



National Atmospheric Deposition Program

Proceedings

NADP Fall Meeting and Scientific Symposium

NADP in a Changing World

October 26-30, 2020
Online



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MEETING INFORMATION

*****ONLINE MEETING*****

Main Link: <https://zoom.us/j/98810626422>

Secondary Link: <https://zoom.us/j/95721715705>

Acknowledgements

The NADP Program Office would like to thank the following people for their support of and contributions to the 2020 Fall Meeting and Scientific Symposium:

Greg Wetherbee, Symposium Chair

NADP Executive Committee

TDEP and MELD Committees

Dr. LaToya Myles, Acting Director, NOAA Air Resources Laboratory, Atmospheric Turbulence & Diffusion Division

Melissa Puchalski, U.S. Environmental Protection Agency

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 2020 Technical Meeting and Scientific Symposium Agenda

Science Committee Meetings

Times (EDST)

Monday, October 26, 2020

Total Deposition (TDEP) I, II

11:00 - 1:00, Break, 2:00 - 4:00

Mercury in the Environment and Links to Deposition (MELD) I, II

1:00 - 3:00, Break, 4:00 - 6:00

Aeroallergen Monitoring Science Committee (AMSC)

4:00 - 6:00

Tuesday, October 27, 2020

Critical Loads of Atmospheric Deposition (CLAD) I, II

12:00 - 1:30, Break, 2:00 - 3:30, Social hour 3:30 - 4:30

Scientific Symposium

Wednesday, October 28, 2020

Logistics: Greg Wetherbee, NADP Vice Chair

9:00 - 9:05

Welcome: David Schmeltz, NADP Chair

9:05 - 9:15

Opening Remarks: Dr. James Schauer, NADP Principal Investigator

9:15 - 9:20

Annual State of the NADP Report: Dr. David Gay, NADP Coordinator

9:20 - 9:40

Keynote Speaker: Dr. LaToya Myles (NOAA)

9:40 - 10:15

BREAK

10:15 - 10:30

Session 1: Emissions and Deposition in a Changing Chemical Climate

Chair: Andrew Johnson,
Maine DEQ

The Role of Atmospheric Deposition in Delivering Nitrogen to the Chesapeake Bay: A Century of Change – Douglas Burns, Ghopal Bhatt, Lewis C. Linker, Jesse O. Bash, Paul D. Capel and Gary W. Shenk

10:30 - 10:50

Temporal Variation of Precipitation pH in the EANET Region 2000-2017 – Hiroshi Hara

10:50 - 11:10

Characteristics and change of ammonia at the rural, urban, and remote sites in China – Zhaoyang Meng, Yu Song, Xuhui Cai, Yuchong Miao, Xingying Zhang, Hong Geng, Xichao Zhang, Hongshen Zhang, Hongbing Cheng, Ting Zhang0 and Shasha Yin

11:10 - 11:30

Northeastern mountain ponds as sentinels of change: current and emerging research and monitoring in the context of shifting atmospheric deposition and climate interactions – <i>Sarah J. Nelson, Rachel A. Hovel, Julia Daly, Amanda Gavin, Stephanie Dykema and William H. McDowell</i>	11:30 - 11:50
Power Sector Emissions and Generation Trends in the First Half of 2020 – <i>Kimberly Liu, Justine Huetteman, Michael Cohen and Charles Frushour</i>	11:50 - 12:10
BREAK	12:10 - 12:40
Session 2: Advances in Atmospheric Deposition Monitoring	Chair: Chris Rodgers, Wood.
Global Importance of Hydroxymethanesulfonate in Ambient Particulate Matter: Implications for Air Quality – <i>Jonathan Moch, Eleni Dovrou, Loretta Mickley, Frank Keutsch, Zirui Liu, Yuesi Wang, Tracy Dombek, Mikinori Kuwata, Stefano Decesari, Marco Paglione and Daniel Jacob</i>	12:40 - 1:00
Exploring the regional-scale atmospheric fate and transport of per- and polyfluoroalkyl substances (PFAS) – <i>Emma D'Ambro, Havala Pye, Chris Allen, Kevin Talgo, Lara REynolds, Kathy Brehme, Robert Gilliam, Jesse Bash and Ben Murphy</i>	1:00 - 1:20
A Method to Measure and Speciate Amines in Ambient Aerosol Samples – <i>Amy Sullivan, Katherine B. Benedict, Christian M. Carrico, Manvendra K. Dubey, Bret A. Schichtel and Jeffrey L. Collett, Jr.</i>	1:20 - 1:40
Atmospheric NO₂ and d¹⁵N in moss in a protected wilderness area impacted through vehicle emissions in Alberta, Canada – <i>Mikayla Donovan, Mary Reid and Ann-Lise Norman</i>	1:40 - 2:00
Advances in the evaluation of reactive nitrogen in Mexico City – <i>Rodolfo Sosa Echeverría, David Gay, John Walker, Gregory Wetherbee, Ana Luisa Alarcón Jimenez, Monica Jaimes Palomera, Pablo Sanchez Alvarez and Elizabeth Vega</i>	2:00 - 2:20
Monitoring springwater nitrate as an indicator of atmospheric deposition in a regional conservation plan – <i>Stuart Weiss</i>	2:20 - 2:40
BREAK	2:40 - 3:00

Session 3: Atmospheric Deposition Effects in Aquatic and Terrestrial Ecosystems

Chair: Dr. John Walker, U.S. Environmental Protection Agency

Throughfall Deposition Chemistry in the Great Smoky Mountains National Park: Long-term Trends and Effects of Stream Water Quality - *John Schwartz, Matt Kulp, Jim Renfro, Andrew Veeneman and Adrian Gonzalez* 3:00 - 3:20

Atmospheric nitrogen deposition drives declines in native plant richness across the Santa Monica Mountains, California - *Justin Valliere, Gary M. Bucciarelli, Andrzej Bytnerowicz, Mark E. Fenn, Irina C. Irvine, Robert F. Johnson and Edith B. Allen* 3:20 - 3:40

Total deposition of inorganic nitrogen to Norway spruce forests – applying a surrogate surface method across a deposition gradient in Sweden – *Per Erik Karlsson, G. Pihl Karlsson, S. Hellsten, C. Akseleson, M. Ferm and H. Hultberg* 3:40 - 4:00

Is weathering sufficient to keep forest harvest from exceeding acidification critical loads in Sweden: Conclusions from QWARTS – Quantifying Weathering Rates for Sustainable Forest Management – *Kevin Bishop, Cecilia Akseleson, Salim Belyazid and Stefan Lofgren* 4:00 - 4:20

Water resources in a changing world: Long-term hydrologic monitoring provides insight into changes in precipitation and stream-water quality at Robinson Forest in eastern Kentucky, Appalachia, USA – *Tanja Williamson, Kenton Sena and Chris Barton* 4:20 - 4:40

Mercury in Fish from Streams and Rivers in New York State: Spatial Patterns and Environmental Drivers – *Karen Riva-Murray, Wayne Richter, N. Roxanna Razavi, Douglas Burns, Lisa Cleckner, Mark Burton and Scott George* 4:40 - 5:00

Thursday, October 29, 2020

Session 4: Global Atmospheric Mercury Assessment

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

A National Survey of Total Gaseous Mercury Stable Isotope Composition and Concentration across the US – *David Krabbenhoft, Michael Tate, Sarah Janssen, John DeWild, Jacob Ogorek and Ryan Lepak* 9:00 - 9 :20

Atmospheric Mercury Monitoring in Japan by using Gold Amalgamation Trap Method - Methodology and Data over 15 Years – <i>Tatsuya Hattori</i>	9:20 - 9:40
Eight-year atmospheric mercury deposition to a tropical high mountain background site downwind of the East Asian continent – <i>Guey-Rong Sheu, Ly Sy Phu Nguyen, Leiming Zhang, Da-Wei Lin and Neng-Huei Lin</i>	9:40 - 10:00
Mercury Emission to the Atmosphere Dominates Annual Mass Balance of a Boreal Peatland and highlights the need for eddy-covariance based measurements of surface -atmosphere Hg exchange – <i>Kevin Bishop, Stefan Osterwalder, Wei Zhu, Chuxian Li and Mats B Nilsson</i>	10:00 - 10:20
Net ecosystem exchange of atmospheric gaseous elemental mercury (GEM) over a temperate forest: seasonality and diel patterns of exchange and annual mass balance of deposition – <i>Daniel Obrist, Eric Roy, Christ Romero, Jun Zhou, J. William Munger, Roisin Commane and John Budney</i>	10:20 - 10:40
Mercury in Soils Across the Conterminous United States: Changes in Pools and Patterns – <i>Connor Olson, Benjamin M. Geyman, Colin P. Thackray, David P. Krabbenhoft, Michael T. Tate, Elsie M. Sunderland and Charles T. Driscoll</i>	10:40 - 11:00
BREAK	11:00 - 11:40
Session 5: Advances in Mercury Monitoring and Research	Chair: Kristi Morris, National Park Service
Passive air sampling for mercury, a newer approach to monitoring – <i>Alexandra Steffen, Geoff Stuppel, Frank Wania, Eric Prestbo, Nicola Pirrone, Carl Mitchell and Attilio Naccarato</i>	11:40 - 12:00
Active and passive systems for measurement of gaseous oxidized, particulate bound, and reactive mercury – <i>Mae Gustin, Sarrah Dunham-Cheatham, Seth Lyman, Stefan Osterwalder, Jiaoyan Huang and Lei Zhang</i>	12:00 - 12:20
Atmospheric Hg Concentration Dynamics Over a Temperate Deciduous Broadleaf Forest – <i>Christ Romero, Daniel Obrist, J. William Munger, Róisín Commane, Jun Zhou and Eric Roy</i>	12:20 - 12:40
Surface-air mercury fluxes and a watershed mass balance in forested and harvested catchments – <i>Chris Eckley, Collin Eagles-Smith, Mike Tate and Dave Krabbenhoft</i>	12:40 - 1:00

Comparison of pre-MATS (Mercury and Air Toxics Standards) rule and post-MATS rule GOM dry deposition measurements in the Four Corners Area – <i>Mark Sather, Shaibal Mukerjee and Luther Smith</i>	1:00 - 1:20
Tracing the depositional history of mercury to two coastal National Parks in the Northeast United States – <i>Vivien Taylor and Joshua D. Landis</i>	1:20 - 1:40
BREAK	1:40 - 2:10
Concurrent Session 6: Advances in Measurement Model Fusion	Chair: Donna Schwede, U.S. Environmental Protection Agency
On model-data fusion approaches for wet deposition in North America – <i>Alain Robichaud, Amanda S. Cole, Mike D. Moran, A. Lupu, M. Beauchemin and V. Fortin</i>	2:10 - 2:30
An Updated Global Model for Terrestrial-Atmospheric Hg Exchange and Storage in Soils – <i>Benjamin Geyman, Colin Thackray, Elizabeth Corbitt, Connor Olson, Charley Driscoll, Dave Krabbenhoft, Michael Tate and Elsie Sunderland</i>	2:30 - 2:50
TDep Measurement Model Fusion (MMF) method to fuse modeled and measured air quality data to estimate total deposition with Python geoprocessing – <i>Shih Ying Chang, Nathan Pavlovic, Gregory Beachley, Melissa Puchalski and Christopher Rogers</i>	2:50 - 3:10
Estimation of ammonia and nitrous oxide emissions from turfgrass systems using a dynamic chamber method and a biogeochemical modeling framework – <i>Alberth Nahas, John T Walker, Limei Ran, Fred Yelverton and Viney Aneja</i>	3:10 - 3:30
An application of machine learning to determine critical loads of nitrogen and sulfur in forest ecosystems in the U.S. – <i>Nathan R. Pavlovic, Charles T. Driscoll, Kenneth Craig, Jiaoyan Huang, Shih Ying Chang and Christopher M. Clark</i>	3:30 - 3:50
Modeled Exceedances of Critical Loads for Total Nitrogen and Sulfur Deposition – <i>Krish Vijayaraghavan, Ross Beardsley, Tejas Shah and John Grant</i>	3:50 - 4:10

Concurrent Session 7: Critical Loads of Atmospheric Deposition	Chair: Dr. Linda Geiser, U.S. Forest Service
Terrestrial Critical Loads of Atmospheric Nitrogen and Sulfur Deposition: Model Development and Regional Assessment based on US-PROPS – <i>Todd McDonnell, Gert Jan Reinds, Wieger Wamelink, Paul Goedhart, Maximilian Posch, Timothy Sullivan and Christopher Clark</i>	2:10 - 2:30
Interpreting terrestrial sulfur critical loads to protect national parks – <i>Emmi Felker-Quinn, Michael D. Bell and Nicholas A. Russell</i>	2:30 - 2:50
Exceedances of Critical Loads for Herbaceous Species in National Parks: Species at Risk, Local Responses, and Regional Trends – <i>Nicholas Russell, Michael D. Bell and Emmi Felker-Quinn</i>	2:50 - 3:10
A Case Study: Critical Load Assessment in Areas above 1000 m in the Great Smoky Mountains National Park – <i>Jason Lynch and Selma Isil</i>	3:10 - 3:30
Assessing nitrogen critical loads at North Cascades National Park Service Complex – <i>Meaghan Petix, Michael D. Bell, Tonnie Cummings, Alida Melse and R. Dave Evans</i>	3:30 - 3:50
Incorporating Air Quality into the Resources Planning Act Assessment with Critical Loads and Deposition – <i>Sarah Anderson, Claire O’Dea and Jennifer Costanza</i>	3:50 - 4:10
<u>Friday, October 30, 2020</u>	
Session 8: Atmospheric Deposition and a Changing Society	Chair: Dr. Pamela Templer, Boston University
Effect of atmospheric deposition on built heritage – <i>Luis Miguel Urbina Leonor, Rodolfo Sosa Echeverría, Rogelio Soto Ayala, Ana L. Alarcón Jiménez, Pablo Sánchez Álvarez and Gilberto Fuentes García</i>	9:00 - 9 :20
Effects of Urbanization and Fragmentation on Atmospheric Nitrogen Deposition, Nitrogen Oxides, and Ozone in New England Forests – <i>Jenna Rindy, Erin Pierce, Sarah Garvey, Jonathan Gewirtzman, Lucy Hutyra and Pamela Templer</i>	9:20 - 9:40
Bioaerosol occurrence in working places – <i>Francesca Buiarelli, Giulia Simonetti, Elisa Sonogo, Carmela Riccardi, Patrizia Di Filippo and Donatella Pomata</i>	9:40 - 10:00
Air Quality in Rocky Mountain National Park during the 2020 COVID19 Shutdown – <i>Lillian Naimie, Katherine Benedict, Amy Sullivan, Bret Schichtel and Jeff Collett</i>	10:00 - 10:20

CASTNET Ozone Response to COVID-19 Related Impacts – Timothy Sharac, Gregory Beachley, Melissa Puchalski, Barkley Sive and Ryan McCammon	10:20 - 10:40
BREAK	10:40 - 11:15
<u>Poster Session</u>	Co-Chairs: Melissa Puchalski (U.S. Environmental Protection Agency) and Gregory Wetherbee (U.S. Geological Survey)
Session Logistics – Co-chairs	11:15 - 11:20
<u>Sub-session I – Emerging Contaminants and Issues</u>	
Biomonitoring of atmospheric deposition of heavy metals in Slovakia – Jana Borovská, Blanka Maňkovská† and Matej Florek	11:20 - 11:25
Comparison of Aerosol Optical Depth from Satellite based observation over Surat region – Ranjithkumar Solanki and Dr.K.N.Pathak	11:25 - 11:30
Particulate Matter Deposition to Urban Rock Pigeon (<i>Columba livia</i>) Feathers – Jennifer Ellis, Dr. Alexandra Ponette-González, Dr. Jeff Johnson and Dr. Matthew Fry	11:30 - 11:35
Initiation of Measurement of PFAS in Wet Deposition at four NADP sites in the Eastern United States – John Offenber, John Walker, Melissa Puchalski, Douglas A Burns, Andrew Johnson and Martin Shafer	11:35 - 11:40
	11:40 – 11:50
Questions and Answers for Sub-session I Presenters	
<u>Sub-session II – Atmospheric Nitrogen and Mercury Assessments</u>	
Varied Host-Specific Mycorrhizal Response to Long-Term Nitrogen Fertilization in Bear Brook Watershed in Maine, USA – Sibi Kizhakkapurakkal, Ivan J Fernandez and Seanna L Annis	11:50 - 11:55
Isotopic Composition of Nitrate and Ammonium in Sao Paulo, Brazil Wet Deposition – Adrianna Chapa, J. David Felix and M Lucia A M Campos	11:55 - 12:00
Influence of meteorological conditions on the wet atmospheric deposition in the Metropolitan Area of Mexico City – Daimy Avila, Rodolfo Sosa Echeverría, Ana Luisa Alarcón Jiménez, Gilberto Fuentes García and Pablo Sánchez Alvarez	12:00 - 12:05

Water-atmosphere flux of ammonia in subtropical semi-arid estuary systems – Warren Dunegan and J. David Felix	12:05 - 12:10
Quantification and Transformation of Water Soluble Organic Nitrogen in a Coastal Urban Airshed – Scilyn Apacible and Dr. Joseph David Felix	12:10 - 12:15
National view of temporal atmospheric mercury deposition across Canada using lake sediment cores – Sarah Roberts, Jane Kirk, Derek Muir, Johan Wiklund, Marlene Evans, Amber Gleason, Paul Drevnick, Ashu Dastoor, Andrei Rvjkov, Benjamin Barst0 and Colin Cooke	12:15 - 12:20
Lower Eastern Shore Ambient Air Quality Monitoring Project – Deborah Sauder, Bernice Bediako, Moses Kairo and Ryan Auvil	12:20 - 12:25
<u>Questions and Answers for Sub-session II Presenters</u>	12:25 - 12:35
<u>Sub-session III – Atmospheric Deposition Modeling</u>	
Atmospheric inorganic nitrogen (N) deposition to Latin American cities: Comparison of field and Geos-Chem model estimates – Alexandra G. Ponette-González, Haley Lews, Barron H. Henderson, Danilo Carnelos, Gervasio Piñeiro, Kathleen C. Weathers and Donna Schwede	12:35 - 12:40
EQUATES: EPA’s Air QUALity TimE Series Project – Kristen Foley, George Pouliot, Jesse Bash and Donna Schwede	12:40 - 12:45
Modeling the Source Sectors Contribution to Nitrogen Deposition in United States – Sharmin Akter, Michael Crowl and Kristina Wagstrom	12:45 – 12:50
<u>Questions and Answers for Sub-session III Presenters</u>	12:50 - 1:00
<u>Sub-session IV – Atmospheric Deposition and Extreme Conditions</u>	
Characterization of Texas Wildfires during the 2011-2014 Drought: A Prelude to Identifying Chemical Signatures of Smoke in Rain – Thomas Williamson, Alexandra G. Ponette-González, Kathleen Weathers and Michael Olson	1:00 – 1:05
Assessing multiple soil resource limitations on dryland soil microbial communities: inferences from a short-term C, N and P addition laboratory incubation experiment – Jennifer Holguin and Dr. Jennie R. McLaren	1:05 – 1:10

Hurricane/tropical storm rainwater chemistry in the US (2008 to 2019) – Yixi Qiu, Yixi Qiu and Joseph David Felix

1:10 – 1:15

Questions and Answers for Sub-session IV Presenters

1:15 - 1:25

End of Symposium

2020 NADP Site Operator Awards

35 Year Award

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
IA23	Jim Secor	McNay Research Center	US Geological Survey	NTN	1985

25 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
KY35	Jeff Stamper	Clark State Fish Hatchery	US Geological Survey	NTN	1995
NM07	Kay Beeley	Bandelier National Monument	National Park Service	NTN	1995
WA24	Robert Barry	Palouse Conservation Farm	US Geological Survey	NTN	1995

20 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
FL41	Tom Bolton	Verna Well Field	US Geological Survey	NTN	2000
IL78	Marty Johnson	Monmouth	US Geological Survey	NTN	2000

15 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
MI53 MI95	Mike Reilly	Wellston	US Forest Service	NTN / AMoN	2005
MN99	Peter Harris	Wolf Ridge	Minnesota Pollution Control Agency	NTN	2005
NY08	Jeff Stayton	Aurora Research Farm	Cornell University	NTN	2005
VA13	Diane Reaver	Horton's Station	Wood / Environmental Protection Agency	NTN / AMoN	2005
WY98	Ted Porwoll	Gypsum Creek	US Forest Service	NTN	2005

10 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
CA28	Kevin Mazzocco	Kings River Experimental Watershed	US Forest Service	NTN	2010
MI26	Mickey Trimmer	Kellogg Biological Station	Michigan State University	NTN	2010
MN28	Ty Johnson	Grindstone Lake	Minnesota Pollution Control Agency	NTN	2010
MT95	Scott Williams	Badger Peak	Northern Cheyenne Tribe	MDN	2010
NJ00	Vinny Turner	Edwin B. Forsythe National Wildlife Refuge	U.S. Fish and Wildlife Service	NTN	2010
NY96	Andrew Seal	Cedar Beach-Southold	Suffolk County / New York State Energy Research and Development Authority	NTN / MDN AMoN	2010
PA29	Robert Ishman	Kane Experimental Forest	US Forest Service / Wood-Environmental Protection Agency	NTN / AMoN	2010
SD18	Misti Hebb	Eagle Butte	Cheyenne River Sioux Tribe	MDN	2010
TW01	Guey-Rong Sheu	Mt. Lulin	Taiwan EPA-National Central University	AMNet	2010
TX43	Brent Auvermann	Cañónceta	Texas A&M University	NTN / AMoN	2010
WV04	Lisa Cochran	Babcock State Park	US Geological Survey	NTN	2010

5 Year Awards (Continued on Following Page)

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
AK02	Mark Lukey	Juneau	US Forest Service	NTN	2015
CA45	Alison Smith	Hopland	US Geological Survey	NTN	2015
CO15	Eric Scherff	Sand Spring	Bureau of Land Management	NTN	2015
ID07	Mary Fauci	Nez Perce	Wood-Environmental Protection Agency	AMoN	2015
IN22	Bill Davis	Southwest Purdue Agriculture Center	Wood-Environmental Protection Agency	AMoN	2015
IN34	Carie Satkoski	Indiana Dunes National Lakeshore	National Park Service / Lake Michigan Air Directors Consortium	NTN / MDN	2015
KY29	Linnie Montgomery	Crockett	Wood-Environmental Protection Agency	AMoN	2015
MA22	Nilotpal Ghosh	Boston University	Boston University	NTN	2015

5 Year Awards Continued

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
MD06	Bonnie Abey	Blackwater NWR	Wood-Environmental Protection Agency	AMoN	2015
ME93	Jodi Reese	Ashland	Wood-Environmental Protection Agency	AMoN	2015
MN02	Jennifer Malinski	Red Lake	Wood-Environmental Protection Agency	AMoN	2015
MS30	Gail Thompson	Coffeeville	US Forest Service / Wood-Environmental Protection Agency	NTN / AMoN	2015
MT05	Ed Eberhardy	Glacier National Park-Fire Weather Station	National Park Service	NTN /MDN	2015
NC02	Phillip Ray Hughes	Cranberry	Wood-Environmental Protection Agency	AMoN	2015
ND11	Linda Clark	Woodworth	US Geological Survey	NTN	2015
NE15	Todd Schimelfenig	Mead	University of Nebraska–Lincoln / Nebraska Department of Environmental Quality	NTN / MDN	2015
OH71	Bethany Herman	Wooster	US Geological Survey	NTN	2015
OH99	Mary Lou Trainer	Quaker City	Wood-Environmental Protection Agency	AMoN	2015
OK17	Ben Dixon	Kessler Farm Field Laboratory	National Oceanic and Atmospheric Administration	NTN	2015
PA97	Linda Henry	Laurel Hill	Wood-Environmental Protection Agency	AMoN	2015
SK27	John Smerek	Pinehouse	Environment and Climate Change Canada	MDN	2015
TN14	James Roberts	Hatchie National Wildlife Refuge	US Geological Survey	NTN	2015
TX22	Jonena Hearst	Guadalupe Mountains National Park Frijole Ranger Station	US Geological Survey	NTN	2015
TX41	Michelle Polite	Alabama-Coushatta	Wood-Environmental Protection Agency	AMoN	2015
WA19	Sharon Sarrantonio	North Cascades National Park-Marblemount Ranger Station	US Geological Survey	NTN	2015
WA98	Katherine Santini	Columbia River Gorge	US Forest Service	NTN	2015

ABSTRACTS

Session 1: Emissions and Deposition in a Changing Chemical Climate

The Role of Atmospheric Deposition in Delivering Nitrogen to the Chesapeake Bay: A Century of Change

Douglas Burns¹, Ghopal Bhatt², Lewis C. Linker³, Jesse O. Bash⁴, Paul D. Capel⁵ and Gary W. Shenk⁶

Pioneering studies during 1980s and 90s in the Chesapeake Bay watershed showed that atmospheric deposition was a major contributor of nitrogen (N) loads, providing 1/3 or more among all sources and a principal driver of hypoxia in the Bay. Reducing atmospheric N deposition later became part of efforts to reduce N loads to the Bay in a previously unprecedented merging of goals under the Clean Air and Clean Water Acts. Atmospheric N deposition has shown sharp declines since 1995 as the 1990 Amendments to the Clean Air Act were implemented. Wet and dry deposition measurements at sites in the Chesapeake Bay watershed indicate decreases in oxidized N deposition of 60% to 72% synchronous with declines in oxidized N emissions during 1995-2019. Reduced N, however, shows contrasting patterns; NH₃ emissions have likely changed little during 1995-2019, and wet NH₄⁺ deposition accordingly has shown no trend. However dry NH₄⁺ deposition has declined by 73% during this period. Dry NH₄⁺ deposition is controlled in part by formation of NO₃⁻ and SO₄²⁻ aerosols resulting in some asynchrony with NH₃ emissions. A century-long atmospheric deposition N time series was developed for 1950-2050 using measurement-modeling fusion and projections based on clean air regulations. This time series shows a peak in atmospheric N deposition of 15 kg N/ha/yr in 1979, a slight decline by the mid-1990s, sharp 40% decreases during 1995-2019, and further decreases of 21% thereafter through 2050. These deposition estimates were compared with century-long watershed estimates of N loads from manure, fertilizer, and wastewater. Atmospheric N deposition was estimated to be 30% of the total N load to the watershed in 1950, reached a peak of 40% in 1973, declined to 28% by 2015, and is projected to further decrease to 24% by 2050. These data indicate the importance of atmospheric N deposition in the Chesapeake Bay watershed and highlight that implementation of the Clean Air Act has contributed to reducing nutrient loads and improving estuarine trophic status.

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Temporal Variation of Precipitation pH in the EANET Region 2000-2017

Hiroshi Hara¹

The EANET measurements of precipitation chemistry were analyzed to assess temporal variations of the pH and major ion concentrations on a regional basis. The concentration, C , was transformed into $pC = -\log C$ to be coherent with pH. Three parameters were chosen to represent the annual chemistry of the region: their annual median (MED), arithmetic mean (MEAN), and VWM which was the negative logarithm of the volume-weighted mean of the raw measurements of the year. For the analysis, the measurements were grouped into three because chemistry of China was sometimes significantly different from those of the other countries: China-ON (the total sites), China-OFF, and China-ONLY. For pH, in the case of China-ON, the MED and MEAN decreased until 2005 whereas the VWM almost remained, and after this year all three pHs continued to increase with fluctuation. Similar temporal variations were noted in China-OFF. In China-ONLY, the mean and the VWM pH decreased until 2010-2011, and then began to increase steeply. On average, the pH first decreased for the first five years and then changed to increase afterwards. In the $p(\text{nss-SO}_4^{2-})$ case, the temporal patterns were different from those of pH. The MED and MEAN in China-ON continued to increase throughout the period whereas the VWM increased steeply until 2009, and then grew slowly. In China-OFF, the MED and MEAN showed general increases over the period whereas the VWM began to decrease slowly in 2009. In China-ONLY, the MEAN and VWM commonly increased with fluctuations. The acid-base chemistry was discussed to understand the pH variations.

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Characteristics and change of ammonia at the rural, urban, and remote sites in China

Zhaoyang Meng¹, Yu Song², Xuhui Cai³, Yuchong Miao⁴, Xingying Zhang⁵, Hong Geng⁶, Xichao Zhang⁷,
Hongshen Zhang⁸, Hongbing Cheng⁹, Ting Zhang¹⁰ and Shasha Yin¹¹

As the most dominant alkaline trace gas in the atmosphere, NH₃ plays a very critical role in the chemical cycle of nitrogen and in aerosol formation processes. In order to better understand temporal and spatial differences in NH₃ concentrations in different regions in China, we present about two years (March 2017 to December 2018) of NH₃ measurements from sixteen urban, rural, and remote sites in China. The measurements were made on daily and 5-day basis using passive samplers under careful quality control.

The observed concentrations show very large geographical differences. The highest NH₃ concentration was observed at Linqing of Shangdong province in eastern China, about 4.8 times higher than that at Meixian of Guangdong in southeast China. The observed levels of NH₃ are compared with the emission data from Multi-resolution Emission Inventory for China, previous passive sampling data, and the satellite measurements. On the whole, the geographical distributions or relative levels of observed NH₃ concentrations agree with those of emissions. However, the comparison results indicate that NH₃ emission around Longfengshan of Heilongjiang province in northeast China seem to be underestimated in existing inventories.

The NH₃ levels in this study are 1.9-4.5 fold higher than those observed during 2007-2008 at remote and regional background sites in Qinghai-Tibetan Plateau, North China Plain, Yangtze River Delta and northeast China, suggesting an increase in NH₃ levels in these regions in China. The higher NH₃ concentrations was found at urban site such as Zhengzhou of Henan in central China, reflecting the mix of the strong influence of the vehicles, industrial emissions in the vicinity and agricultural emissions from the suburban areas.

At most sites, the concentrations of NH₃ peaked in warmer seasons, which is consistent with the seasonal changes of NH₃ sources. The meteorological conditions such as temperature and precipitation have the important impacts on the spatial and seasonal distributions of ammonia.

The ground measurements of NH₃ in 2017 are compared with NH₃ columns retrieved by the Infrared Atmospheric Sounding Interferometer (IASI) satellite. The comparisons between ground and satellite measurements suggest that in most cases, the IASI NH₃ columns capture the geographical differences in the ground NH₃ and correlate fairly well to ground measurements of NH₃ at ten of the sixteen sites.

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Northeastern mountain ponds as sentinels of change: current and emerging research and monitoring in the context of shifting atmospheric deposition and climate interactions

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Mountain ponds in the northeastern US have undergone acidification and subsequent recovery due to changes in atmospheric deposition, and now additionally reflect physical and biological responses to climate change. These ponds are distinct from other lakes and ponds in the region as they are higher in elevation, often forested, have a legacy of significant acidification followed by recovery, and have little direct impact from human land use in their watersheds. They are relatively small and could be vulnerable to the increases in extreme weather events, overall warming, and shortening of winter that are occurring throughout the northeastern US. We compiled data for mountain ponds >560 meters elevation and <60 ha surface area across the northeastern US (Northern Appalachians and Adirondack Mountains) spanning 1978-2019. The full dataset includes 257 ponds, most sampled intermittently, and 36% of sites sampled at sufficient frequency to conduct trend analyses. We found strong and widespread significant declining trends in sulfate (95% of sites, ~45% decline) and increasing ANC at 53% of sites. Declining conductivity at 97% of sites (32% decline) suggested dilution approaching hypothetical baseline concentrations (13.9 $\mu\text{S}/\text{cm}$ by the 2010s), and also reflected low chloride concentrations at these sites compared to others in the region experiencing road salt contamination. DOC increased in 54% of ponds. Increasing DOC has been attributed to both changing sulfate and climate, specifically related to increases in precipitation and air temperature. Although these lakes are typically colder and experience more persistent winter snowpack than lower elevation lakes, their thermal structure is sensitive to warming air temperatures, which impacts water temperature, stratification, and ice duration. Zooplankton communities of eastern mountain lakes may be slowly shifting towards pre-acidification community composition; however, densities and community composition are sensitive to a suite of water chemistry conditions, and the trajectories of primary and secondary production are confounded by increasing DOC and the multiple impacts of climate change. Based on this synthesis and case studies documenting insights from integrating chemical, physical, and biological research, we developed a conceptual model and framework for research and monitoring to support broader baseline data collection and measurements of change in these ecosystems. The records in our assembled dataset indicate the importance of eastern mountain ponds for understanding the combined impacts of atmospheric deposition and climate change in lake ecosystems, and highlight current gaps and areas for future research directions.

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Power Sector Emissions and Generation Trends in the First Half of 2020

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EPA's Clean Air Markets Division (CAMD) within the Office of Atmospheric Programs (OAP) collects detailed hourly power plant emissions and operational data for federal emissions trading and air quality programs affecting the power sector, including the Acid Rain Program (ARP), the Cross-State Air Pollution Rule (CSAPR), the CSAPR Update and the Mercury and Air Toxics Standards (MATS). In the first half of 2020, as compared to the first half of 2019, emissions of sulfur dioxide (SO₂), nitrogen oxide (NO_x), mercury (Hg), and carbon dioxide (CO₂) fell by 31%, 23%, 23%, and 16%, respectively. This was primarily due to the decreased utilization of coal-fired power plants and a concurrent increase in natural gas-fired and renewable generation. While prevailing economic and regulatory conditions that affect the shift from coal to natural gas and renewables are largely responsible for the observed emission reductions, an analysis of hourly regional electricity demand in 2020 indicates a change in the pattern of hourly electricity demand in April and May, when stay-at-home orders for the majority of states in the US were most stringently in place in response to the COVID-19 pandemic. The shift in hourly load was most discernable in the PJM Interconnection (a regional transmission organization that coordinates the movement of wholesale electricity in much of the Mid-Atlantic region), primarily in peak hours, and persisted even when accounting for the variation in weather across years. This analysis will provide an overview of general power sector trends, focusing primarily on the first halves of 2019 and 2020, before delving into a more granular analysis of hourly generation activity for any indication of pandemic-related impacts. Power Sector Emission Data used in this analysis can be found at <https://ampd.epa.gov/ampd/>.

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Session 2: Advances in Atmospheric Deposition Monitoring

Global Importance of Hydroxymethanesulfonate in Ambient Particulate Matter: Implications for Air Quality

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Sulfur compounds are an important constituent of particulate matter, with impacts on climate and public health. While most sulfur observed in particulate matter has been assumed to be sulfate, laboratory experiments reveal that hydroxymethanesulfonate (HMS), an adduct formed by aqueous phase chemical reaction of dissolved HCHO and SO₂, may be easily misinterpreted in measurements as sulfate. Here we present observational and modeling evidence for a ubiquitous global presence of HMS. We find that filter samples collected in Shijiazhuang, China, and examined with ion chromatography within 9 days show as much as 7.6 μg m⁻³ of HMS, while samples from Singapore examined 9–18 months after collection reveal ~0.6 μg m⁻³ of HMS. The Shijiazhuang samples show only minor traces of HMS 4 months later, suggesting that HMS had decomposed over time during sample storage. In contrast, the Singapore samples do not clearly show a decline in HMS concentration over 2 months of monitoring. Measurements from over 150 sites, primarily derived from the IMPROVE network across the United States, suggest the ubiquitous presence of HMS in at least trace amounts as much as 60 days after collection. The degree of possible HMS decomposition in the IMPROVE observations is unknown. Using the GEOS-Chem chemical transport model, we estimate that HMS may account for 10% of global particulate sulfur in continental surface air and over 25% in many polluted regions. Our results suggest that reducing emissions of HCHO and other volatile organic compounds may have a co-benefit of decreasing particulate sulfur.

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Exploring the regional-scale atmospheric fate and transport of per- and polyfluoroalkyl substances (PFAS)

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Per- and polyfluoroalkyl substances (PFAS) are a class of man-made compounds whose emissions to air may contribute, via transport and deposition, to concentrations in surface water, ground water, and private well water in the vicinity of sources. Air quality modeling techniques can be used to quantify air concentrations and deposition fluxes to help parse the role of exposure pathways such as direct inhalation and ingestion via contaminated water. We apply the Community Multiscale Air Quality model (CMAQ) version 5.3.2 to a case study in Eastern North Carolina to model the PFAS emissions from a source location and transport at fine scale (1 km resolution). The 23 PFAS with the largest emissions by mass are identified and added explicitly to CMAQ, along with an aggregate “other PFAS” species to represent the balance of the emissions. An updated deposition parameterization (Surface Tiled Aerosol and Gaseous Exchange, STAGE) is utilized along with estimated chemical properties for each species to simulate the deposition flux to specific, sub-grid land surface types. Thus, the updated model (CMAQ-PFAS) captures the dynamic phase transformations and removal processes that affect the extent of atmospheric transport of PFAS. We evaluate model performance against deposition sampling at sites within 5 km of the facility. We further demonstrate the impact of one potentially important atmospheric transformation, the hydrolysis of acyl fluorides to carboxylic acids, on the deposition of specific compounds and the total PFAS mixture. Our results are an important step in understanding the behavior of PFAS emissions from a point source and can be used to inform studies quantifying exposure and biological effects.

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A Method to Measure and Speciate Amines in Ambient Aerosol Samples

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Ambient reactive nitrogen is a mix of organic compounds that contain nitrogen and inorganic compounds including nitric acid, nitrate, ammonia, and ammonium. These various forms of nitrogen are found in oxidized and reduced forms and in both the aerosol and gas-phases. The aerosol-phase reduced nitrogen is predominately thought to include ammonium and amines. In ambient samples the ammonium concentration is often routinely determined, but the contribution of amines is not. In addition, in the traditional chromatography methods currently used to measure ammonium and other common inorganic ions there is significant overlap with amines that is not accounted for. Therefore, we have developed a method to discretely measure amines from ambient aerosol samples. It employs ion chromatography using a Dionex CS-19 column with conductivity detection and a 3 step methanesulfonic acid eluent separation. This method allows for quantification of 18 different amines, including the series of methylamines and ethylamines as well as the different isomers of butylamine. Here we will present the details of the method. We will also examine data from the analysis of ambient filter samples collected in Rocky Mountain National Park (RMNP) and Greeley, CO as well as from biomass burning source samples. Almost all of the amines quantifiable by this technique were measured regularly when this method was applied to the samples collected in RMNP and Greeley. The sum of the amines was generally $\sim 0.02 \mu\text{g}/\text{m}^3$. This increased to 0.04 and 0.09 $\mu\text{g}/\text{m}^3$ at RMNP and Greeley, respectively, when being impacted by biomass burning smoke, largely due to observable increases in methylamine and dimethylamine.

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Atmospheric NO₂ and d¹⁵N in moss in a protected wilderness area impacted through vehicle emissions in Alberta, Canada

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Vehicle emissions increase the amount of nitrogen oxides (NO_x) in the air, which may increase the amount of plant usable nitrogen. Nitrogen is a limiting nutrient that influences ecosystem processes, such as nitrogen sequestration by plants, plant quality for herbivores and decomposers, and ecosystem productivity. Changes in ecosystem processes as a result of increases in nitrogen availability are at odds with the goals of protected wilderness areas that are typically accessed by vehicles.

In this study, we used data from 2003 to 2019 to determine if vehicle emissions had an observable impact on the ecosystem in a protected wilderness valley, Kananaskis Valley, near a major city (Calgary, Alberta). We examined the concentration of NO₂ in the air and the abundance of combustion-derived nitrogen isotopes (δ¹⁵N) in naturally-occurring moss (*Hylocomium splendens* and *Pleurozium schreberi*) within 20 meters of the highway as a function of traffic levels that varied along the highway and among years.

Within the valley, we observed a gradient in the number of vehicles that was greatest at the main access to the valley in the north and decreased moving south. Traffic volumes increased over the years with more than 320,000 additional vehicles in 2019 than in 2003. Within years, NO₂ concentration in the air increased with the gradient of traffic along the valley as expected. δ¹⁵N values in moss increased with the traffic gradient along the valley and were positively correlated with traffic both within and among years, signalling that nitrogen from vehicle emissions entered the local ecosystem. We conclude that seemingly small anthropogenic influences, such as vehicle emissions, in protected areas along roadways with relatively low levels of traffic, can be observed through impacts on the ecosystem.

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Advances in the evaluation of reactive nitrogen in Mexico City

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Mexico City is a Megalopolis that represents a challenge in terms of air pollution. For more than 30 years, the air quality of criteria pollutants has been measured by the Automatic Atmospheric Monitoring Network (RAMA), and since 2003 wet atmospheric deposition has been monitored through the Atmospheric Deposition Network (REDDA). Nitrogen compounds in oxidized forms, such as nitrogen oxides (NO_x) are measured in ambient air. In wet atmospheric deposition, nitrogen is measured as nitrates (NO₃⁻) in oxidized form and as ammonium (NH₄⁺) in its reduced form.

Trends of nitrogen compounds in ambient air (NO_x) and in wet atmospheric deposition (NH₄⁺ and NO₃⁻) at Mexico City are evaluated in this study. NO_x levels have been decreasing since 2003 at all monitoring stations; however, photochemical pollution and acidic precipitation are important issues.

The REDDA of the Secretary of the Environment of Mexico City has been working continuously with the University of Mexico (UNAM), collecting the wet atmospheric deposition at 16 sampling sites located throughout the city, while the UNAM is responsible for the chemical analysis of the samples. Over time, the collaboration with the National Atmospheric Deposition Program and the U.S. Environmental Protection Agency has strengthened field sampling protocols, and participation in United States Geological Survey (USGS) and World Meteorological Organization (WMO) laboratory inter-comparison programs has strengthened chemical analysis performance.

Among the obtained results in wet atmospheric deposition, the presence of NH₄⁺ stands out as the major ion in the chemical composition of precipitation (71%), and the NH₄⁺/NO₃⁻ ratio interestingly varies among regions of the city. The average ratio NH₄⁺/NO₃⁻ was 2.5, which is similar to other urban areas in North America, such as the Denver/Boulder, Colorado metropolitan area. The highest values are in the region of high urban and industrial activities, as well as landfill sources.

To develop effective strategies for controlling secondary particulate matter, it is necessary to characterize both oxidized and reduced forms of nitrogen in the atmosphere of Mexico City. Establishment of an ammonia (NH₃) measurement network is needed to determine the concentration of reduced nitrogen in ambient air. It is recommended to collaborate with other urban areas in North America and establish monitoring approaches like the Network for Urban Atmospheric Nitrogen Chemistry in Denver and the RAMA and REDDA in Mexico City.

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Monitoring springwater nitrate as an indicator of atmospheric deposition in a regional conservation plan

Stuart Weiss¹

Atmospheric nitrogen deposition is a major threat to biodiversity. Serpentine grasslands and the Bay Checkerspot butterfly have become “poster children” for biodiversity impacts, with non-native grasses overrunning flower-filled fields on nutrient-poor soils. Atmospheric deposition was a major nexus for the development of The Santa Clara Valley Habitat Plan, a Habitat Conservation Plan/Natural Communities Conservation Plan. Patterns of deposition in space and time have been identified as a critical area for monitoring and research. Springwater derived from serpentine grasslands downwind of Silicon Valley have highly elevated nitrate levels, up to 5.5 ppm NO₃-N, indicating severe N-saturation. Low biomass, strong seasonality, shallow soils, and fractured bedrock contribute to high leaching levels. Nitrate levels follow deposition gradients, with higher levels at low elevations closer to San Jose, and nitrate from relatively clean-air sites are well below 1 ppm NO₃-N. Residence times for shallow groundwater are on the order of 1-3 years, so it should be possible to track deposition through time as a multi-year average. After 5 years, a set of sites showed slight increases in NO₃-N, in line with estimates from TDEP. TDEP provides insights into the forms of deposition – in Silicon Valley, oxidized N has decreased with strong regulation, but reduced N has increased with unregulated vehicular NH₃ emissions. Sampling about 20 sites at the end of the dry season (Sep.-Oct.) costs less than \$10,000, and provides a robust, integrated measure of total deposition.

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Session 3: Atmospheric Deposition Effects in Aquatic and Terrestrial Ecosystems

Throughfall Deposition Chemistry in the Great Smoky Mountains National Park: Long-term Trends and Effects of Stream Water Quality

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Significant declines in acid deposition has been reported in the eastern United States, particularly sulfate since the mid-2000s. Annual declines in acid deposition have also been observed in Great Smoky Mountains National Park (GRSM) at the Noland Divide high-elevation monitoring station. Since 1991, this monitoring station continues to collect wet deposition, throughfall, and soil and stream chemistry. After 2008 significant declines in annual loadings and average concentrations were recorded. Annual sulfate loadings prior to 2003 were generally above 100 kg/ha, and prior to 2008 were above 60 kg/ha. After 2008, annual sulfate loadings have been consistently below 15 kg/ha and coincides with the installation and operation of air pollution controls at two Tennessee Valley Authority coal fired power plants in East Tennessee. Stream sulfate in the Noland Divide watershed has shifted from mass retention as reported for years prior to 2003 to now mass export. However, stream sulfate concentrations have not statistically changed around 40 $\mu\text{eq/L}$, but may have declined slightly though continued long-term monitoring is needed to detect a trend due to annual variability. Stream pH at the Noland Divide site has increased slightly from about 5.6 in 2006 to 5.8 in 2019. Because of the major decline in annual sulfate and nitrate deposition at Noland Divide, it assumed the same would be observed throughout the GRSM. The last park-wide mapping of acid deposition was conducted by Weathers and others in 2000. In the Weather's study, elevation was a dominant factor to annual deposition loadings, where below 1000 m sulfur was about 5 kg/ha and above 3000 m it was about 45 kg/ha. Similar annual loading trends were observed for inorganic nitrogen. In 2016 a park-wide survey of throughfall deposition was conducted to update our understanding of changes that have occurred. A total of 22 sites among seven watersheds were selected along an elevation gradient in which annual sulfur loadings ranged from 1.47 kg/ha to 7.17 kg/ha, and inorganic nitrogen ranged from 1.84 kg/h to 9.05 kg/ha. As would be expected, the annual loadings for sulfur and inorganic nitrogen had significantly declined. However, an elevation gradient of annual loading was not significant. In contrast, there was a significant elevation gradient for pH and acid neutralizing capacity (ANC) from means of about 6.0 and 90 $\mu\text{eq/L}$ at 1000 m to 5.6 and 15 $\mu\text{eq/L}$ at 2000 m, respectively. Research related to the base cations in throughfall deposition is ongoing.

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Atmospheric nitrogen deposition drives declines in native plant richness across the Santa Monica Mountains, California

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Anthropogenic nitrogen deposition has been shown to reduce plant diversity in a variety of ecosystems worldwide. However, the impacts of nitrogen deposition on the diversity of many plant communities, such as those of Mediterranean-type ecosystems, remains relatively unexplored. California's coastal sage scrub, a Mediterranean-type shrubland, is one of the most threatened plant communities in the United States and a biodiversity hotspot. Our previous work, and that of others, has demonstrated that elevated nitrogen deposition negatively impacts coastal sage scrub in a number of ways, such as promoting nonnative plant invasion and exacerbating drought-induced shrub mortality. However, despite a rich body of literature documenting nitrogen-induced changes to this plant community, impacts on plant diversity are poorly quantified. We evaluated patterns of plant richness of coastal sage scrub across the Santa Monica Mountains National Recreation Area of southern California, the largest urban national park in the country. While this park was created in part to serve as an "air shed" of protected land in the region, it experiences a strong gradient of atmospheric nitrogen deposition due to its proximity to urban Los Angeles. We measured soil nitrogen, plant cover, and plant richness at 30 sites of mature, intact coastal sage scrub across this gradient and used regression analyses to explore relationships between vegetation parameters, nitrogen deposition, and other environmental variables. Soil nitrogen availability was positively correlated with rates of deposition. We documented significant declines in native plant richness with increasing nitrogen deposition across the mountain range, primarily due to decreases in native forb species. Increased nonnative plant cover at high deposition sites and aridity also appeared to contribute to reduced native richness. Overall, these results highlight the severe threat posed by anthropogenic nitrogen deposition to the conservation of biodiversity in this already imperiled ecosystem, as well as other Mediterranean-type ecosystem worldwide.

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Total deposition of inorganic nitrogen to Norway spruce forests – applying a surrogate surface method across a deposition gradient in Sweden

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The dry and wet deposition of nitrate, NO₃⁻, and ammonium, NH₄⁺ were estimated for Norway spruce forests at ten monitoring sites across Sweden for the years 2014-2017. The particulate dry deposition was estimated based on measurements using Teflon string samplers as surrogate surfaces, in combination with the net throughfall deposition for sodium (throughfall subtracted with wet deposition). The wet deposition was estimated from bulk deposition measurements, corrected for dry deposition to the collectors. There was a strong gradient for total inorganic nitrogen (N) deposition across Sweden from north to southwest, ranging from 2 to 20 kg N ha⁻¹ yr⁻¹. The values for N deposition derived from measurements were for most sites exceeding the corresponding values derived from modelling with the MATCH and EMEP models, in southern Sweden by up to 4 – 6 kg N ha⁻¹ yr⁻¹. Based on comparisons between total and throughfall deposition, the canopy uptake of atmospheric N deposition to Norway spruce forests in Sweden was estimated to be in the range of 0-7 kg N ha⁻¹ yr⁻¹.

Reference:

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Is weathering sufficient to keep forest harvest from exceeding acidification critical loads in Sweden:
Conclusions from QWARTS – Quantifying Weathering Rates for Sustainable Forest Management?

Kevin Bishop¹, Cecilia Akselsson², Salim Belyazid³ and Stefan Lofgren⁴

Sweden has ambitious plans for increased primary forest biofuel harvest at rates that are not sustainable according to official Critical Load calculations based on the PROFILE/FORSAFE modeling platform (PFMP). But are those estimates reliable? This presentation summarizes a 7-year multi-investigator project aimed at disproving the hypothesis that the PFMP was appropriate for assessing forest management alternatives. We compared PFMP with other, independent approaches. We also investigated specific process representations, in particular whether there were biological and chemical feedbacks missing from the PFMP that might result in underestimates of weathering. Base cation and aluminium binding reactions, mineralogical determination, and integration of weathering to the catchment scale, were some of the fundamental science questions investigated.

The project found that the major biological effect, removal of weathering products by root uptake, were adequately represented in the PFMP, so a major driver of weathering had not been missed. Refinements were suggested for representation of several processes. The most far-reaching process change was strengthening of weathering “brakes” in the saturated zone. This relates to delivery of weathering products to streams.

In conclusion, the project was able to improve, and suggest further improvements, in the PROFILE/FORSAFE modeling platform, but not able to disprove its essential validity for estimating weathering rates of relevance to national environmental goals. The overall tendency of these changes, and the comparison with other models suggested that there will be a net loss of weathering products from forest soils under many future scenarios in large areas of Sweden unless the intensity of forest harvesting is reduced or weathering products are replaced. This is a major concern, and the export of weathering products by forestry is comparable to the remaining acid deposition.

The reduction of sulfur deposition from the atmosphere means that the transport of sulfate from soil to surface water, with accompanying cations, is lower than before. So while the landscape will continue to lose its overall store of weathering products, and recovery from acidification will be delayed under many future scenarios, the effects on tree health and surface water acidity will be limited, except in areas with high anion fluxes (e.g. sea-salt deposition events or mobilization of nitrogen), particularly where soils are thin.

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Water resources in a changing world: Long-term hydrologic monitoring provides insight into changes in precipitation and stream-water quality at Robinson Forest in eastern Kentucky, Appalachia, USA

Tanja Williamson¹, Kenton Sena² and Chris Barton³

A hydrologic monitoring network was established at the University of Kentucky's (UK) 6000 ha Robinson Forest in 1971. The result is a 40+ year record of precipitation and streamflow, as well as water chemistry for headwater catchments in eastern Kentucky. These data present a valuable opportunity to evaluate linkages among atmospheric deposition and stream chemistry, the impacts of environmental policy, and effects from nearby land disturbance in the form of surface mining. A key fact is that, while many of the monitored Robinson Forest basins are minimally impaired, the Forest is surrounded by active surface mining. Preliminary findings show that the temporal patterns of precipitation-chemistry constituents (pH, sulfate, nitrate, and sum of anions & cations) sampled on Robinson Forest show more variability than those at the closest National Atmospheric Deposition sites which show consistent trends that together indicate a regional improvement in air quality since 1985. This variability carries over to streamflow, which was evaluated as decadal time steps (1974-83, 1984-93, 1994-2003, 2004-2013) in order to separate the influence of climate (as streamflow volume) and land management effects. Comparison of the first two decades shows decreases in flow-adjusted sulfate concentration and increases in pH across all basins, reflecting similar changes in local precipitation chemistry. Each of these changes is attributed to land management effects and is interpreted as implementation of the Clean Air Act (1982). In contrast, flow-adjusted concentrations of nitrate and major cations increased between these two decades, correlating with an increase in local surface mining between 1985 and 1995. However, when the first decade (1974-83) is compared to the most recent decade (2004-2013), pH has decreased in all monitored streams (<6 pH units), and there are differences in sulfate and nitrate concentration trends between the pair of larger (~1500 ha) basins relative to the pair of nested, smaller (~85 ha) basins. This finding indicates that as this landscape adjusts to ongoing acid deposition, not all parts of the Forest are responding in the same way and small areas of disturbance result in significant differences in streamflow chemistry.

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Mercury in Fish from Streams and Rivers in New York State: Spatial Patterns and Environmental Drivers

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Mercury (Hg) concentrations in freshwater fish across the state of New York frequently exceed guidelines considered harmful to humans and wildlife, but statewide distribution and temporal changes are not well known for the state's streams and rivers. We analyzed existing data to describe recent spatial patterns and identify key environmental drivers of these patterns. Size classes within sportfishes and prey fishes formed 'functional taxa' (FT), and standardized scores were generated from 2007-2016 data for 218 sites. Muscle Hg in ≥ 1 sportfish FT exceeded human-health guidelines of 50 ng/g (sensitive populations) and 300 ng/g (general population, GP) at 93% and 56% of sites, respectively, but exceeded 1000 ng/g (a state threshold) at only 10% of sites. Whole-body Hg in ≥ 1 prey fish FT exceeded wildlife thresholds of 40 ng/g and 100 ng/g at 91% and 51% of sites, respectively. Environmental drivers of recent spatial patterns include extent of forest cover and storage, the latter an indicator of wetlands. Standardized Hg scores increased with increasing atmospheric Hg deposition and storage across rural 'upland' regions of New York. However, scores were not related to atmospheric deposition in more-developed 'lowland' regions due to the limited methylation potential of urban landscapes. Some recent stream and river fish Hg spatial patterns differed from those of lake-based studies, highlighting the importance of New York's flowing waters to future Hg monitoring and risk assessment.

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Session 4: Global Atmospheric Mercury Assessment

A National Survey of Total Gaseous Mercury Stable Isotope Composition and Concentration across the US

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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) initiated a national-scale effort to establish a baseline of total gaseous mercury (TGM) and Hg stable isotopic compositions using bulk-air sampling at 31 sites distributed across North America over a two-year period (March 2016 – May 2018). To facilitate this effort, the USGS Mercury Research Laboratory developed a simple, small sampling device for TGM that is easily deployed in most any environmental setting using AC or DC power. A priority of our device was that it would allow accurate measurement of TGM, but also allow for measurement of stable Hg isotopes – the first known such effort at a continental scale. Because the isotope measurements require about 5 ng of Hg, the sampling interval for this effort was typically 5-14 days, and as such the measurements represent a time-integrated sample. Approximately two thirds of our TGM samplers were operated at MDN or AMNet sites. The other selected sites were chosen to fill geographic gaps in coverage that were principally in the western US. The network includes a highly diverse set of sites ranging from remote (e.g., Denali National Park, Alaska, Mauna Loa, Hawaii, and Nova Scotia) to highly urbanized locations (e.g., Bronx, New York and Boston, Massachusetts). Measured mass-dependent fractionation (MDF, $\delta^{202}\text{Hg}$) at urban sites were consistently lighter in $\delta^{202}\text{Hg}$ compared to remote background sites, suggesting the influence of near-field Hg emission sources that based on previous studies supports the notion that the isotopes are reliable indicators of nearby sources. The site at Oak Ridge National Lab, near the contaminated Y12 plant, had also showed a depleted Hg isotope source signature - mean $\delta^{202}\text{Hg}$ of $-0.04 \pm 0.36\%$. Overall, our study results suggest Hg concentration and isotope enrichments in regional settings. The most prominent example of this is from the northeastern United States: from the Ohio River Valley to remote sites in northern Maine and Nova Scotia. The long-term goal of this effort is to provide baseline assessments of atmospheric Hg concentrations and isotope abundances that will play a key role in helping to conduct the Minamata effectiveness evaluation.

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Atmospheric Mercury Monitoring in Japan by using Gold Amalgamation Trap Method - Methodology and Data over 15 Years

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Currently, the most common method of atmospheric mercury monitoring in the world is to use automated mercury analyzers. These instruments have good accuracy and time resolution; however, it is not easy to monitor many sites, due to their requirements (cost, power source, shelter etc.). On the other hand, monitoring method using passive sampler has advantage for its ease of installation on sampling site, but its monitoring data are still not many.

In Japan, atmospheric mercury monitoring has been conducted by manual active sampling method. In this method, mercury in the atmosphere is trapped in a small gold-coated amalgamation cartridge. The sampling equipment for this method is simple. It consists of a gold cartridge, a portable air pump, and their tubing. Therefore, it is very easily carried and installed at sites of various situations. In normal cases, sampling time required is 24 hours to avoid diurnal variation. This method can detect atmospheric mercury at background levels (1-2ng/m³) within approximately 3 hours of sample collection. Most types of air pumps can be driven by batteries, which therefore enables this equipment to be located in remote sites.

Mercury collected on the gold amalgamation cartridges is measured by using Atomic Absorption Spectrometer (AAS) or Atomic Fluorescent Spectrometer (AFS). Mercury collected in a gold cartridge is heated to be desorbed and introduced into the absorption cell of AAS or AFS. After the measurement, the gold cartridge can be reused for the next survey or monitoring period. Gold amalgamation trap method has advantages in its cost, availability, and handling. It is a complementary method to other methods of atmospheric mercury survey and monitoring, such as automated analyzer and passive sampling methods, to fulfill the global monitoring gaps.

Gold amalgamation trap method is an official ambient air monitoring method in Japan. There are over 200 monitoring sites, and monthly atmospheric mercury monitoring is conducted at each site. In the official method, quality assurance processes such as operation blank, travel blank (field blank), and duplicate analysis are required, in order to ensure the comparability of the monitoring data. In this presentation, an overview of this methodology and collected data will be introduced.

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Eight-year atmospheric mercury deposition to a tropical high mountain background site downwind of the East Asian continent

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Atmospheric deposition has been identified as an important source of mercury (Hg) to terrestrial and aquatic ecosystems. Although East Asia is the major atmospheric Hg emission source region, very few studies have been conducted to quantify atmospheric Hg deposition in its downwind region. In this study, 8-year (2009–2016) atmospheric Hg deposition was reported at the Lulin Atmospheric Background Station (LABS; 120.87°E, 23.47°N, 2862 m a.s.l.), a high mountain forest site in central Taiwan. Dry deposition of speciated Hg was estimated using a bi-directional air-surface flux exchange model for gaseous elemental mercury (GEM) and dry deposition models for gaseous oxidized mercury (GOM) and particulate-bound mercury (PBM), making use of the monitored speciated atmospheric Hg concentrations. Wet deposition of Hg was calculated as the product of rainwater Hg concentration and rainfall depth. Annual total Hg dry deposition ranged from 51.9 to 84.9 $\mu\text{g m}^{-2} \text{yr}^{-1}$ with a multi-year average of 66.1 $\mu\text{g m}^{-2} \text{yr}^{-1}$. Among the three forms of atmospheric Hg, GEM was the main contributor to the total dry deposition, contributing about 77.8% to the total, due to the high density of forest canopy as well as the much higher concentration of GEM than GOM and PBM at LABS. Mercury dry deposition is higher in winter and spring than in summer and fall, partly due to the elevated Hg concentrations associated with air masses from East and Southeast Asia with high atmospheric Hg emissions. Annual wet Hg deposition ranged from 10.9 to 48.9 $\mu\text{g m}^{-2} \text{yr}^{-1}$ with a multi-year average of 27.7 $\mu\text{g m}^{-2} \text{yr}^{-1}$. The mean annual dry/wet deposition ratio of 2.8 at LABS indicated that Hg deposition to its surrounding forest landscape was governed by dry rather than wet deposition. The modeled dry and measured wet depositions at this tropical mountain site were significantly higher than those reported for remote sites in temperate regions. Such a finding has important implications in Taiwan and other tropical Southeast Asian countries since most land covers of mountains in this region are forests.

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Mercury Emission to the Atmosphere Dominates Annual Mass Balance of a Boreal Peatland and highlights the need for eddy-covariance based measurements of surface -atmosphere Hg exchange

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While wet deposition of mercury (Hg) is well quantified by Hg deposition networks, it remains challenging to determine the surface-atmosphere exchange of gaseous elemental Hg (GEM). This generates great uncertainty in recent estimates of global surface-atmosphere fluxes. Improving quantification of surface-atmosphere GEM exchange is of paramount importance to research and policy making because the GEM flux is a major control on how fast the environment will recover from anthropogenic Hg pollution. The first annual Hg budget based on continuous measurements of peatland-atmosphere Hg⁰ exchange using a relaxed eddy accumulation (REA) system revealed that the annual net GEM emission ($9 \mu\text{g m}^{-2}$) exceeded annual wet bulk deposition ($4 \mu\text{g m}^{-2}$) and annual discharge export ($1 \mu\text{g m}^{-2}$). We hypothesize that the net loss of Hg from this peatland is explained by the halving of atmospheric Hg concentrations from peak levels in the 1970's. These reductions could have turned the peatland from being a sink of Hg for millennia into a source of Hg emission. The Hg concentration gradients in the superficial peat from a chronosequence of nearby peatlands support this interpretation. We suggest that the strong Hg evasion demonstrated in this study means that open boreal peatlands and thus downstream ecosystems may recover more rapidly from past atmospheric Hg deposition than previously assumed.

Given the current international efforts to protect human health and the environment from the adverse effects of mercury in accordance with the United Nation's 2013 Minamata Convention on Mercury, we believe our findings contribute to a better understanding of mercury cycling in northern peatlands and their role for the mercury status of fresh water fish in the Northern Hemisphere. Our findings also raise the question as to whether recent reductions of atmospheric mercury concentrations lead to changes in the sink/source strength of other ecosystems as well, such as forests and oceans. We believe that micrometeorological flux measurement techniques should be applied more widely to define the balance between new emissions and re-emission for different ecosystems. These findings also point to the need to develop direct eddy covariance as a "gold standard" for spatially and temporally representative measurements. Progress in this direction from months of measurements over the Baltic Sea and a temperate grassland (with eddy covariance used on the latter site) show the promise for better quantification.

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Net ecosystem exchange of atmospheric gaseous elemental mercury (GEM) over a temperate forest: seasonality and diel patterns of exchange and annual mass balance of deposition

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The goal of this study was to measure net gaseous elemental mercury (GEM) exchange fluxes using a micrometeorological flux-gradient approach over a remote deciduous temperate forest in Massachusetts. We aimed to quantify the magnitude, seasonality and diel patterns of GEM exchange fluxes and characterize controlling variables and relationships to carbon dioxide exchange. A major challenge was to detect small GEM concentration differences between the two inlets above the canopy (at 24 and 31 m). Measured GEM concentration differences were in fact very small with a median of 0.0015 ng m⁻³, equal to 0.1% of atmospheric concentrations and about four times lower than previous measurements conducted over grasslands/shrubs. Detailed analysis of null gradients, i.e. potentially systematic biases in concentrations between the inlet lines, along with analysis of spectral patterns and autocorrelations showed that measured gradients were real, statistically highly significant and characterized by strong diel patterns.

Calculated daily GEM fluxes generally were positive (i.e., emissions) during the winter months (December through February), with median rates of emissions between 1.1 to 4.5 ng m⁻² hr⁻¹. All other months, specifically summer and fall months, experienced negative GEM fluxes with monthly median net deposition between -2.0 to -8.3 ng m⁻² hr⁻¹. Cumulative GEM flux exchange over the duration of a full year showed that the forest was a strong GEM sink, driven by a pronounced summertime and fall GEM deposition (23.9 µg m⁻² between May to November). We attribute the pronounced summertime and fall GEM uptake to GEM assimilation by vegetation during peak vegetation period. Detailed analysis of diel patterns in July, August, September, and October supported pronounced midday deposition GEM enhancement, in accordance to similar daytime deposition maxima for CO₂. Calculating an annual mass balance, we estimate gaseous GEM deposition (e.g., dry deposition) to account to 72% of the total annual Hg deposition of 24.6 µg m⁻² at this forest and exceeding wet deposition three to four-fold.

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Mercury in Soils Across the Conterminous United States: Changes in Pools and Patterns

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Mercury is a ubiquitous and toxic metal, whose negative impacts on human and wildlife health have generated considerable interest among researchers and policy makers alike. Research on mercury has largely focused on its transport and transformation in the atmosphere or transformation and accumulation in biota, particularly in aquatic environments. Notably, there has been relatively little attention devoted to mercury in soils, despite the fact that soil pools are an important sink for atmospheric mercury, as well as an important source for re-emission to the atmosphere and leaching into downstream aquatic ecosystems. This paucity of information on mercury in soils can be attributed to difficulty in acquiring uniformly collected datasets containing adequate spatial and temporal coverage with which mercury patterns can be examined. Here, we present an analysis of mercury from a large soil survey (3 horizons, ~4,800 sites) across the coterminous US, collected by the United States Geological Survey. Spatial patterns of mercury in soils are largely driven by organic carbon content and vary markedly over different ecoregions and land use types. Median mercury concentrations decrease downward through the soil profile and are greatest in forested and developed landscapes. Concentrations are highest in heavily forested ecoregions and those along the Pacific coast, while North American Deserts contain the lowest concentrations. Mercury soil pools are calculated for the top 1 m of soil and are substantially larger than previous estimates focusing on only organic soils. Using mercury-to-titanium ratios as a proxy for native Hg fractions, we estimated that between ~73 – 97% of total mercury is derived from external additions. Finally, recent soils pools (2007 – 2010) compared to older surveys (1961 – 1974) find that mercury in soils has dramatically decreased (~ 56%) over ~ 60 years, suggesting that soil mercury may be more dynamic than once thought.

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Session 5: Advances in Mercury Monitoring and Research

Passive air sampling for mercury, a newer approach to monitoring

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Atmospheric mercury (Hg) has been measured for decades around the world. Air monitoring has evolved over time from manual weekly traps to sophisticated instruments sampling on very short intervals. The next wave of Hg sampling has been developed using passive air sampling for even longer measurement time periods. Overall, it is the end goal of the monitoring that dictates what sampling method should be employed. Should processes research in an aircraft be the study, then the automated instrument is selected; should a regional network to investigate trends be the goal, then weekly traps is selected. With the goal of long-term trend monitoring and filling in large regional gaps such as that of the Minamata Convention on Mercury (MCM), the passive sampling method is a good tool to select.

In collaboration with Environment and Climate Change Canada (ECCC), the University of Toronto Scarborough developed a passive air sampler for gaseous Hg. This sampling system has been fully characterized and is now in commercial production by Tekran Inc. and sold under the MerPAS name. The MerPAS passive air sampler uses sulfur-impregnated activated carbon as the sorbent for Hg which undergoes diffusive uptake and accumulation on the sorbent. This method has been shown to have accuracy on par with currently acceptable methodologies for measuring Hg in the atmosphere and demonstrates excellent precision. However, this is not the only passive sampling method being used around the world. In addition to the MerPAS, the Italian Institute of Atmospheric Pollution Research (CNR-IIA) and the Swedish Environmental Research Institute (IVL) have also developed passive sampling devices for Hg. Thus, in the winter of 2019, a field based intercomparison and a controlled blind performance comparison among 3 different devices was undertaken. Preliminary results from this intercomparison will be presented.

As presented at last fall's NADP meeting, ECCC has initiated a pilot study to investigate the application of passive sampling of atmospheric Hg on a global scale by developing a global network made up of currently existing networks (i.e. a "network of networks") in combination with the expansion of some of those networks to reduce areas with no coverage. NADP is now a partner in this pilot global network with 5 sites in the US at Beltsville, Sequoia and Kings Canyon, Mingo National Wildlife Refuge, Toolik and Marcell. We now have 29 countries and almost 50 sites currently collecting data with more to come. Updates on this project will be presented in addition to the challenges experienced in undertaking this kind of new network monitoring.

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Active and passive systems for measurement of gaseous oxidized, particulate bound, and reactive mercury

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Two systems that are viable for measurement of reactive Hg (RM=gaseous oxidized Hg (GOM) + particulate bound Hg (PBM) include: 1) the Aerohead designed to measure GOM dry deposition; and 2) the University of Nevada, Reno - Reactive Mercury Active System (RMAS) configured to measure RM, GOM, and PBM chemistry and concentrations. Data collected using Aeroheads in Florida were a first step in demonstrating the Tekran speciation system does not adequately measure reactive Hg concentrations. This was further demonstrated by research associated with the Reno Atmospheric Mercury Intercomparison eXperiment (RAMIX) and confirmed in many other studies. The Tekran system is an automated system designed to measure gaseous elemental Hg, GOM, and PBM, and has been used by researchers for the past ~20 y.

The surface used to measure dry deposition in the Aerohead samplers is a cation exchange membrane (CEM). The CEM is also used in the RMAS to quantify RM concentrations, while nylon membranes are used to determine the chemistry. CEM are digested and analyzed using EPA method 1631. Chemistry of the compounds is determined using thermal desorption analysis of nylon membranes. Concentrations measured with the CEM are 2- to 13-times higher than the Tekran system measurement. Concentrations measured by the CEM have been demonstrated to be accurate using a calibrated dual channel system.

Chemistry determined using the nylon membranes observed in Hawaii, Nevada, Utah, and Maryland agreed with ancillary data and sources defined using HYSPLIT analyses. A polytetrafluoroethylene membrane has been introduced into the RMAS, providing a means of determining GOM and PBM concentrations and chemistry. The Aerohead samplers and RMAS were deployed together in Svalbard, Norway, along with a Tekran system. Using the RMAS together with the Aeroheads and modeling provided a means of estimating dry deposition rates of specific compounds.

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Atmospheric Hg Concentration Dynamics Over a Temperate Deciduous Broadleaf Forest

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Assimilation of gaseous atmospheric mercury – Hg(0) – by vegetation activity is considered the most important deposition process in terrestrial environments. Subsequent mobilization of Hg from soils provides a source of Hg to aquatic ecosystems where it enables production of methylmercury which bioaccumulates in the aquatic food chain posing a threat to human and wildlife health. Previous studies have shown strong seasonality of gaseous atmospheric Hg(0) concentrations with summertime minima and wintertime maxima and strong correlations to CO₂ and attributed these patterns to vegetation uptake of Hg(0) along with CO₂ during growing periods. However, diurnal patterns of Hg(0) were inconsistent and flux measurements of Hg(0) to confirm these linkages are largely missing. Here, we characterized the seasonal and diel dynamics of atmospheric Hg(0) concentrations along with direct ecosystem-level Hg(0) flux measurements by means of a micrometeorological flux-gradient approach. In addition, we measured concentrations and fluxes of other trace gases, in particular CO₂, O₃ along with CO and meteorological variables to assess quantitative relationships among these variables. The study was conducted over a temperate deciduous broadleaf forest located at the Harvard Forest research site located in Petersham, MA, USA for two full years (2018-2020).

Atmospheric Hg concentration patterns both over the canopy as well as above the forest floor showed strong minima from July to October and wintertime maxima for both years, with an average seasonal amplitude of 0.12 ng m⁻³ (equivalent of 10.5% of mean annual concentrations). Growing season Hg(0) concentration declines were consistent with observed ecosystem-level Hg(0) deposition, providing direct indication that seasonality in concentrations at this remote site was in fact determined by a regional forest Hg sink. In addition, seasonality of Hg(0) concentrations was strongly related to CO₂ concentrations and fluxes. Notably, however, seasonal Hg(0) concentration minima occurred later (September) than those of CO₂ (August) and the pronounced forest Hg(0) sink lasted through November, while the CO₂ sink largely ceased by late October. Diel patterns of Hg(0) concentrations, in contrast, were inconsistent with diel patterns of Hg(0) fluxes and patterns of CO₂, with Hg(0) concentrations showing lower values during nighttime and highest concentrations during midday. We attribute the contrasting patterns to boundary layer mixing leading to advection of air masses aloft with enriched Hg(0) concentrations during turbulent daytime planetary boundary layers. Finally, we observed Hg(0) sources attributable to transport of polluted air masses, which was pronounced particularly during the spring season. In conclusion, a regional Hg(0) sink led to strong growing-season atmospheric Hg(0) concentration declines, yet diel patterns and correlations to other trace gases also showed that Hg(0) levels were co-determined by emission sources and boundary layer mixing.

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Surface-air mercury fluxes and a watershed mass balance in forested and harvested catchments.

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The cycling of mercury (Hg) within forested ecosystems is impacted by atmospheric deposition, sequestration in soils and vegetation, surface emissions, and mobilization in runoff. Mercury cycling can be impacted by forestry operations where clear-cut logging most of the vegetation cover by impacting several of the key flux processes, as well as foodweb dynamics and bioaccumulation. This paper measured surface-air Hg fluxes from catchments in the Pacific Northwest, USA to determine if there is a difference between forested and logged catchments. These measurements were conducted as part of a larger project on the impact of forestry operations on Hg cycling which include measurements of water fluxes as well as impacts on biota (published separately). Surface-air Hg fluxes were measured using a commonly applied dynamic flux chamber (DFC) method that incorporated diel and seasonal variability in elemental Hg (Hg⁰) fluxes at multiple forested and harvested catchments. The results showed that the forested ecosystem had depositional Hg⁰ fluxes throughout most of the year (annual mean: -0.26 ng/m²/h). In contrast, the harvested catchments showed mostly emission of Hg⁰ (annual mean: 0.63 ng/m²/h). Differences in solar radiation reaching the soil was the primary driver resulting in a shift from net deposition to emission in harvested catchments. The surface-air Hg fluxes were larger than the fluxes to water and accounted for 97% of the differences in Hg sequestered in forested versus harvested catchments.

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Comparison of pre-MATS (Mercury and Air Toxics Standards) rule and post-MATS rule GOM dry deposition measurements in the Four Corners Area

Mark Sather¹, Shaibal Mukerjee² and Luther Smith³

Gaseous oxidized mercury (GOM) dry deposition measurements using surrogate surface passive samplers were collected at six sites in the Four Corners area, U.S.A., for the two-year period August, 2017-August, 2019, after the implementation of large power plant mercury emission reductions across the U.S.A. Two-year baseline GOM dry deposition measurements at the same six sites in the Four Corners area, taken before the implementation of U.S.A. power plant mercury control regulations, were conducted earlier from August, 2009-August, 2011. The GOM dry deposition rate estimate decreased at the Four Corners area high elevation remote mountain site of Molas Pass, Colorado (3249 m asl) from 0.4 ng/m²h for August, 2009-August, 2011 to 0.3 ng/m²h for August, 2017-August, 2019. In contrast, GOM dry deposition rate estimates for the remaining five sites increased for August, 2017-August, 2019, ranging from 0.8-1.3 ng/m²h, up from the August, 2009-August, 2011 range of 0.6-1.0 ng/m²h. Comparisons of median GOM dry deposition values showed a statistically significant decrease of 17 ng/m² at the Molas Pass site between August, 2009-August, 2011 and August, 2017-August, 2019, and a statistically significant increase of 66 ng/m² and 64 ng/m², respectively, at the Mesa Verde National Park and Farmington Substation sites between August, 2009-August, 2011 and August, 2017-August, 2019. In light of the unexpected increases in GOM dry deposition rates at the non-remote sites, it is suggested that large regional wildfires and local anthropogenic mercury emission sources from nearby cities and oil/gas production areas are possible notable contributors to the GOM dry deposition measurements collected in the Four Corners area.

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Tracing the depositional history of mercury to two coastal National Parks in the Northeast United States

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Establishing records of mercury (Hg) accumulation at sensitive sites provides an important means of assessing previous environmental conditions and historic Hg inputs from atmospheric deposition. Robust records of Hg deposition can also be important for evaluating legislation on atmospheric loading, and for predicting future needs. Lake sediment archives from undisturbed environments have been found to be the most reliable records of Hg accumulation rates. However, while sediment Hg records in some regions are well-established, the geographic distribution of deposition archives across the North American continent is sparse and coastal sites along the Eastern United States present an important data gap. In this work, we assess Hg accumulation in lake sediments at two coastal National Parks in the Northeast U.S. - Acadia National Park and Cape Cod National Seashore, and apply Hg isotopic signatures to investigate the sources and processes mediating deposition at each site. Records at both sites showed increasing rates of Hg accumulation since pre-industrial times. Hg concentrations in Acadia increased ~4 times since the early 1800's and peaked in the 1970's, whereas concentrations in Cape Cod ponds continued to increase in recent years reaching levels ~8 times higher than 200 years ago. The decreased flux of Hg in the past ~40 years in Acadia is consistent with reduced atmospheric Hg emissions and has been observed at other sites, however the ongoing elevated Hg flux at the Cape Cod site suggests continued watershed inputs of Hg, despite a minimal watershed area. Isotopic signatures of Hg in both Acadia and Cape Cod ponds show a large positive shift in $\delta^{202}\text{Hg}$ with industrialization and subsequent decrease in recent years at the Acadia site only. Previous studies have suggested this shift is due to increased wet relative to dry deposition of Hg. A coinciding large positive shift in $\Delta^{199}\text{Hg}$ (from -0.5 ‰ to -0.005 ‰) occurred at the Acadia site, whereas $\Delta^{199}\text{Hg}$ values were relatively constant (from -0.1 ‰ to 0.04 ‰) over time in the Cape Cod site. The positive shift in $\Delta^{199}\text{Hg}$ at Acadia also suggests a change in atmospheric deposition, whereas the shift in $\delta^{202}\text{Hg}$ but not $\Delta^{199}\text{Hg}$ suggests a potential marine influence at this site. The differences in these two coastal records emphasize the role of landscape and location on the processes controlling Hg flux in lake sediment archives. The reduction in Hg flux may lag atmospheric emissions where residence time in the catchment is long.

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Session 6: Advances in Measurement Model Fusion

On model-data fusion approaches for wet deposition in North America

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Environment and Climate Change Canada's ADAGIO project (Atmospheric Deposition Analysis Generated by optimal Interpolation from Observations) generates maps of wet, dry and total annual deposition of oxidized and reduced nitrogen (N) and sulphur (S) in Canada and the United States by fusion of observed and modeled data. Optimal interpolation methods are used to integrate seasonally-averaged surface concentrations of gaseous, particulate, and precipitation species into concentration fields predicted by Environment and Climate Change Canada's in-line regional air quality model GEM-MACH. The result, a product called objective analysis (OA), corresponds to an interpolation of the difference between the modeled and measured values at network observation sites. In model-data fusion, the weights attributed to model and observations are usually derived from error statistics from both model and observation. However, there is no real consensus on how to choose the best method to derive error statistics (weights for model and observations) for data-fusion products. Most methods have been successfully applied in the free troposphere and stratosphere but the extrapolation to the surface is not straightforward. This is because at the surface, model-data fusion deals with observations near emission sources and the presence of turbulent flows highly dependent on the topography or land cover. Consequently, near the surface, the representativeness error is likely to be more significant compared to the free troposphere. Therefore, modification of existing techniques is required. A new approach is presented here for model-data fusion based on a modification of the Hollingsworth and Lonnberg method. It consists of three steps: 1) performing sensitivity tests using 5 independent ensembles (each containing 80% of the data) to identify the optimum correlation length L_c (i.e. having the lowest analysis error), 2) with these initial error statistics, running the solver for the objective analysis by scaling both the model and observation error by the value of a diagnostic parameter (χ^2 : xhi squared) obtained by the first pass in the OA solver. The second pass would then correspond to the tuned weights or error statistics (model and observation errors), 3) independent validation using the remaining 20% of the data. The method is robust, converges very rapidly (no more than a few iterations) and performs well when verifying against independent observations. In this presentation, the method will be described along with examples of wet deposition and concentration for sulfate, nitrate and ammonium. The resulting trends in these fields from 2010 through 2016 will also be shown.

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An Updated Global Model for Terrestrial-Atmospheric Hg Exchange and Storage in Soils

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While the terrestrial biosphere plays important roles in the uptake, storage, and re-emission of atmospheric mercury (Hg), the details of terrestrial biogeochemical Hg cycling have received little attention in global models. Through uptake and oxidation of elemental Hg (Hg(0)) in leaf tissues, vegetation has been proposed as an important surface characteristic driving dry gaseous Hg(0) deposition to watersheds. Once incorporated into soils, the return flux of Hg back to the atmosphere is sensitive to spatially variable climate, redox conditions, and organic carbon dynamics. Soils are a significant legacy reservoir of anthropogenic Hg and understanding the timescales over which they redistribute and return Hg to the atmosphere is critical to understanding the global biogeochemical cycle. We will present recent results from an updated global terrestrial mercury model, featuring a revised parameterization for Hg dry deposition and bi-directional coupling with the GEOS-Chem global chemical transport model. We will then discuss the modeling constraints provided by observations from NADP Hg monitoring initiatives and will finish with discussion of the implications for modeled concentration and deposition patterns across the contiguous United States.

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TDep Measurement Model Fusion (MMF) method to fuse modeled and measured air quality data to estimate total deposition with Python geoprocessing

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To assess spatial and temporal trends in annual atmospheric deposition, the Total Deposition Science Committee (TDep) under the National Atmospheric Deposition Program (NADP) developed a measurement-model fusion (MMF) method to estimate fluxes of total, wet, and dry deposition of sulfur, nitrogen, base cations, and chloride. The TDep method provides interpolated maps of annual deposition from the year 2000 to the present, using a modeling approach that fuses the Community Multiscale Air Quality (CMAQ) model data with data from ambient air quality and wet deposition monitoring sites. Due to its large spatial coverage, fine spatial resolution (i.e. 4 x 4 km²), and multiple data sources, the TDep approach involves complex geoprocessing steps that require an organized and iterable implementation to support ongoing data production and future process enhancements. In an effort to modernize and streamline the method and facilitate the development of new features, a new modularized Python geoprocessing TDep application was developed. In this presentation, we will focus on the methodology of the TDep MMF method and the development and structure of the updated Python geoprocessing application. The developed Python framework breaks down the TDep approach into six modules: (1) data ingestion, (2) data interpolation, (3) bias adjustment for modeled data, (4) data fusion, (5) data aggregation, and (6) product export. Through the modularized framework, the Python application has greatly reduced the complexity of the codebase and will support streamlined processing. The new TDep framework will facilitate future improvements to the TDep MMF method, such as inclusion of satellite data or CMAQ-modeled wet deposition to improve the accuracy of interpolation for locations without available monitoring sites.

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Estimation of ammonia and nitrous oxide emissions from turfgrass systems using a dynamic chamber method and a biogeochemical modeling framework

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Turfgrass management is characterized by intensive use of fertilizers, irrigation, and pesticides that contributes to reactive nitrogen emissions to the atmosphere. This work aimed to estimate ammonia (NH₃) and nitrous oxide (N₂O) emissions from turfgrass systems by combining measurements from field experiments and simulations from a biogeochemical model. Field experiments were conducted seasonally using a dynamic flux chamber on a 50 ft by 50 ft experimental plot of tall fescue at Lake Wheeler Turfgrass Field Laboratory, Raleigh, NC. Measurements indicate a wide range of emissions for NH₃ (3.5-117.5 ng NH₃-N m⁻² s⁻¹) and N₂O (7.2-24.3 ng N₂O-N m⁻² s⁻¹). Both NH₃ and N₂O emissions were higher during spring and summer, suggesting that the emissions are influenced by temperature-regulated soil processes (e.g., NH₃ volatilization and microbially-driven denitrification). Meanwhile, the biogeochemical modeling simulations were performed using the Environmental Policy Integrated Climate (EPIC) model. The model utilized customized input files such as site information, daily weather data, soil physical and chemical characteristics, fertilizer types, and the site management options. Trace gas fluxes predicted by EPIC showed moderate to good correlation with measured fluxes (0.5-0.8) but tended to be biased low. Ongoing work seeks to refine the model configuration to reduce the observed bias. EPIC will then be used to explore optimal fertilization scenarios that balance turfgrass productivity with minimizing trace gas emissions.

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An application of machine learning to determine critical loads of nitrogen and sulfur in forest ecosystems in the U.S.

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Different approaches have been used to determine critical loads of air pollutants for the protection and recovery of ecosystems, including the application of steady-state and dynamic models and the development of empirical relationships or empirical critical loads. Critical load values derived from these approaches often have high uncertainty due to confounding factors, data limitations, and characteristics of the models themselves. Improving the characterization, quantification, and communication of uncertainty associated with critical load estimates, and reducing those uncertainties, have been established as important goals in future efforts to further develop and refine national-scale critical loads data. Machine learning models have shown great promise across a range of predictive tasks in the geosciences, substantially reducing inaccuracy in predictions by leveraging empirical relationships in input data. In this study, we investigate the potential application of machine learning techniques to determine critical loads of nitrogen and sulfur for forest ecosystems. Using the tree growth and survival database developed by Horn et al. (2018), we develop a machine learning regression model using the gradient boosted trees algorithm. The regression incorporates total nitrogen and sulfur deposition, as well as environmental factors such as mean annual temperature and precipitation. Using model interpretation techniques, including SHapley Additive exPlanations (SHAP) multi-variate partial plots, we interrogate the relationships between tree health and environmental factors including deposition, and we compare our relationships to those of Horn et al. We further examine the response surface of tree species health with changes in deposition to assess objective criteria for establishing a value of critical load. Our results indicate opportunities for using machine learning to develop critical load values. Future work will expand the data layers considered - including soil acidity, soil texture, available water storage, elevation and topography - to examine how environmental factors affect tree species response to changes in atmospheric deposition. In addition to examining the structural responses to variations in atmospheric deposition, we plan to evaluate functional responses of forest ecosystems (e.g., carbon and nitrogen sequestration, forest biomass production) to changes in atmospheric deposition.

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Modeled Exceedances of Critical Loads for Total Nitrogen and Sulfur Deposition

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The atmospheric deposition of nitrogen and sulfur and their relation to critical loads of atmospheric deposition is an important consideration for the preservation of national parks, wilderness areas, national monuments, wildlife refuges and other areas of interest. In this paper, we investigate the deposition of nitrogen and sulfur compounds in Kansas, Oklahoma, and Texas using the advanced photochemical grid model, CAMx. The model simulates the atmospheric chemistry, dispersion and dry and deposition of nitrogen and sulfur emissions from diverse anthropogenic sources as well as natural sources such as wildfires and biogenic emissions. Estimated future deposition rates due to projected cumulative emission sources in 2030 are compared with critical loads of acidity for surface waters and forests, and to empirical critical loads for nutrient nitrogen. The analysis uses critical load values from the National Critical Load Database that are dependent on a specific site and ecoregion. Specifically, the comparison was performed for sulfur and nitrogen acidity at over 145 surface waters and over 100,000 modeled forest ecosystem locations and for empirical critical loads of nutrient nitrogen at several federal Class I areas to estimate future potential exceedances of critical loads for atmospheric deposition at these sensitive ecosystems.

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Session 7: Critical Loads of Atmospheric Deposition

Terrestrial Critical Loads of Atmospheric Nitrogen and Sulfur Deposition: Model Development and Regional Assessment based on US-PROPS

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Forest understory plant communities in the eastern United States are often diverse and are potentially sensitive to changes in climate and atmospheric inputs of nitrogen caused by air pollution. In recent years, empirical and process-based mathematical models have been developed to investigate such changes in plant communities. A robust set of understory vegetation response functions (US-PROPS v2) has been developed based on observations of forest understory and grassland plant species presence/absence and associated abiotic characteristics derived from spatial datasets. Improvements to the US-PROPS model, relative to version 1, were mostly focused on inclusion of additional input data, development of custom species-level input datasets, and implementation of methods to address uncertainty. The US-PROPS v2 models have been used to evaluate the potential impacts of atmospheric nitrogen (N) and sulfur (S) deposition, and climate change on forest ecosystems at three forested sites located in New Hampshire, Virginia, and Tennessee in the eastern United States. Species-level N and S critical loads (CLs) were determined under ambient deposition at all three modeled sites. The lowest species-level CLs of N deposition at each site were between 2 and 11 kg N/ha/yr. Similarly, the lowest CLs of S deposition, based on the predicted soil pH response, were less than 2 kg S/ha/yr among the three sites. Critical load exceedance was found at all three model sites. The New Hampshire site included the largest percentage of species in exceedance. Simulated warming air temperature typically resulted in lower maximum occurrence probability, which contributed to lower CLs of N and S deposition. The US-PROPS v2 models are currently being used to derive CLs for understory plants within Great Smoky Mountains National Park.

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Interpreting terrestrial sulfur critical loads to protect national parks

Emmi Felker-Quinn¹, Michael D. Bell² and Nicholas A. Russell³

Most critical load research in the United States aims to protect ecosystems from the fertilizing effects of nitrogen deposition or from the acidifying effects of combined nitrogen and sulfur deposition. An analysis by Horn et al (2018) generated a set of species-specific critical loads to protect common species against growth and survival declines by correlating tree response with total nitrogen and total sulfur deposition. The sulfur-only critical loads protect 66 tree species against declines in growth or survival. The National Park Service is applying these sulfur critical loads within national parks and considering how to interpret the impacts of sulfur deposition on trees. We joined the S critical loads with park species lists along with annual total S deposition rates from Tdep to determine which parks and which tree species received S deposition in exceedance of their critical loads, and what the extent of the predicted declines in growth and survival were based on recent S deposition rates.

The tree-S critical loads ranged from 0.2 kg to 4.1 kg-S ha⁻¹ y⁻¹, while total S deposition from 2016-2018 within national parks ranged from 0.2 to 12.9 kg-S ha⁻¹ y⁻¹. There were 14 tree species with a growth or survival CL less than 1.0 kg-S ha⁻¹ y⁻¹; we considered designating these species as 'highly sensitive species' and not including their CLs in park CL summaries. Land managers applying these low CLs have reported healthy stands of trees in areas where deposition rates would predict dramatic declines, and with low S CLs, variation in annual S deposition rates attributable to changes in precipitation rather than changes in S emissions appeared to threaten park species. Of the 245 national park units with both S deposition data and CLs, 207 park units had at least one highly sensitive species. There were 61 parks whose only growth S CLs were for highly sensitive species, and 42 parks whose only survival S CLs were for highly sensitive species. These parks were in the Pacific West and Intermountain West Regions with S deposition rates ranging from 0.2 to 3.2 kg ha⁻¹ y⁻¹ in 2016-2018, and ponderosa pine set the lowest S CL for both growth and survival across the majority of these parks. It may be more appropriate to apply low S CLs regionally rather than exclude them in summarizing park critical loads.

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Exceedances of Critical Loads for Herbaceous Species in National Parks: Species at Risk, Local Responses, and Regional Trends

Nicholas Russell¹, Michael D. Bell² and Emmi Felker-Quinn³

The U.S. National Park Service uses critical loads to fulfill its mandate to preserve and protect natural resources, including protecting the integrity of native plant communities against the effects of nitrogen (N) deposition. Most N critical loads protect ecosystems on broad scales such as ecoregions and species alliances. However, recent research established critical loads for 205 herbaceous species based on conterminous United States (CONUS) presence-absence data for 348 herbaceous species from field-based studies. This research identified at-risk herbaceous species and applied predictive equations to create N critical loads for herbaceous species in national parks. First, we used N critical loads of probability of occurrence to evaluate potential risk to herbaceous species within 244 national parks in CONUS. Second, we used vegetation plots from nine case-study national parks to evaluate individual herbaceous species' responses to N deposition and create site-specific N critical loads based on total sulfur deposition as well as edaphic and climatic qualities.

All 348 of the selected herbaceous species were found to be present within the 244 national parks included in this study. Seventeen of these species occurred in over 60% of the national park's vegetation surveys. Critical loads for individual species ranged from 1.3 kg N ha⁻¹ yr⁻¹ to 18.95 kg N ha⁻¹ yr⁻¹ across the national parks. We found that an average of 17 species per national park were in exceedance of their CL based on maximum total N deposition. Of the species included in this analysis 64 were expected to respond to N deposition with an increase in probability of occurrence, 41 with a decrease, and 131 with an increase followed by a decrease. We found that 266 of the 348 herbaceous species were present in the nine case study parks, with 13,499 occurrences of one or more species within a vegetation plot overall. Using a subset of species that occurred in multiple plots, we found that 96% of the edaphic, temperature, and precipitation data values for these species fell within the range of data used to set the critical load. This study provides a framework for creating species- and location-specific critical loads, and results of this research will help park managers identify individual species most at risk to negative impacts of N deposition to prioritize future management.

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A Case Study: Critical Load Assessment in Areas above 1000 m in the Great Smoky Mountains National Park

Jason Lynch¹ and Selma Isil²

In the eastern U.S., there are considerable areas above 800 m where cloud/fog deposition is an important component of the deposition to ecosystems. Many of these areas include National Parks, protected Class I and Wilderness areas, and other preserves with rare and endangered species and ecologically important habitats. Protections of ecosystems in Class I and Wilderness areas from air pollution are mandated by Federal laws such as The Clean Air Act (CAA) and Wilderness Act. In addition, many of these landscapes are also sensitive to terrestrial and aquatic acidification because of their geology and landscape position. Over the past two decades, interest in better understanding of atmospheric inputs of pollutants to terrestrial and aquatic ecosystems has increased substantially within the scientific community through the use of the critical load (CL) approach. In order to develop scientifically defensible CLs and to evaluate whether ecosystems are protected from deposition resulting from air pollution, it is essential to have estimates of all components of deposition. This is particularly important for areas at high elevation where cloud/fog deposition is high and where many wilderness and sensitive ecosystems occur. Critical loads are being used more and more to assess management and regulations decisions. Critical loads help to inform whether a forest, stream, or area is at risk of being ecologically harmed from deposition caused by air pollution. In this case study, we examine the importance of cloud/fog deposition on CL exceedances (i.e., deposition > critical load) in areas above 1000 m in the Great Smoky Mountains National Park (GSMNP) in the southeastern United States, with parts in Tennessee and North Carolina.

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Assessing nitrogen critical loads at North Cascades National Park Service Complex

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Anthropogenic nitrogen (N) deposition (N_{dep}) contributes globally to disruptions in nutrient cycling, ecosystem functioning, and shifts in community composition. National Park Service (NPS) lands, including the North Cascades National Park Service Complex (NOCA), contain ecosystems that are potentially sensitive to N_{dep} . Accurate measurements of N_{dep} are needed to determine N critical loads, levels of N_{dep} that can be sustained without adverse biological effects. However, in the western U.S., complex topography and weather patterns can lead to difficulty in accurately estimating N_{dep} with predictive models. The N concentration of epiphytic lichens can be utilized to monitor N_{dep} because the relationship between lichen N concentration and N_{dep} can be modeled for a given region.

The goal of this study is to assess patterns of N_{dep} in NOCA and determine which ecosystems are affected by N_{dep} . We established 30 plots across NOCA to determine lichen community composition and N content and stable isotope composition in the summer of 2018 and 2019. Lichen N content (% dw) varied between 0.25 and 0.49 and estimated throughfall total inorganic N_{dep} spanned a range from 0.10 to 0.63 kg N ha⁻¹ year⁻¹, indicating low levels of N_{dep} throughout the park. We found levels of N_{dep} increased moving east in the northern portion of the park. There was not a strong relationship for lichen N content along an elevational gradient. Results will be incorporated with lichen community composition and atmospheric chemistry models in a GIS framework to develop a powerful approach to evaluate N critical load exceedance in the North Cascades. Integration with U.S. Forest Service (USFS) lichen air quality datasets will allow for further assessment of patterns of N_{dep} across the region.

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Incorporating Air Quality into the Resources Planning Act Assessment with Critical Loads and Deposition

Sarah Anderson¹, Claire O'Dea² and Jennifer Costanza³

The Forest and Rangelands Renewable Resources Planning Act (RPA) of 1974 requires the Forest Service to prepare an assessment of renewable natural resources on all the nation's forests and rangelands. The RPA Assessment, updated every five years, provides a snapshot of current U.S. forest and rangeland conditions and trends on all ownerships; identifies economic, social, and biophysical drivers of change; and projects conditions 50 years into the future. Resources covered include forests, rangelands, urban forests, forest products, carbon, wildlife and fish, biodiversity, outdoor recreation, wilderness, water, and the effects of socioeconomic and climate change on these resources.

A chapter focused on disturbances to forests and rangelands is being included for the first time in the 2020 RPA Assessment (anticipated publication early 2022). The chapter will focus on fire, drought, invasive species, and outbreaks of insects and diseases. Air quality as an ecological stressor will be included in the chapter as a sidebar with the goal of creating a platform from which future RPA work can explore current and projected impacts of air quality under different future scenarios.

Within the sidebar, EPA's Critical Loads Mapper is used to provide an illustrative example of how to understand air quality issues such as deposition and their impacts through critical loads. The advances in deposition and mapping critical loads allow us to demonstrate one way to make projections of future impacts and analyze future trends, demonstrating the relevance of addressing air quality in future RPA Assessments. The work of NADP and in particular CLAD is foundational to allowing us to make this demonstration and incorporate deposition and critical loads into the 2020 RPA Assessment.

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Session 8: Atmospheric Deposition and a Changing Society

Effect of atmospheric deposition on built heritage

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Although the everlasting preservation of cultural heritage is impossible, it is possible to improve conditions for them to last longer, but first we need to understand the complex relationship between different atmospheric conditions and the decay. Among them, atmospheric deposition plays a crucial role, because is an important cause of decay for built heritage which has been studied for more than half a century, but there have been more discoveries during the last couple of decades, as the relatively low impact of wet deposition (regardless its acidity) compared to dry deposition, the major importance of other atmospheric deposition-related mechanisms as salt recrystallization or the role of biodeterioration. Traditionally, most research on the subject has focused on carbonaceous stone, but nowadays it is known that the damage to building materials is caused by different physicochemical mechanisms into the atmosphere, most involving rainwater. This subject has been scarcely studied for different materials and in places outside Europe, although some researches have been done worldwide so this study is an advance to identify the effect of atmospheric deposition on built heritage in Mexico.

Among its lines of research, the National Autonomous University of Mexico (UNAM) participates with the CDMX Atmospheric Monitoring System (SIMAT) to evaluate the atmospheric deposition, its causes and provenance. The UNAM has also carried surveys on several heritage important sites, as Tulum, Puerto Morelos and El Tajín. Using the data, an Accelerated Weathering Chamber was designed and used to perform test on the mass loss due to the most acidic deposition sampled that the limestone used as building material in the Mayan area will have. Results show that average mass loss is about 241.64 $\mu\text{g}/\text{year}$. A decay function was proposed.

To continue the work and deepen the understanding of built heritage decay on different building materials under different conditions, we have chosen two sites in Mexico City: Templo Mayor, built with volcanic stone and the University City of UNAM built with Portland cement, and one site at Veracruz, San Juan de Ulúa, built with limestone. In this research, currently on development, we have already identified the atmospheric conditions (meteorology, air quality and atmospheric deposition) and will use the data to perform accelerated weathering test to different kinds of decay mechanisms, including salt recrystallization, leaching, dry deposition and thermal fatigue.

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Effects of Urbanization and Fragmentation on Atmospheric Nitrogen Deposition, Nitrogen Oxides, and Ozone in New England Forests

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In the northeastern U.S., rates of atmospheric nitrogen deposition are almost an order of magnitude greater than pre-industrial levels and are twice as high in urban compared to rural areas. Fragmentation of forests in this region is increasing as a result of urbanization. Previous studies show greater rates of atmospheric deposition at forest edges compared to forest interiors — a consequence of increased exposure of edge trees to atmospheric inputs, known as an edge effect. As the prevalence of fragmented forests increase throughout this region, it is important to understand how fluxes of atmospherically deposited and ambient pollutants affect nutrient cycling in forested ecosystems. In order to understand if edge effects are intensified due to urbanization, we quantified rates of nitrogen deposition and ambient concentrations of nitrogen oxides (NO_x) and ozone (O₃) across the forest edge to interior along an urbanization gradient that spanned 120 km from Boston to central Massachusetts. A transect established at each site extended from the forest edge (0 m) to 90 m into the forest interior, where three throughfall collectors and two Ogawa passive samplers for gasses were placed at each distance (n=6 throughfall and n=4 passive samplers per site). Additionally, three bulk throughfall collectors were placed in open fields nearby to each forest site. Across the years 2018 and 2019, we found a significant increase in the amount of nitrogen deposited at urban forest edges compared to interiors, while the pattern was not displayed in rural forests. Specifically, total nitrogen deposition at urban forest edges was 1.5-times that of urban interiors (5.0 ± 0.3 and 3.4 ± 0.3 kg N/ha/yr, respectively), while nitrogen deposition at rural forest edges was not significantly different from rural interiors — a finding which indicates an exacerbation of edge effects in urban areas. Additionally, concentrations of both NO_x and O₃ were two times higher in urban forests than rural forests, while edge and interior concentrations were only found to be significantly different in the urban sites. Results of this study provide insight into how forest fragmentation promotes increased atmospheric deposition and concentrations of ambient pollutants in both urban and rural forests and contributes to knowledge of how these pollutants are affected by both urbanization and fragmentation.

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Bioaerosol occurrence in working places

Francesca Buiarelli¹, Giulia Simonetti², Elisa Sonego³, Carmela Riccardi⁴, Patrizia Di Filippo⁵ and Donatella Pomata⁶

Bioaerosol represents the totality of aerosolized particles of biological origin. The aerodynamic diameters of particles can range from several nanometers to a few hundred micrometers.

Bioaerosols include bacterial and fungal spores/cells, algae, pollen, viruses, amoebae, lichens, archaea, aggregates of these particles, and fragments of larger organisms including, skin scales, animal and plant debris. Metabolites, excretion products, endotoxins, sensitizing substances and volatile organic compounds are included, as well. Biological particles have been linked to different health concerns, from simple mucous membrane irritation to inflammatory lung diseases, hypersensitivity pneumonitis etc., depending on both their characteristics and different penetrative capacity in our respiratory system.

Nowadays there is still a lack of information on biological risks in workplaces due to the objective difficulty of unequivocally measuring bioaerosol.

This study aimed to develop and improve the bioaerosol monitoring technique that uses proper biomarkers and their conversion factors as a tool. The results were compared with those obtained with classical biological approach and show that the chemical method covers some gaps in the information. Bioaerosol presence was monitored in working places affected by biological risk, with particular attention to wastewater treatment plants, composting plants, livestock farms. Differences up to two orders of magnitude are observed, by comparing the results obtained by biomarkers and by cultivation-dependent methods.

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Air Quality in Rocky Mountain National Park during the 2020 COVID19 Shutdown

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The air quality in Rocky Mountain National Park (RMNP) has been monitored over recent years to examine the influence of sources in the Front Range and other regions on fine particulate matter and trace gas concentrations. Reactive nitrogen species have been examined closely due to their contributions to excess nitrogen deposition and its impacts on RMNP ecosystems. Monitoring was originally not planned for 2020 but reinstated after the start of the COVID19 pandemic to explore whether the shutdown significantly changed the composition or concentration of key aerosol and gas species. Data collection began on April 25, 2020. Measurements were made using URG denuder-filter-pack sampling to measure inorganic gas and particle composition and wet-only precipitation sampling to measure wet deposition. The URG sampling began at daily (24 hr) time resolution and switched to twice weekly on June 8. Precipitation sampling began with bucket switches three times a week and switched to a weekly basis on June 8. Concentrations of $PM_{2.5}$, NH_4^+ , NO_3^- , and SO_4^{2-} and gaseous NH_3 , HNO_3 , and SO_2 were compared to concentrations measured in 2016-2019. The period of the shutdown was analyzed directly by comparing the data from April 25 – May 31 (a period when Colorado was under the tightest pandemic activity restrictions) to the previous years. No evidence was found of significant decreases in concentrations of the measured species during the COVID shutdown.[N1] While this result is somewhat surprising, it is important to keep in mind that, given the distance of RMNP from major pollutant sources, changes in meteorology (transport patterns, precipitation occurrence) play a large role in determining the likelihood of emissions from those sources reach the park. Air quality data from the Front Range will be examined to see if stronger pollutant trends are apparent closer to major source regions. The RMNP wet deposition data will also be examined to compare nitrogen deposition during the shutdown period to previous years. As upslope events with transport from the Front Range are major contributors to RMNP reactive N deposition, transport conditions from this year will also be compared to previous years.

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CASTNET Ozone Response to COVID-19 Related Impacts

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The Clean Air Status and Trends Network (CASTNET) is a long-term monitoring network designed to measure acidic pollutants and ambient ozone (O₃) concentrations in rural areas across the United States. CASTNET is managed collaboratively by the U.S. Environmental Protection Agency – Clean Air Markets Division (EPA), the National Park Service – Air Resources Division (NPS), and the Bureau of Land Management – Wyoming State Office (BLM-WSO). In addition to EPA, NPS, and BLM-WSO, numerous other participants provide site operator support and grant land access including North American tribes, other federal agencies, States, private landowners, and universities.

On March 13, 2020 the White House issued a national emergency concerning the COVID-19 outbreak and subsequently US state governors began issuing stay-at-home orders beginning with California on March 19, 2020 followed up by an additional 12 states issuing similar stay-at-home orders by March 23, 2020. By April 3, 2020, all but five US states have issued state-wide or partial-state stay-at-home orders.

We hypothesize that the stay-at-home orders likely reduced mobile, commercial, and industrial ozone-precursor emissions sufficiently to detect changes in regional air quality. To test this hypothesis, we compare hourly and daily maximum eight-hour average (DMA8) ozone values from 2020 against annual weekly averaged values from 2015-2019 from 75 CASTNET sites with more than 5 years of monitoring data.

Beginning the week of the declaration of the national emergency, March 9th, through August 9th, preliminary CASTNET ozone data show average relative percent differences of -7.4% in the 90th percentile 1-hour ozone values.

We compare the CASTNET ozone data with meteorological datasets from CASTNET, NOAA, and the National Atmospheric Deposition Program (when present) to determine meteorological impacts on ozone formation. Lastly, we analyze mobility changes based on Google community mobility reports, inferring that changes in mobility patterns suggest reduced emissions from the transportation sector.

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Poster Session

Emerging Contaminants and Issues

Biomonitoring of atmospheric deposition of heavy metals in Slovakia.

Jana Borovská¹, Blanka Maňkovská†² and Matej Florek³

The use of bryophytes as pollutant accumulators for monitoring changes in atmospheric deposition of heavy metals in Slovakia started more than 30 years ago. The Slovak survey is part of the ICP Vegetation programme: European surveys of heavy metal accumulation in mosses established in 1980. The surveys are conducted every five years. The last one in 2015/16.

In 1990, in connection with problems of forest dying in Slovakia, was in cooperation with ICP Forest Slovakia established a permanent monitoring net 16x16. For monitoring are sampled pleurocarpous mosses *Pleurozium schreberi*, *Hylocomium splendens*, *Hypnum cupressiforme* and *Dicranum* sp. Collected mosses are analysed in Joint Institute for Nuclear Research in Dubna, Russia by INAA method and in National Forest Centre in Zvolen, Slovakia are analysed N by EA method, Cu, Cd, Pb by ETA AS method.

It is assumed that in the Slovakia a large gradient of the atmospheric deposition load of elements exists because part of the territory belongs to the most polluted area in central Europe known as the 'Black Triangle II'.

Analyses from 68 monitoring plots detected (median) in mg.kg⁻¹: Ag(0.058); Al(706); As(0.456); Au(0.0017); Ba(42.6); Ca(3490); Cd(0.263); Ce(1.07); Co(0.329); Cr(2.78); Cs(0.192); Cu(9.11); Dy(0.340); Eu(0.053); Fe(672.5); Gd(0.162); Hf(0.091); I(0.73); In(0.014); K(8340); La(0.617); Lu(0.109); Mg(731.5); Mn(342); Mo(0.172); N(19.75); Na(174.5); Nd(1.415); Ni(2.26); Pb(0.946); Rb(12.4); S(1695); Se(0.223); Sb(0.217); Sc(0.192); Sm(0.098); Sr(15.3); Ta(0.016); Tb(0.013); Th(0.165); Tm(0.037); Ti(48.45); U(0.074); V(1.495); W(0.250); Yb(0.087); Zn(42.95); Zr(6.87).

The marginal hot spots were revealed in eastern part of Slovakia - near dumps of stone chips, manufacture of basic metals and fabricated metal product, chemical and military products (Snina, Strážske, Stropkov), Volovské Mts. (Central Spiš), Kremnické and Štiavnické Mts. (nonferrous ores processing and aluminium factories).

In comparison to the average Austrian and Czech values of heavy metal contents in mosses, the Slovak atmospheric deposition loads found to be higher on average. Spatial trends of heavy metal concentrations in mosses were metal-specific. Since 1990 has decreased the concentration of Cu, Cr, Fe, Ni, Pb, S, Zn and increased Cd, Mn and N.

References:

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Comparison of Aerosol Optical Depth from Satellite based observation over Surat region

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Aerosol Optical Depth (AOD) observed at Surat, Gujarat (INDIA), Coastal region near the Tapi River at the Gulf of Khambhat. Using MODIS Satellite data for Aerosol Optical Depth (AOD) have been collected from the Giovanni site (<http://giovanni.gsfc.nasa.gov/giovanni/>) developed by NASA. Results of the data for the 5-year period (January to December 2015-2019) have been discussed here. Daily, Monthly and Seasonal variations of Aerosol Optical depth (AOD) are related to changes in the regional meteorological conditions. The data collected during January to December 2015-2019 indicated annual average AOD variation. The mean annual variations of Aerosol Optical Depth (AOD) indicated maxima around the monsoon. The seasonal mean Aerosol Optical Depth (AOD) is lowest values are observed during the pre-monsoon, and relatively moderate AOD is observed during the winter season. Variation of aerosol optical depth (AOD) in post-monsoon season shows similar variation as of winter and pre-monsoon in 2016 while values increased afterwards and reached maxima in both Aqua and Terra observations which are mostly related to the changes in the local boundary layer.

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Particulate Matter Deposition to Urban Rock Pigeon (*Columba livia*) Feathers

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Birds have been used extensively as biomonitors of anthropogenic pollution with most research focused on internal accumulation of pollutants in bone, tissue, and feathers, and less on the external deposition of pollutants to bird surfaces. Rock pigeons (*Columba livia*) are a common bird species in urban environments and thus can serve as a useful study species for investigating how pollutant deposition varies across the landscape. This research investigates particulate matter (PM) deposition to rock pigeons in urban environments within Denton County, Texas. In summer 2020, feathers were sampled from rock pigeons at three locations varying in degree of urban development and distance to emissions sources. Coarse-scale land cover data and the fine-scale HERCULES classification were used to characterize rock pigeon habitat within a 2-km radius of each sampling location. In addition, a low-cost portable particle counter was used to monitor small and large particle concentrations at the sites. Birds were captured using walk-in funnel traps baited with bird seed. From each bird, older feathers based on molting pattern, one primary from each wing and two tail feathers, were sampled and the bird released unharmed. From each population sampled, a total of two new primary feathers were also plucked for comparison. Feathers will be washed with double deionized water and acetone, and the solution vacuum filtered sequentially to separate three fractions of PM: (1) large particles greater than 10 μm , (2) coarse particles 2.5 – 10 μm (PM_{10}); and (3) fine particles $\leq 2.5 \mu\text{m}$ ($\text{PM}_{2.5}$). PM mass will be determined by gravimetric analysis and calculated per unit feather surface area. Preliminary findings on PM deposition to bird feathers will be presented. Such information will prove valuable for determining the suitability of feathers of a common urban bird species to monitor variations in PM in small-scale urban environments.

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Initiation of Measurement of PFAS in Wet Deposition at four NADP sites in the Eastern United States

John offenberg¹, John Walker², Melissa Puchalski³, Douglas A Burns⁴, Andrew Johnson⁵ and Martin Shafer⁶

Per- and polyfluorinated alkyl substances (PFAS) are key chemicals associated with the production of fluorinated polymers. While PFAS compounds are known to be released to the environment, relatively little is known about the emissions to air of PFAS from production, commercial uses, end product uses, including aqueous film forming foams (AFFF) often used in firefighting applications, and disposal or incineration. Once released, it is currently believed that these PFAS compounds may be transported, may undergo chemical transformations, and may deposit to the earth's surface. Consequently, to begin to explore and evaluate the occurrence, and distribution of PFAS in precipitation, wet-only deposition sampling was initiated at four NADP sites. The four sites are Duke Forest, NC; Whiteface Mountain, NY; Washington's Crossing, NJ; and Casco Bay – Wolfe's Neck Farm, ME; NC30, NJ99, NY98 and ME96, respectively. These sites were selected as they span the east coast of the US, providing information on the spatial distribution of PFAS. Weekly integrated precipitation samples are being collected using existing NTN protocols, with the addition of a separate methanol bucket rinse designed to capture PFAS. Chemical analysis of the combined precipitation sample plus bucket rinse will be performed for 39 targeted PFAS using a modified ISO Method 21675 LC/MS approach developed by Wisconsin State Laboratory of Hygiene. Sampling began in September 2020, and will continue for two years, with additional investigation of replicate sampling to occur at NC30.

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Atmospheric Nitrogen and Mercury Assessments

Varied Host-Specific Mycorrhizal Response to Long-Term Nitrogen Fertilization in Bear Brook Watershed in Maine, USA

Sibi Kizhakkepurakkal¹, Ivan J Fernandez² and Seanna L Annis³

Chronic elevated N deposition over the decades has altered the biogeochemistry of temperate forests in many areas and affected belowground biota. The Bear Brook Watershed in Maine (BBWM) is a paired watershed manipulation experiment where one watershed was treated bi-monthly with nitrogen (N) and sulfur (S) as ammonium sulfate [(NH₄)₂SO₄] for 27 years to study the impacts of elevated N and S deposition on forest function. Prior research at BBWM reported a negative fertilization effect on fungal:bacterial ratio, although no further research was conducted to evaluate these findings. We hypothesized that long-term N treatment could have caused a decline in mycorrhizal colonization in all tree species throughout the treated watershed. We investigated ectomycorrhizal (ECM) and arbuscular mycorrhizal (AMF) root colonization in American beech (*Fagus grandifolia*), sugar maple (*Acre saccharum*) and red spruce (*Picea rubens*) in both the treated and reference watersheds. Soil and root samples were collected by randomly selecting seven trees of each species within each watershed. From each tree, two samples were collected in a 10 x 10 cm frame from the upper 10 cm of O horizon. Soils were analyzed for various chemical variables. For quantification of mycorrhizal root colonization, the gridline intersect method was used with stained mycorrhizal roots to estimate proportion of colonization, and the total root length with the presence of a Hartig net for ECM and vesicles/arbuscles/hyphae inside the cortical cells for AMF. A boosted regression model was used to determine the relative influence of soil chemical variables on mycorrhizal colonization. Our results demonstrated that treatment with N and S has significantly reduced ECM colonization in red spruce with 83 ± 2.7% and 69 ± 1.8% colonization, and significantly reduced AMF in sugar maple with 65 ± 2.2% and 49 ± 2.1% colonization, in reference and treated watersheds, respectively, while there was no significant effects on mycorrhizal colonization in American beech. For both types of mycorrhizal colonization, exchangeable Al was found to be the most influential soil variable. Our hypothesis was supported by only two of the three tree species thereby indicating a host-specific mycorrhizal response to the treatment. This study highlights the need to better understand the interaction between soil chemical variables, mycorrhiza, and their host in order to determine the effects of chronic N enrichment on forest ecosystem function.

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Isotopic Composition of Nitrate and Ammonium in Sao Paulo, Brazil Wet Deposition

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Humans have altered the nitrogen cycle by emitting excess reactive nitrogen into the atmosphere causing ammonia (NH₃) and nitrogen oxide (NO_x) concentrations in the atmosphere to increase exponentially over the last century. This excess nitrogen causes negative environmental and health effects by contributing to acid rain, decreased air quality, soil acidification, eutrophication, and a change in biodiversity. In order to better understand the nitrogen cycle, emission sources, and mitigation strategies, regional emissions of NH₃ and NO_x should be quantified. This study will measure the stable isotopic composition of nitrate (NO₃⁻) and ammonium (NH₄⁺) in wet deposition in order to estimate NH₃ and NO_x emission sources in the Ribeirao Preto region of Sao Paulo, Brazil. Wet deposition in the form of rain samples were collected after every rain event in Ribeirao Preto from October 2018 through October 2019. Preliminary δ¹⁵N-NO₃⁻ and δ¹⁵N-NH₄⁺ data from October 2018 to June 2019 ranged from -6.4 to 14.4‰ (n = 25) and -19.8 to 11.3‰ (n = 17) with an average of -0.9 ± 4.4‰ and -8.6 ± 7.4‰ respectively. The δ¹⁵N-NO₃⁻ and δ¹⁵N-NH₄⁺ values in rainwater will be corrected for fractionation processes and along with δ¹⁵N values of NO_x and NH₃ emission sources will be applied to the Stable Isotope Analysis in R (SIAR) mixing model program to estimate source contributions. This project will help understand the emission sources affecting air quality in Sao Paulo, Brazil and provide information on the emission and transportation of NO_x and NH₃ in the environment.

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Influence of meteorological conditions on the wet atmospheric deposition in the Metropolitan Area of Mexico City

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In the Mexico City Metropolitan Zone (MCMZ) the wet atmospheric deposition is a problem with great environmental impact due to its potential effects on ecosystems and cultural heritage. The understanding of the atmospheric emissions and the meteorological conditions of the study area allows us to know which are the specific conditions that aggravate it and gives us a key tool to reduce it and thus protect the environment.

The objective of this study was to evaluate the influence of meteorological conditions on the wet atmospheric deposition in the MCMZ. The rain samples were collected by the Wet Atmospheric Deposit Network (REDDA) operated by SIMAT, in the period 2013-2016 and analyzed in the University of Mexico (UNAM) laboratory. Meteorological information was obtained from the Meteorology and Solar Radiation Network (REDMET) operated by SIMAT. The chemical analysis of the samples consisted in the determination of the parameters recommended by the NADP protocol, which are: pH, electrical conductivity, concentration of cations (Na^+ , NH_4^+ , K^+ , Mg^{2+} , Ca^{2+}) and anions (Cl^- , NO_3^- and SO_4^{2-}). The NH_4^+ was the ion with the highest concentration ($\mu\text{Eq/L}$), while SO_4^{2-} present the highest deposition (kg/ha). The South region of the MCMZ showed the most acid pH. In addition, the relationships between the meteorological variables and the ion concentrations were analyzed by the Spearman correlation method, obtaining that the SO_4^{2-} ($r=20$) presented a greater contribution to the acidity of the rain and that the Ca^{2+} ($r=38$) contributed to the neutralization of acidic compounds. Likewise, the correlation showed that at higher temperature, the pH and ions concentrations are higher, while with greater precipitation and relative humidity, pH and ions concentration are lower. Through the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT), it was identified that the zones of origin of the acid rain precursors are those of the north (N), north-northwest (NNO) and north-northeast (NNE). Finally, measures were proposed such as the use of fuels fossils with less sulfur in energy and industrial sectors both in and outside MCMZ, in order to prevent, minimize and control acid rain precursors.

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Water-atmosphere flux of ammonia in subtropical semi-arid estuary systems

Warren Dunegan¹ and J. David Felix²

Water-atmosphere flux of ammonia (NH₃) remains an uncertainty in the global NH₃ budget and quantification is fundamental for estimating nitrogen deposition loading and cycling in sensitive coastal ecosystems. This study quantifies monthly water-atmosphere NH₃ flux at 10 sites (nine estuary sites and one Gulf of Mexico site) spanning ~400 km of the Texas Coastal Bend from 9/2018 to 4/2019. The regional average NH₃ flux was $2.52 \pm 3.57 \text{ ng m}^{-2} \text{ s}^{-1}$ denoting net NH₃ emission and the annual range among the 10 sites was -2.61 to 8.68 $\text{ng m}^{-2} \text{ s}^{-1}$. This range falls within the range of the very limited number of reported water-atmosphere NH₃ fluxes in the open ocean and estuaries. Generally, NH₃ flux in fall months featured NH₃ emission from surface waters while winter featured NH₃ deposition and spring months varied between emission and deposition. Many physical and chemical factors (e.g. temperature, salinity, NH₄⁺ (aq), atmospheric NH₃, wind speed, pH) impact the direction and magnitude of NH₃ flux and principal component analysis is employed to provide insight to the significant influences on flux. The overall annual emission flux of $0.79 \text{ kg ha}^{-1} \text{ yr}^{-1}$ is ~18% of recently modeled total dry N deposition for the region ($4.5 \text{ kg ha}^{-1} \text{ yr}^{-1}$). An approximate total of 0.33 Mg NH₃ is emitted from the nine estuaries per year, and although still dwarfed by agricultural emissions, this is ~4.6 and 1.2 times greater than National Emissions Inventory estimated emissions for electric generating units and on-road vehicles, respectively, in surrounding Texas Coastal Bend counties. As a potentially substantial contributor to NH₃ concentrations in local ambient air and emission/deposition pathway in sensitive coastal environments, the water-atmosphere flux of NH₃ requires comprehensive quantification across varying estuary systems to aid nitrogen loading estimates and guide NH₃ emission mitigation efforts.

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Quantification and Transformation of Water Soluble Organic Nitrogen in a Coastal Urban Airshed

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In recent years, atmospheric organic nitrogen (ON) has been garnering attention, however, studies have been limited. This can be attributed to ON's complex chemical composition which can undergo biological/photochemical transformation and the historical view that ON was not readily bioavailable. In this study, the deposition and concentration of water soluble inorganic nitrogen species (WSIN; NO_3^- , NH_4^+) and water soluble organic nitrogen (WSON) in $\text{PM}_{2.5}$ and PM_{10} was quantified in a coastal urban airshed, Corpus Christi, Texas. The measured concentration of WSON and WSIN showed variation on a monthly and seasonal basis. It was observed that for WSIN PM_{10} , nitrate (NO_3^-) had higher concentration in winter ($0.81 \mu\text{g m}^{-3}$) compared to other seasons (fall = $0.72 \mu\text{g m}^{-3}$ and spring = $0.61 \mu\text{g m}^{-3}$). While ammonium (NH_4^+) concentration decreases from fall to spring (0.17 to $0.078 \mu\text{g m}^{-3}$). The PM_{10} annual deposition flux of NO_3^- was $231.8 \text{ mg m}^{-2} \text{ yr}^{-1}$ and NH_4^+ was $21.2 \text{ mg m}^{-2} \text{ yr}^{-1}$. On the other hand, the seasonal trends of $\text{PM}_{2.5}$ WSIN were the opposite. Both NO_3^- and NH_4^+ concentrations were higher in the fall ($0.24 \mu\text{g m}^{-3}$; $0.085 \mu\text{g m}^{-3}$) and in winter, a decrease in concentration ($0.075 \mu\text{g m}^{-3}$; $0.011 \mu\text{g m}^{-3}$). Then in spring there is a gradual increase of concentration ($0.19 \mu\text{g m}^{-3}$; $0.035 \mu\text{g m}^{-3}$) for NO_3^- and NH_4^+ respectively. Compared to WSIN PM_{10} , $\text{PM}_{2.5}$ annual fluxes ($\text{NO}_3^- = 58.8 \text{ mg m}^{-2} \text{ yr}^{-1}$; $\text{NH}_4^+ = 9.41 \text{ mg m}^{-2} \text{ yr}^{-1}$) were much lower. In addition, the seasonal mean WSON concentration decreased from fall to spring ($0.26 \pm 0.16 \mu\text{g m}^{-3}$, $0.064 \pm 0.017 \mu\text{g m}^{-3}$, $0.038 \pm 0.013 \mu\text{g m}^{-3}$) in $\text{PM}_{2.5}$. The WSON PM_{10} , also decreased from fall to winter ($0.23 \pm 0.14 \mu\text{g m}^{-3}$, $0.084 \pm 0.075 \mu\text{g m}^{-3}$), but WSON in the spring gradually increased ($0.12 \pm 0.14 \mu\text{g m}^{-3}$). The WSON annual fluxes in PM_{10} is much greater ($1026.8 \text{ mg m}^{-2} \text{ yr}^{-1}$) than in $\text{PM}_{2.5}$ ($91.4 \text{ mg m}^{-2} \text{ yr}^{-1}$). Furthermore, comparing the $\text{PM}_{2.5}$ and PM_{10} WSON values with those reported in literature indicate that WSON concentrations are within similar range of those in Indian Ocean (Amsterdam Island), Florida (Tampa Bay) and N. California (Davis), Kofu and Rishiri Island, Japan. Overall, the $\text{PM}_{2.5}$ and PM_{10} annual deposition fluxes were $838.83 \text{ mg m}^{-2} \text{ yr}^{-1}$ and $7607.7 \text{ mg m}^{-2} \text{ yr}^{-1}$, accordingly.

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National view of temporal atmospheric mercury deposition across Canada using lake sediment cores

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Mercury (Hg) is a pollutant of concern globally which is emitted into the atmosphere largely from coal combustion, gold mining and metal smelting, and can be transported over large distances due to its long atmospheric residence time. Due to a paucity in atmospheric Hg deposition measurements, the relationship between implementation of emission controls and deposition fluxes to the landscape are not well constrained. In this study, we apply statistical methods to Hg flux data obtained from 82 dated lake sediment cores spanning latitudinal and longitudinal gradients across Canada to examine recent trends (post-1990) in atmospheric Hg deposition. Cores were collected from 2007 to 2018 from lakes located nearby known point sources, such as Flin Flon and Thompson (MB) smelters and urban centres (Toronto and Montreal), as well as within remote locations such as Kejimikujik National Park (NS) and Experimental Lakes Area, Northwestern Ontario. Redundancy analyses show that variation in recent anthropogenic Hg flux is driven largely by proximity to point sources. Not surprisingly, lakes located nearby (< 100 km) point sources were hotspots for Hg deposition, such as the Flin Flon smelter. A longitudinal gradient was also observed, with greater recent (post-2005) change in anthropogenic Hg fluxes recorded in eastern lakes. Eastern and remote sites across Canada also exhibited significantly increasing trends in recent (post-2005) anthropogenic Hg deposition while western sites showed either a plateau or decreasing trend. Comparison of sediment-derived anthropogenic Hg fluxes with modelled Hg fluxes across Canada, obtained from the Global Regional Atmospheric Heavy Metals Model (GRAHM) demonstrate that Hg fluxes obtained from these different methods compare well, with the exception of Hg hotspot regions. At sites where Hg in precipitation is being monitored, we are comparing sediment-derived Hg fluxes to Hg wet deposition data and results will be presented. Overall, our results show that dated lake sediment cores, particularly when multiple cores are collected from one region, can reliably track changes in anthropogenic Hg atmospheric deposition over broad geographical areas where monitoring data is lacking.

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Lower Eastern Shore Ambient Air Quality Monitoring Project

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The Eastern Shore of Maryland is home to some 500 CAFO- Concentrated Animal Feeding Operations raising 30,000-560,000 chickens at a time. Recent citizen complaints about air pollution and offensive odors emanating from chicken houses have led to a project by the Maryland Department of the Environment in collaboration with faculty from the Department of Natural Sciences at the University of Maryland Eastern Shore with funding provided by the Delmarva Poultry Industry, Inc. and the Keith Campbell Foundation for the Environment. This one-year project will measure ambient air quality on the Lower Eastern Shore of Maryland. Ammonia, PM2.5, PM10 and meteorological conditions will be monitored continuously at four separate locations. Two sites are on the lower shore (with one having a significant number of CAFOs nearby), one on Horn Pt in Cambridge MD and one in Baltimore City. A comparison and air quality analysis between the four sites will be performed following the one year of measurements.

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Atmospheric Deposition Modeling

Atmospheric inorganic nitrogen (N) deposition to Latin American cities: Comparison of field and Geos-Chem model estimates

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In Latin America, atmospheric deposition is a major, and sometimes the primary, vector of nitrogen (N) inputs to terrestrial ecosystems. In this study, our objectives were to: (1) estimate rates of atmospheric wet inorganic N ($\text{NH}_4\text{-N} + \text{NO}_3\text{-N}$) deposition to 16 Latin American cities using observed and modeled N deposition data; and (2) evaluate the performance of a global 3-D chemical transport model in predicting observed wet N deposition rates within and across sites. Published estimates of wet or bulk (hereafter wet) inorganic N deposition measured between 2006-2010 were compiled and annual wet, dry particulate, and dry inorganic N deposition to Latin America was modeled using the GEOS-Chem Chemical Transport Model. We evaluated the performance of GEOS-Chem for modeling inorganic wet N deposition to Latin American cities using spatial assessments, linear regression analysis, and the normalized mean bias. Mean annual inorganic N deposition for sites with in-situ measurements of both $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ ranged from 2.78-16.8 kg N ha⁻¹ yr⁻¹. Ammonium-N was generally the dominant form of N deposited, comprising 48-90% of observed inorganic N. Spatial patterns of observed N were similar to modeled estimates of wet N deposition. However, the model underestimated observed $\text{NH}_4\text{-N}$ deposition at most sites, while the model both over- and under-estimated $\text{NO}_3\text{-N}$ deposition. Use of modeled wet plus dry particulate N as a predictor of observed N did not improve R² values but resulted in a slight improvement in normalized mean bias for $\text{NH}_4\text{-N}$ and inorganic N. GEOS-Chem captured variation in N deposition across sites better than variation among years at any given site. Our preliminary findings suggest that even at coarse spatial resolution, GEOS-Chem performs relatively well when compared to in-situ measured deposition in under-sampled urban areas of Latin America.

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EQUATES: EPA's Air QUALity TimE Series Project

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The Community Multiscale Air Quality modeling system (CMAQ; <https://www.epa.gov/cmaq>) estimates atmospheric concentrations and deposition for numerous chemicals, including ozone, PM_{2.5} and its constituents, and deposition of important nitrogen and sulfur species. CMAQ concentration and deposition values are an important input to the NADP Total Deposition (TDep) maps and grids. The current TDep maps are based on a time series (2002-2012) of model values using CMAQv5.0.2. The US EPA is developing a set of 2002 through 2017 meteorology and air quality simulations to be used to update the TDep maps and support other EPA tools and data products (e.g. EnviroAtlas, model-observation "fused" maps of ozone and PM_{2.5}). Modeled datasets cover the Conterminous US at a 12 km horizontal grid spacing and the Northern Hemisphere at a 108 km using WRFv4.1.1 for meteorology and CMAQv5.3.2 for air quality modeling. CMAQv5.3.2 contains many important science updates which can impact both concentration and deposition. New hemispheric and North American emissions inventories were also developed using, to the extent possible, consistent input data and methods across all years to improve model estimated trends. This poster presentation will describe the development of the model simulations and plans for sharing the model output to support a wide variety of human health and ecological applications.

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Modeling the Source Sectors Contribution to Nitrogen Deposition in United States

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The excessive deposition of atmospheric nitrogen containing species to aquatic systems and watersheds can lead to harmful algae growth and loss of biodiversity, particularly in coastal waterways. It increases the risk of acidification and hypoxia by reducing oxygen levels for living organisms in marine environments. It is important to determine the major species, source sectors, and source regions responsible for atmospheric nitrogen deposition to develop effective watershed management systems. We use the Comprehensive Air Quality Model with extensions (CAMx) version 6.0, along with the Particulate Matter Source Apportionment Technology (PSAT), to identify and separate source sector contributions to atmospheric nitrogen deposition. We model the amount of atmospheric nitrogen deposition from different source sectors such as electricity generating units, biogenic emissions, area fugitive dust, on-road non-refueling, on-road refueling, residential wood combustion, agricultural emissions, non-point source oil and gas, point source oil and gas, fires, non-road mobile equipment sources, marine vessels and locomotives, and other non-point sources in the contiguous United States, southern Canada, and northern Mexico. We use emissions, meteorology, boundary conditions, and ozone column inputs from the United States Environmental Protection Agency's 2011 Modeling Platform. We evaluate the wet and dry deposited mass of atmospheric nitrogen containing species against measurements. This information will aid environmental regulators in developing watershed management plans to protect the health of aquatic and terrestrial ecosystems.

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Atmospheric Deposition and Extreme Conditions

Characterization of Texas Wildfires during the 2011-2014 Drought: A Prelude to Identifying Chemical Signatures of Smoke in Rain

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From 2011 to 2014, the most severe and intense drought in Texas recorded history led to widespread wildfires across the state, with unknown effects on atmospheric nutrient and pollutant deposition. This research aims to: (1) characterize the frequency, magnitude, and spatiotemporal distribution of Texas wildfires and (2) examine the influence of wildfire on rainwater chemistry during this exceptional drought period. We coupled wildfire data from the Monitoring Trends in Burn Severity (MTBS) database and the Hazard Mapping Fire and Smoke (HMS) product from the National Atmospheric and Oceanic Administration to begin to address these objectives. During the focal period, 324 wildfires burning ≥ 405 ha were recorded, 234 of which occurred in 2011. Over the entire period, we identified 17 extreme wildfires, defined as those falling in the 95th percentile of hectares burned. These fires represented 5% of all wildfires but accounted for 90% of the total hectares burned from 2011 to 2014. Extreme wildfires were also spatially concentrated, with 14 of 17 occurring in West Texas ecoregions (i.e., Chihuahuan Desert, High Plains, Southwestern Tablelands, Edwards Plateau). The HMS data showed that the Texas NTN sites with the highest number of registered smoke days in 2011 were TX03 (Beeville; $n = 81$) and TX56 (LBJ National Grasslands, $n = 73$). These sites were also more affected by heavy smoke days compared to the other sites. The primary origins of smoke at Beeville were Texas (25), Mexico (21), and the Gulf of Mexico (21). LBJ was heavily impacted by these same source areas, but was also affected by neighboring states New Mexico, Oklahoma, and Arkansas). Future work will investigate chemical signatures of smoke in rain to determine wildfire impacts on deposition loading to ecosystems.

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Assessing multiple soil resource limitations on dryland soil microbial communities: inferences from a short-term C, N and P addition laboratory incubation experiment

Jennifer Holguin¹ and Dr. Jennie R. McLaren²

Numerous nitrogen (N) addition studies suggest that anthropogenic N deposition is one of the most prominent factors driving global change. Our understanding of the effects of N deposition on ecosystem structure and function however, has been derived from studies concentrated in temperate mesic systems, thus leaving us relatively incomplete understanding on how N deposition can impact drylands, the largest terrestrial surface on earth. Dryland response to N enrichment is likely to differ from more mesic systems, due to the unique climatic and environmental characteristics that drylands possess. Drylands are frequently characterized as being primarily water limited or co-limited by water and N but they also contain low standing stocks of soil organic matter. Therefore, in addition to N, other critical resources, such as carbon (C) and biologically derived phosphorous (P) may also be limiting to dryland biota. Knowledge of resource limitation is fundamental to our understanding of how ecosystems respond to change. In this study, we seek to determine if dryland soil microbes are limited by C, N and/or P when given sufficient water. We conducted a short-term (16-day), fully factorial C, N and P addition laboratory incubation experiment using soil collected from a semi-arid Chihuahuan Desert grassland, located at the Carlsbad Caverns National Park. Measurements include soil microbial biomass C, N and P (MBC, MBN and MBP respectively). After 16 days, MBC increased when N or P were added (alone and in combination), where the greatest increase was observed under the C, N and P combination treatment, suggesting that the dryland microbial community is nutrient limited. When C, N and P were added in combination MBN (i.e., N storage by soil microbes) increased. MBP increased with the addition of N, suggesting N-limitations to P uptake by microbes. Overall, our results suggest that soil microbial communities in this dryland ecosystem are indeed limited by multiple resources. Therefore, while ecosystem function can be altered by N deposition, responsiveness to N enrichment may be dependent on the system's ability to overcome other resource limitations. In sum, multiple resource limitations may constrain our ability to predict the effects of anthropogenic N deposition in dryland ecosystems.

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Hurricane/tropical storm rainwater chemistry in the US (2008 to 2019)

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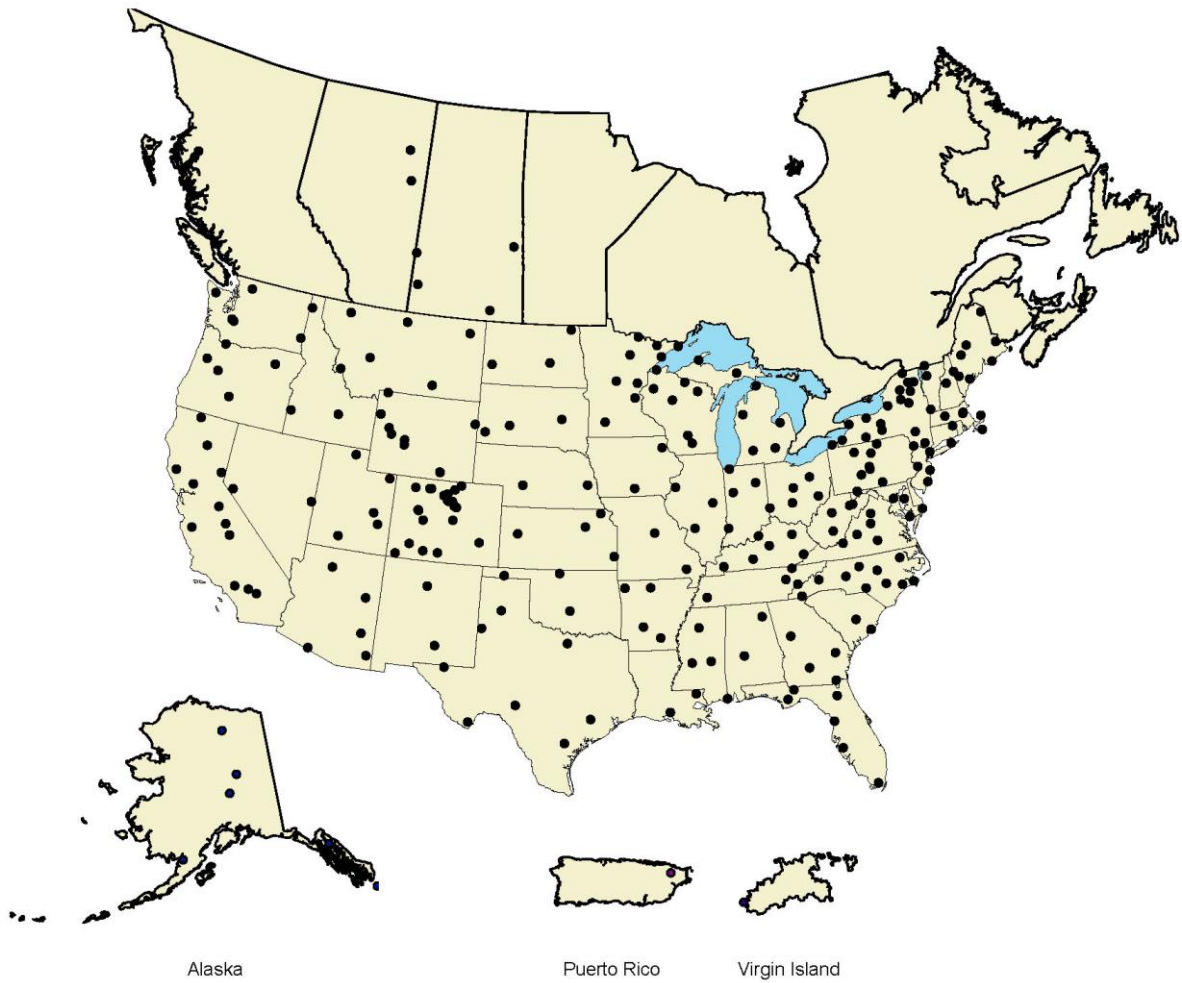
Rainwater chemistry is well documented worldwide but the components of extreme rain events are not well characterized. This is despite an increasing trend in intensity and frequency of extreme events and the potential excess loading of essential elements to ecosystems that can rival total annual loading. As extreme rain events become more prevalent, an assessment of the impacts imposed by hurricane/tropical storm events can be valuable for future resiliency strategies. Here the chemical characteristics of hurricane/tropical storms and normal rain events from 2008 to 2019 were acquired from the National Atmospheric Deposition Program (NADP). It was found that the average pH of hurricane/tropical storm events (5.36) was slightly higher ($p < 0.05$) than that of normal events (5.14). About 81% of 164 hurricane/storm samples and 85% of 5602 normal rain samples had pH below 5.6. NH_4^+ was the dominant neutralization ion for both hurricane/tropical storm and normal rain events. On average, one single hurricane/tropical storm event can deposit 8% of yearly rain volume in the hurricane affected region. It can also deposit an annual mean of 6% of Ca^{2+} , 10% of Mg^{2+} , 10% of K^+ , 11% of Na^+ , 4% of NH_4^+ , 3% of NO_3^- , 11% of Cl^- and 5% of SO_4^{2-} . Hurricane Barry alone contributed 52%, 56% and 55% of yearly deposition of Mg^{2+} , Na^+ and Cl^- , respectively, in 2019. Tropical Storm Colin contributed 47%, 19%, 15% and 15% of yearly deposition of Ca^{2+} , NH_4^+ , NO_3^- and SO_4^{2-} , respectively, in 2016. Investigating ionic composition via principal component analysis suggests five potential sources (i.e. marine, crust, fossil fuel combustion, agriculture and biomass burning) contribute to the chemical composition of rain. Mg^{2+} , Na^+ and Cl^- were primarily marine-originated in both normal and hurricane/tropical storms events. Hurricane/tropical storms events could bring considerable sea-salt SO_4^{2-} and Ca^{2+} whereas biomass burning and crust dust from wind erosion was the dominant source of SO_4^{2-} and Ca^{2+} , respectively, in normal rain events. Extreme rain events are associated with high wind speeds and suspend soil materials in the air, subsequently depositing crust-originated ions (i.e. K^+ and Ca^{2+}). Agriculture and fossil fuel were the primary sources of NH_4^+ and NO_3^- , respectively, in both rain events. Results will provide a comprehensive assessment of the rainwater chemistry of hurricane/tropical storms and insight to expected ecosystem loading for future extreme events.

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National Atmospheric Deposition Program

National Trends Network (NTN)



Sites Active in 2019

NTN

Site ID	Site Name	Site Sponsor	Start Date
AB32	Fort Mackay	Wood Buffalo Environmental Association	9/13/2016
<u>AB34</u>	Stony Mountain	Wood Buffalo Environmental Association	4/24/2019
<u>AB36</u>	Wapasu	Wood Buffalo Environmental Association	11/5/2019
AK01	Poker Creek	USDA - Forest Service	12/29/1992
AK02	Juneau	USDA - Forest Service	6/22/2004
AK03	Denali National Park-Mt. McKinley	National Park Service - Air Resources Division	6/17/1980
AK96	Toolik Field Station	University of Alaska-Fairbanks	10/12/2017
AK97	Katmai National Park - King Salmon	National Park Service - 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	National Park Service - Air Resources Division	7/13/1982
AR27	Fayetteville	U.S. Geological Survey	5/13/1980
AZ03	Grand Canyon National Park-Hopi Point	National Park Service - Air Resources Division	8/11/1981
AZ06	Organ Pipe Cactus National Monument	National Park Service - Air Resources Division	4/15/1980

AZ97	Petrified Forest National Park-Rainbow Forest	National Park Service - 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	USDA - Forest Service	4/24/2007
CA42	Tanbark Flat	USDA - Forest Service	1/12/1982
CA45	Hopland	U.S. Geological Survey	10/3/1979
CA50	Sagehen Creek	U.S. Geological Survey	11/6/2001
CA66	Pinnacles National Monument-Bear Valley	National Park Service - Air Resources Division	11/2/1999
CA67	Joshua Tree National Park-Black Rock	National Park Service - Air Resources Division	9/19/2000
CA75	Sequoia National Park-Giant Forest	National Park Service - 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	USDA - Forest Service	5/9/2006
CA96	Lassen Volcanic National Park-Manzanita Lake	National Park Service - Air Resources Division	6/13/2000
CA99	Yosemite National Park-Hodgdon Meadow	National Park Service - 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	6/5/1984
CO06	CAMP	City 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 / National Park Service - Air Resources Division	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
CO13	Fort Collins	U.S. Geological Survey	12/4/2018
CO15	Sand Spring	U.S. Bureau of Land Management	3/20/1979
CO19	Rocky Mountain National Park-Beaver Meadows	National Park Service - Air Resources Division	5/29/1980
CO21	Manitou	USDA - Forest Service	10/17/1978
CO22	Pawnee	Colorado Department of Public Health and Environment	5/22/1979
CO84	Betasso	U.S. Geological Survey	5/2/2017
CO85	Boulder	Colorado Department of Public Health and 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 and Environment	1/10/2017
CO90	Niwot Ridge-Southeast	INSTAAR - University of Colorado	1/24/2006
CO91	Wolf Creek Pass	USDA - Forest Service	5/26/1992
CO92	Sunlight Peak	U.S. Environmental Protection Agency - Clean Air Markets	1/13/1988
CO93	Buffalo Pass - Dry Lake	USDA - Forest Service	10/14/1986
CO94	Sugarloaf	U.S. Environmental Protection Agency - Clean Air Markets	11/4/1986
CO96	Molas Pass	USDA - Forest Service	7/29/1986
CO97	Buffalo Pass - Summit Lake	USDA - 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	U.S. Fish and Wildlife Service	8/27/1996
FL11	Everglades National Park- Research Center	National Park Service - 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	U.S. Fish and Wildlife Service	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	USDA - Forest Service	12/31/2002
ID03	Craters of the Moon National Monument	National Park Service - 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	lhambra	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	National Park Service - 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	National Park Service - 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	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	National Park Service - 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
MA22	Boston University	Boston University	6/16/2015
MA98	Arnold Arboretum	Harvard 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	Maine Department of Environmental Protection	4/14/1980
ME02	Bridgton	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	11/20/1979
ME94	Indian Township	Passamaquoddy Tribe	10/3/2013
ME96	Casco Bay-Wolfe's Neck Farm	Maine Department of Environmental Protection	1/6/1998
ME98	Acadia National Park-McFarland Hill	National Park Service - 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	U.S. Fish and Wildlife Service	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	USDA - Forest Service	10/10/1978
MI99	Chassell	USDA - Forest Service	2/15/1983
MN01	Cedar Creek	Minnesota Pollution Control Agency	12/31/1996
MN08	Hovland	Minnesota Pollution Control Agency	12/31/1996
MN16	Marcell Experimental Forest	USDA - 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	National Park Service - 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	USDA - 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	National Park Service - 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	USDA - 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
NC25	Coweeta	USDA - Forest Service	7/5/1978
NC29	Hofmann Forest	U.S. Geological Survey	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
NC41	Finley Farm	North Carolina State University	10/3/1978
NC45	Mt. Mitchell	U.S. Geological Survey	11/26/1985
ND00	Theodore Roosevelt National Park-Painted Canyon	National Park Service - Air Resources Division	1/30/2001
ND08	Icelandic State Park	U.S. Geological Survey	10/25/1983
ND11	Woodworth	U.S. Geological Survey	11/19/1983
NE15	Mead	University of Nebraska–Lincoln - State Agricultural Experiment Station	7/25/1978
NE99	North Platte Agricultural Experiment Station	U.S. Geological Survey	9/24/1985
NH02	Hubbard Brook	USDA - Forest Service	7/25/1978
NJ00	Edwin B. Forsythe National Wildlife Refuge	U.S. Fish and Wildlife Service	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	National Park Service - 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	National Park Service - Air Resources Division	1/15/1985
NY01	Alfred	U.S. Geological Survey	8/17/2004

NY06	Bronx	New York State Energy Research and 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 and 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 and Development Authority	12/31/2012
NY43	Rochester	New York State Energy Research and 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 and 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 and Development Authority	10/29/2013
NY93	Paul Smith's	New York State Energy Research and Development Authority	1/1/2013
NY94	Nick's Lake	New York State Energy Research and Development Authority	11/3/2015

NY96	Cedar Beach-Southold	Suffolk County (New York)	11/25/2003
NY98	Whiteface Mountain	U.S. Geological Survey	7/3/1984
NY99	Westpoint	U.S. Geological Survey	9/13/1983
OH09	Oxford	U.S. Geological Survey	8/14/1984
OH17	Delaware	USDA - 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	USDA - 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
PA13	Allegheny Portage Railroad National Historic Site	The Pennsylvania State University	7/26/2011
PA15	Penn State	National Oceanic and Atmospheric Administration - Air Resources Laboratory	6/7/1983
PA18	Young Woman's Creek	U.S. Geological Survey	4/20/1999
PA29	Kane Experimental Forest	USDA - Forest Service	7/18/1978
PA30	Erie	The Pennsylvania State University	7/27/2011
PA42	Leading Ridge	The Pennsylvania State University	4/25/1979

PA72	Milford	USDA - Forest Service	12/27/1983
PA90	Hills Creek State Park	Pennsylvania Department of Environmental Protection	7/26/2011
PR20	El Verde	USDA - Forest Service	2/12/1985
SC05	Cape Romain National Wildlife Refuge	U.S. Fish and Wildlife Service	11/21/2000
SC06	Santee National Wildlife Refuge	U.S. Geological Survey	7/19/1984
SD04	Wind Cave National Park-Elk Mountain	National Park Service - 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	National Park Service - 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
TX04	Big Bend National Park - K-Bar	National Park Service - 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	Texas A&M University	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	National Park Service - Air Resources Division	11/11/1997
UT95	East McKee	USDA - Forest Service	12/5/2017
UT98	Green River	U.S. Geological Survey	4/25/1985
UT99	Bryce Canyon National Park-Repeater Hill	National Park Service - 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	National Park Service - Air Resources Division	5/12/1981
VA99	Natural Bridge Station	USDA - Forest Service	7/2/2002
VI01	Virgin Islands National Park-Lind Point	National Park Service - 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	National Park Service - Air Resources Division	5/20/1980
WA19	North Cascades National Park-Marblemount Ranger Station	U.S. Geological Survey	2/7/1984
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	USDA - Forest Service	5/7/2002
WA99	Mount Rainier National Park-Tahoma Woods	National Park Service - Air Resources Division	10/26/1999
<u>WI06</u>	UW Arboretum	University of Wisconsin State Laboratory of Hygiene	2/11/2019
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	USDA - 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	USDA - Forest Service	7/5/1978
<u>WV99</u>	Canaan Valley Institute	National Oceanic and Atmospheric Administration - Air Resources Laboratory	8/27/2019
WY00	Snowy Range	USDA - 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	National Park Service - Air Resources Division	6/5/1980
WY94	Grand Tetons National Park	Wyoming Department of Environmental Quality	9/27/2011
WY95	Brooklyn Lake	USDA - Forest Service	9/22/1992
WY97	South Pass City	USDA - Forest Service-Shoshone National Forest	4/30/1985
WY98	Gypsum Creek	USDA - Forest Service-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)



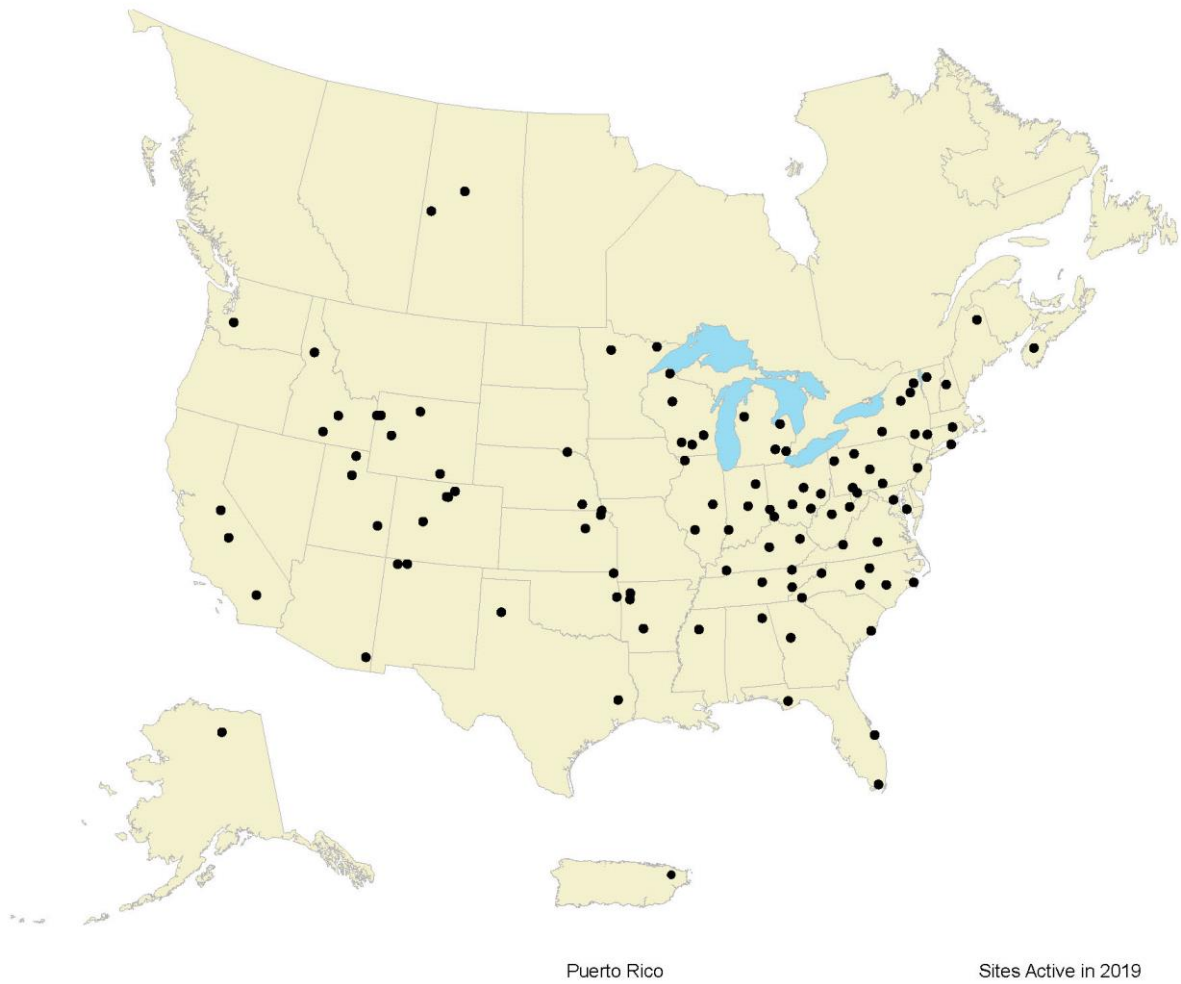
Sites Active in 2019

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
<u>AB35</u>	Elk Island	Alberta Ministry of Environment and Parks	10/15/2019
AK96	Toolik Field Station	U.S. Bureau of Land Management	9/4/2018
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	National Park Service - Air Resources Division	3/22/2011
CA44	Yosemite NP - Turtleback Dome	National Park Service - Air Resources Division	3/15/2011
CA67	Joshua Tree National Park-Black Rock	National Park Service - Air Resources Division	3/1/2011
CA83	Sequoia NP - Ash Mountain	National Park Service - 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	National Park Service - Air Resources Division	5/10/2011
CO98	Rocky Mountain National Park-Loch Vale	National Park Service - 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	National Park Service - 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	National Park Service - Air Resources Division	6/7/2010
ID07	Nez Perce	U.S. Environmental Protection Agency - Clean Air Markets	12/15/2015
ID14	Kimberly	USDA-Agricultural Research Service	6/13/2017
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
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
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	8/22/2018
NE09	Homestead	National Park Service - Air Resources Division	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 and Climate Change 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
NY96	Cedar Beach-Southold	U.S. Environmental Protection Agency/ County of Suffolk-Department of Health Services- Peconic Estuary Program	8/5/2014
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
OH32	Kenyon College	Kenyon College	8/22/2017

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
PA00	Arentsville	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	USDA - Forest Service	3/4/2014
SC05	Cape Romain National Wildlife Refuge	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007
SK27	Pinehouse	Environment and Climate Change Canada	3/24/2017
SK28	Flat Valley	Environment and Climate Change Canada	3/22/2017
TN01	Great Smoky Mountains NP - Look Rock	National Park Service - 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	Cañonceta	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	National Park Service - 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	National Park Service - Air Resources Division	3/16/2011
WI01	Odanah	Bad River Band of Lake Superior Chippewa	10/2/2018
WI06	UW Arboretum	University of Wisconsin State Laboratory of Hygiene	2/19/2019
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
WI94	Bakken's Pond	Private	8/6/2019
WV05	Cedar Creek State Park	U.S. Environmental Protection Agency - Clean Air Markets	1/13/2015

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
WY92	Grand Targhees	USDA - Forest Service	10/1/2019
WY93	Basin - Big Horn	U.S. Bureau of Land Management	6/2/2015
WY94	Grand Tetons National Park	National Park Service - 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 2019

MDN

Site ID	Site Name	Site Sponsor	Start Date
AB14	Genesee	Intrinsic Corp	7/18/2006
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 and Climate Change Canada	9/1/2009
CA75	Sequoia National Park- Giant Forest	National Park Service - Air Resources Division	7/22/2003
CA94	Converse Flats	USDA - Forest Service	4/20/2006
CO96	Molas Pass	U.S. Bureau of Land Management	6/30/2009
CO97	Buffalo Pass - Summit Lake	USDA - Forest Service	9/29/1998
CO99	Mesa Verde National Park-Chapin Mesa	National Park Service - Air Resources Division	12/26/2001
FL05	Chassahowitzka National Wildlife Refuge	U.S. Fish and Wildlife Service	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	U.S. Fish and Wildlife Service	7/29/1997
IL11	Bondville	University of Illinois - ISWS	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
KS32	Lake Scott State Park	Kansas Department of Health and Environment	6/10/2008
KY10	Mammoth Cave National Park-Houchin Meadow	National Park Service - Air Resources Division	8/27/2002
MA01	North Atlantic Coastal Lab	National Park Service - Air Resources Division	7/29/2003
MD00	Smithsonian Environmental Research Center	Maryland Department of Natural Resources	12/7/2006
MD08	Piney Reservoir	Maryland Department of Natural Resources	6/29/2004
MD99	Beltsville	Maryland Department of Natural Resources	6/1/2004
ME00	Caribou	Maine Department of Environmental Protection	5/9/2007
ME02	Bridgton	Maine Department of Environmental Protection	6/3/1997
ME04	Carrabassett Valley	Penobscot Indian Nation	2/17/2009

ME09	Greenville Station	Maine Department of Environmental Protection	9/3/1996
ME96	Casco Bay-Wolfe's Neck Farm	Maine Department of Environmental Protection	1/6/1998
ME98	Acadia National Park-McFarland Hill	USDA - Forest Service-Acadia National Park / 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	U.S. Fish and Wildlife Service	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	USDA - Forest Service-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
MO46	Mingo National Wildlife Refuge	U.S. Fish and Wildlife Service	3/26/2002
MS12	Grand Bay NERR	National Oceanic and Atmospheric Administration - Air Resources Laboratory	3/9/2010
MT05	Glacier National Park-Fire Weather Station	National Park Service - Air Resources Division	10/28/2003
MT95	Badger Peak	Northern Cheyenne Tribe	11/2/2010

NC08	Waccamaw State Park	North Carolina Department of Environmental Quality	2/27/1996
NC26	Candor	North Carolina Department of Environmental 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	10/1/2013
NF19	Stephenville	Environment and Climate Change Canada	2/23/2010
NJ30	New Brunswick	New Jersey Department of Environmental Protection	1/17/2006
NS01	Kejimikujik National Park	Environment and Climate Change Canada	7/2/1996
NY06	Bronx	New York State Department of Environmental Conservation	1/9/2008
NY20	Huntington Wildlife	New York State Energy Research & Development Authority	12/10/1999
NY43	Rochester	New York State Department of Environmental Conservation	1/8/2008
NY68	Biscuit Brook	New York State Energy Research & Development Authority	3/9/2004

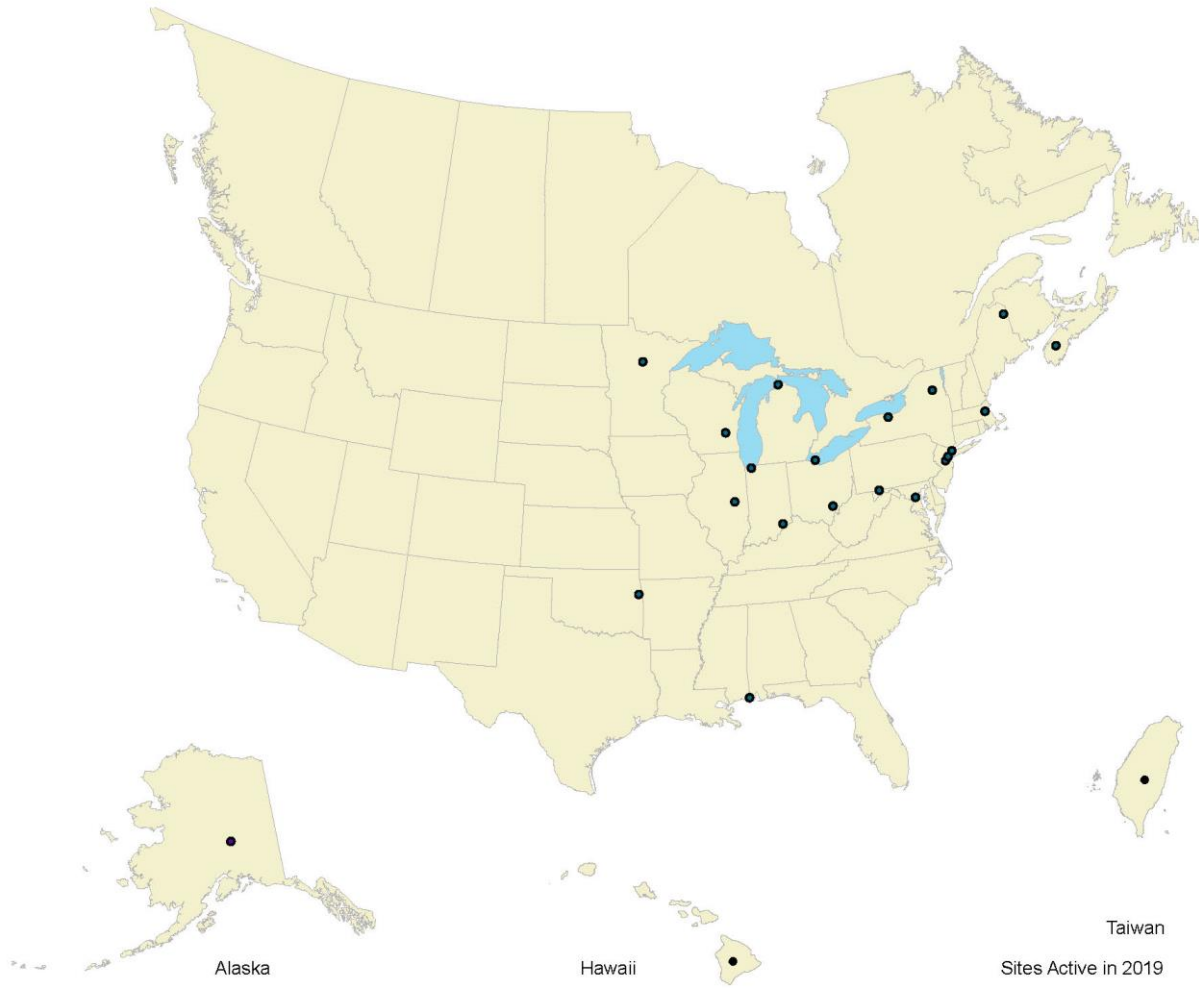
NY96	Cedar Beach-Southold	New York State Energy Research & Development Authority	9/24/2013
OH02	Athens Super Site	Ohio Environmental Protection Agency	12/28/2004
OH16	Northeast Ohio Regional Sewer District (NEORS D)	Northeast Ohio Regional Sewer District (NEORS D)	11/29/2017
OH52	South Bass Island	Ohio Environmental Protection Agency	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	Choctaw Nation of Oklahoma	12/19/2017
OK06	Wichita Mountains NWR	Oklahoma Department of Environmental Quality	11/20/2007
OK31	Copan	Oklahoma Department of Environmental Quality	10/24/2006
OK97	Tuskahoma	Choctaw Nation of Oklahoma	12/27/2017
OK99	Stilwell	Cherokee Nation Environmental Programs	4/29/2003
ON07	Egbert	Environment and Climate Change Canada	3/7/2000
PA00	Arendtsville	The Pennsylvania State University	11/14/2000
PA13	Allegheny Portage Railroad National Historic Site	The Pennsylvania State University	1/7/1997
PA30	Erie	The Pennsylvania State University	6/20/2000

PA42	Leading Ridge	The Pennsylvania State University	3/2/2010
PA90	Hills Creek State Park	The Pennsylvania State University	1/7/1997
PR20	El Verde	U.S. Geological Survey	8/6/2014
SC05	Cape Romain National Wildlife Refuge	U.S. Fish and Wildlife Service	3/2/2004
SC19	Congaree Swamp	South Carolina Department of Health and Environmental Control	3/5/1996
SD18	Eagle Butte	Cheyenne River Sioux Tribe	3/21/2007
SK27	Pinehouse	Environment and Climate Change Canada	5/14/2015
TN11	Great Smoky Mountains National Park-Elkmont	National Park Service - Air Resources Division	1/30/2002
TN12	Great Smoky Mountains National Park-Clingmans Dome	National Park Service - Air Resources Division	4/28/2015
VA28	Shenandoah National Park-Big Meadows	National Park Service - Air Resources Division	10/22/2002
VT99	Underhill	The University of Vermont	7/27/2004
WA03	Makah National Fish Hatchery	Wisconsin State Laboratory of Hygiene	3/2/2007
WA18	Seattle/NOAA	Eurofins Frontier Global Sciences	3/19/1996
<u>WI06</u>	UW Arboretum	University of Wisconsin State Laboratory of Hygiene	3/5/2019
WI08	Brule River	Wisconsin Department of Natural Resources	3/5/1996

WI10	Potawatomi	Forest County Potawatomi Community	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	National Park Service - Air Resources Division	3/10/2014
HI00	Mauna Loa	National Oceanic and Atmospheric Administration - Air Resources Laboratory	12/30/2010
IN21	Clifty Falls State Park	Lake Michigan Air Directors Consortium	4/29/2016
IN34	Indiana Dunes National Lakeshore	Lake Michigan Air Directors Consortium	10/3/2018
MA22	Boston University	Boston University	7/21/2017
MD08	Piney Reservoir	Maryland Department of Natural Resources	1/1/2008
MD98	Beltsville Second Instrument	National Oceanic and Atmospheric Administration - Air Resources Laboratory	1/26/2007
MN06	Leech Lake	Leech Lake Band of Ojibwe	5/1/2018
MS12	Grand Bay NERR	National Oceanic and Atmospheric Administration - Air Resources Laboratory	9/29/2006
NJ30	New Brunswick	U.S. Environmental Protection Agency - Clean Air Markets	10/1/2015
NJ54	Elizabeth Lab	U.S. Environmental Protection Agency - Clean Air Markets	10/1/2015
NY06	Bronx	New York State Department of Environmental Conservation	8/27/2008
NY20	Huntington Wildlife	New York State Energy Research and Development Authority	11/21/2007
NY43	Rochester	New York State Department of Environmental Conservation	9/26/2008
OH02	Athens Super Site	Ohio Environmental Protection Agency	1/1/2007

OH52	South Bass Island	Ohio Environmental Protection Agency	1/2/2011
TW01	Mt. Lulin	Taiwan EPA-National Central University	1/1/2010
WI07	Horicon Marsh	Lake Michigan Air Directors Consortium	12/31/2011

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National Atmospheric Deposition Program