency - Clean Air Markets	4/24/1984
WA24	Palouse Conservation Farm	U.S. Geological Survey	8/20/1985
WA98	Columbia River Gorge	USFS - Pacific Northwest Region	5/7/2002
WA99	Mount Rainier National Park-Tahoma Woods	NPS-Air Resources Division	10/26/1999
WI08	Brule River	Wisconsin Department of Natural Resources	4/22/2014
WI10	Potawatomi	Forest County Potawatomi Community	6/7/2005
WI31	Devil's Lake	Wisconsin Department of Natural Resources	1/7/2014
WI35	Perkinstown	U.S. Environmental Protection Agency - Clean Air Markets	1/26/1999
WI36	Trout Lake	Wisconsin Department of Natural Resources	1/22/1980
WI37	Spooner	U.S. Forest Service	6/3/1980
WV04	Babcock State Park	U.S. Geological Survey	9/6/1983
WV05	Cedar Creek State Park	U.S. Environmental Protection Agency - Clean Air Markets	1/26/1999
WV18	Parsons	U.S. Forest Service	7/5/1978
WY00	Snowy Range	U.S. Forest Service	4/22/1986
WY02	Sinks Canyon	U.S. Bureau of Land Management	8/21/1984
WY06	Pinedale	U.S. Bureau of Land Management	1/26/1982
WY08	Yellowstone National Park-Tower Falls	NPS-Air Resources Division	6/5/1980
WY94	Grand Tetons National Park	Wyoming Department of Environmental Quality	9/27/2011
WY95	Brooklyn Lake	U.S. Forest Service	9/22/1992
WY97	South Pass City	Bridger-Teton National Forest	4/30/1985
WY98	Gypsum Creek	Bridger-Teton National Forest	12/26/1984
WY99	Newcastle	U.S. Bureau of Land Management	8/11/1981

National Atmospheric Deposition Program

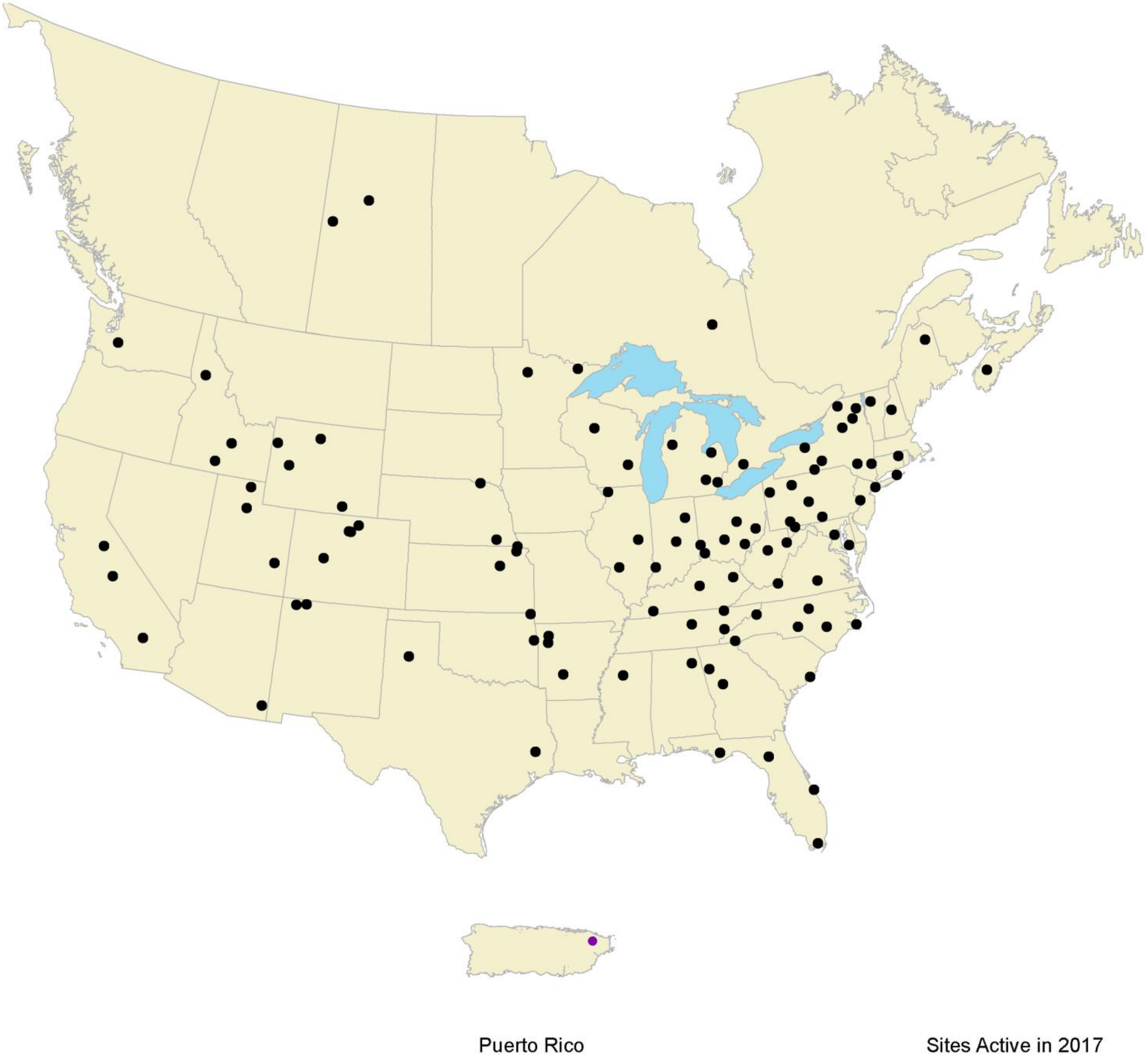
Atmospheric Integrated Research Monitoring Network (AIRMoN)

AIRMoN

Site ID	Site Name	Site Sponsor	Start Date
NY67	Ithaca	National Oceanic and Atmospheric Administration - Air Resources Laboratory	9/30/1992
PA15	Penn State	National Oceanic and Atmospheric Administration - Air Resources Laboratory	10/6/1992
TN00	Walker Branch Watershed	National Oceanic and Atmospheric Administration - Air Resources Laboratory	9/23/1992
WV99	Canaan Valley Institute	National Oceanic and Atmospheric Administration - Air Resources Laboratory	6/1/2000

National Atmospheric Deposition Program

Ammonia Monitoring Network (AMoN)



AMoN

Site ID	Site Name	Site Sponsor	Start Date
AL99	Sand Mountain Research & Extension Center	U.S. Environmental Protection Agency - Clean Air Markets	3/29/2011
AR03	Caddo Valley	U.S. Environmental Protection Agency - Clean Air Markets	3/1/2011
AR09	Rambo Hill	U.S. Department of Agriculture - Agricultural Research Service	10/6/2015
AR15	LC Farms	U.S. Department of Agriculture - Agricultural Research Service	10/6/2015
AZ98	Chiricahua	NPS-Air Resources Division	3/22/2011
CA44	Yosemite NP - Turtleback Dome	NPS-Air Resources Division	3/15/2011
CA67	Joshua Tree National Park-Black Rock	NPS-Air Resources Division	3/1/2011
CA83	Sequoia NP - Ash Mountain	NPS-Air Resources Division	3/22/2011
CO10	Gothic	U.S. Environmental Protection Agency - Clean Air Markets	9/11/2012
CO13	Fort Collins	U.S. Environmental Protection Agency - Clean Air Markets	11/27/2007
CO88	Rocky Mountain National Park - Longs Peak	NPS-Air Resources Division	5/10/2011
CO98	Rocky Mountain National Park-Loch Vale	NPS-Air Resources Division	5/10/2011
CT15	Abington	U.S. Environmental Protection Agency - Clean Air Markets	3/29/2011
FL11	Everglades National Park-Research Center	NPS-Air Resources Division	3/15/2011
FL19	Indian River	U.S. Environmental Protection Agency - Clean Air Markets	4/26/2011
FL23	Sumatra	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
GA41	Georgia Station	U.S. Environmental Protection Agency - Clean Air Markets	6/7/2011
ID03	Craters of the Moon National Monument	NPS-Air Resources Division	6/7/2010
ID07	Nez Perce	U.S. Environmental Protection Agency - Clean Air Markets	12/15/2015
IL11	Bondville	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007
IL37	Stockton	U.S. Environmental Protection Agency - Clean Air Markets	4/26/2011

AMoN

Site ID	Site Name	Site Sponsor	Start Date
IL46	Alhambra	U.S. Environmental Protection Agency - Clean Air Markets	3/3/2011
IN20	Roush Lake	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
IN22	Southwest Purdue Agriculture Center	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
IN99	Indianapolis	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007
KS03	Reserve	Kansas Department of Health and Environment	10/11/2011
KS31	Konza Prairie	U.S. Environmental Protection Agency - Clean Air Markets	3/1/2011
KS97	Kickapoo Tribe - Powhattan	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
KY03	Mackville	U.S. Environmental Protection Agency - Clean Air Markets	3/1/2011
KY29	Crockett	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
KY98	Cadiz	U.S. Environmental Protection Agency - Clean Air Markets	3/15/2011
MD06	Blackwater NWR	U.S. Environmental Protection Agency - Clean Air Markets	1/20/2015
MD08	Piney Reservoir	Maryland Department of Natural Resources	8/3/2010
MD99	Beltsville	Maryland Department of Natural Resources	8/3/2010
ME93	Ashland	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
MI51	Unionville	U.S. Environmental Protection Agency - Clean Air Markets	1/18/2015
MI52	Ann Arbor	U.S. Environmental Protection Agency - Clean Air Markets	2/3/2015
MI95	Hoxeyville	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
MI96	Detroit	U.S. Environmental Protection Agency - Clean Air Markets	10/29/2007
MN02	Red Lake	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
MN18	Fernberg	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007
MS30	Coffeeville	U.S. Environmental Protection Agency - Clean Air Markets	1/6/2015
NC02	Cranberry	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
NC06	Beaufort	U.S. Environmental Protection Agency - Clean Air Markets	4/27/2010

AMoN

Site ID	Site Name	Site Sponsor	Start Date
NC25	Coweeta	U.S. Environmental Protection Agency - Clean Air Markets	5/24/2011
NC26	Candor	U.S. Environmental Protection Agency - Clean Air Markets	4/26/2011
NC30	Duke Forest	U.S. Environmental Protection Agency - Clean Air Markets	6/24/2008
NC35	Clinton Crops Research Station	U.S. Environmental Protection Agency - Clean Air Markets	8/5/2008
NC98	Duke Forest Flux Tower	U.S. Environmental Protection Agency - Clean Air Markets	8/21/2018
NE09	Homestead	National Park Service	7/26/2016
NE98	Santee	U.S. Environmental Protection Agency - Clean Air Markets	4/26/2011
NH02	Hubbard Brook	U.S. Environmental Protection Agency - Clean Air Markets	6/5/2012
NJ98	Washington Crossing CASTNET	U.S. Environmental Protection Agency - Clean Air Markets	3/1/2011
NM98	Navajo Lake	U.S. Environmental Protection Agency - Clean Air Markets	1/11/2008
NM99	Farmington	U.S. Environmental Protection Agency - Clean Air Markets	1/9/2008
NS01	Kejimkujik National Park	Environment Canada	10/8/2013
NY16	Cary Institute	Cary Institute	10/13/2009
NY20	Huntington Wildlife	U.S. Environmental Protection Agency - Clean Air Markets	6/5/2012
NY67	Ithaca	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007
NY91	Claryville	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
NY94	Nick's Lake	U.S. Environmental Protection Agency - Clean Air Markets	11/20/2012
NY98	Whiteface Mountain	U.S. Environmental Protection Agency - Clean Air Markets	11/20/2012
OH02	Athens Super Site	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007
OH09	Oxford	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
OH27	Cincinnati	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007
OH54	Deer Creek State Park	U.S. Environmental Protection Agency - Clean Air Markets	3/1/2011
OH99	Quaker City	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
OK98	Quapaw	U.S. Environmental Protection Agency	10/6/2015
OK99	Stilwell	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007

AMoN

Site ID	Site Name	Site Sponsor	Start Date
PA00	Arendtsville	U.S. Environmental Protection Agency - Clean Air Markets	10/13/2009
PA29	Kane Experimental Forest	U.S. Environmental Protection Agency - Clean Air Markets	3/8/2011
PA56	M. K. Goddard	U.S. Environmental Protection Agency - Clean Air Markets	12/30/2014
PA96	Penn State - Fairbrook Park	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
PA97	Laurel Hill	U.S. Environmental Protection Agency - Clean Air Markets	7/17/2015
PR20	El Verde	U.S. Forest Service	3/4/2014
SC05	Cape Romain National Wildlife Refuge	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007
TN01	Great Smoky Mountains NP - Look Rock	NPS-Air Resources Division	3/15/2011
TN04	Speedwell	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
TN07	Edgar Evins	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
TX41	Alabama-Coushatta	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
TX43	Cañónceta	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007
UT01	Logan	Utah Department of Environmental Quality	11/8/2011
UT09	Canyonlands National Park-Island in the Sky	NPS-Air Resources Division	5/6/2014
UT97	Salt Lake City	Utah Department of Environmental Quality	11/8/2011
VA13	Horton's Station	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015
VA24	Prince Edward	U.S. Environmental Protection Agency - Clean Air Markets	3/1/2011
VT99	Underhill	U.S. Environmental Protection Agency - Clean Air Markets	11/20/2012
WA99	Mount Rainier National Park-Tahoma Woods	NPS-Air Resources Division	3/16/2011
WI07	Horicon Marsh	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007
WI35	Perkinstown	U.S. Environmental Protection Agency - Clean Air Markets	3/29/2011
WV05	Cedar Creek State Park	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015

AMoN

Site ID	Site Name	Site Sponsor	Start Date
WV18	Parsons	U.S. Environmental Protection Agency - Clean Air Markets	6/7/2011
WY06	Pinedale	U.S. Environmental Protection Agency - Clean Air Markets	1/14/2015
WY93	Basin - Big Horn	U.S. Bureau of Land Management/ Air Resource Specialists	6/2/2015
WY94	Grand Tetons National Park	NPS-Air Resources Division	9/22/2011
WY95	Brooklyn Lake	U.S. Environmental Protection Agency - Clean Air Markets	6/19/2012

National Atmospheric Deposition Program

Mercury Deposition Network (MDN)

Sites active in 2017

MDN

Site ID	Site Name	Site Sponsor	Start Date
AB14	Genesee	Jacques Whitford Stantec Axys Limited	7/18/2006
AB33	Fort McKay South	Environment Canada	-
AK96	Toolik Field Station	University of Alaska Fairbanks	10/10/2017
AK98	Kodiak	State of Alaska Department of Environmental Conservation	9/18/2007
BC16	Saturna Island	Environment Canada	9/1/2009
CA75	Sequoia National Park-Giant Forest	NPS-Air Resources Division	7/22/2003
CA94	Converse Flats	U.S. Forest Service	4/20/2006
CO96	Molas Pass	U.S. Bureau of Land Management	6/30/2009
CO97	Buffalo Pass - Summit Lake	U.S. Forest Service	9/29/1998
CO99	Mesa Verde National Park-Chapin Mesa	NPS-Air Resources Division	12/26/2001
FL05	Chassahowitzka National Wildlife Refuge	USFWS-Air Quality Branch	7/1/1997
FL11	Everglades National Park-Research Center	South Florida Water Management District	3/5/1996
FL95	Everglades - South Palm Beach County	South Florida Water Management District	4/7/2015
FL97	Everglades-Western Broward County	South Florida Water Management District	11/8/2006
GA09	Okefenokee National Wildlife Refuge	USFWS-Air Quality Branch	7/29/1997
IL11	Bondville	Illinois State Water Survey	1/6/1999
IN21	Clifty Falls State Park	Lake Michigan Air Directors Consortium	1/12/2001
IN22	Southwest Purdue Agriculture Center	Lake Michigan Air Directors Consortium	12/31/2013
IN34	Indiana Dunes National Lakeshore	Lake Michigan Air Directors Consortium	10/27/2000
KS03	Reserve	Kansas Department of Health and Environment	1/2/2008
KS05	Coffey County Lake	Kansas Department of Health and Environment	12/30/2008
KS24	Glen Elder State Park	Kansas Department of Health and Environment	5/27/2008

MDN

Site ID	Site Name	Site Sponsor	Start Date
KS32	Lake Scott State Park	Kansas Department of Health and Environment	6/10/2008
KY10	Mammoth Cave National Park-Houchin Meadow	NPS-Air Resources Division	8/27/2002
MA01	North Atlantic Coastal Lab	National Park Service-Cape Cod National Seashore	7/29/2003
MD00	Smithsonian Environmental Research Center	Smithsonian Environmental Research Center/ Maryland Department of Natural Resources	12/7/2006
MD08	Piney Reservoir	University of Maryland - Appalachian Laboratory/ Maryland Department of Natural Resources	6/29/2004
MD99	Beltsville	University of Maryland	6/1/2004
MD99	Beltsville	Maryland Department of Natural Resources	6/1/2004
ME00	Caribou	EPA/Maine Dept. of Environmental Protection	5/9/2007
ME02	Bridgton	Maine Department of Environmental Protection/ U.S. Environmental Protection Agency	6/3/1997
ME04	Carrabassett Valley	Penobscot Indian Nation/ U.S. Environmental Protection Agency	2/17/2009
ME09	Greenville Station	U.S. Environmental Protection Agency/ Maine Department of Environmental Protection	9/3/1996
ME96	Casco Bay-Wolfe’s Neck Farm	Maine Department of Environmental Protection/ U.S. Environmental Protection Agency	1/6/1998
ME98	Acadia National Park-McFarland Hill	Acadia National Park/ U.S. Environmental Protection Agency	3/5/1996
ME98	Acadia National Park-McFarland Hill	Maine Department of Environmental Protection	3/5/1996
MI09	Douglas Lake	Lake Michigan Air Directors Consortium	12/31/2013
MI48	Seney National Wildlife Refuge-Headquarters	USFWS-Air Quality Branch	11/11/2003
MI52	Ann Arbor	Lake Michigan Air Directors Consortium	12/31/2013
MN06	Leech Lake	Leech Lake Band of Ojibwe	6/23/2014
MN16	Marcell Experimental Forest	Minnesota Pollution Control Agency/ Northern Research Station	2/27/1996
MN18	Fernberg	Minnesota Pollution Control Agency	3/5/1996
MN23	Camp Ripley	Minnesota Pollution Control Agency	7/2/1996
MN27	Lamberton	Minnesota Pollution Control Agency	7/2/1996

MDN

Site ID	Site Name	Site Sponsor	Start Date
MO46	Mingo National Wildlife Refuge	U.S. Fish and Wildlife Service	3/26/2002
MS12	Grand Bay NERR	Mississippi Department of Environmental Quality/ Northern Research Station	3/9/2010
MT05	Glacier National Park-Fire Weather Station	NPS-Air Resources Division	10/28/2003
MT95	Badger Peak	Northern Cheyenne Tribe	11/2/2010
NC08	Waccamaw State Park	North Carolina Department of Environment and Natural Resources, Division of Air Quality	2/27/1996
NC17	University Research Farm	U.S. Department of Energy	1/30/2015
NC26	Candor	North Carolina Department of Environment and Natural Resources, Division of Air Quality	11/8/2005
ND01	Lostwood National Wildlife Refuge	U.S. Fish and Wildlife Service	11/25/2003
NE15	Mead	Nebraska Department of Environmental Quality	6/26/2007
NE98	Santee	Santee Sioux Nation of Nebraska/ U.S. Environmental Protection Agency	10/1/2013
NF19	Stephenville	Environment Canada	2/23/2010
NJ30	New Brunswick	New Jersey Department of Environmental Protection	1/17/2006
NS01	Kejimkujik National Park	Environment Canada	7/2/1996
NY06	Bronx	New York State Department of Environmental Conservation	1/9/2008
NY20	Huntington Wildlife	U.S. Environmental Protection Agency/ New York State Energy Research & Development Authority	12/10/1999
NY43	Rochester	New York State Energy Research & Development Authority	1/8/2008
NY68	Biscuit Brook	New York State Energy Research & Development Authority	3/9/2004
NY96	Cedar Beach-Southold	New York State Energy Research & Development Authority	9/24/2013
OH02	Athens Super Site	Lake Michigan Air Directors Consortium	12/28/2004
OH52	South Bass Island	Lake Michigan Air Directors Consortium	5/8/2014
OK01	McGee Creek	Oklahoma Department of Environmental Quality	10/31/2006
OK04	Lake Murray	Oklahoma Department of Environmental Quality	10/30/2007
OK05	Hugo	U.S. Environmental Protection Agency	12/19/2017
OK06	Wichita Mountains NWR	Oklahoma Department of Environmental Quality	11/20/2007

MDN

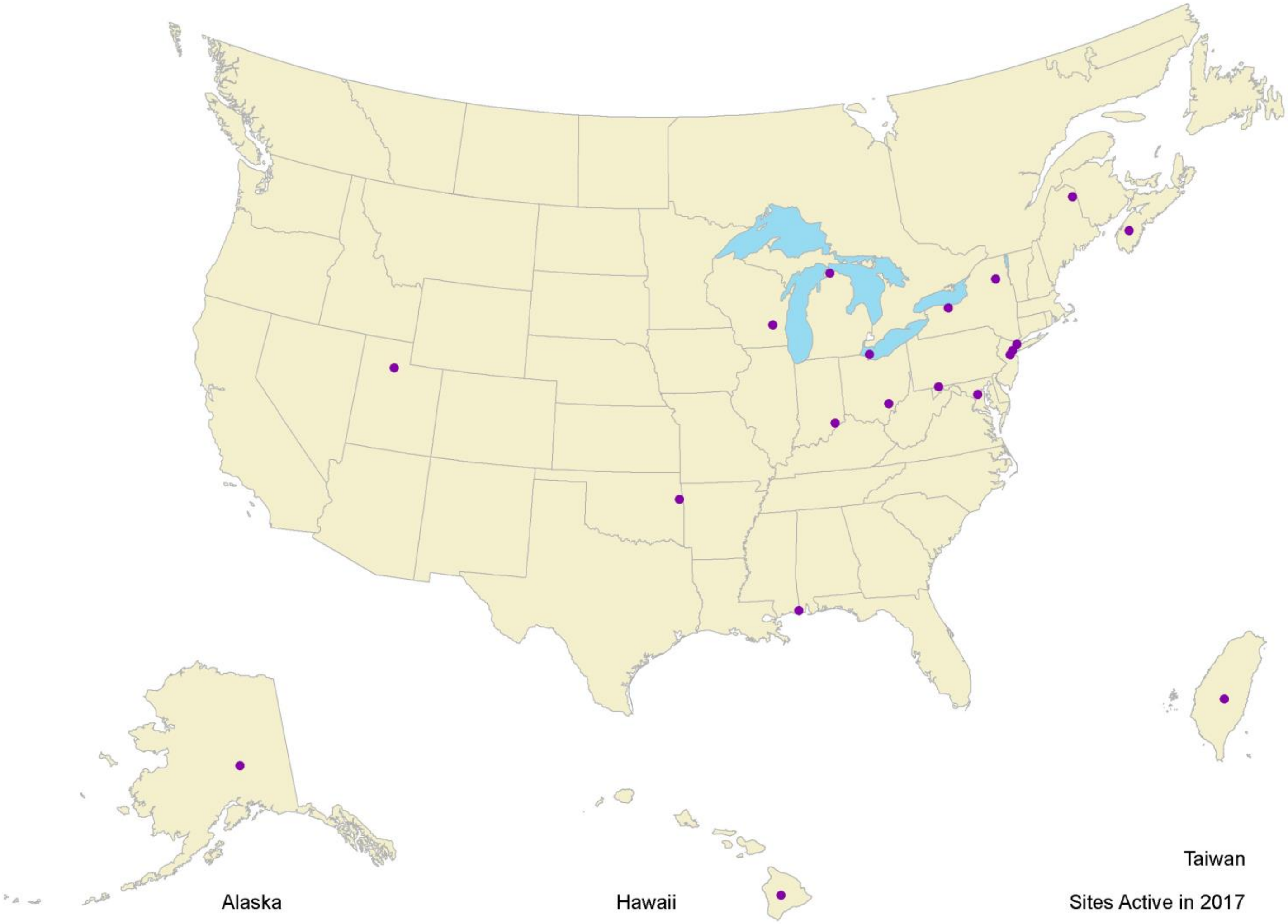
Site ID	Site Name	Site Sponsor	Start Date
OK31	Copan	Oklahoma Department of Environmental Quality	10/24/2006
OK97	Tuskahoma	U.S. Environmental Protection Agency	12/27/2017
OK99	Stilwell	U.S. Environmental Protection Agency/ Cherokee Nation	4/29/2003
ON07	Egbert	Environment Canada	3/7/2000
PA00	Arendtsville	Pennsylvania Department of Environmental Protection/ Pennsylvania State University	11/14/2000
PA13	Allegheny Portage Railroad National Historic Site	Pennsylvania State University/ Pennsylvania Department of Environmental Protection	1/7/1997
PA18	Young Woman's Creek	Pennsylvania State University	10/22/2013
PA30	Erie	Pennsylvania State University/ Pennsylvania Department of Environmental Protection	6/20/2000
PA42	Leading Ridge	Pennsylvania State University/ Pennsylvania Department of Environmental Protection	3/2/2010
PA90	Hills Creek State Park	Pennsylvania State University/ Pennsylvania Department of Environmental Protection	1/7/1997
PR20	El Verde	U.S. Geological Survey	8/6/2014
SC05	Cape Romain National Wildlife Refuge	USFWS-Air Quality Branch	3/2/2004
SC19	Congaree Swamp	South Carolina Department of Health and Environmental Control	3/5/1996
SD18	Eagle Butte	U.S. Environmental Protection Agency/ Cheyenne River Sioux Tribe Environmental Protection Department	3/21/2007
SK27	Pinehouse	Environment Canada	5/14/2015
TN11	Great Smoky Mountains National Park-Elkmont	NPS-Air Resources Division	1/30/2002
TN12	Great Smoky Mountains National Park-Clingmans Dome	NPS-Air Resources Division	4/28/2015
VA28	Shenandoah National Park-Big Meadows	NPS-Air Resources Division	10/22/2002
VT99	Underhill	National Oceanic and Atmospheric Administration - Air Resources Laboratory/ University of Vermont - Rubinstein School of Environment & Natural Resources	7/27/2004

MDN

Site ID	Site Name	Site Sponsor	Start Date
VT99	Underhill		7/27/2004
WA03	Makah National Fish Hatchery	Eurofins Frontier Global Sciences/ Washington State Department of Ecology	3/2/2007
WA18	Seattle/NOAA	NADP PO/ Washington State Department of Ecology	3/19/1996
WI08	Brule River	Wisconsin Department of Natural Resources	3/5/1996
WI10	Potawatomi	Forest County Potawatomi Community/ U.S. Environmental Protection Agency	6/7/2005
WI31	Devil's Lake	Wisconsin Department of Natural Resources	1/11/2001
WI36	Trout Lake	Wisconsin Department of Natural Resources	3/5/1996
WY08	Yellowstone National Park-Tower Falls	Wyoming Department of Environmental Quality	10/21/2004
WY26	Roundtop Mountain	Wyoming Department of Environmental Quality	12/20/2011

National Atmospheric Deposition Program

Atmospheric Mercury Network (AMNet)



AMNet

Site ID	Site Name	Site Sponsor	Start Date
AK03	Denali National Park-Mt. McKinley	NPS-Air Resources Division	3/10/2014
AK03	Denali National Park-Mt. McKinley	NPS-Air Resources Division	3/10/2014
MD08	Piney Reservoir	State of Maryland	1/1/2008
MD98	Beltsville Second Instrument	U.S. Environmental Protection Agency/ National Oceanic and Atmospheric Administration	1/26/2007
MD99	Beltsville	U.S. Environmental Protection Agency/ National Oceanic and Atmospheric Administration	11/7/2006
ME97	Presque Isle	Aroostook Band of Micmacs	12/6/2013
MI09	Douglas Lake	Lake Michigan Air Directors Consortium	8/11/2015
MS12	Grand Bay NERR	National Oceanic and Atmospheric Administration	9/29/2006
NJ30	New Brunswick	State of New Jersey	10/1/2015
NJ54	Elizabeth Lab	State of New Jersey	10/1/2015
NS01	Kejimkujik National Park	Environment Canada	1/26/2009
NY06	Bronx	State of New York	8/27/2008
NY20	Huntington Wildlife	New York State Energy Research & Development Authority	11/21/2007
OH52	South Bass Island	Lake Michigan Air Directors Consortium	12/31/2011
TW01	Mt. Lulin	EPA Taiwan	1/1/2010
WI07	Horicon Marsh	Lake Michigan Air Directors Consortium	1/2/2011
MD08	Piney Reservoir	State of Maryland	1/1/2008
MD98	Beltsville Second Instrument	U.S. Environmental Protection Agency	1/26/2007
MD98	Beltsville Second Instrument	National Oceanic and Atmospheric Administration	1/26/2007
WV99	Canaan Valley Institute	National Oceanic and Atmospheric Administration - Air Resources Laboratory	6/1/2000

National Atmospheric
Deposition Program

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