Proceedings

NADP Fall Meeting and Scientific Symposium

Atmosphere-Biosphere Exchange and Ecosystem Processes: New Frontier of Measurements and Models

October 25 – November 2, 2021

Online

National Atmospheric Deposition Program

Table of Contents

Agenda 2
2021 NADP Site Operator Awards 9
In Memoriam: Ellis B. Cowling 12
Abstracts – Session 1 13
Abstracts – Session 2 19
Abstracts – Session 3 25
Posters – Session 1 32
Posters – Session 2 36
Posters – Session 3 40
Abstracts – Session 4 44
Abstracts – Session 5 50
Abstracts – Session 6 57
Abstracts – Session 7 61
Network Site Maps and Listings 67

MEETING INFORMATION - ***ONLINE***

Main Link: NADP Link#1 (zoom.us)

Link#1 will be used for:
MELD (10/25)
TDep/Sustainability (10/26)
Scientific Symposium (10/27-10/29)
Joint/NOS/EOS (11/01-11/02)

Secondary Link: NADP Link#2 (zoom.us)

Link#2 will be used for:
AMSC (10/25)
CLAD (10/25)

Acknowledgements

The NADP Program Office would like to thank the following people for their support of and contributions to the 2021 Fall Meeting and Scientific Symposium:

Dr. John Walker, Symposium Chair
Dr. Delphine Farmer, Colorado State University
NADP Executive Committee

In addition, we thank everyone who submitted abstracts and 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 Fall Meeting and Scientific Symposium
Atmosphere-Biosphere Exchange and Ecosystem Processes: New Frontier of Measurements and Models

Note all times are in EDT

Science Committee Meetings

Monday, October 25

11:00 – 15:00	Mercury in the Environment and Links to Deposition (MELD) Meeting
12:00 – 15:00	Aeroallergen Science Monitoring Committee (AMSC) Meeting
15:00 – 15:30	Break
15:30 – 18:30	Critical Loads of Atmospheric Deposition (CLAD) Meeting

Tuesday, October 26

11:00 – 15:00	Total Deposition (Tdep) Meeting
15:00 – 15:30	Break
15:30 – 17:30	Collaboration for Network Sustainability Meeting

Scientific Symposium

Wednesday, October 27

10:00 – 10:10	Welcome and logistics
10:10 – 10:20	Opening of Symposium, Jamie Schauer, Director Wisconsin State Laboratory of Hygiene
10:20 – 10:40	Annual State of the NADP Address, David Gay, Program Coordinator
10:40 – 11:15	Keynote Address, Delphine Farmer (Colorado State University) - *Masters of their fate: Revisiting atmospheric particle dry deposition and lifetime*
11:15 – 11:30	Break

Session 1: The Clean Air Act and the past, present, and future of acid deposition

Chair: Mike Bell (National Park Service)

11:30 – 11:50	Reid Harvey (Retired EPA) - *An overview of the Clean Air Act policy and implementation*
11:50 – 12:10	John Schwartz (University of Tennessee) - *Examining shifts in biochemical processes from long-term monitoring of water quality in the Great Smoky Mountains National Park*
12:10 – 12:30	Pat Brewer (Retired National Park Service) - *Regional haze, fire, and reducing deposition*
12:30 – 12:50	Stephanie Connolly (US Forest Service) - *Best management practices for addressing the long-term effects of acid deposition on federal lands*
12:50 – 1:20	Break
1:20 – 1:40	James Boylan (Georgia Dept. of Natural Resources) - *Acid deposition modeling and projections in the southeastern US*
1:20 – 2:00	Kathy Stecker (Maryland Dept. of the Environment) - *Atmospheric deposition and Clean Water Act TMDLs*

Session 2: Linkages between deposition and ecosystem processes

Chair: Jeremy Ash (US Forest Service)

2:00 – 2:20	Christopher Clark (US EPA) - *Recent advances in critical loads research from the US EPA Office of Research and Development*
2:20 – 2:40	Douglas Burns (USGS) - *Responses of forest ecosystems to decreasing nitrogen deposition in eastern North America*
2:40 – 3:00	Barry Baldigo (USGS) - *Evidence of ecosystem recovery in streams of the Adirondack Mountains in northern New York*
3:00 – 3:20	Break
3:20 – 3:40	Jana Compton (US EPA) - *Decadal impact of Clean Air Act policies on US stream nitrogen concentrations*
3:40 – 4:00	Nathan Pavlovic (Sonoma Technology, Inc.) - *Empirical nitrogen and sulfur critical loads of U.S. tree species and their uncertainties with machine learning*
4:00 – 4:20	Kayla Wilkins (Trent University) - *Ecological thresholds under atmospheric nitrogen deposition for 1200 herbaceous species and 24 communities across the U.S.*

Thursday, October 28

Session 3: Measurement and modeling of air-surface exchange

Chair: Ryan Fulgham (US EPA)

10:00 – 10:20	Glenn Wolfe (NASA) - *What goes up comes down…eventually*
10:20 – 10:40	Zhiyong Wu (US EPA) - *State of the science and future direction of air-surface exchange models for reactive compounds*
10:40 – 11:00	Jianlin Shen (Chinese Academy of Sciences) - *Atmospheric nitrogen deposition in an agricultural catchment in subtropical China and its ecological effects*
11:00 – 11:20	Pascal Wintjen (Thünen Institute of Climate-Smart Agriculture, Germany) - *Forest-atmosphere exchange of reactive nitrogen in a low polluted region - temporal dynamics and annual budgets*
11:20 – 11:40	Eiko Nemitz (UK Center for Ecology and Hydrology, Scotland) - *Review of methods for assessing deposition of reactive nitrogen pollutants across complex terrain with focus on the UK*
11:40 – 12:00	Abdullah Mamun (Environment and Climate Change Canada) - *Estimation of atmospheric dry and wet deposition of particulate elements in the Canadian Athabasca oil sands region*
12:00 – 12:20	Jun Zhou (University of Massachusetts) - *Comparison of net ecosystem exchange of atmospheric gaseous elemental mercury (GEM) between a temperate evergreen needle-leaf and a nearby deciduous broadleaf forest*
12:20 – 12:50	Break

Posters

Chair: John Walker (US EPA)

Poster Session 1

12:50 – 12:55	Moh Naseem (Jawaharlal Nehru University, India) - *Ammonia Availability Index and fraction acidity of rainwater at an urban site of National Capital Region-Delhi, India*
12:55 – 1:00	Ankita Katoch (Jawaharlal Nehru University, India) - *Dry deposition of particles on natural surfaces in the indoor air at New Delhi (India)*
1:00 – 1:05	Daimy Avila Rodríguez (National Autonomous University of Mexico) - *Nitrogen compounds in the atmosphere of the Gulf of Mexico. Case study: State of Veracruz*
1:05 – 1:10	Alberto Antonio Espinosa Guzmán (Universidad Autonoma de Campeche, Mexico) - *Temporal variation and chemical composition of wet atmospheric deposition from a coastal site in the Gulf of Mexico from 2007 to 2012*
1:10 – 1:20	Question and answer for poster session 1

Poster Session 2

1:20 – 1:25	Cara Mathers (North Carolina State University) - *Improving predictions of dry surface layer thickness and soil resistance with a simple, physically-based model*
1:25 – 1:30	Da Pan (Colorado State University) - *Ammonia surface-atmosphere exchange processes in Rocky Mountain National Park*
1:30 – 1:35	Hannah Rubin (University of Tennessee) - *Revisiting global nitrogen and sulfur budgets using a measurement-model fusion approach*
1:35 – 1:40	Luis Miguel Urbina-Leonor (National Autonomous University of Mexico) - *Atmospheric deposition study importance on the conservation of built heritage*
1:40 – 1:50	Question and answer for poster session 2

Poster Session 3

1:50 – 1:55	Rebecca Dalton (US EPA) - *Regional variation in sensitivity of trees to nitrogen and sulfur deposition across the United States*
1:55 – 2:00	Meaghan Petix (Washington State University) - *Using epiphytic lichen tissue N concentration to evaluate the TDep N deposition model in the Pacific Northwest*
2:00 – 2:05	Jian Feng (Environment and Climate Change Canada) - *Temporal and regional trends of Inorganic chemical components in precipitation in the eastern U.S. and eastern Canada during 1989-2016*
2:05 – 2:10	Eric Uram (NADP) - *Viability of pollen analysis using existing NADP equipment*
2:10 – 2:20	Question and answer for poster session 3
2:20 – 2:40	Break

Session 4: Recent advances in measurements of atmospheric chemistry

Chair: Katie Benedict (Los Alamos National Laboratory)

2:40 – 3:00	Jordan Krechmer (Aerodyne Research, Inc.) - *Recent advances in chemical ionization mass spectrometry for fast, speciated, and in-situ measurements of atmospheric constituents*
3:00 – 3:20	Lynne Gratz (Colorado College) - *Observations of ambient elemental and oxidized mercury from a continental mountaintop site using an improved dual-channel measurement system*
3:20 – 3:40	Jackson Seymore (Texas A&M University) - *Molecular characterization of dissolved organic matter in São Paulo, Brazil wet deposition by ultra-high resolution mass spectrometry*

Session 4: Recent advances in measurements of atmospheric chemistry

3:40 – 4:00	Natalie Szponar (University of Toronto) - *Tracing atmospheric sources of mercury through passive air sampling and isotopic characterization*
4:00 – 4:20	Joshua Landis (Dartmouth College) - *Systematics of fallout radionuclides (FRNs): towards their use as biogeochemical tracers of aerosol deposition*
4:20 – 4:40	David Pfotenhauer (Wisconsin Department of Natural Resources) - *PFAS mass concentrations and flux in Wisconsin rainwater through analysis of wet deposition samples from National Trends Network*

Friday, October 29

Session 5: Routine monitoring of atmosphere and ecosystem processes: Recent advances and remaining challenges

Chair: Greg Wetherbee (USGS)

10:00 – 10:20	Guey-Rong Sheu (National Central University, Taiwan) - *Variability of wet mercury deposition measurements using different types of samplers*
10:20 – 10:40	Umesh Kulshrestha (Jawaharlal Nehru University, India) - *Atmospheric deposition of reactive nitrogen in India*
10:40 – 11:00	David Kelleghan (University College Dublin, Ireland) - *Monitoring and modelling atmospheric deposition impacts and effects in the Republic of Ireland*
11:00 – 11:20	Yuk Tang (UK Centre for Ecology & Hydrology, Scotland) - *UK Air Pollution Impacts on Ecosystems Networks (APIENs): An integrated approach to assess impacts of key air pollutants on sensitive freshwater and terrestrial ecosystems*
11:20 – 11:40	Theresa Crimmins (USA National Phenology Network) - *Phenology monitoring infrastructure and data: Fundamental resources supporting scientific discovery, natural resource management, and Earth observations*
11:40 – 12:00	Irene Cheng (Environment and Climate Change Canada) - *Long term atmospheric deposition of nitrogen and sulfur at Canadian rural locations*
12:00 – 12:20	Katrina Macsween (Environment and Climate Change Canada) - *Global mercury passive sampler network: one year on*
12:20 – 12:50	Break

Session 6: Measurement-model fusion

Chair: Amanda Cole (Environment and Climate Change Canada)

12:50 – 1:10 Jeffrey Geddes (Boston University) - *The WMO measurement model fusion for global total atmospheric deposition initiative: Supporting science, policy, and sustainable development goals*

1:10 – 1:30 Greg Beachley (US EPA) - *Evaluation of changes in annual deposition fluxes estimated with the modernized TDep Measurement Model Fusion method using the EQUATES time-series dataset*

1:30 – 1:50 Sarah Benish (US EPA) - *Evaluation of a measurement model fusion approach for improving predictions of wet deposition from EQUATES*

1:50 – 2:10 Alain Robichaud (Environment & Climate change Canada) - *ADAGIO: A simple and effective data-fusion algorithm for particle dry and wet deposition*

2:10 – 2:30 Sharmin Akter (University of Connecticut) - *Modeling the urban areas contribution to nitrogen deposition in US*

2:30 – 2:50 Break

Session 7: Climate, air quality, and deposition

Chair: Rick Haeuber (US EPA)

2:50 – 3:10 Christopher Nolte (US EPA) - *The impacts of climate change on air quality and deposition: Recent advances and future directions*

3:10 – 3:30 Qasim Mehdi (Syracuse University) - *Future changes in atmospheric emissions and deposition under U.S. policies to decarbonize the electricity sector*

3:30 – 3:50 Rodolfo Sosa Echeverría (Universidad Nacional Autónoma de México) - *Sulfate:nitrate and ammonium:nitrate ratios in wet atmospheric deposition as indicators of atmospheric pollution in different regions of México*

3:50 – 4:10 Gregory Lawrence (USGS) - *The recent past, present and future of acidic deposition effects on Adirondack biogeochemistry*

4:10 – 4:30 Christopher Lawrence (University of Albany) - *Changes in atmospheric aqueous chemistry at Whiteface Mountain: Shifting focus from acid rain*

4:30 Close of symposium

Technical Meetings

Monday, November 1

11:00 – 13:30	Joint Session Meeting
13:30 – 14:30	Break
14:30 – 18:30	Network Operations Subcommittee (NOS) Meeting

Tuesday, November 2

11:00 – 13:30	Education and Outreach Subcommittee (EOS) Meeting
13:30 – 14:30	Break
14:30 – 18:30	Joint Session Meeting

2021 NADP Site Operator Awards

35 Year Award

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
VT01	Dan Taylor	Bennington	US Geological Survey	NTN	1986

30 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
IN22	Angie Thompson-Hewitt	Southwest Purdue Agriculture Center	US Geological Survey/ Lake Michigan Air Directors Consortium	NTN, MDN	1991
OR18	Cheryl Borum	Starkey Experimental Forest	US Geological Survey	NTN	1991

25 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
MD15	Francis “Hoss” Parks	Smith Island	National Oceanic and Atmospheric Administration	NTN	1995
MN27	Lee Klossner	Lamberton	Minnesota Pollution Control Agency	NTN/MDN	1996

20 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
CA76	Eric Olson	Montague	US Geological Survey	NTN	2001
CAN5	Serge D’Amour	Frelighsburg	US Geological Survey	NTN	2001
CO00	Ted Smith	Alamosa	US Geological Survey	NTN	2001
ME08	Kurt Johnson	Gilead	US Geological Survey	NTN	2001
WI31	Alex Nyhus	Devils Lake	Wisconsin Department of Natural Resources	NTN/MDN	2001

15 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
AB14	Dean Yustak	Genesee	Jacques Whitford Stantec Axys Limited	MDN	2006
CA94	David Jones	Converse Flats	US Forest Service	NTN/MDN	2006
CO93	Nicolai Bencke	Buffalo Pass - Dry Lake	US Forest Service	NTN	2006
CO97	Nicolai Bencke	Buffalo Pass - Summit Lake	US Forest Service	NTN/MDN	2006
MN01	Jim Krueger	Cedar Creek	Minnesota Pollution Control Agency	NTN	2006
OK01	Bryan Sims	McGee Creek	Oklahoma Department of Environmental Quality	MDN	2006
TN04	Roger Russell	Speedwell	Wood-Environmental Protection Agency	NTN/AMoN	2006

10 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
CO02	Jennifer Morse	Niwot Saddle	INSTAAR-University of Colorado	NTN	2011
CO90	Jennifer Morse	Niwot Ridge-Southeast	INSTAAR-University of Colorado	NTN	2011
CO94	Jennifer Morse	Sugarloaf	Wood-Environmental Protection Agency	NTN	2011
FL19	Charles Vogt	Indian River	Wood-Environmental Protection Agency	AMON	2011
GA20	Andy Jones	Bellville	Wood-Environmental Protection Agency	NTN	2011
MT07	Kim Schierenbeck	Clancy	US Geological Survey	NTN	2011
NC08	Robert Hodges	Waccamaw State Park	North Carolina Department of Environmental Quality	MDN	2011
NS01	Margo L Delong	Kejimkujik National Park	Environment and Climate Change Canada	MDN/AMoN	2011
OK99	Jacque Adam	Stilwell	Cherokee Nation Environmental Programs	MDN/AMoN	2011
ON07	Dennis Krejci	Egbert	Environment and Climate Change Canada	MDN	2011
WY02	Steve Renner	Sinks Canyon	Bureau of Land Management	NTN	2011

5 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
AZ98	Jessica Garcia	Chiricahua	Wood-Environmental Protection Agency/National Park Service	NTN/AMoN	2016
CA88	Matt Read	Davis	US Geological Survey	NTN	2016
KY98	Michael Bridges	Cadiz	Wood-Environmental Protection Agency	AMON	2016
LA12	Greg Williams	Iberia Research Station	US Geological Survey	NTN	2016
LA30	Shannon Forbes	Southeast Research Station	US Geological Survey	NTN	2016
MD18	Brian Sturgis	Assateague Island National Seashore-Woodcock	Maryland Department of Natural Resources	NTN	2016
MI09	Adam Schubel	Douglas Lake	Michigan State University/ Lake Michigan Air Directors Consortium	MDN/NTN	2016
MO46	Brad Pendley	Mingo National Wildlife Refuge	U.S. Fish and Wildlife Service	MDN	2016
NC29	John Sanders	Hofmann Forest	US Geological Survey	NTN	2016
ND01	Kory Richardson	Lostwood National Wildlife Refuge	U.S. Fish and Wildlife Service	MDN	2016
NE09	Jesse Bolli	Homestead	National Park Service	AMON	2016
OH27	Ron Bitner	Cincinnati	Wood-Environmental Protection Agency	AMON	2016
OR10	Greg Cohn	H. J. Andrews Experimental Forest	U. Forest Service	NTN	2016
SK31	Daniel Buye	Fox Valley	Saskatchewan Ministry of Environment	NTN	2016
WA99	Scott Anderson	Mount Rainier National Park-Tahoma Woods	National Park Service	NTN/AMoN	2016
WY93	Jessica Reinig	Basin - Big Horn	Air Resource Specialists, Inc.	AMON	2016

In Memoriam

Ellis B. Cowling
1932-2021

Professor Ellis B. Cowling inspects one of 125 field monitoring sites used to detect acid rain.

Ellis B. Cowling received a B.S. in Wood Technology from Syracuse University in 1954, a M.S. in Forest Pathology from Syracuse in 1956, and a Ph.D. in Plant Pathology and Biochemistry from the University of Wisconsin in 1959. He received a Filosofie Doktor (Ph.D.) in Physiological Botany from the University of Uppsala in 1970. It was his time in Sweden that introduced him to the scientists and science of acid deposition; he brought these issues back to the U.S. when he returned to his position at North Carolina State University. Beginning in 1975, he led development of the proposal for project NC-141 to the U.S. State Agricultural Experiment Stations, later adopted as the National Research Support Project - 3, which established a permanent national precipitation chemistry monitoring network – the National Atmospheric Deposition Program / National Trends Network.

Elected to the National Academy of Sciences and recipient of many awards, Cowling was an eminent scholar and teacher of forest pathology. Over his life he used his notable energy, intellect, and humility to bring together scientific and other communities to address pressing environmental and societal issues ranging from tropospheric ozone and sustainable animal waste management, to moving an iconic lighthouse in the face of sea level rise and university systems of promotion and tenure.

Ellis Cowling was Chair of the NADP Executive Committee from 1978 to 1983 and worked to sustain support for monitoring sites in North Carolina and the national network even after his retirement from NC State as University Distinguished Professor At-Large in 2008. His passion for the longevity of NADP is embodied in the title of his keynote address at the 2008 NADP Annual Meeting, *"Thirty Years Down and a Century to Go."*

- History of Acid Precipitation Research in the US: Part 1 – with Ellis Cowling
- History of Acid Precipitation Research in the US: Part 2 – with Ellis Cowling
- Cowling Obituary

Abstracts

Session 1: The Clean Air Act and the past, present, and future of acid deposition

An overview of the Clean Air Act policy and implementation

Reid Harvey[1]

The Clean Air Act of 1970 (CAA), along with the 1990 amendments, represent one of the most sweeping American environmental laws enacted, while also addressing evolving scientific and policy concerns. Air pollution has decreased dramatically. For power plants in particular, annual sulfur dioxide (SO2) emissions from decreased by 95 percent from 1990 to 2020 and annual emissions of nitrogen oxides (NOX) fell 88 percent from 1990 to 2020. Multiple analyses have shown that the Acid Rain provisions of the Act have been very cost-effective in helping to drive these power plant emissions reductions.

Despite these successes, there are challenges that the Act has not fully addressed. For example, multiple regulations over the last twenty years to address interstate air pollution (the “good neighbor” provisions of Title I of the Act) have been extensively litigated, resulting in delays in air quality improvements. Congress has also failed to tackle the policy problems associated with climate change, which can exacerbate the damages from criteria air pollutants.

[1] retired, former director US EPA CAMD, reid.harvey@gmail.com

Examining Shifts in Biochemical Processes from Long-term Monitoring of Water Quality in the Great Smoky Mountains National Park

John Schwartz[1] and Matt Kulp[2]

TF deposition of sulfate (S) and inorganic nitrogen (N as $NO_3^- + NH_4^+$) are key drivers to stream acidification in base-poor regions of eastern United States (US). Significant declines in S and N deposition in the past 20 years have been observed in this region, including the Great Smoky Mountain National Park (GRSM). GRSM has been intensively studied since 1991, however the last spatial TF survey was conducted in 2000. A substantial decline in S and N deposition occurred in 2008 and the decline quantified at the Noland Divide Watershed (NDW) high-elevation monitoring station. A critical need exists to obtain current TF deposition loads in order to support on-going biogeochemical studies. Recent findings indicate S ranged between 1.6 and 5.5 kg ha^{-1} yr^{-1} compared to 6.5 and 33.6 kg ha^{-1} yr^{-1} in 2000; N ranged between 2.6 and 11.6 kg ha^{-1} yr^{-1} compared to 4.8 to 25.0 kg ha^{-1} yr^{-1} in 2000. Annual S and N deposition loads significantly increased with increasing elevation. However, TF deposition loads for the base cations (BC) declined slightly with increasing elevation. This inverse relation may partially explain why stream pH and acid neutralizing capacity remains relatively unchanged from the 2000s to the present. Shifts in biogeochemical processes were assessed through the review of long-term watershed ion input-output budgets at NDW, where prior to 2008, S was retained annually in the watershed and recent budgets shown annual mass S export. N and BC budgets have also shifted between pre- and post-2008 periods. The role or organic S in retention and export was also examined in 2018, where a dominant S sink was quantified as organic S in the A/O soil horizon. This research demonstrated the important role of carbon dynamics in the watershed and influences on stream water quality. In 2020, because of the potential effect of organic acids on stream acidity, a survey of dissolved organic carbon was conducted in the GRSM and data are reported here within. Continued long-term research in the GRSM provides necessary data to support biogeochemical modeling efforts to predict the recovery period of stream water quality from acidification, and has implications to the possible environmental effects of climate change.

[1]University of Tennessee, jschwart@utk.edu
[2]National Park Service, Matt_Kulp@nps.gov

Regional Haze, Fire, and Reducing Deposition

Pat Brewer[1]

The Clean Air Act sets air quality protection regulations for human health and for secondary welfare standards that cover visibility and ecosystem health. Since 1990 the Acid Rain and Regional Haze provisions have resulted in significant reductions in sulfur dioxide and nitrogen oxide emissions, beyond those reductions required under the primary health standards. Emissions reductions were most dramatic in the 2010-2018 period; over the next decade, emissions reductions are projected to be slower than the past decade. Our visibility, deposition, and water quality monitoring networks in national parks and wilderness areas have demonstrated improvements in response to emissions reductions to date, but additional emissions reductions are needed to protect visibility and ecosystem health. Looking forward, lessons learned from regional haze implementation may be useful to the acid deposition community as we consider how to communicate ecosystem effects, progress, and future prognosis.

The regional haze regulatory framework requires states to demonstrate visibility progress every 10 years at Class I national parks and wilderness areas. In states' current regulatory plans for regional haze, visibility progress in 2028 is compared to a uniform rate of progress glidepath toward the Clean Air Act goal of no anthropogenic impairment of visibility by 2064. However, tracking visibility improvement is confounded by wildfire smoke, particularly in the western United States. EPA acknowledged the role of wildfire and prescribed wildland fire in their 2017 revisions to the regional haze rule. For the revised visibility tracking metric EPA uses the IMPROVE aerosol monitoring data to set thresholds for carbon and dust concentrations to exclude data impacted by "episodic extreme" fire and dust events. Days selected for tracking visibility are those days most likely to be impaired by anthropogenic emissions. The Western Regional Air Partnership used regional air quality models to further define the relative contributions to haze from U.S. anthropogenic, international anthropogenic, natural, and fire emissions. Lessons learned from regional haze modeling and application to tracking deposition trends will be discussed in this presentation.

[1] retired, National Park Service, brmountainaire@gmail.com

Best management practices for addressing the long-term effects of acid deposition on federal lands

Stephanie Connolly[1]

Acid deposition can affect forest management in the Eastern U.S. Those effects are observed across multiple resource areas. Land managers try to address the long-term effects by monitoring changes in the ecosystem, terrestrial and aquatic, and by providing recommendations for best management practices (BMPs) to ensure sustainable forest management and reduce erosion and sedimentation from land disturbance. Those BMPs help to maintain as much of the nutrient capital that the soil has to offer on site. In addition to BMPs, several national forests in the East have taken a more proactive management approach in restoring base cations to both terrestrial and aquatic systems. One case study is occurring on the Monongahela National Forest (MNF) in West Virginia. The MNF has both treated water and soil to address adverse impacts. The soils in the MNF are acidic due to sandstone parent material, acid deposition, uptake of base cations by vegetation, and release of organic acids by organic matter (OM) decomposition. Increases in soil acidity have caused declines in forest health and changed species composition and nutrient status. Liming can neutralize soil acidity, but no large-scale liming projects have been done on acid forest soils in the USA. In anticipation of acquiring funding for a proposed liming project in the MNF, in 2007 and 2009 10 sites were selected to sample and analyze soils before lime was applied. In 2018, funds were approved, and a total of 284 ha (700 ac) were limed by helicopter in the MNF near Richwood, WV. Liming material particle size varied from small sand to small gravel chips and the liming rate was targeted for 6.7 to 11.2 Mg/ha (3 to 5 tons/ac). These same 10 sampling sites representing Limed and Unlimed areas were then resampled in 2019 (previous sampling dates were simplified to 2009) using the same procedures and analyses. In addition to this forest management practice, the Monongahela National Forest has an active stream liming program which is utilized to restore acid neutralizing capacity to impacted streams to support aquatic habitats including fishing for recreational uses as part of forest management. Together these two management actions have been utilized to try to keep watersheds healthy which have been historically impacted by acid deposition.

[1] United States Forest Service, stephanie.connolly@usda.gov

Acid Deposition Modeling and Projections in the Southeastern U.S.

James Boylan[1]

Twenty years ago, the Southern Appalachian Mountain Initiative (SAMI) modeled nine episodes between 1991-1995 and projected ozone, visibility, and acid deposition for three control strategies in 2010 and 2040. More recently, Visibility Improvement State and Tribal Association of the Southeast (VISTAS) modeled visibility and acid deposition in 2011 and 2028. The 2028 annual wet and dry deposition fluxes were calculated at NADP sites in the Eastern U.S. by multiplying the annual relative response factor (RRF) by the applicable 2011 annual observed deposition flux. Annual dry deposition projections were calculated for sulfate (SO4), nitrate (NO3), nitric acid (HNO3), sulfur dioxide (SO2), ammonia (NH4), and chloride (Cl). Annual wet deposition projections were calculated for SO4, NO3, NH4, and Cl. This presentation will provide a summary of the SAMI and VISTAS deposition projections in the Southeastern U.S.

[1] Georgia Dept. of Natural Resources, James.Boylan@dnr.ga.gov

Atmospheric Deposition and Clean Water Act TMDLs

Kathy Stecker[1]

The Clean Water Act requires states to develop lists of surface waters that do not meet water quality standards. The Act further requires states to calculate reductions in pollutants needed for those waters to meet standards. These requirements apply regardless of the sources of the pollutants.

Tennessee's 2008 list of impaired waters included several waterbodies in the Great Smoky Mountains National Park with low pH associated with atmospheric deposition. Similarly, North Carolina had listed several waterbodies at high elevations in western North Carolina in 2010 for low pH, attributable to deposition of sulfur and nitrogen compounds.

There were no direct discharges of pollutants in any of the watersheds, and they received some of the highest measured amounts of sulfate and nitrate deposition in the U.S. Tennessee and North Carolina calculated target loads (Total Maximum Daily Loads or TMDLs) for acid neutralizing capacity that satisfied Clean Water Act requirements; however, the Act does not regulate atmospheric deposition. Implementing these and similar TMDLs remains a challenge.

Examples of other TMDLs that include air sources are North Carolina's statewide mercury TMDL and the Chesapeake Bay TMDLs for nitrogen.

[1] Maryland Dept. of the Environment, kathy.stecker@maryland.gov

---

Recent advances in critical loads research from the US EPA Office of Research and Development

Christopher Clark[1], Jennifer Phelan[2], Marwa Salem[3], Michael Bell[4], Robert Sabo[5], Kemen Austin[6], Gray Martin[7], Jeff Herrick[8], Kris Novak[9], J Travis Smith[10], Tara Greaver[11], Rebecca Dalton[12], Jesse Miller[13], Todd McDonnell[14], Linda Pardo[15], Nathan Pavlovic[16], and Charley Driscoll [17]

Nitrogen and sulfur deposition have declined dramatically since peaking in the 1980s and 1990s in the U.S., yet many areas still receive atmospheric deposition in excess of known thresholds for ecological harm, termed "critical loads." Years of collaborative research between the EPA, National Park Service, US Forest Service, and various universities and companies have yielded a wealth of information on critical loads for various ecosystems and taxonomic groups. This presentation will provide an overview of some of the more recent advances from the US EPA Office of Research and Development. Specifically, we will discuss four atmospheric deposition projects: (1) extending the point-estimate herbaceous critical loads for richness (Simkin et al. 2016) and individual species (Clark et al. 2019) to the CONUS, and extensions of tree species critical loads (Horn et al. 2018) to include (2) ozone, (3) regional variation in the sensitivity to N and S deposition, and (4) additional mechanistic drivers. Finally, we will discuss extensions to these approaches to examine species-level sensitivity to climate change. In total this work helps improve our understanding of the vulnerability of forest and herbaceous ecosystems to various environmental stressors, to try and inform local and regional environmental management

[1]US EPA, clark.christopher@epa.gov
[2]RTI International, jenphelan@rti.org
[3]RTI International, msalem@rti.org
[4]National Park Service, mdbell@nps.gov
[5]US EPA, sabo.robert@epa.gov
[6]RTI International, kaustin@rti.org
[7]RTI International, gdmartin@rti.org
[8]US EPA, herrick.jeffrey@epa.gov
[9]US EPA, novak.kristopher@epa.gov
[10]US EPA, smith.jtravis@epa.gov
[11]US EPA, greaver.tara@epa.gov
[12]US EPA, dalton.rebecca@epa.gov
[13]US EPA, miller.jesse.n@epa.gov
[14]E&S Environmental Chemistry, Inc., todd.mcdonnell@esenvironmental.com
[15]US Forest Service, linda.pardo@usda.gov
[16]Sonoma Technology, Inc., npavlovic@sonomatech.com
[17]Syracuse Univ., ctdrisco@mailbox.syr.edu

Responses of forest ecosystems to decreasing nitrogen deposition in eastern North America

Douglas Burns[1], Frank S. Gilliam[2], Charles T. Driscoll[3], Serita D. Frey[4], Gary M. Lovett[5] and Shaun A. Watmough[6]

Historical increases in emissions and atmospheric deposition of oxidized and reduced nitrogen (N) during the 20th century provided the impetus for extensive, global-scale research that investigated the effects of excess N in terrestrial and aquatic ecosystems, and several regions within the Eastern Deciduous Forest of the United States (U.S.) were found to be susceptible to negative effects of excess N. The Clean Air Act and associated rules have led to decreases in emissions and deposition of oxidized N, especially in the eastern U.S., representing a research challenge and opportunity for ecosystem ecologists and biogeochemists. Here, we predict changes in the structure and function of eastern North American forest ecosystems in a future of decreased N deposition. Hysteresis is a property of a system wherein output is not a strict function of corresponding input, incorporating lag, delay, or history dependence, particularly when the response to decreasing input is different from the response to increasing input. We suggest a conceptual hysteretic model predicting varying lag times in recovery of soil acidification, plant biodiversity, soil microbial communities, forest carbon (C) and N cycling, and surface water chemistry toward pre-N impact conditions. Nearly all these ecosystem measures are expected to respond strongly to reductions in N deposition. Most responses are expected to show some degree of hysteresis, with the greatest delays in response occurring in processes most tightly linked to “slow pools” of N in wood and soil organic matter. Because experimental studies of declines in N loads in forests of North America are lacking and because of the expected hysteresis, it is difficult to generalize from experimental results to patterns expected from declining N deposition. These responses to declining N deposition will likely be long-term phenomena, difficult to distinguish from other, concurrent environmental changes affecting the N cycle, including elevated atmospheric CO_2, climate change, reductions in acidity, invasions of new species, and long-term vegetation responses to past disturbance.

[1] U.S. Geological Survey, daburns@usgs.gov
[2] Univ. of West Florida, fgilliam@uwf.edu
[3] Syracuse Univ., ctdrisco@mailbox.syr.edu
[4] Univ. of New Hampshire, serita.frey@unh.edu
[5] Cary Institute of Ecosystem Studies, lovettg@caryinstitute.org
[6] Trent Univ., swatmough@trentu.ca

Evidence of ecosystem recovery in streams of the Adirondack Mountains in northern New York

Barry Baldigo[1], Scott D. George[2] and Gregory B. Lawrence[3]

Acid deposition has affected poorly buffered watersheds in eastern North America for at least fifty years. The 1990 Clean Air Act Amendments (CAAA) helped decease acidic deposition by substantially reducing SO_2 and NO_x emissions. In response, the acidity of waters in the Adirondack Mountain region of New York has declined; yet few studies investigated or documented widespread recovery of stream ecosystems. Nationwide emissions and regional deposition of sulfur and nitrogen were related to changes in water chemistry and fish assemblages from lakes and streams in the Adirondacks between 1991 (or earlier) and 2020 to assess the present-day status of chemical and biological recovery. During the period, total annual emissions of SO_2 and NO_x in the US decreased by 94% and 85%, respectively, and mean annual concentrations of sulfate and nitrate in wet deposition in the Adirondacks declined by 87% and 65%, respectively. Long-term chemistry records indicate that sulfate, nitrate, and inorganic aluminum concentrations generally decreased, and that pH, acid neutralizing capacity, and dissolved organic carbon concentrations increased significantly in streams over the same period. With noted improvements in water quality, the abundance of Brook Trout in several lakes increased but not regionwide. More noteworthy, semi-quantitative surveys from a set of 42 streams found that mean richness, density, and biomass of fish communities increased significantly between 1979 and 1999 or between 1979 and 2020. The duration of acutely toxic acid-Al_i episodes also decreased significantly in several streams over the past 40 years. The mean density and biomass of Brook Trout populations, however, did not increase in the 42 streams ostensibly because of growing competition from non-native and acid-sensitive fish species. These results indicate that aquatic ecosystems in the region are benefiting from the 1990 CAAA, but that chemical and biological recovery is incomplete, and the progression of biological recovery will be complicated.

[1]U.S. Geological Survey, bbaldigo@usgs.gov
[2]U.S. Geological Survey, sgeorge@usgs.gov
[3]U.S. Geological Survey, glawrenc@usgs.gov

Decadal Impact of Clean Air Act policies on US stream nitrogen concentrations

Jana Compton[1], Jiajia Lin[2], Alan Herlihy[3], Robert Sabo[4], Ryan Hill[5], Marc Weber[6], J. Renee Brooks[7], Steve Paulsen[8] and John Stoddard[9]

US Clean Air Act regulations have resulted in decreased nitrogen (N) deposition in the US over the last two decades. To explore whether wadeable streams responded to declining deposition, we combined US EPA's National Nutrient Inventory with the National Rivers and Streams Assessment (NRSA) from three surveys spanning between 2000 and 2014. The inventory allowed identification of NRSA watersheds where deposition is the largest N input source. Weighted change analysis indicated that stream total N (TN) concentrations declined significantly in the Appalachian region, consistent with reductions in N input rates. Similar regional reductions in stream TN concentrations or inputs were not observed in the Western and Plains regions. Among the stream population we examined that had deposition as the largest N source, the ecoregional percent length of eastern (Appalachian region) streams with TN > 0.7 mg N/L (the TN threshold for oligotrophic/mesotrophic streams) decreased from 18% to 8% between the first and third NRSA surveys, while the ecoregional value increased from 25% to36 % during the same timeframe for streams in the Plains. Conditions of streams we studied in the Western region appeared to stay relatively constant regarding TN concentrations, which was due to the lack to change in the regional N input rate. The variations in regional stream response to reduced deposition N can be attributed to many factors, such as lag time, weather/climate, nutrient legacy pool, and more. The systematic reduction in N concentrations of wadeable streams in the eastern US where deposition is the largest N source supports the effectiveness of air and water quality regulations.

[1]US EPA ORD CPHEA, compton.jana@epa.gov
[2]formerly ORISE
[3]Oregon State University
[4]US EPA ORD CPHEA
[5]US EPA ORD CPHEA
[6]US EPA ORD CPHEA
[7]US EPA ORD CPHEA
[8]US EPA ORD CPHEA
[9]US EPA ORD CPHEA

Empirical nitrogen and sulfur critical loads of U.S. Tree species and their uncertainties with machine learning

Nathan Pavlovic[1], ShihYing Chang[2], Joey Huang[3], Kenneth Craig[4], Christopher Clark[5], Kevin Horn[6] and Charles T. Driscoll[7]

Critical loads (CLs) of atmospheric deposition are used to support decision making related to regulation and land management. CLs are frequently calculated using empirical methods, and the certainty of the results from these methods depends on their accurate representation of underlying ecological processes. Many methods fail to incorporate important aspects of these relationships, including non-linearities and variable interactions. Moreover, CLs are often defined without an explicit quantification of uncertainty. Machine learning models perform well in modeling processes with non-linear characteristics and significant variable interactions, and can be used to assess uncertainty in results. We used bootstrap machine learning ensemble methods to develop CL estimates and assess uncertainties of CLs for the growth and survival of over 100 tree species in the conterminous United States. We trained machine learning models to predict tree growth and survival, and used partial dependence to characterize the relationship between deposition and tree species response. Using four statistical methods, we quantified the uncertainty of CLs in 95% confidence intervals and compared these results to previously reported CL values. Our analysis shows that bootstrap machine learning ensembles can be effectively used to quantify critical loads and their uncertainties. We show that the CLs for many tree species are significantly uncertain (CI = + >10 kg N or S ha-1 yr-1). CL uncertainty from techniques such as bootstrap machine learning ensembling can be used to support decision making with respect to atmospheric deposition.

[1]Sonoma Technology, Inc., npavlovic@sonomatech.com
[2]Sonoma Technology, Inc., cchang@sonomatech.com
[3]Sonoma Technology, Inc., jhuang@sonomatech.com
[4]Sonoma Technology, Inc., kcraig@sonomatech.com
[5]U.S. Environmental Protection Agency, Clark.Christopher@epa.gov
[6]U.S. Agency for International Development, 3horns@gmail.com
[7]Department of Civil and Environmental Engineering, Syracuse University, ctdrisco@syr.edu

Ecological thresholds under atmospheric nitrogen deposition for 1200 herbaceous species and 24 communities across the U.S.

Kayla Wilkins[1], Chris Clark[2] and Julian Aherne[3]

Elevated atmospheric nitrogen (N) deposition can influence ecosystems through mechanisms that lead to changes in plant community composition, including decreases in biodiversity or shifts from N sensitive to N tolerant species. While total N deposition has decreased in some areas of the U.S. over the last 30 years, it still remains elevated above levels shown to have negative ecological effects in many regions. Therefore, there is a desire to regulate N deposition to protect plant species, sensitive habitats, and general ecosystem health in the U.S.; however, the threshold for protecting sensitive species and habitats is still largely unknown.

To help fill that knowledge gap, we applied Threshold Indicator Taxon Analysis (TITAN) to abundance data of over 12,000 herbaceous plant species across 24 vegetation communities (i.e. alliances) in the US to determine at what point along the N deposition gradient the rate change in abundance was maximized (i.e. the change point). Further, we assessed which sites were previously and are currently at risk from N dep, based on a comparison of the change points to total N deposition (TDep) values. Our results uniquely found:

- Over 75% of the individual species assessed had a change point along the N deposition gradient in at least one vegetation alliance;
- Distinct N deposition change points (i.e. maximized rate of change) for 23 of the 24 communities assessed, ranging from 1.8–14.3 kg N ha^{-1} yr^{-1}, for species decreasing in abundance;
- A spatial trend showing that change points were lower in the west than the east, which may suggest eastern communities, where N deposition has been historically higher, may have already lost many N sensitive species; and
- An encouraging decrease in the percentage of plots at risk to N deposition over the last 30 years; however, 35% of the over 12,000 vegetation plots studied still had N deposition values above their N deposition change point.

Our presentation will convey these results, and also explain how TITAN can compliment other assessment tools in informing critical loads, including an explanation of limitations of the technique.

[1]Trent University, kaylawilkins@trentu.ca
[2]U.S. Environmental Protection Agency, Clark.Christopher@epa.gov
[3]School of Environment, Trent University, jaherne@trentu.ca

What Goes Up Comes Down . . . Eventually

Glenn Wolfe[1]

Deposition begins with emissions. Gases such as nitrogen oxides (NO_x) and ammonia (NH_3) are emitted from both natural and anthropogenic sources, undergo a series of chemical transformations, and eventually (though not always permanently) return to the Earth via wet or dry deposition. Quantifying the magnitude and speciation of reactive N fluxes – in both directions – is critical for linking processes to impacts. In this overview, I will highlight recent advances in our ability to measure and model air-surface exchange of reactive gases. The multi-scale perspective afforded by cutting-edge instrumentation, refined process models, and space-based satellite observations offers new opportunities to challenge our understanding of the integrated Earth system.

[1] NASA GSFC, glenn.m.wolfe@nasa.gov

State of the science and future direction of air-surface exchange models for reactive compounds

Zhiyong Wu[1], John Walker[2], Rick Saylor[3], Leiming Zhang[4] and Jesse Bash[5]

Air-surface exchange models simulate the exchange of gases and aerosols between the atmosphere and biosphere. They are used to develop site-specific dry deposition budgets, examine flux processes, and some forms are used in 3-D chemical transport models. Air-surface exchange models span a range of complexity from simple resistance-based "big-leaf" parameterizations to multilayer models that simulate in- and above-canopy exchange processes, chemistry and turbulence. As new measurements continue to illustrate the complexity of air-surface exchange of reactive compounds (i.e., bidirectional exchange, upward particle fluxes), models must evolve to more accurately simulate leaf- to canopy-scale processes. Additionally, the need to link deposition, air quality, weather and climate in predictions of long-term ecosystem change places greater demand on models to incorporate complex interactions (i.e., biogeochemistry, in-canopy air chemistry, ecophysiology) while maintaining computational efficiency. This presentation briefly summarizes the state of the science of several categories of air-surface exchange models (e.g, big-leaf and multilayer resistance, inverse source-sink, canopy-scale chemical transport). We then explore the future direction of air-surface exchange modeling for reactive compounds and the types of measurements that will be needed to facilitate model advances.

[1]US EPA, wu.zhiyong@epa.gov
[2]US EPA, walker.johnt@epa.gov
[3]NOAA, rick.saylor@noaa.gov
[4]Environment and Climate Change Canada, Leiming.Zhang@ec.gc.ca
[5]US EPA, bash.jesse@epa.gov

Atmospheric nitrogen deposition in an agricultural catchment in subtropical China and its ecological effects

Jianlin Shen[1]

Atmospheric reactive nitrogen emissions are high in China in recent decades due to the huge consumption of fertilizer, animal products as well as fossil fuels. High atmospheric nitrogen deposition had also been demonstrated in regions with fast economic development, such as in North China Plain and the low reach of Yangtze River. In this study, we measured atmospheric wet and dry nitrogen depositions in an agricultural catchment (105 m^2) in subtropical central China in ten years (2011-2020). Three sampling sites were set up to be located in the main land use types in the catchment, i.e., paddy field, tea field and forest. The results showed that averaged wet nitrogen depositions across the sampling sites were 21-23 kg N ha-1 yr-1, while the averaged dry nitrogen depositions were 12-19 kg N ha-1 yr-1 in the ten years. The dry nitrogen deposition showed decreased with the year, while the wet nitrogen did not change significant with the year. The whole catchment showed net source of NH3, with livestock production and chemical fertilizer application as the major NH3 sources. In the whole catchment, the estimated contribution of atmospheric nitrogen deposition to the riverine nitrogen export was as high as 21.6%. The nitrogen deposition had also increased the N2O and NO emissions in the catchment, but decreased CH4 uptake.

[1] jlshen@isa.ac.cn

Forest-atmosphere exchange of reactive nitrogen in a low polluted region - temporal dynamics and annual budgets

Pascal Wintjen[1], Frederik Schrader[2], Martijn Schaap[3], Burkhard Beudert[4], Richard Kranenburg[5] and Christian Brümmer[6]

Total nitrogen deposition at regional to continental scale is commonly estimated using chemical transport models. Reactive forms of nitrogen such as ammonia (NH_3), nitrogen monoxide (NO), nitrogen dioxide (NO_2), nitric acid (HNO_3), nitrous acid (HONO), ammonium (NH_4^+), and nitrate (NO_3^-) are the largest contributors to nitrogen deposition. The sum of these compounds is often described as total reactive nitrogen (ΣN_r). Reactive nitrogen is essential for plant growth, but intensive supply of nitrogen through atmospheric deposition may be harmful for natural ecosystems such as peatlands or forests. It may lead to a loss of biodiversity through soil acidification and eutrophication. Thus, nitrogen deposition needs to be accurately estimated in order to identify exceedances of critical loads and situations when environmental protection guidelines need to come into effect. Flux measurements of reactive nitrogen have become useful tools to compare temporal patterns and annual budgets with model simulations.

In combination with a fast-response chemiluminescence detector (CLD), the Total Reactive Atmospheric Nitrogen Converter (TRANC) allows for continuous flux measurements of ΣN_r. Due to a low detection limit and a response time of about 0.3 s, the TRANC-CLD system can be used for flux calculation based on the eddy-covariance (EC) technique.

In this study, we compared four different approaches to estimate the annual total reactive nitrogen dry deposition to a remote mixed-forest forest in the Bavarian National Park in south-east Germany over a period of 2.5 years: (i) Direct EC flux measurements with the TRANC, (ii) an in-situ application of the bidirectional inferential resistance scheme DEPAC (Deposition of Acidifying Compounds), called DEPAC-1D, (iii) DEPAC within the the chemical transport model LOTOS-EUROS (LOng Term Ozone Simulation – EURopean Operational Smog) v2.0, and (iv) the canopy budget technique (CBT).

Averaged annual ΣN_r dry deposition was determined to be 4.3±0.3 and 4.5±0.2 kg N ha^{-1} a^{-1} with TRANC measurements using the Mean-Diurnal-Variation approach with DEPAC-1D as well as solely DEPAC-1D as gap-filling approaches. DEPAC-1D predicted 5.6±0.1 kg N ha^{-1} a^{-1}, whereas 5.0±0.1 to 6.6±0.2 kg N ha^{-1} a^{-1} were predicted using DEPAC within LOTOS-EUROS, depending on the weighting of land-use classes within the site's grid cell. Dry deposition estimates determined with the CBT were in the range of 4.6±0.8 and 7.5±0.8 kg N ha^{-1} a^{-1} using two different approaches. Differences of DEPAC-1D and LOTOS-EUROS to TRANC fluxes were found to be most likely related to input data used for model simulations, to uncertainties in the modeled exchange pathways of reactive gases, and to the spatial resolution of the CTM. Taking locally measured wet-only deposition into account, the annual total reactive nitrogen deposition at the site ranged from 10.8 to 15.2 kg N ha^{-1} a^{-1} and thus in the order of critical loads for deciduous and coniferous forests.

Our study provides novel insights in the understanding of temporal dynamics of atmospheric nitrogen deposition to forests and gives a robust quantification of annual deposition budgets by combining measurement and modeling techniques.

[1]Thünen Institute of Climate-Smart Agriculture, pascal.wintjen@thuenen.de
[2]Thünen Institute of Climate-Smart Agriculture, frederik.schrader@thuenen.de
[3]TNO, Climate Air and Sustainability, martijn.schaap@tno.nl
[4]Bavarian Forest National Park, Burkhard.Beudert@npv-bw.bayern.de
[5]TNO, Climate Air and Sustainability, richard.kranenburg@tno.nl
[6]Thünen Institute of Climate-Smart Agriculture, christian.bruemmer@thuenen.de

Review of methods for assessing deposition of reactive nitrogen pollutants across complex terrain with focus on the UK

Eiko Nemitz[1] , Nick Cowan[2], Peter Levy[3], Marsailidh Twigg[4], John T Walker[5], John J Finnigan[6], Nuria Bachiller-Jareno[7], Phil Trembath[8], David Fowler[9], Rob Kinnersley[10] and Christine Braban[11]

Complex terrain represents hilly areas of complex topography as well as areas of complex mixtures of landuse. An accurate quantification of the deposition of reactive nitrogen (Nr) compounds to complex terrain is important. In the UK, much of the sensitive vegetation is found in complex upland areas, which also feeds may water catchments. Yet, the atmospheric deposition of pollutants to complex terrain is poorly understood for a number of reasons: on the modelling side, numerical weather prediction models are usually too coarse to fully resolve the topographic rain fall enhancements and the seeder-feeder process, and to predict the transport of Nr compounds (and in particular ammonia) from farming areas into the uplands and the atmospheric chemistry and transport models use dry deposition routines that describe the deposition to flat, homogeneous vegetation and do not reflect the additional turbulence features caused by complex topography or vegetation edge effects. The problem is also difficult to address with measurements, making it difficult to obtain the data needed to validate the modelling approaches: wet, bulk and occult deposition measurements are difficult at windy and exposed sites and micrometeorological flux measurement approaches, typically used to quantify dry deposition rates, are not suitable to complex terrain.

Overall, the issue of nitrogen deposition to complex terrain remains a fairly intractable problem. This talk reviews the literature and approaches available to make progress in the area and seeks to estimate the scale of the problem for the UK. Several studies have looked at the impact of complex terrain on tracer transport (e.g. in the context of nuclear accidents), on the impact on fluxes at individual sites to help with the siting of carbon flux towers on the impact of hills on wind farms. Very few studies have attempted to study Nr deposition in complex terrain explicitly and virtually all modelling studies that have looked at tracer transport in complex terrain have ignored the fact that the existing dry deposition schemes are not applicable. Based on the current literature it is estimated that Nr deposition to UK complex terrain may be underestimated in the range of 40 to 150%. New large-scale measurement initiatives would be needed to narrow down this uncertainty.

[1]UK Centre for Ecology & Hydrology, en@ceh.ac.uk
[2]UK Centre for Ecology & Hydrology, en@ceh.ac.uk
[3]UK Centre for Ecology & Hydrology, plev@ceh.ac.uk
[4]UK Centre for Ecology & Hydrology, sail@ceh.ac.uk
[5]USEPA, walker.johnt@epa.gov
[6]CSIRO, john.finnigan@csiro.au
[7]UK Centre for Ecology & Hydrology, nuri@ceh.ac.uk
[8]UK Centre for Ecology & Hydrology, phtr@ceh.ac.uk
[9]UK Centre for Ecology & Hydrology, dfo@ceh.ac.uk
[10]UK Environment Agency, rob.kinnersley@environment-agency.gov.uk
[11]UK Centre for Ecology & Hydrology, chri2@ceh.ac.uk

Estimation of atmospheric dry and wet deposition of particulate elements in the Canadian Athabasca oil sands region

Abdulla Mamun[1] , Irene Cheng, Leiming Zhang, Valbona Celo, Ewa Dabek-Zlotorzynska and Jean-Pierre Charland

A framework has been developed for estimating the atmospheric deposition of particulate elements. Dry deposition fluxes were estimated from measured ambient concentrations and size-resolved modeled dry deposition velocities. Wet deposition fluxes were estimated from measured ambient concentrations, precipitation rates, and a literature database of scavenging ratios of elements. Using this framework, deposition fluxes of 35 elements (including 8 USEPA elements) at four monitoring sites (AMS01, AMS04, AMS17, and AMS18) in the Athabasca oil sands region (AOSR) of western Canada were estimated for 2016-2017. Annual total (dry+wet) deposition of the individual elements in PM10 were generally consistent with their respective concentration patterns and varied from 3 (µg/m2/year) for Yb to 172,237 (µg/m2/year) for Si. Spatial variations of fluxes were different for crustal and anthropogenic elements. Among the elements associated with bitumen extraction, upgrading, and byproducts (e.g., Mo, Ni, S, and V), only S showed significantly ($p < 0.05$) higher fluxes at AMS01 (26%) and AMS17 (38%) (both of these sites are closer to the oil sands facilities) compared to the flux at AMS18 (background site). The wet deposition was the dominant mechanism of deposition for most of the elements. For individual elements, the dry deposition flux contribution to the total (dry+wet) deposition varied from 10% (Zn) to 60% (S). Seasonal variations of fluxes were dependent on several factors including flux type, site, and elements. Seasonal variations of the dry deposition were mainly regulated by the element concentrations in different seasons, whereas the seasonal variation of wet deposition mainly varied with sites owing to the geographical variations of precipitation amounts in different seasons. Combined total fluxes of Si, Ca, Al, and Fe accounted for 79-90% of the total elemental fluxes at the four sites, suggesting the prevalence of fugitive dust sources in the AOSR. The total (dry+wet) deposition of the individual USEPA priority toxic elements considered in this study decreased in the order: Zn>Cu>Ni>Cr>Sb>As>Pb>Cd, and ranged from 6 (µg/m2/year) for Cd to 2291 (µg/m2/year) for Zn.

[1] Environment and Climate Change Canada, abdulla.mamun@ec.gc.ca

Comparison of net ecosystem exchange of atmospheric gaseous elemental mercury (GEM) between a temperate evergreen needle-leaf and a nearby deciduous broadleaf forest

Jun Zhou[1], Silas Bollen[2], Róisín Commane[3], Shawn Fraver[4], David Hollinger[5], John Lee[6], Eric Roy[7] and Daniel Obrist[8]

Mercury (Hg) is a global pollutant and large amounts of Hg are emitted to the atmosphere (>6,000–8,000 Mg Hg yr^{-1}) by anthropogenic activities, biomass burning, geogenic degassing and legacy emissions from land and oceans. Up to two-thirds of terrestrial Hg emissions are deposited back onto land, predominantly through vegetation uptake of Hg. Atmospheric gaseous elemental mercury (GEM) deposition through foliage uptake accounts for 90% of the total vegetation uptake.

We present direct measurements of ecosystem–atmosphere GEM exchanges using tower-based flux-gradient approaches in both a deciduous and coniferous forest in New England. We measured an annual GEM deposition of 25 $\mu g\ m^{-2}$ in the deciduous forest and a deposition of about 8 $\mu g\ m^{-2}$ between November to August in the needle-leaf forest where annual measurements are still ongoing. Daily GEM fluxes generally were either positive (i.e., emissions) or neutral during winter months in both forests, and both forests showed pronounced GEM deposition in the summer months. However, summertime GEM deposition was more pronounced in the deciduous forest, which also showed high midday GEM deposition corresponding to CO_2 uptake. Summertime GEM deposition in the needle=leaf forest was weaker and dominated by nighttime uptake, however. Our study results suggest net GEM deposition in two New England forests with substantial differences in GEM sinks as well as timing and underlying environmental drivers of deposition.

[1] University of Massachusetts - Lowell, jun_zhou@uml.edu
[2] University of Massachusetts - Lowell, Silas_Bollen@student.uml.edu
[3] Lamont-Doherty Earth Observatory, Columbia University, r.commane@columbia.edu
[4] School of Forest Resources, University of Maine, Orono, shawn.fraver@maine.edu
[5] Northern Research Station, USDA Forest Service, Durham, NH, david.hollinger@usda.gov
[6] School of Forest Resources, University of Maine, Orono, jtlee@maine.edu
[7] University of Massachusetts - Lowell, Eric_Roy@student.uml.edu
[8] University of Massachusetts - Lowell, daniel_obrist@uml.edu

Ammonia Availability Index and Fraction Acidity of Rainwater at an Urban Site of National Capital Region -Delhi, India

Moh Naseem[1] and Umesh Chandra Kulshrestha[2]

The present study reports the Ammonia Availability Index (AAI) and Fraction Acidity (FA) along with the neutralization factors and ionic composition of rainwater an urban site (Baraut) of National Capital Region-Delhi. In addition, the wet deposition fluxes of Nr species (NH_4^+-N and NO_3^--N) and their potential sources along with the delineation of the advection path and potential source-regions of the air masses, accompanying these Nr species to the sampling site, were also assessed addressing the objectives of GCRF-South Asian Nitrogen Hub and DRSNet-India programmes. The study was carried out for a year-long period from October 2017 to September 2018. The collected rainwater samples were analysed for anions and cations by using an Ion chromatography (Metrohm 883 basic plus), calibrated with the Merck (Certipur®) standards. The AAI was observed to be >100% (103.49%), signifying the presence of sufficient NH_4^+ to absolutely neutralize H_2SO_4 and HNO_3. The FA value (0.0021) was observed to be extremely deviated from unity, thereby, further corroborating the absolute neutralization of H_2SO_4 and HNO_3 in collected rainwater, which culminated into an annual mean (±SE) pH of 6.77 ± 0.06. The sequential order of neutralization by different alkaline ionic constituents was observed as NH_4^+ (1.03) > Ca^{2+} (0.84) > K^+ (0.13) > Mg^{2+} (0.12) > Na^+ (0.04). The sequentially descending order of percent contribution of different analyte ions in total annual VWM ionic concentration was observe as $NH_4^+ > Ca^{2+} > SO_4^{2-} > NO_3^- > Cl^- > K^+ > Mg^{2+} > Na^+ > F^-$. In addition, the annual wet deposition of NH_4^+-N, NO_3^--N and TIN (NH_4^+-N + NO_3^--N) were estimated to be 19.48 kg N ha^{-1} yr^{-1}, 12.17 kg N ha^{-1} yr^{-1} and 31.64 kg N ha^{-1} yr^{-1}, respectively. The inferences from enrichment factor analysis, principal component analysis and Pearson correlation coefficient analysis suggested that virtually all NH_4^+-N and NO_3^--N depositions were originated anthropogenically. The results from clustering air mass back trajectories exhibited that most of the air masses transported to sampling point from South-West direction followed by South-East direction. Furthermore, the back-trajectory analysis also suggested that the potential source regions of air masses, reaching the sampling point during sampling days, were local, regional and transboundary-continental.

[1]School of Environmental Sciences, Jawaharlal Nehru University, mohnaseemmalik@gmail.com
[2]School of Environmental Sciences, Jawaharlal Nehru University, umesh@mail.jnu.ac.in

Dry Deposition of Particles on Natural Surfaces in the Indoor Air at New Delhi (India)

Ankita Katoch[1] and Umesh Chandra Kulshrestha[2]

It is considered that the vegetation is more efficient in capturing dry deposition of particulate matter as compared to surrogate surfaces. This study also aimed at the dry deposition of dust particles (dustfall) on natural surfaces i.e. plant foliage in indoor air at the industrial and residential sites in New Delhi. It was observed that dustfall fluxes were higher on the plants at the industrial site as compared to the residential site and chemically, the deposited dust was less basic at the industrial site as compared to the residential site indicating more acidic emissions in the industrial area which affected the indoor air too. Seasonal variations in dustfall indicated that it was the highest in the winter season and the lowest in the monsoon season. Chemical profiling of the deposited dust showed that Cl^- and SO_4^{2-} were the most abundant anions at residential and industrial sites whereas Ca^{2+} was ubiquitously the most abundant cation at both the sites. The abundance of other ions in the aqueous extract of dust such as K^+, NO_3^- and NH_4^+ etc. indicated the influence of anthropogenic activities. The number of particles deposited on the foliar surfaces of the plants was also estimated and divided into three categories based on their sizes such as PM_1, $PM_{2.5}$ and PM_{10}. As the particle number or count is more appropriate than particle mass for reporting the smaller particles and hence, particle number flux (number of particles present on 1 mm^2 of the foliar surfaces) has been used to calculate PM accumulation on the foliar surfaces of plants for the present study. The mean particle number flux on the foliar surfaces of the selected plant species followed the order, $PM_1 > PM_{2.5} > PM_{10}$ at both the sites. The abaxial foliar surfaces of the plants showed interspecies variability, unlike adaxial surfaces, due to differences in micromorphological characteristics such as the presence of grooves and undulations, high stomatal density etc. The results suggested that the plant species having leaves with densely arranged grooves and the presence of epicuticular wax are suitable for particle accumulation. Such studies are particularly useful in assessing the abundance and nature of ambient dust and selection of the species for plantation which can perform a dual function of improving indoor air quality and providing aesthetic as well as recreational value.

[1]School of Environmental Sciences Jawaharlal Nehru University, ankitakatoch@gmail.com
[2]School of Environmental Sciences Jawaharlal Nehru University, umesh@mail.jnu.ac.in

Nitrogen compounds in the atmosphere of the Gulf of Mexico. Case study: State of Veracruz

Daimy Avila Rodríguez[1], Rodolfo Sosa Echeverría[2], Ana Luisa Alarcón Jiménez[3], Gilberto Fuentes García[4] and Pablo Sánchez Alvarez[5]

This study aims to analyze the concentrations of NO2 in ambient air, NO3- and NH4+ ions concentration in wet atmospheric deposition in the Gulf of Mexico and their relationship with meteorological conditions, presenting the State of Veracruz as a case study in the years 2017 and 2018. Hourly NO2 concentrations were obtained from the Air Quality System (AQS) of the United States of America and the Veracruz's Government in Mexico. NO3- and NH4+ data used corresponding to the USA were obtained from the National Trends Network (NTN), a network belonging to the NADP and in Mexico they were sampled at "La Mancha" (LM) and Veracruz's Port (VP) stations operated by the Environmental Pollution Section of the Center for Atmospheric Sciences of the National Autonomous University of Mexico (SCA-CCA-UNAM) and then analyzed at the laboratory. The analysis of NO2 concentrations showed that the levels of the established national ambient air quality standards were not exceeded and that the high concentrations occurred during the peak vehicle traffic hours. NO3- and NH4+ showed that stations with the highest concentrations (μeq/L) were found in states of greatest industrialization, while stations with highest volume of rainfall showed the highest depositions (kg/ha). From the analysis of backward trajectories, the seasonality of the wind was observed, with north wind prevailing in winter and east wind in summer, which allowed us to observe that in addition to local sources, regional industrial sources can also contribute significant amounts of pollutants to Veracruz.

[1] National Autonomous University of Mexico (UNAM), ardaimy@gmail.com
[2] National Autonomous University of Mexico (UNAM), rodsosa@unam.mx
[3] National Autonomous University of Mexico (UNAM), ana.alarcon@atmosfera.unam.mx
[4] National Autonomous University of Mexico (UNAM), fuenbeto@icloud.com
[5] National Autonomous University of Mexico (UNAM), pasa@unam.mx

Temporal variation and Chemical composition of wet atmospheric deposition from a coastal site in the Gulf of Mexico from 2007 to 2012

Alberto Antonio Espinosa Guzmán[1] , Rodolfo Sosa Echevería[2], Javier Reyes Trujeue[3], Julia Griselda Cerón Bretón[4], Rosa María Cerón Bretón[5], Ana Luisa Alarcón Jimenez[6] and Pablo Sánchez Alvarez[7]

Atmospheric pollution is a complex phenomena characterized by a mixture of substances that has adverse effects on the environment. Ionic species such as NH_4^+, NO_3^-, SO_4^{-2}; cause negative impact on natural an urban ecosystems and are cause of health problems. In addition, they are active species involved in deterioration of monuments in historical heritage sites. However, these ions are present in both rainfall and particulate matter, because of that, it is necessary to make the its total measurements in order to evaluate both, the inputs and outputs of these components in different ecosystems as a result of the atmospheric deposition and thus relate emission patterns with the current deposition in different areas.

Unpublished data wet atmospheric deposition collected during the cyclic warm and dry periods in San Francisco de Campeche (SFC) City, Mexico are presented. The behavior of the ionic species in wet deposition periods between 2006 to 2012 are described. A comparison with data in La Mancha-Veracruz and Carmen City-Campeche is also carried out. Data on ion concentrations in atmospheric wet deposition samples for the study period were analyzed to assess the effects of acid precipitation and to determine sources of secondary compounds in heritage cities. The concentrations of ionic species such as Na^+, NH_4^+, K^+, Mg^{+2}, Ca^{+2}, Cl^-, NO_2^-, NO_3^-, SO_4^{-2} were measured with Ionic Chromatography (IC). During the study, the Volume Weighted Mean pH values 6.5 indicate active neutralization of the acidic species caused by the alkaline particles present in the regional atmosphere. The evaluation of SO_4^{-2}/NO_3^- shown a mean ratio of 1.36, it suggests vehicular emission sources with greater contribution of sulfur over nitrogen species and the formation of secondary compounds. The Cluster Analysis (CA) was used as an exploratory tool to identify possible sources of soluble ions in this study. CA showed a strong correlation between Na^+, Cl^-, Mg^{2+}, due to marine aerosols was observed; Ca^{+2}, K^+, with soil origin; SO_4^{-2}, NO_3^-; suggesting vehicular emissions and NH_4^+ associated with burning of crop fields.

[1] Universidad Autonoma de Campeche, aaespino@uacam.mx
[2] Universidad Nacional Autonoma de Mexico, rodsosa@unam.mx
[3] Universidad Autonoma de Campeche, javreyes@uacam.mx
[4] Universidad Autonoma de Carmen, jceron@pampano.unacar.mx
[5] Universidad Autonoma de Carmen, rceron@pampano.unacar.mx
[6] Universidad Nacional Autonoma de Mexico, ana.alarcon@atmosfera.unam.mx
[7] niversidad Nacional Autonoma de Mexico, meteoromania@gmail.com

Improving predictions of dry surface layer thickness and soil resistance with a simple, physically-based model

Cara Mathers[1], Joshua Heitman[2], John Walker[3], Wayne Robarge[4] and Chadi Sayde[5]

Soil gas flux is moderated by the presence of a dry surface layer (DSL), the formation of which will depend on both soil physical characteristics and surface boundary conditions. Current parameterizations of DSL thickness in hydrologic and ammonia emissions modeling rely on values of soil relative wetness, and also lack experimental validation. Two sets of experiments were performed to test soil condition and boundary effects on DSL formation, and evaluate the accuracy of model predictions. DSL thickness was analyzed in short (10 cm) soil columns of varying texture and initial water content (low and high water content; both below field capacity) under a potential evaporation (PE) rate of 0.65 mm h-1 for 24 h. In the second set of experiments, soils were packed in long columns (30 cm) to extend drying duration to 10-14 days to observe drying dynamics in late stages of evaporation, and the columns were tested at low, moderate, and high PE rates (0.33, 0.65, 1 mm h-1). Based on experimental results, we employed a simple physically-based DSL model, which depends on cumulative evaporation, initial and residual water contents, and compared it to observed DSL thickness. The evaporation-based model performed better than commonly used relative-wetness based models; soil resistance values were also calculated using the models and compared. Our findings show that while soil texture and water content do play a role in the formation of a DSL, cumulative evaporation is the main driver and determinant of DSL thickness. Although field trials will be needed to further test the efficacy of the evaporation based model, integration of cumulative evaporation into soil resistance models appears promising.

[1]North Carolina State University, cmather@ncsu.edu
[2]North Carolina State University, jlheitma@ncsu.edu
[3]EPA National Risk Management Research Laboratory, Walker.Johnt@epa.gov
[4]North Carolina State University, wayne_robarge@ncsu.edu
[5]North Carolina State University, csayde@ncsu.edu

Ammonia Surface-Atmosphere Exchange Processes in Rocky Mountain National Park

Da Pan[1] , Lillian E. Naimie[2], John T. Walker[3], Amy P. Sullivan[4], Katherine B. Benedict[5], Aleksandra Djurkovic[6], Bret A. Schichtel[7], Rebecca Perrin[8], Amrita Singh[9], Mark A. Zondlo[10] and Jeffrey L. Collett, Jr.[11]

For sensitive ecosystems, elevated reactive nitrogen (N_r) deposition leads to decreased biological diversity and increased soil acidification. Ammonia (NH_3) dry deposition is a critical component of N_r deposition, particularly within and downwind of agricultural areas where high NH_3 concentrations have been observed. Satellite observations showed that 26 out of 46 national parks could be impacted by nearby NH_3 hotspots. However, NH_3 dry deposition has rarely been measured in these parks. Rocky Mountain National Park (RMNP), where alpine ecosystems are particularly sensitive to increasing N_r deposition, is one of those areas. In this study, we examine NH_3 bidirectional exchange processes in RMNP from our previous campaign in 2015 and 2016 for grasslands and an on-going project for alpine forests at the RMNP National Ecological Observation Network (NEON) site. In the summers of 2015 and 2016, NH_3 fluxes were measured with the eddy covariance method using an open-path NH_3 sensor. Summer NH_3 fluxes were calculated using observed and modeled fluxes. Deposition occurring with impacts from agricultural sources accounted for more than 40% of the total dry NH_3 deposition to the grassland. Beginning in September 2021, air-surface exchange fluxes of NH_3 and other N_r species (i.e., nitric acid, particulate ammonium, and particulate nitrate) have been measured above an evergreen forest canopy using the modified Bowen ratio method with annular denuder/filter pack systems. Together with measurements of micrometeorology, soil and vegetation NH_3 emission potentials, and canopy structure, four NH_3 surface-atmosphere exchange models, including both multilayer and bi-directional approaches, will be evaluated and optimized using measured NH_3 fluxes. These models will also be assessed in the context of using NH_3 concentrations measured with low-cost passive air samplers as used by the National Atmospheric Deposition Program (NADP) Ammonia Monitoring Network (AMoN), which have a lower temporal resolution (biweekly) but can significantly increase the temporal coverage of NH_3 flux with inferential methods. For instance, at the NEON RMNP site, passive NH_3 samplers will be deployed from 2021 to 2022 to drive the NH_3 air-surface exchange model, providing the annual budget of NH_3 dry deposition. Our results provide critical insights on NH_3 surface-atmosphere exchange processes over grasslands and alpine forests in RMNP, facilitating effective mitigation of elevated N_r deposition in the park. Furthermore, our study could significantly improve the applicability of bidirectional inferential methods to estimate NH_3 dry deposition at other montane sites, improving our understanding of N_r deposition on the national scale.

[1]Colorado State University, da.pan@colostate.edu
[2]Colorado State University, lilly.naimie@colostate.edu
[3]US EPA, walker.johnt@epa.gov
[4]Colorado State University, amy.sullivan@colostate.edu
[5]Los Alamos National Laboratory, amy.sullivan@colostate.edu
[6]US EPA, Djurkovic.Aleksandra@epa.gov
[7]Colorado State University, bret.schichtel@colostate.edu
[8]US EPA, perrin.rebecca@epa.gov
[9]US EPA, singh.amrita@epa.gov
[10]Princeton University, mzondlo@princeton.edu
[11]Colorado State University, Jeffrey.Collett@colostate.edu

Revisiting Global Nitrogen and Sulfur Budgets Using a Measurement-Model Fusion Approach

Hannah Rubin[1] and Joshua Fu[2]

Global nitrogen (N) deposition has increased from around 30 Tg in 1860 to about 100 Tg by 2000 and will continue to increase imminently due to industry and agriculture. Elevated deposition levels are associated with environmental damage such as eutrophication, soil and water acidification, and loss of biodiversity. While sulfur deposition is expected to decrease over the next 80 years, nitrogen deposition has not yet returned to pre-2000s levels in large regions of the world and is still a serious environmental hazard. With new regional wet deposition measurements now available, we update the global deposition budget for nitrogen and sulfur in 2010, improving the ensemble results of eleven global climate models from the second phase of Task Force Hemispheric Transport of Air Pollution (HTAP-II). We use an inverse-distance weighting approach to correct the HTAP-II grid with ground-based measurements in Europe, Asia, and North America. We also incorporate satellite data from the Ozone Measuring Instrument (OMI) onboard the Aura satellite and the Infrared Atmospheric Sounding Interferometer (IASI) onboard MeTop-A for more complete global coverage in regions without ground-based measurements. Results demonstrate that the global N wet deposition budget is closer to 140 Tg than the previously modeled 123 Tg and that the sulfur deposition budget is very similar to the modeled 51 Tg from the HTAP-II ensemble results. This methodology demonstrates the improvements that measurement-model fusion can bring to both model estimates and satellite data and provides a framework for future fusion efforts.

[1]Department of Civil and Environmental Engineering, University of Tennessee, Knoxville, TN, hrubin@vols.utk.edu
[2]Department of Civil and Environmental Engineering, University of Tennessee, Knoxville, TN, jsfu@utk.edu

Atmospheric deposition study importance on the conservation of built heritage

Luis Miguel Urbina-Leonor[1] , Rodolfo Sosa-Echeverría[2], Rogelio Soto-Ayala[3], Ana Alarcón-Jiménez[4], Pablo Sánchez-Álvarez[5] and Jonathan Kahl[6]

In this presentation, we discuss how atmospheric deposition study is mandatory and needed to study and model the built heritage decay, and the importance to develop it towards a worldwide conservation of this kind of heritage.

It is known that atmospheric deposition is directly related with material decay of built heritage, either as dry or wet deposition. However the research has focused only on carbonate stones, neglecting other important materials, as cement or volcanic stone. Atmospheric deposition research, however, is done in relatively few places, mostly in developed countries, making it very difficult to model the decay of heritage materials through damage functions elsewhere, because the lack of information.

We summarize the effect of different environmental parameters on building materials, how conservation of building materials is affected by atmospheric deposition, and a glance on damage functions, highlighting the important role of remote sensing in present and future conservation, and pointing out opportunity areas to capitalize the knowledge to preserve humankind heritage worldwide.

[1] Environmental Engineering Posgraduate Program, UNAM, luis.miguel.urbina.leonor@gmail.com
[2] Atmospheric Sciences Center, UNAM, rodsosa@unam.mx
[3] Engineering Faculty, UNAM, rsoto54@hotmail.com
[4] Atmospheric Sciences Center, UNAM, ana.alarcon@atmosfera.unam.mx
[5] Atmospheric Sciences Center, UNAM, pasa@unam.mx
[6] University of Wisconsin-Milwaukee, kahl@uwm.edu

Regional variation in sensitivity of trees to nitrogen and sulfur deposition across the United States

Rebecca Dalton[1] , Jesse N. Miller[2], Kemen G. Austin[3], Jennifer N. Phelan[4], R. Quinn Thomas[5], Tara L. Greaver[6] and Christopher M. Clark[7]

Atmospheric nitrogen (N) and sulfur (S) deposition impact tree demographic process via changes in nutrient pools, soil acidification, and biotic interactions. In a recent study, Horn et al. (2018) analyzed the relationships between atmospheric N and S deposition and the survival and growth of 94 tree species in the contiguous U.S. and found that demographic processes of most tree species were affected by N and S deposition. In this study, we expand the analysis of Horn et al. (2018) by subdividing the national dataset into United States Forest Service (USFS) divisions to characterize the regional variation in response to atmospheric N and S deposition among tree species. First, species that occur in more USFS divisions, are more likely to have differential survival and growth responses to N and S across divisions. Second, the shape of the survival and growth response to atmospheric N and S (i.e., increase, decrease, unimodal, tabletop, or no relationship) for a given tree species varies across divisions. Finally, both positive and negative effects of N and S deposition on tree growth and survival occur across the continental U.S., even in areas of low deposition. Next, we plan to combine these regional species responses to N and S with functional traits, phylogenetic relatedness, and division-wide estimates of climate and edaphic factors to determine which factors drive regional variation in response to N and S deposition. *Disclaimer*: The views expressed in this abstract are those of the author[s] and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.

[1]Environmental Protection Agency, dalton.rebecca@epa.gov
[2]Environmental Protection Agency, miller.jesse.n@epa.gov
[3]RTI International, kaustin@rti.org
[4]RTI International, jenphelan@rti.org
[5]Virginia Polytechnic Institute and State University, rqthomas@vt.edu
[6]Environmental Protection Agency, greaver.tara@epa.gov
[7]Environmental Protection Agency, clark.christopher@epa.gov

Using epiphytic lichen tissue N concentration to evaluate the TDep N deposition model in the Pacific Northwest

Meaghan Petix[1], Michael D. Bell[2] and R. Dave Evans[3]

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 in the Pacific Northwest contain lichen communities critical to ecosystem function that are expected to be 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, model estimates have a high degree of uncertainty, especially in mountainous regions. The N concentration of epiphytic lichens can be utilized as a bioindicator of N_{dep} because their tissue N is pulled from atmospheric sources and their N stable isotope composition (^{15}N) can assess contributions of different N pollution sources. We are using the U.S. Forest Service (USFS) lichen air quality datasets to assess modeled outputs of TDep N_{dep} across the Pacific Northwest region. Combining modeled values with environmental characteristics from survey locations allow us to create relative confidence metrics for the TDep model. The GIS framework is a powerful approach to model that is being used to develop critical loads and evaluate N critical load exceedance. In these analyses we address whether incorporating lichen datasets (lichen community and elemental data) helps improve estimates of N_{dep} as well as address limitations.

[1]Washington State University, meaghan.petix@wsu.edu
[2]Air Resources Division, National Park Service, michael_d_bell@nps.gov
[3]Washington State University, rdevans@wsu.edu

Temporal and regional trends of Inorganic chemical components in precipitation in the eastern U.S. and Eastern Canada during 1989-2016

Jian Feng[1], Robert Vet[2], Amanda Cole[3], Leiming Zhang[4], Irene Cheng[5], Jason O'Brien[6] and Anne-Marie Macdonald[7]

With the implementation of the Clean Air Act Amendments of 1990 in the U.S. and similar emission reduction measures in Canada, sulfur dioxide (SO_2) and nitrogen oxides ($NOx = NO + NO_2$) emissions in the eastern U.S. and Eastern Canada declined significantly during the period 1989-2016. Correspondingly, air quality over the region improved tremendously and sulfate, nitrate and acidity in precipitation decreased significantly. In this study, we analyzed measurement data in the eastern U.S. and Eastern Canada from the two national long-term wet deposition networks, the National Atmospheric Deposition Program / National Trends Network (NADP/NTN) in the U.S. and the Canadian Air and Precipitation Monitoring Network (CAPMoN) in Canada, to reveal the spatial-temporal trends of precipitation concentrations and wet deposition of sulfate, nitrate, ammonium and acid in the eastern part of North America (broken into 4 different regions) for the period of 1989-2016. Comparing 2014-2016 to 1989-1991, the results show that the acid, sulfate and nitrate wet deposition decreased by 78%, 69% and 46% for 1989-2016, and decreased annually at rates of $-2.8\sim-3.6\%\ yr^{-1}$, $-2.5\sim-2.9\%\ yr^{-1}$, and $-1.6\sim-2.0\%\ yr^{-1}$ over different regions, respectively. It also revealed that there were no statistically significant trends for the annual mean wet concentrations of ammonium (NH_4^+) in precipitation in the Midwest and the Mid-Atlantic of the U.S. ($P > 0.4$ respectively). However, there were statistically significant increasing trends of annual wet deposition of NH_4^+ over these latter two regions ($P = 0.01 \sim 0.13$) with an annual rate of increase of 0.6% and 0.4%, respectively. In 20 years (2010-2014 *vs.* 1990-1994), the frequency of acidic rain with $pH < 5$ was reduced from 72% to 49% in the Northeast U.S. and Eastern Canada, 88% to 37% in the Midwest, 97% to 60 % in the Mid-Atlantic and 79% to 49% in the Southeast. We also explained the larger unbalance of measured cations and anions during the recent years was due to extra H^+ getting disassociated from dissolved weak organic acids when the pH of precipitation increased.

[1]Air Quality Measurement and Analysis Research Section, Atmospheric Science and Technology Directorate, jian.feng@ec.gc.ca
[2]Air Quality Measurement and Analysis Research Section, Atmospheric Science and Technology Directorate, rvet@rogers.com
[3]Air Quality Measurement and Analysis Research Section, Atmospheric Science and Technology Directorate, amanda.cole@ec.gc.ca
[4]Air Quality Measurement and Analysis Research Section, Atmospheric Science and Technology Directorate, leiming.zhang@ec.gc.ca
[5]Air Quality Measurement and Analysis Research Section, Atmospheric Science and Technology Directorate, irene.cheng@ec.gc.ca
[6]Air Quality Measurement and Analysis Research Section, Atmospheric Science and Technology Directorate, jason.obrien2@ec.gc.ca
[7]Air Quality Measurement and Analysis Research Section, Atmospheric Science and Technology Directorate, annemarie.macdonald@ec.gc.ca

Viability of Pollen Analysis Using Existing NADP Equipment

Eric Uram[1], Terri Williams[2], David Gay[3] and Jobi Carlisle[4]

Pollen serves as a natural sentinel of change for climate and growing seasons and is increasingly becoming a health concern related to allergies and asthma. During this year's pollen season, NADP began a comparative assessment for qualitative and quantitative aspects of airborne pollen using existing equipment and methods. Three sites were identified – North Carolina (NC30) at the Duke Forest, NC; Utah (UT01) near Logan, UT; and Wisconsin (WI93) near the NADP Program Offices in Madison, WI. Precipitation and air filters were collected weekly and filtered/stained for presence and abundance of tree, weed and grass pollen. Comparisons were made to existing reporting through the National Allergy Bureau (Roto-rod) and an emerging technology – PollenSense.

As of Sept 1, 2021, we have many samples to begin our comparison (7 wet, 7 high volume, hourly for PollenSense). Results are preliminary, but we are able to conclude two things – 1) NTN samples do contain pollen in relative amounts to what is measured using other equipment, and 2) the various analytical methods used with differing equipment result in highly variable results, even when making direct comparisons.

Data detailing wet deposition collection, high volume air sampling, PollenSense data and NAB Roto-rod sampling will be presented along with indications of strengths and weaknesses in the approaches. PollenSense equipment is becoming useful for identifying all particulates using a near real-time computerized sensor. Designed for pollen, the sensor scans and reads images using artificial intelligence.

SAMPLING METHODS AT SITES FOR THIS STUDY

WI93 - PollenSense, continuous high-volume air sampler, NTN precipitation collector and NAB data

NC30 - PollenSense, NTN collector, Roto-rod

UT01 - PollenSense, NTN collector

[1]Wisconsin State Laboratory for Hygiene, Eric.Uram@slh.wisc.edu
[2]Wisconsin State Laboratory for Hygiene, Terri.Williams@slh.wisc.edu
[3]Wisconsin State Laboratory for Hygiene, dgay2@wisc.edu
[4]Utah State University Agricultural Research Station, jobie@usu.edu

Recent Advances in Chemical Ionization Mass Spectrometry for Fast, Speciated, and *in-situ* Measurements of Atmospheric Constituents

Jordan Krechmer[1]

Gaseous volatile organic compounds (VOCs) are emitted from a wide variety of human and non-human sources. Some VOCs play important roles in secondary particulate and ozone formation, while others are directly hazardous to human health. Measurements of atmospheric gases, both in magnitude and direction, can intercept and interpret signals between living systems, including plants, microbes, and humans, as well as help understand anthropogenic influence on the environment. Due to the sheer number and complexity of atmospheric gaseous constituents, there is an ever-present need for greater sensitivity and specificity for *in-situ* measurement techniques.

In this talk I will present recent advances in online chemical ionization mass spectrometry (CIMS) by myself and colleagues that have increased the range of molecular volatility and functional groups that can be measured with high sensitivity by field-deployable mass spectrometers. Improvements in new inert materials and better inlets that reduce contact between sample gas and instrument walls have enabled the detection of extremely low volatility gases, enhancing understanding of new particle formation and inorganic, ‘sticky’ pollutants. Newly applied chemical reagent ions are used as a tool to enhance analytical specificity, focus detection on target molecular groups and increasing limits of detection by reducing unneeded background signals. I will also describe how advances in coupling pre-separation techniques such as gas chromatography can be leveraged to increase specificity without fully sacrificing time resolution. Finally, I will provide some brief results from ongoing projects that have benefited from these technological improvements, such as soil microbial VOC emissions, truck-based mobile volatile gas measurements, and indoor human emissions.

[1]Aerodyne Research, Inc., krechmer@aerodyne.com

Observations of ambient elemental and oxidized mercury from a continental mountaintop site using an improved dual-channel measurement system

Lynne Gratz[1], Seth Lyman[2], Tyler Elgiar[3], Zoe Zwecker[4], A. Gannet Hallar[5] and Rainer Volkamer[6]

Mercury (Hg) is a globally-distributed hazardous air pollutant. While gaseous elemental mercury (Hg^0) is relatively non-toxic at its low ambient concentrations, oxidized mercury (Hg^{II}) is more water soluble, reactive, and bioavailable for methylation and incorporation into ecosystems. The dynamic and complex cycling between these forms is central to the fate of atmospheric Hg; however, the governing chemistry and transport pathways remain highly uncertain. One challenge is that most oxidized mercury measurements are made using KCl-denuder-based systems that have a well-documented low bias. Moreover, most measurement systems are not routinely calibrated for Hg^{II}. In March 2021, we began a multi-season, multi-year study at the high elevation Storm Peak Laboratory (SPL) in Steamboat Springs, CO (3220 m AMSL) to investigate the origins and chemistry of atmospheric Hg in a continental atmosphere. We use an improved dual-channel measurement system with an automated calibrator to generate high temporal resolution and verified measurements of Hg^0 and Hg^{II}. Criteria gases, radon, aerosol properties and concentration, reactive gases, and meteorological variables are concurrently measured. Here, we share preliminary results from the first six months of this study and discuss ongoing measurement and modeling efforts. In spring and summer 2021, mean (± 1σ) hourly oxidized mercury concentrations were 77 ± 54 pg m^{-3} and 116 ± 39 pg m^{-3}, respectively, with a maximum concentration of 520 pg m^{-3}. For comparison, a previous study at SPL using the KCl-denuder system showed an average springtime oxidized mercury measurement of 20 pg m^{-3} with a maximum of 137 pg m^{-3}. From mid-March to early April, Hg^{II} showed a strong diurnal pattern with higher daytime concentrations, a behavior that dissipated during snowmelt and the transition to summer. In spring and early summer there were also several multi-day episodes of enhanced Hg^{II} and depleted Hg^0 ($r^2 = 0.4 – 0.8$) when relative humidity was low (< 30%) and 10-day HYSPLIT back-trajectories depict high altitude westerly flow over the Pacific Ocean, similar to past observations of in situ upper tropospheric oxidation. Lastly, summertime wildfires notably impacted ambient Hg and overall air quality at SPL. Within local smoke plumes (< 25 km), 10-minute Hg^0 and Hg^{II} concentrations exceeded 4 ng m^{-3} and 400 pg m^{-3}, respectively. These early results demonstrate the ability of the dual-channel method to accurately quantify ambient mercury, as well as the potential of our ongoing work to address pertinent questions about the sources and chemistry of ambient Hg in a continental atmosphere.

[1]Colorado College, Environmental Studies Program, lgratz@coloradocollege.edu
[2]Utah State University, Bingham Research Center, seth.lyman@usu.edu
[3]Utah State University, Bingham Research Center, tyler_elgiar@yahoo.com
[4]Colorado College, Environmental Studies Program, z_zwecker@coloradocollege.edu
[5]University of Utah, Department of Atmospheric Science, gannet.hallar@utah.edu
[6]University of Colorado, Department of Chemistry, CIRES, rainer.volkamer@colorado.edu

Molecular characterization of dissolved organic matter in São Paulo, Brazil wet deposition by ultra-high resolution mass spectrometry

Jackson Seymore[1], J. David Felix[2], Hussain Abdulla[3], Daniela Bergmann[4], Lucia Campos[5] and Jacques Florencio[6]

Rainwater dissolved organic matter (DOM) is a complex mixture of organic compounds, the composition of which remains to a large extent unknown. This is despite its central role in a host of fundamentally important atmospheric processes (e.g. aerosol hygroscopicity, light absorption, etc.). The molecular composition of DOM has been used to infer emission sources and investigate atmospheric reactions that produce secondary organic aerosols (SOA), which comprise the main contributor of uncharacterized compounds in rainwater organics. Recent pandemic related influences on anthropogenic emissions as well as increased biomass burning may show effects on rainwater DOM composition in the São Paulo region of Brazil. This work investigates the molecular composition of DOM in rainwater collected from February 2020 to June 2021 (n = 32 of rain samples) in Ribeirão Preto, SP to identify probable sources and indications of secondary processing of atmospheric DOM using Orbitrap mass spectrometry with novel statistical analysis. This approach strives to provide a detailed, ultra-high resolution, high-throughput method for future rainwater DOM investigations. By coupling this ultra-high resolution data set with knowledge of pandemic lockdown periods and increased biomass burning, this work provides stakeholders with insight to how varying anthropogenic activities and burning events impact their atmospheric chemistry and air quality.

[1]Texas A&M University - Corpus Christi, jseymore@islander.tamucc.edu
[2]Texas A&M University - Corpus Christi, joseph.felix@tamucc.edu
[3]Texas A&M University - Corpus Christi, hussain.abdulla@tamucc.edu
[4]Texas A&M University - Corpus Christi, dbergmann@islander.tamucc.edu
[5]Universidade de Sao Paulo, lcampos@ffclrp.usp.br
[6]Universidade de Sao Paulo, jacquesflorencio@usp.br

Tracing Atmospheric Sources of Mercury through Passive Air Sampling and Isotopic Characterization

Natalie Szponar[1], Yushan Su[2], Geoff Stupple[3], David McLagan[4], Claudia Vega[5], Luis Fernandez[6], Carl Mitchell[7], Alexandra Steffen[8], Frank Wania[9] and Bridget A. Bergquist[10]

The applications of mercury (Hg) stable isotopes to trace different atmospheric Hg emission sources and to understand transformations and fate of Hg in the atmosphere relies on the ability to collect amounts of Hg sufficient for artifact-free isotopic analysis. Mercury has seven stable isotopes and undergoes mass dependent fractionation (MDF) and several types of mass independent fractionation (MIF), making Hg isotopes a powerful tool for understanding Hg sources and cycling in the environment. Common methods for atmospheric Hg collection use active pumping through gold-coated bead/sand or activated carbon traps. However, such sampling requires long pumping times that increases the chances that traps could become prone to trap passivation or contamination. In addition, the energy requirements of active pumping also limit the spatial resolution of data generated by these methods. Here we assess the ability of a newly developed passive air sampler (PAS), which samples gaseous elemental Hg (GEM), to collect and preserve Hg for Hg isotopic analysis and show results from two reconnaissance studies on the spatial distribution of GEM concentrations and isotopes across large regions (Ontario, Canada and Madre de Dios, Peru). One-to-three-month deployments were sufficient to collect enough GEM (about 5 ng) for isotopic analysis in both experimental and field deployments. Laboratory and field experiments showed that no MIF occurs during GEM sampling by the PAS, but that there was a consistent MDF offset of ≈-1 ‰ in delta^{202}Hg. The application of the PAS allowed for regional and local sources to be distinguished in both Ontario and Peru. In Ontario, southern regions with greater local urban/industrial emission sources and/or trans-regional air masses containing industrial sources contained GEM that was isotopically distinct from northern regions, where there are fewer emission point sources. In Madre de Dios, Peru, artisanal and small-scale gold mining (ASGM) activity is a main emission Hg source to the region and isotopically distinct. This allowed us to assess the contribution of Hg emitted from ASGM to the atmospheric GEM pool. In both studies, vegetation uptake of GEM also appears to play an important role on the concentration and isotopic composition of the residual atmospheric pool.

[1]University of Toronto, natalie.szponar@mail.utoronto.ca
[2]Ontario Ministry of the Environment, Conservation and Parks, Yushan.Su@ontario.ca
[3]Environment and Climate Change Canada, geoff.stupple@canada.ca
[4]University of Toronto Scarborough, david.mclagan@mail.utoronto.ca
[5]Wake Forest University, CINCIA, vegacm@wfu.edu
[6]Wake Forest University, CINCIA, fernanle@wfu.edu
[7]University of Toronto Scarborough, carl.mitchell@utoronto.ca
[8]Environment and Climate Change Canada, alexandra.steffen@canada.ca
[9]University of Toronto Scarborough, frank.wania@utoronto.ca
[10]University of Toronto, bergquist@es.utoronto.ca

Systematics of fallout radionuclides (FRNs): towards their use as biogeochemical tracers of aerosol deposition

Joshua Landis[1], Carl Renshaw[2], James M. Kaste[3] and Xiahong Feng[4]

We introduce several long-term datasets aimed at better understanding how fallout radionuclides (FRNs) can be leveraged for new insights into aerosol-terrestrial interactions. ^{7}Be (half-life 54 days) and ^{210}Pb (half-life 22.3 years) are both produced in the atmosphere from gaseous precursors and trace accumulation-mode aerosols. The FRNs are appealing tracers because they offer unique insights over defined time frames based and can provide chronometry of aerosol biogeochemical cycling. At our site in Hanover, NH USA (43.7022° N, 72.2896° W, 165 m.a.s.l) we measure bulk deposition in weekly intervals 2011-present (n=526), paired with 0.5 um filtration and sorption/desorption experiments to examine operational speciation of FRNs (n=138), co-located measurements of ambient PM10 (particulate matter >10 um; n=201), monthly collections of tree leaves (n=94), and event-based measurements of openfall and throughfall under red oak, white pine and Norway spruce canopies (n=92). FRNs are measured by gamma spectrometry and major/trace elements (MTEs) by ICP-OES and ICP-MS.

We observe that multiple, distinct aerosol populations contribute to bulk deposition. These are discriminated by ^{7}Be:^{210}Pb ratios: washout, rainout, PM10, and recycled dust, the latter with a mean time in recirculation of ca. 200 days. Filtration and sorption/desorption experiments with FRNs and ambient PM confirm that partitioning of FRNs to PM is strong, irreversible, and is driven by affinity of FRNs to organic matter. Both ^{7}Be and ^{210}Pb, and trace-metals including, Hg, Al, and Pb accumulate in tree leaves linearly with time during active growth (May-Sept.) and continuing through leaf senescence (Oct.-April); leaves of red oak persist in the canopy following abscission. We show that leaf ^{7}Be:^{210}Pb ratios maintain quasi-equilibrium with our co-located record of bulk deposition, confirming that accumulation of FRNs in vegetation occurs primarily by wet deposition. Moreover, this accumulation is permanent, and weathering or removal processes operate with a half-time >365 days. Consistent with observations of leaves, at the canopy-scale openfall-throughfall comparisons show that ca. 40% of event-based ^{7}Be flux is retained by the forest canopy. Yields from the canopy of ^{210}Pb are significantly greater than ^{7}Be, from which we estimate that approximately 23% of net ^{210}Pb throughfall deposition represents weathering of legacy deposition from long-lived tissues of the canopy (phyllosphere). We suggest that our observations of FRNs can provide new strategies for tracing pathways and timescales for aerosol biogeochemical cycling in terrestrial systems.

[1]Dartmouth College, joshua.d.landis@dartmouth.edu
[2]Dartmouth College, carl.e.renshaw@dartmouth.edu
[3]The College of William and Mary, jmkaste@wm.edu
[4]Dartmouth College, xiahong.feng@dartmouth.edu

PFAS Mass Concnetrations and Flux in Wisconsin Rainwater Through Analysis of Wet Deposition Samples from National Trends Network

David Pfotenhauer[1], Katie Praedel[2], Jamie Gauthier[3], Erin Howard[4] and Martin Shafer[5]

Growing concern over the human health and environmental impacts of polyfluoroalkyl substances (PFAS) has spurred research efforts to better understand the sources of these compounds to the environment and their mechanisms for transport and accumulation once released. Recent findings suggest that atmospheric transport and processing is a substantial dissemination pathway and significant mode for PFAS deposition to terrestrial and aquatic environments. To investigate PFAS transport and deposition via precipitation, the Wisconsin Department of Natural Resources collaborated with the Wisconsin State Lab of Hygiene (WSLH) in 2020 to use the National Atmospheric Deposition Program's (NADP) National Trends Network (NTN) precipitation collection network to study PFAS in rainwater. 98 precipitation samples were collected weekly across eight Wisconsin NADP-NTN sites from April 14th through October 27th of 2020. Samples were processed at the WSLH with 36 PFAS compounds quantified by LC/MS/MS after SPE concentration and clean-up. Concentrations of individual PFAS compounds in the precipitation samples were typically below 0.5 ng/L, though levels approaching 2 ng/L were occasionally observed. PFHpA, PFOA, PFHxA, PFNA, PFPeA and PFBA were the most frequently detected PFAS compounds, each quantified in over 90% of the precipitation samples. Carboxylates dominated the PFAS species, representing on average over 92% of the total PFAS quantified. Median concentrations of PFOA and PFOS were 0.18 ng/L and 0.10 ng/L respectively, though concentrations varied from <0.1 to over 1.6 ng/L across the sites. Four species of PFAS (PFBA, 6:2 FTSA, PFOA, PFOS) showed statistically significant differences in mass concentrations between the sites, suggesting that influence from local sources can be observed through analysis of rainwater. PFAS deposition was relatively uniform across the study sites, averaging just over 5 ng/m^2/day for the study period. However, higher deposition (nearly 8.5 ng/m^2/day) was measured at two sites in central WI, where studies are ongoing.

[1]Wisconsin Department of Natural Resources, David.Pfotenhauer@Wisconsin.gov
[2]Wisconsin Department of Natural Resources, Katie.Praedel@wisconsin.gov
[3]Wisconsin Department of Natural Resources, jamie.gauthier@wisconsin.gov
[4]Wisconsin Department of Natural Resources, erina.howard@wisconsin.gov
[5]Wisconsin State Lab of Hygiene, mmshafer@wisc.edu

Variability of Wet Mercury Deposition Measurements Using Different Types of Samplers

Guey-Rong Sheu[1], Da-Wei Lin[2], Kohji Marumoto[3] and Neng-Huei Lin[4]

Atmospheric wet mercury (Hg) deposition is usually quantified by analyzing the total Hg concentrations in rainwater samples that are collected by wet deposition samplers. However, there is no standard type of wet deposition sampler globally. For example, the N-CON collector is commonly used for sampling sites of Mercury Deposition Network (MDN), while MIC-B type collector is used for sampling sites of the Asia Pacific Mercury Monitoring Network (APMMN) and Taiwan's wet Hg deposition monitoring network. KASC-02 collector is used in Japan. These wet deposition samplers vary in shapes, sensors, sampling trains, and hence sampling efficiencies, which may cause measurement bias in Hg concentrations of rainwater samples being collected by different types of samplers. To quantify the variability of wet Hg deposition measurements among different types of samplers, a sampler inter-comparison study has been conducted on the campus of National Central University in Taiwan. One N-CON, one KASC-02 and two MIC-B wet deposition samplers were set up side by side to collect weekly rainwater samples concurrently. Rainwater Hg concentrations between the two MIC-B samplers were well correlated ($R^2 = 0.97$) with a slope of 1.09. Rainwater Hg concentrations between N-CON and MIC-B samplers were also well correlated ($R^2 = 0.97$) with a slope of 0.84, with N-CON rainwater Hg concentrations being 16% lower than those of MIC-B samples. Rainwater Hg concentrations between KASC-02 and MIC-B samplers were also well correlated ($R^2 = 0.96$) with a slope of 0.99, indicating very good agreement between KASC-02 and MIC-B samplers.

[1]National Central University, grsheu@atm.ncu.edu.tw
[2]National Central University, dwlin@g.ncu.edu.tw
[3]National Institute For Minamata Disease, KOJI_MARUMOTO@env.go.jp
[4]National Central University, nhlin@ncu.edu.tw

Atmospheric Deposition of Reactive Nitrogen in India

Umesh Kulshrestha[1], Manisha Mishra[2], Anshu Sharma[3], Yogender Singh[4], Moh Naseem[5], Ankita Katoch[6], Sudesh[7], Sunaina[8], Mudita Chaturvedi[9] and Akansha Roy[10]

During last few decades, global population has increased dramatically so the demand of food and energy. This has resulted in higher rates of fertilizer production and fossil fuel combustion causing an increase in reactive nitrogen species (Nr) in air. The increased levels of reactive nitrogen species might have adverse impacts on humans, environment and climate. This study reports wet deposition fluxes of NH_4^+ and NO_3^- at different sites of DRS-Net India network and some of the sites of UKRI GCRF South Asian Nitrogen Hub project in India. The annual wet deposition fluxes of total inorganic nitrogen (NH_4^+-N + NO_3^--N) was recorded the highest at rural site followed by urban and industrial sites. The average flux of total inorganic nitrogen was calculated as 18.6 kg/ha/y. The NH_4^+-N/NO_3^--N mass and molar ratios were found to be greater than the unity across all the sites indicating the dominance of NH_3 sources over NOx sources. The values of these were observed to be higher during monsoon period than during non-monsoon periods due to wash out effect. Concentration and phase distribution results showed that the particulate NH_4^+ was lower than gaseous NH_3 indicating an important role of tropical meteorology in this region. Most of these contributions were estimated as of local origin. However, the snowmelt chemistry indicated the long-range transport of NO_3^- at the Himalayan sites. Therefore, the wet deposition of NH_4^+ and NO_3^- on the soils, vegetation and water bodies needs to be assessed in order to find out their future impacts on the ecosystem.

[1]School of Environmental Sciences Jawaharlal Nehru University, umesh@mail.jnu.ac.in
[2]School of Environmental Sciences Jawaharlal Nehru University, manishamishra30j90@gmail.com
[3]School of Environmental Sciences Jawaharlal Nehru University, anshuu.jnu@gmail.com
[4]School of Environmental Sciences Jawaharlal Nehru University, yogendersinghdhanda@gmail.com
[5]School of Environmental Sciences Jawaharlal Nehru University, mohnaseemmalik@gmail.com
[6]School of Environmental Sciences Jawaharlal Nehru University, ankitakatoch@gmail.com
[7]School of Environmental Sciences Jawaharlal Nehru University, sudeshyadav1902@gmail.com
[8]School of Environmental Sciences Jawaharlal Nehru University, sunainakanojia1111@gmail.com
[9]School of Environmental Sciences Jawaharlal Nehru University, mudita.chaturvedi@hotmail.com
[10]School of Environmental Sciences Jawaharlal Nehru University, akanksharoy59@gmail.com

Monitoring and modelling atmospheric deposition impacts and effects in the Republic of Ireland.

David Kelleghan[1] , Y. Sim Tang[2], Bill Bealey[3], Laurence Jones[4], Thomas Cummins[5], Thomas P. Curran[6], Cristina Martin Hernandez[7], Kasia Sawicka[8], Massimo Vieno[9], Felicity Hayes[10] and Ed C. Rowe[11]

Under the European National Emissions Reduction Commitments Directive (NECD 2016/2284), European Union Member States are required to monitor and report air pollution pressures, impacts and effects on sensitive ecosystems. These ecosystems need to be representative of each country's freshwater, forest, natural and semi-natural habitats. Air quality impacts are considered exceedance of critical thresholds, where effects reflect the influence of air quality on ecology. Ireland's response to this requirement has been the design of the National Ecosystem Monitoring Network (NEMN). While this network is still being implemented, its current design pairs air quality with ecological monitoring. In order for this network to be successful, it requires collaboration between numerous state bodies in order to maximise its potential. Pivoting existing monitoring required under the Habitats Directive (92/43/EEC), by creating permanent sites and quadrats will allow for changes and improvements in effects to be observed over time as part of existing programs. It is vitally important that sites selected to be included within this network are representative of an impact gradient, including both polluted and unpolluted sites. The best way to identify such impact gradients is to use advanced concentration and deposition models, to inform and assess site coverage. It is intended, that the air quality monitoring being done can be used to validate these models in the future; allowing for more accurate predictions of drivers, impacts and effects on other sensitive sites. The air pollution impacts of interest are in the first instance those relating to the substances for which reduction commitments are set in Annex II to the NECD (i.e. SO_2, NO_X, NMVOC and NH_3), that is those contributing to acidification and eutrophication of ecosystems, and as precursors of ozone damage to vegetation growth and biodiversity changes. The primary atmospheric pollutant of concern on sensitive ecosystems in Ireland is nitrogen concentrations and deposition. As a result, the NEMN is primarily focused on monitoring the impact (exceedance of thresholds) and effect (impact on vegetation and biodiversity) of nitrogen deposition across the country. The development of the NEMN is intended to be an iterative process, with incremental improvements over time. The existing network is composed of International Co-operative Programme (ICP) Forests and Waters sites operated under the Air Convention (UN-ECE CLRTAP) and Water Framework Directive (2000/60/EC), respectively.

[1]University College Dublin, david.kelleghan@ucd.ie
[2]UK Centre for Ecology and Hydrology, yst@ceh.ac.uk bil
[3]UK Centre for Ecology and Hydrology, bib@ceh.ac.uk
[4]UK Centre for Ecology and Hydrology, lj@ceh.ac.uk
[5]University College Dublin, thomas.cummins@ucd.ie
[6]University College Dublin, tom.curran@ucd.ie
[7]UK Centre for Ecology and Hydrology, crimar@ceh.ac.uk
[8]UK Centre for Ecology and Hydrology, katwic55@ceh.ac.uk
[9]UK Centre for Ecology and Hydrology, mvi@ceh.ac.uk
[10]UK Centre for Ecology and Hydrology, fhay@ceh.ac.uk
[11]UK Centre for Ecology and Hydrology, ecro@ceh.ac.uk

UK Air Pollution Impacts on Ecosystems Networks (APIENs): An integrated approach to assess impacts of key air pollutants on sensitive freshwater and terrestrial ecosystems

Yuk Tang[1] , Christine Braban[2], Philip Taylor[3], Philip Taylor[4], Bill Bealey[5], Massimo Vieno[6], Peter Levy[7], Amy Stephens[8], Marsailidh Twigg[9], Ulli Dragosits[10] and Plus 19 other co-authors[11]

The UK Air Pollution Impacts on Ecosystems Networks (APIENs) was formed in 2018 to monitor and report on the negative impacts of priority air quality pollutants (SO_X, NO_X, NH_3 and ground level ozone) on ecosystems (acidification, eutrophication, ozone damage or changes in biodiversity). Sites were integrated from long-term national air quality (e.g. UK Eutrophying and Acidifying Air Pollutants Network) and ecological (e.g. UK Environmental Change Network) networks, with representation across freshwater, natural and semi-natural habitats and forest ecosystem types in the UK, and across the major pollution gradients. The intensive APIENs data, complemented by modelled exceedances of critical loads and levels, and combined with extensive data from national surveys (e.g. UK Countryside Surveys), were reported for the first time to the European Environment Agency in 2019, as required under Article 9 of the EU National Emission reduction Commitments Directive (NECD, 2016/2284/EU). With EU exit, future reporting will be to the UK National Emission Ceilings Regulations (NECR) 2018, Part 5, and aligned to the 4-yearly reporting cycle of the EU NECD. The integrated dataset is also publicly accessible on the APIS website (http://www.apis.ac.uk). This is a valuable resource, as a baseline against which any changes and recovery in ecosystem response to future emissions reductions may be assessed, while providing a unique opportunity for developing integrated long-term ecosystem research in the UK and internationally.

[1]UK Centre for Ecology & Hydrology (UKCEH), yst@ceh.ac.uk
[2]UK Centre for Ecology & Hydrology (UKCEH), chri2@ceh.ac.uk
[3]UK Centre for Ecology & Hydrology (UKCEH), crimar@ceh.ac.uk
[4]UK Centre for Ecology & Hydrology (UKCEH), philor@ceh.ac.uk
[5]UK Centre for Ecology & Hydrology (UKCEH), bib@ceh.ac.uk
[6]UK Centre for Ecology & Hydrology (UKCEH), mvi@ceh.ac.uk
[7]UK Centre for Ecology & Hydrology (UKCEH), plevy@ceh.ac.uk
[8]UK Centre for Ecology & Hydrology (UKCEH), amstep@ceh.ac.uk
[9]UK Centre for Ecology & Hydrology (UKCEH), sail@ceh.ac.uk
[10]UK Centre for Ecology & Hydrology (UKCEH), ud@ceh.ac.uk
[11]see abstract, see abstract

Phenology monitoring infrastructure and data: fundamental resources supporting scientific discovery, natural resource management, and Earth observations

Theresa Crimmins[1] , Greg Wetherbee[2] and David Gay[3]

The USA National Phenology Network (USA-NPN) supports science and decision-making in a wide range of natural resource management applications by collecting, storing, and freely sharing plant and animal phenology data and derived data products. A primary activity of the Network is to host *Nature's Notebook*, a phenology observing program available for use by professionals and volunteers alike, and now in its 13th year of data collection.

Since the program's launch in 2009, participants have contributed over 26M phenology records to *Nature's Notebook* at over 16,000 sites across the U.S. These data have been used in over 100 peer-reviewed studies, enabling researchers to document how the timing of seasonal events are changing differentially among species and across geography, disentangle what cues these seasonal events, and validate satellite imagery. These observations have also been used to establish indicators of live fuel moisture in fire-prone ecosystems, guide the timing of invasive species management activities to achieve optimal success, and indicate peaks in airborne pollen to guide treatment of allergenic rhinitis, and even assist Hollywood producers in planning on-location filming. There is great unrealized potential to utilize these data in evaluating impacts of nitrogen deposition, especially with respect to critical loads exceedances in sensitive ecosystems.

The Network also offers a growing suite of gridded maps and short-term forecasts of when key seasonal events in plants and animals are anticipated to occur. In this presentation, we will describe the USA-NPN's phenology data resources and forecasts. We will also share examples of how these data are being used in scientific discoveries as well decision-making applications.

[1] USA National Phenology Network, theresa@usanpn.org
[2] US Geological Survey, wetherbe@usgs.gov
[3] Wisconsin State Laboratory of Hygiene, dgay2@wisc.edu

Long term Atmospheric Deposition of Nitrogen and Sulfur at Canadian Rural Locations

Irene Cheng[1], Zhuanshi He[2], Amanda Cole[3], Jian Feng[4], Jason O'Brien[5], Anne Marie Macdonald[6], Jeffrey Brook[7], Leiming Zhang[8], Daniel Houle[9], Julian Aherne[10] and Hazel Cathcart[11]

The Canadian Air and Precipitation Monitoring Network (CAPMoN) measures inorganic ions, ozone, mercury and particulate matter for the purpose of monitoring trends in air pollutants and acidic deposition across Canada. Spatiotemporal trends in atmospheric deposition of inorganic nitrogen and sulfur were analyzed from 2000 to 2018 in this study. Total (dry+wet) nitrogen deposition fluxes ranged from 1.7-9.5 kg N/ha/yr among the fifteen sites, though dry deposition of NH_3 and some oxidized nitrogen species were not captured. Wet deposition comprised 71-95% and dry deposition comprised 5-29% of total measured nitrogen deposition, which was dominated by wet NO_3^- and wet NH_4^+ deposition. Contributions to dry nitrogen deposition were 40-74% from HNO_3, 11-40% from pNH_4^+ and 5-25% from pNO_3^-. Total sulfur deposition fluxes ranged from 1.3-8.5 kg S/ha/yr. Relative percentages of wet and dry sulfur deposition were 45-89% and 11-55%, and total sulfur deposition were largely from wet SO_4^{2-} deposition and dry SO_2 deposition. Acidic deposition fluxes were greatest in southeastern Canada and were comparable among the west coast, prairie, remote and Atlantic Canada sites. Total nitrogen fluxes were nearly equivalent to total sulfur deposition fluxes in early 2000, whereas total nitrogen deposition exceeded that of total sulfur during 2014-2018. Oxidized nitrogen (dry HNO_3, dry pNO_3^-, wet NO_3^-) deposition was greater than that of reduced nitrogen (dry pNH_4^+, wet NH_4^+) in early 2000. In 2014-2018, reduced nitrogen deposition surpassed that of oxidized nitrogen in the southeastern region. Total nitrogen and sulfur deposition decreased significantly at a rate of -0.03 to -0.25 kg N/ha/yr (-1.1 to -3.3%/yr) and -0.08 to -0.66 kg S/ha/yr (-3.5 to -6.6%/yr), respectively, among the sites. The weak declining trend in total nitrogen deposition at the west coast and non-significant trend at the prairie sites were consistent with the slower decline in NO_x emissions in western Canada. Reductions in total nitrogen deposition were driven by oxidized nitrogen as trends in reduced nitrogen were non-significant. Anthropogenic NO_x and SO_2 emissions reductions in both eastern Canada and eastern U.S. were highly effective in reducing total oxidized nitrogen and total sulfur deposition, respectively, in eastern Canada. Curbing emissions in western Canada had a more direct impact on reducing total oxidized nitrogen and sulfur deposition at a west coast site than emissions reductions in western U.S. Preliminary analysis indicates that critical loads exceedances have decreased owing to the significant declines in nitrogen and sulfur deposition, which is conducive to the recovery from historical acidification.

[1]Air Quality Research Division, Environment and Climate Change Canada, Toronto, Ontario, Canada, irene.cheng@ec.gc.ca
[2]Air Quality Research Division, Environment and Climate Change Canada, Toronto, Ontario, Canada, Zhuanshi.He@ec.gc.ca
[3]Air Quality Research Division, Environment and Climate Change Canada, Toronto, Ontario, Canada, Amanda.Cole@ec.gc.ca
[4]Air Quality Research Division, Environment and Climate Change Canada, Toronto, Ontario, Canada, Jian.Feng@ec.gc.ca
[5]Air Quality Research Division, Environment and Climate Change Canada, Toronto, Ontario, Canada, Jason.OBrien2@ec.gc.ca
[6]Air Quality Research Division, Environment and Climate Change Canada, Toronto, Ontario, Canada, AnneMarie.Macdonald@ec.gc.ca
[7]Dalla Lana School of Public Health, University of Toronto, Toronto, Ontario, Canada, jeff.brook@utoronto.ca
[8]Air Quality Research Division, Environment and Climate Change Canada, Toronto, Ontario, Canada, Leiming.Zhang@ec.gc.ca
[9]Aquatic Contaminants Research Division, Environment and Climate Change Canada, Montréal, Quebec, Can, Daniel.Houle@ec.gc.ca
[10]Trent University, Peterborough, Ontario, Canada, jaherne@trentu.ca
[11]Air Quality Research Division, Environment and Climate Change Canada, Toronto, Ontario, Canada, Hazel.Cathcart@ec.gc.ca

Global mercury passive sampler network: one year on

Katrina Macsween[1], Geoff Stupple[2], Alexandra Steffen[3] and Frank Wania[4]

Mercury's unique chemical properties allows it to reside in the atmosphere for extended periods, causing it to be transported across global scales. The Global and toxic nature of Hg means that ongoing monitoring of mercury in the atmosphere is critical for the implementation and assessment of regulatory measures and to help understand the impact of climate perturbations. In response to the need for greater monitoring capabilities, we have introduced a global mercury passive sampler network comprised of pre-existing and expanded monitoring networks. The use of passive samplers enables coverage across a much broader spatial range, including areas that currently lack sufficient Hg measurements due to difficult to reach environments and/or, the highly specialised nature of traditional measurement techniques. The network, established in 2019, currently has over 41 sites operating across 23 countries. The mercury passive samplers are uniquely designed to be cost effective and easily deployed without the need for pre-existing infrastructure. The samplers work by diffusive uptake of mercury onto sulfur impregnated carbon housed within a mesh tube in a blue protective container. Concentrations are determined based on accumulated mercury over time exposed and the sampling rate. 2019-2020 results show a global average atmospheric mercury concentration of 1.24 ng m^{-3} (SD 0.31 ng m^{-3}), on par with current active and modelled global concentrations. Samplers have enabled a much greater spatial distribution than current long term monitoring sites with concentrations ranging from 1.87 ng m^{-3} at Pathum Thani, Thailand to 0.84 ng m^{-3} at Arauca in Columbia. Despite increased spatial resolution, there are still a large number of gaps, such as much of the southern hemisphere including Africa, Australia and South America and Russia and Eastern Europe.

[1]Environment and Climate Change Canada, katrina.macsween@ec.gc.ca
[2]Environment and Climate Change Canada, geoff.stupple@ec.gc.ca
[3]Environment and Climate Change Canada, alexandra.steffen@ec.gc.ca
[4]University of Toronto, frank.wania@utoronto.ca

The WMO Measurement Model Fusion for Global Total Atmospheric Deposition Initiative: Supporting Science, Policy, and Sustainable Development Goals

Jeffrey Geddes[1]

Atmospheric deposition is strongly linked to several of the United Nations' Sustainable Development Goals, but many stakeholders and local governments around the world currently lack the information or capacity to construct maps of atmospheric deposition required to guide their policymaking and planning decisions as they relate to these goals. The Measurement-Model Fusion for Global Total Atmospheric Deposition (MMF-GTAD) Initiative is a WMO Global Atmospheric Watch initiative that aims to help countries and other stakeholders meet their commitments towards the SDGs by providing this information and carrying out other capacity-building activities. Measurement-model fusion approaches merge the best available observational data with state of the art chemical transport modeling predictions to derive spatially continuous maps of deposition, simultaneously filling in gaps in sparse observational coverage while constraining the large uncertainties associated with model-only estimates. Among the MMF-GTAD initiative's objectives (which include creating awareness, stakeholder engagement, and harmonizing resources and data), is the provision of frequently updated high resolution global-scale maps of total (wet + dry) atmospheric deposition of nitrogen, sulfur, and ozone. This presentation will introduce the MMF-GTAD activities and highlight the initiative's progress so far, and serve as an introduction to the wider measurement-model fusion research related to atmospheric deposition.

[1] Department of Earth & Environment, Boston University, jgeddes@bu.du

Evaluation of changes in annual deposition fluxes estimated with the modernized TDep Measurement Model Fusion method using the EQUATES time-series dataset

Greg Beachley[1], Shih Ying Chang[2], Nathan Pavlovic[3], Kristen Foley[4], Sarah Benish[5], Jesse Bash[6], Melissa Puchalski[7] and Chris Rogers[8]

The U.S. EPA and National Atmospheric Deposition Program (NADP) Total Deposition Science Committee (TDep) have used the measurement model fusion model (TDep v2018.2) originally described by Schwede and Lear, 2014 to provide estimates of annual wet, dry, and total deposition fluxes over the contiguous U.S. since 2015. The model fuses measured data from the Clean Air Status Trends Network (CASTNET) and NADP National Trends Network (NADP NTN) with modeled datasets of deposition velocity and flux from the Community Multiscale Air Quality (CMAQ) model and precipitation fields from the Parameter-elevation Regression on Independent Slopes Model (PRISM). The deposition estimates are widely utilized by ecologists for calculation of critical loads.

Recently, the model has been modernized and recoded with Python geoprocessing (TDep v2021.1) in order to simplify the software and improve on the script flexibility to allow it to be more accessible to users and extensible for future modifications. A comparison of the models was done with the 2010 dataset and it was found that annual total deposition estimates for N and S species were within ~±30% for 90 percent of the grid cells. This variation was due to method and data corrections and improvements. Forthcoming estimates from the TDep v2021.1 will utilize EPA's Air QUAlity TimE Series (EQUATES) dataset ranging from 2002-2017 which includes CMAQ v5.3.2 air quality modeling data. The previous version (TDep v2018.2) utilized the ECODEP time-series and the CMAQ v5.0.2 dataset spanning from 2002-2012. The changes in the estimated annual deposition fluxes for the 2010 comparison year will be evaluated for both the method modernization and the updated CMAQ time-series data for nitrogen, sulfur, and base cation species.

[1]US EPA, beachley.gregory@epa.gov
[2]Sonoma Technology, Inc., Petaluma, CA, cchang@sonomatech.com
[3]Sonoma Technology, Inc., Petaluma, CA, npavlovic@sonomatech.com
[4]U.S. Environmental Protection Agency, Research Triangle Park, NC, Foley.Kristen@epa.gov
[5]Oak Ridge Institute for Science and Education (ORISE), U.S. Environmental Protection Agency, Researc, Benish.Sarah@epa.gov
[6]U.S. Environmental Protection Agency, Research Triangle Park, NC, Bash.jesse@epa.gov
[7]U.S. Environmental Protection Agency, Washington, DC, Puchalski.Melissa@epa.gov
[8]Wood Environment & Infrastructure Solutions, Inc., Jacksonville, FL, christopher.rogers@woodplc.com

Evaluation of a Measurement Model Fusion Approach for Improving Predictions of Wet Deposition from EQUATES

Sarah Benish[1], Jesse Bash[2], Kristen Foley[3], Christian Hogrefe[4] and Wyat Appel[5]

Chemical transport models (CTMs), such as the EPA's Community Multiscale Air Quality (CMAQ) model, simulate the distribution and temporal trends of nitrogen and sulfur deposition. However, model biases and uncertainty in the chemical and physical processes governing deposition, including due to model resolution, can result in errors designating critical load exceedances. Measurement Model Fusion methods are often used to improve deposition estimates, including by the National Atmospheric Deposition Program (NADP) Total Deposition (TDEP) Science Committee. In this presentation, we assess deposition from multiyear simulations from the EPA's Air QUAlity TimE Series (EQUATES) project employing a consistent modeling framework using CMAQv5.3.2 and the previous timeseries utilizing CMAQv5.0.2. We provide an overview of the measurement model fusion approach previously published by Zhang et al. (2019) that bias-corrects CMAQ wet deposition output using observation-based gridded precipitation data provided by the Parameter-elevation Regressions on Independent Slopes Model (PRISM). We evaluate the model's ability to reproduce wet deposition of nitrate, ammonium, and sulfate over U.S. climate regions from 2002-2017 using measurements collected by the NADP National Trends Network (NTN). We show that the Measurement Model Fusion technique applied to the EQUATES simulations improves model performance of wet deposition, decreasing the normalized mean bias across the United States by as much as 20-30% annually compared to CMAQv5.3.2. While model performance varies by climate region, particularly in areas with complex terrain and localized precipitation patterns, the Measurement Model Fusion technique applied to the EQUATES simulations may help improve ecological and nutrient assessments.

[1]ORISE/EPA, benish.sarah@epa.gov
[2]EPA, bash.jesse@epa.gov
[3]EPA, Foley.Kristen@epa.gov
[4]EPA, Hogrefe.Christian@epa.gov
[5]EPA, Appel.Wyat@epa.gov

ADAGIO: A simple and effective data-fusion algorithm for particle dry and wet deposition

Alain Robichaud[1], Amanda Cole[2], Mike Moran[3], Alex Lupu[4] and Verica Savic-Jovcic[5]

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. The result of data-fusion, a product called objective analysis (OA), corresponds to an interpolation of the difference between the modeled (GEM-MACH) and measured values at network observation sites in North America (NADP, AIRS, CASTNET, CAPMON, NBPN). In model-data fusion, the weights attributed to model and observations are usually derived from, error statistics (difference model – observations). However, there is no real consensus on how to choose the best method to derive error statistics (weights for model and observations) for near-surface data-fusion products. This is because near 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 which makes non-trivial the evaluation of error statistics. Consequently, near the surface, the representativeness error is likely to be more significant compared to the free troposphere. Complicated, resource demanding and sophisticated methods exist for data fusion such as Kalman filters, ensemble methods, etc. However, optimal interpolation methods if properly tuned lead to a simple, precise and effective data-fusion algorithm. The method presented here consists of three steps: 1) performing sensitivity tests using NI independent observation sets (each containing 100(1-1/NI)% of the complete data) to identify the optimum correlation length Lc; 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 (χ2); 3) making independent validation using the remaining (100/NI)% of the data. The method is robust, efficient and performs well when verifying against independent observations. Deposition of N and S are presented over North America for the years 2010, 2013 and 2016.

[1]Environment and Climate Change Canada (ECCC), alain.robichaud@canada.ca
[2]Environment and Climate Change Canada (ECCC), amanda.cole@canada.ca
[3]Environment and Climate Change Canada (ECCC), mike.moran@canada.ca
[4]Environment and Climate Change Canada (ECCC), alex.lupu@canada.ca
[5]Environment and Climate Change Canada (ECCC), verica.savic-jovcic@canada.ca

Modeling the Urban Areas Contribution to Nitrogen Deposition in U.S.

Sharmin Akter[1] and Kristina Wagstrom[2]

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 urban areas contributions to atmospheric nitrogen deposition. We model the amount of atmospheric nitrogen deposition from the 20 largest metropolitan areas in the contiguous United States. We use emissions, meteorology, boundary conditions, and ozone column inputs from the United States Environmental Protection Agency's 2011 Modeling Platform. This information will aid environmental regulators in developing watershed management plans to protect the health of aquatic and terrestrial ecosystems. The contributions of nitrogen deposition from New York City, NY and Houston, TX contributed disproportionately higher to deposition than other locations.

[1]University of Connecticut, sharmin.akter@uconn.edu
[2]University of Connecticut, kristina.wagstrom@uconn.edu

The Impacts of Climate Change on Air Quality and Deposition: Recent Advances and Future Directions

Christopher Nolte[1]

Climate change has the potential to affect air quality and deposition in myriad ways. Many emissions processes are sensitive to meteorology, including wildfires and vegetative emissions of volatile organic compounds (VOCs). In addition to increasing temperatures, climate change may also affect wind speeds, mixing depths, humidity, clouds, and precipitation, which all influence pollutant formation and removal rates. This talk will briefly summarize the current state of knowledge of the impacts of climate change on air quality. It is now well established that for a given level of anthropogenic emissions of precursor pollutants, climate change leads to higher concentrations of ground-level ozone over polluted continental regions. However, this general picture is complicated, as continued decreases in nitrogen oxide (NOx) emissions combined with increases in biogenic VOCs are likely to cause some regions to transition to NOx-limited chemical regimes. The effects of climate change on particulate matter (PM) concentrations are even more uncertain, with some studies suggesting increased biogenic VOC emissions will increase organic aerosol concentrations, while other studies indicate more frequent precipitation could increase removal rates, thereby lowering PM concentrations. Wildfires are becoming increasingly important emissions sources, both in absolute magnitude and in a relative sense as other anthropogenic sources are controlled. While there is high confidence in the prediction that wildfire frequency and intensity will continue to increase over the 21st century, the impact of those increases on air quality and deposition remain highly uncertain and are an area of active research.

[1]US EPA, nolte.chris@epa.gov

Future changes in atmospheric emissions and deposition under U.S. policies to decarbonize the electricity sector

Qasim Mehdi[1], Qasim Mehdi[2], Petros Vasilakos[3], Peter Wilcoxen[4], Armistead Russell[5], Kathy Lambert[6] and Charles Driscoll[7]

Policy choices for addressing greenhouse gas emissions from the electricity sector are prominent in national conversations on climate change. In this study, we explore potential changes in emissions of criteria pollutants and atmospheric deposition for 12 electricity sector policies to mitigate carbon emissions from 2020-2050 that are relevant to current national discussions. These policies include recent rules promulgated by the U.S. EPA; clean electricity standards; national cap and trade policies; and carbon prices in the electricity sector. Each electricity sector policy is compared to a business-as-usual (BAU) reference case to estimate changes in carbon dioxide and co-pollutant emissions of sulfur dioxide, nitrogen oxides, and mercury; air quality constituents; and atmospheric deposition of sulfur and nitrogen. We use outputs from the Integrated Planning Model to estimate changes in electricity generation, carbon and co-pollutant emissions, and system costs. Emission estimates are used in the Community Multiscale Air Quality model to simulate changes in air quality, including concentrations of gaseous and particulate sulfur and nitrogen species and ozone, and atmospheric sulfur and nitrogen deposition across the coterminous U.S. resulting from these policies. All high-ambition policies drive down coal generation quickly, with large near-term reductions in sulfur dioxide, nitrogen oxide and mercury emissions. High ambition decarbonization policies are projected to result in marked decreases in aerosol and gaseous sulfate and nitrate and ozone, particularly in the eastern U.S. and prominently in the Ohio River Valley. Interestingly, decarbonization policies resulted in decreases in ammonium deposition due to decreases in atmospheric scavenging by sulfate and nitrate.

[1]Syracuse University, mmehdi@syr.edu
[2]Syracuse University, mmehdi@syr.edu
[3]Georgia Tech, peter.vasilakos@gatech.edu
[4]Syracuse University, wilcoxen@syr.edu
[5]Georgia Tech, ted.russell@gatech.edu
[6]Harvard University, kathleen.lambert3@gmail.com
[7]Syracuse University, ctdrisco@syr.edu

Sulfate:nitrate and ammonium:nitrate ratios in wet atmospheric deposition as indicators of atmospheric pollution in different regions of México

Rodolfo Sosa Echeverría[1], Ana Luisa Alarcón Jiménez[2], Gilberto Fuentes Garcia[3], Monica Jaimes Palomera[4], Pablo Sanchez Alvarez[5], Elizabeth Vega[6], David Gay[7], John Walker[8] and Gregory Wetherbee[9]

Sulfate/nitrate and ammonium/nitrate ratios (SO_4^{2-}/NO_3^- and NH_4^+/NO_3^-, respectively) have been applied in Mexico as indicators of effectiveness to control acid rain precursors, sulfur oxides and nitrogen oxides, as well as to evaluate the contribution of reactive nitrogen either in its reduced or oxidized form. By comparing these indicators among the different sites studied in Mexico, the potential sources of atmospheric emissions can be identified, as well as strengthening the prevention, minimization and control strategies.

In Mexico City, wet atmospheric deposition has been evaluated starting in 2003, through collaboration between the Secretary of the Environment of the Government of Mexico City (SEDEMA) and the National Autonomous University of Mexico (UNAM). The SEDEMA is responsible for sampling at 16 sampling sites distributed in the Mexico City Metropolitan Area (MCMA), while UNAM is responsible for the laboratory analysis and interpretation of the information. Results include ratios of 1.5 and 2.5 for SO_4^{2-}/NO_3^- and NH_4^+/NO_3^- respectively. By comparison, the SO_4^{2-}/NO_3^- ratio in the Denver-Boulder, Colorado metropolitan area (DBMA, USA) wet deposition is ten times lower than in the MCMA, and the NH_4^+/NO_3^- ratio is approximately 2.8 in the DBMA.

Wet deposition data from the Gulf of Mexico coast have been studied by UNAM, for the "La Mancha" (LM) sampling site, which has been operating since 2003. Others sampling sites located in this region are the "El Tajín" Archaeological Zone (TAJ), "Fortaleza de San Juan de Ulula" (FSU) and the "Universidad Veracruzana Campus Mocambo" (UVM), which were operated from 2003 to 2006.

The obtained results for SO_4^{2-}/NO_3^- and NH_4^+/NO_3^- ratios were: 4 and 1.3 for LM; 3.4 and 0.71 for TAJ; 1.9 and 0.58 for SJU and 3.3 and 2.3 for the UVM. From 2017 to 2020, the Port of Veracruz (PV) was operating a sampling site, registering values of 2.9 and 0.82 for SO_4^{2-}/NO_3^- and NH_4^+/NO_3^- ratios, respectively.

An oceanographic research cruise on the Gulf of Mexico was conducted by UNAM and National Oceanic and Atmospheric Administration (NOAA) in 1986. Sampling results indicated SO_4^{2-}/NO_3^- ratio of 2.17 and NH_4^+/NO_3^- ratio of 0.13 in wet deposition, indicating that coastal ratios generally increased over 35 years.

From the results, it was observed that in Mexico the SO_4^{2-}/NO_3^- ratio is high mainly due to the consumption of fossil fuels with high sulfur content. The NH_4^+/NO_3^- ratio is less than 1 in coastal areas, while in urban areas it is greater than 2, highlighting an urban contribution of reduced nitrogen.

[1] Universidad Nacional Autónoma de México (UNAM), rodsosa@unam.mx
[2] UNAM, ana.alarcon@atmosfera.unam.mx
[3] UNAM, fuenbeto@icloud.com
[4] SEDEMA. Gobierno de la Ciudad de México, mjaimes@sedema.cdmx.gob.mx
[5] UNAM, pasa@unam.mx
[6] UNAM, evega@atmosfera.unam.mx
[7] National Atmospheric Deposition Program, dgay2@wisc.edu
[8] U.S. Environmental Protection Agency, WalkerJohnt@epa.gov
[9] United States Geological Survey, wetherbe@usgs.gov

Changes in Atmospheric Aqueous Chemistry at Whiteface Mountain: Shifting Focus from Acid Rain

Christopher Lawrence[1], Sara Lance[2], Paul Casson[3], James Dukett[4], Phil Synder[5], Dan Kelting[6] and Elizabeth Yerger[7]

Whiteface Mountain is home to an historical cloud water monitoring site, with cloud water collection dating as far back as the 1970s. The cloud collection was largely founded to investigate and monitor the growing problems associated with acid deposition with regular monitoring beginning in 1994 and continuing to this date. Findings from sites like Whiteface Mountain help contributed to the Clean Air Act Amendments of 1990s which contributed to significant reductions in emissions of SO_2 and NO_x, leading to significant decreases in SO_4^{2-} and NO_3^- concentrations in both Whiteface Mountain cloud water and NADP National Trend Network sites nationwide. Recently, a significant milestone for acid deposition was reached at WFM: median concentrations of Ca^{2+} were higher than SO_4^{2-} concentrations, with a correspondingly high median pH of 6.3 in 2020. Additionally, there are increasing trends in Ca^{2+}, K^+, Mg^{2+}, and potentially total organic carbon, while NH_4^+ and NO_3^- exhibit no trend. These changes point to a considerably different chemical system that have important implications for not only acid deposition but for nitrogen deposition, base cation deposition, and secondary organic and inorganic aerosol formation.

This presentation will discuss the significant changes to major base cations and organic carbon (total organic carbon and organic acids) and their inter-relationships. Statistical techniques such as factor analysis and positive matrix factorization will be used for source apportionment. Comparisons of cloud composition will be made with regional NADP National Trend Network sites to investigate the potential changes in base cation deposition. Lastly, future implications will be discussed for air quality, ecosystem health, and climate.

[1]University of Albany, celawrence@albany.edu
[2]University of Albany, smlance@albany.edu
[3]University of Albany, pcasson@albany.edu
[4]Adirondack Lake Survey Corp, jdukett@adirondacklakessurvey.org
[5]Adirondack Lake Survey Corp, pksnyder@adirondacklakessurvey.org
[6]Adirondack Watershed Institute, dkelting@paulsmiths.edu
[7]Adirondack Watershed Institute, eyerger@paulsmiths.edu

The Recent Past, Present and Future of Acidic Deposition Effects on Adirondack Biogeochemistry

Gregory Lawrence[1], Baldigo, B.P[2], Siemion, J.[3], Scanga, S.E.[4], Sabo, R.D.[5], Roy, K.M.[6], McHale, M.R.[7], George, S.D.[8], Antidormi, M.R.[9] and Bondville, D.B.[10]

By the early 2000s, depletion of base cations in soils had become largely accepted as a major reason for the slow recovery of surface waters despite ongoing decreases in acidic deposition. With this recognition, concern also developed for soil effects on forest ecosystems with trees such as sugar maple that have high calcium (Ca) demand. Nevertheless, streams have continued a slow recovery and some indications of improved soil conditions have been reported in the twenty-tens. To provide an update of ecosystem effects from acidic deposition this presentation will focus on data collected in the Adirondack region of New York from the late 1990s to 2020, which are also presented in four papers published in 2020-2021. The Adirondack region provides a useful case study for recovery because acidic deposition effects were particularly severe into the 1990s and monitoring of ecosystem effects has continued at a high level.

The clearest improvement in Adirondack streams has been a pronounced decrease in inorganic monomeric aluminum (Al_i), the toxic form of this element that is mobilized by acidic deposition. Randomized survey sampling during spring snowmelt in 2004-2005 showed that Al_i in 56 percent of western Adirondack streams exceeded the minimum concentration harmful to fish (1.0 µmol L^{-1}). In 2018-2019, this percentage had decreased to 35%. The remainder of the Adirondack region has been less impacted, but Al_i decreases are also less pronounced. Concentrations of Al_i exceeded 1.0 µmol L^{-1} during snowmelt in 20% of streams in 2011, 10% in 2018 and 16% in 2021.

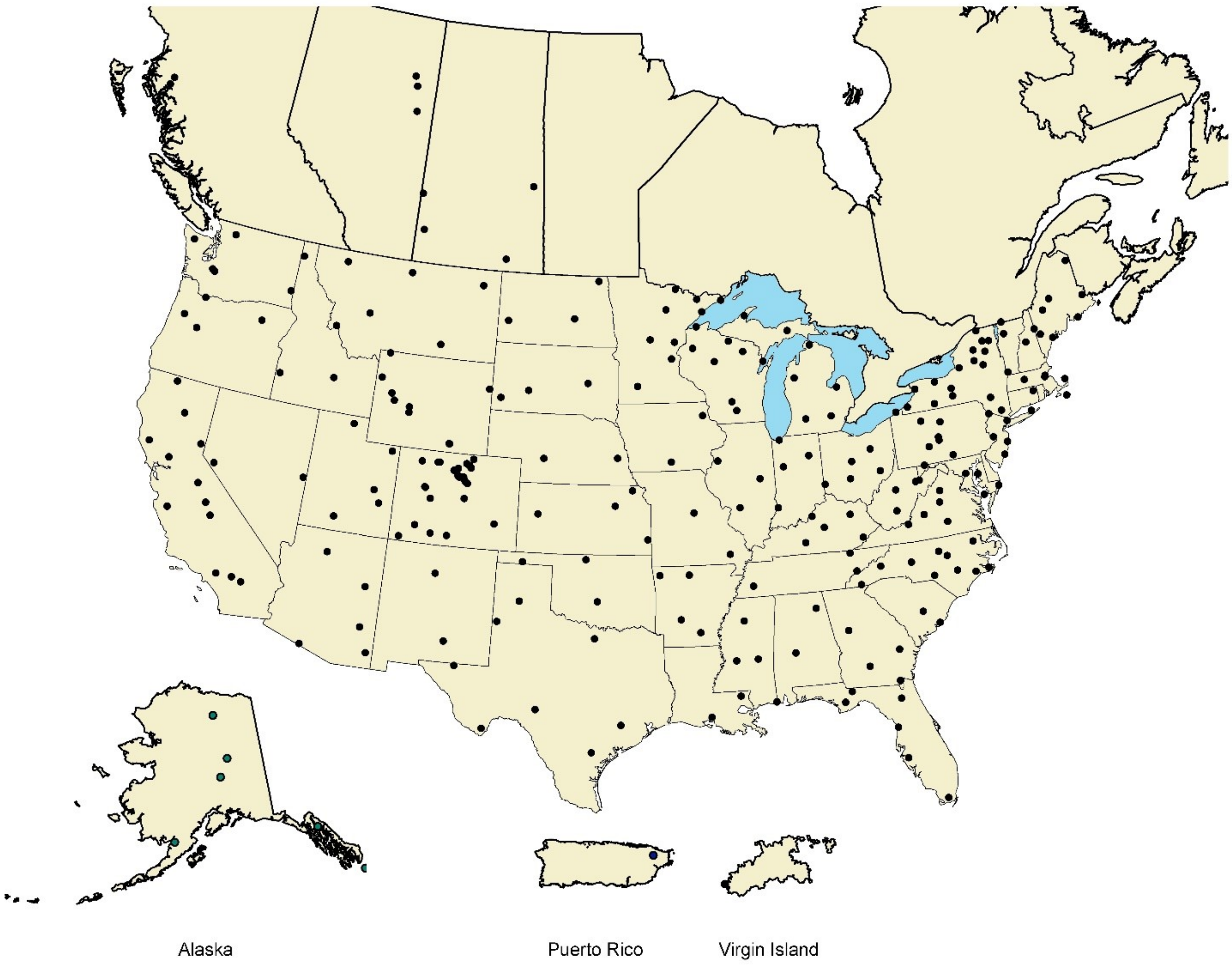
Decreased Al_i in streams has been achieved by lowering Al_i mobility in soil through decreased concentrations of sulfate (SO4), and to a small extent nitrate. There is also evidence in the most recent data that soil Ca availability is beginning to increase and that this has had a small effect on stream chemistry, although stream Ca concentrations continue to decrease. Decreasing SO4 and Ca continue to dilute stream waters, which is the primary driver of nearly universal increases in stream DOC concentrations that are likely continue to. Impacted streams have not increased in pH sufficiently to reach the pH at which DOC solubility is strongly increased (> pH 6.2), and minimally impacted waters with relatively high pH values have not been showing strong pH increases.

In summary, recovery processes continue, but the legacy of acidic deposition persists, largely through past acidification effects on soils that have only recently begun to recover.

[1]U.S. Geological Survey, glawrenc@usgs.gov
[2]U.S. Geological Survey, bbaldigo@usgs.gov
[3]U.S. Geological Survey, jsiemion@usgs.gov
[4]Utica College, sescanga@utica.edu
[5]U.S. Environmental Protection Agency, sabo.robert@epa.gov
[6]New York State Department of Environmental Conservation, karen.roy@dec.ny.gov
[7]U.S. Geological Survey, mmchale@usgs.gov
[8]U.S. Geological Survey, sgeorge@usgs.gov
[9]U.S. Geological Survey, mantidormi@usgs.gov
[10]U.S. Geological Survey, dbonville@usgs.gov

National Atmospheric Deposition Program

National Trends Network (NTN)



Sites Active in 2020

NTN

Site ID	Site Name	Site Sponsor	Start Date
AB32	Fort Mackay	Wood Buffalo Environmental Association	9/13/2016
AB34	Stony Mountain	Wood Buffalo Environmental Association	4/24/2019
AB36	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

NTN

Site ID	Site Name	Site Sponsor	Start Date
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

NTN

Site ID	Site Name	Site Sponsor	Start Date
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
FL00	Austin-Cary Forest	U.S. Environmental Protection Agency - Clean Air Markets	3/29/2016
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

NTN

Site ID	Site Name	Site Sponsor	Start Date
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

NTN

Site ID	Site Name	Site Sponsor	Start Date
ME09	Greenville Station	Maine Department of Environmental Protection	11/20/1979
ME94	Indian Township	Passamaquoady 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

NTN

Site ID	Site Name	Site Sponsor	Start Date
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

NTN

Site ID	Site Name	Site Sponsor	Start Date
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

NTN

Site ID	Site Name	Site Sponsor	Start Date
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

NTN

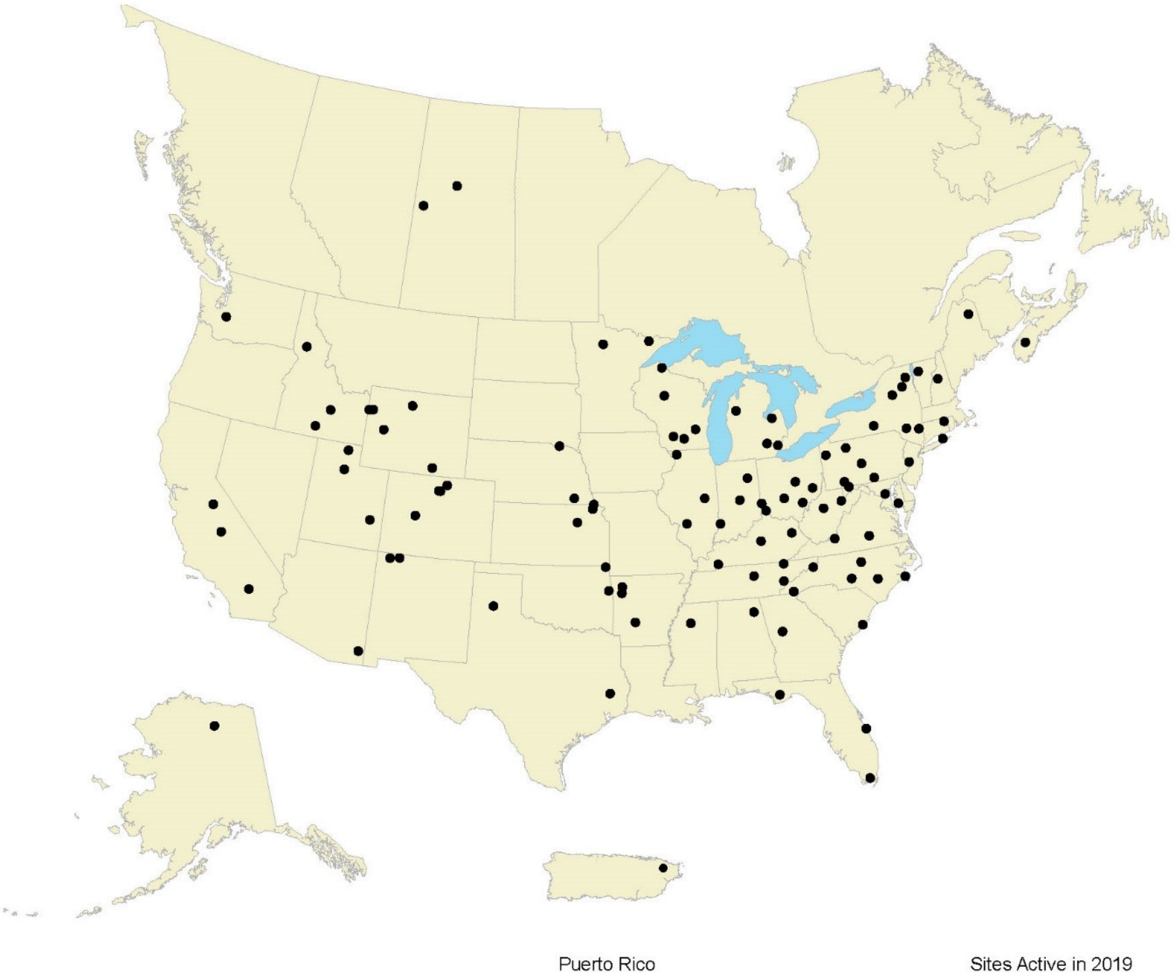
Site ID	Site Name	Site Sponsor	Start Date
TX04	Big Bend National Park - K-Bar	National Park Service - Air Resources Division	4/10/1980
TX10	Attwater Prairie Chicken National Wildlife Refuge	U.S. Geological Survey	7/3/1984
TX16	Sonora	U.S. Geological Survey	6/26/1984
TX22	Guadalupe Mountains National 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
WI06	UW Arboretum	University of Wisconsin - State Laboratory of Hygiene	2/11/2019

NTN

Site ID	Site Name	Site Sponsor	Start Date
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
WV99	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

Ammonia Monitoring Network (AMoN)



AMoN

Site ID	Site Name	Site Sponsor	Start Date
AB35	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

AMoN

Site ID	Site Name	Site Sponsor	Start Date
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

AMoN

Site ID	Site Name	Site Sponsor	Start Date
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

AMoN

Site ID	Site Name	Site Sponsor	Start Date
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	Cañónceta	U.S. Environmental Protection Agency - Clean Air Markets	10/30/2007
UT01	Logan	Utah Department of Environmental Quality	11/8/2011
UT09	Canyonlands National Park-Island in the Sky	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

AMoN

Site ID	Site Name	Site Sponsor	Start Date
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	Intrinsik 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

MDN

Site ID	Site Name	Site Sponsor	Start Date
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

MDN

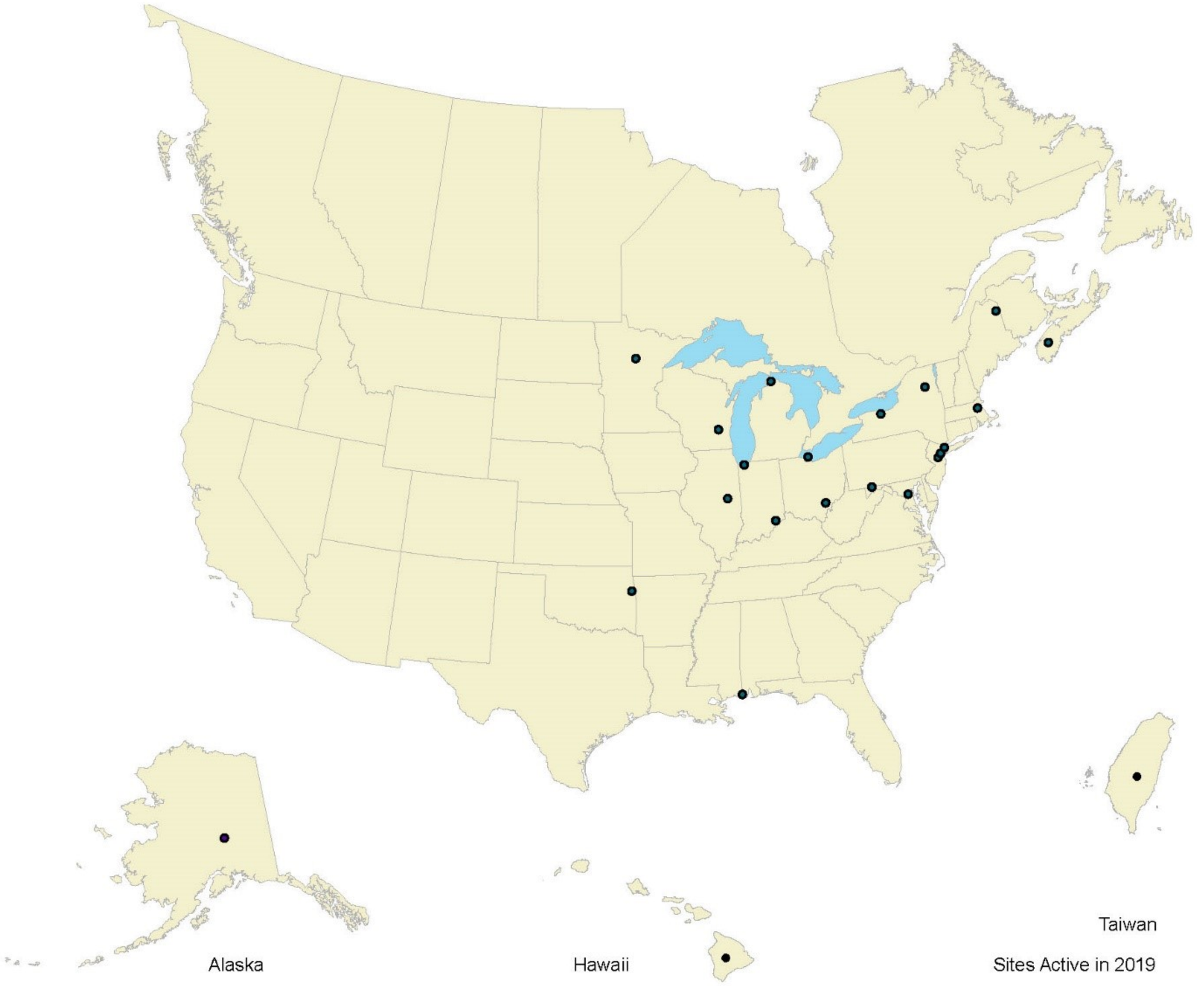
Site ID	Site Name	Site Sponsor	Start Date
NJ30	New Brunswick	New Jersey Department of Environmental Protection	1/17/2006
NS01	Kejimkujik National Park	Environment and Climate Change Canada	7/2/1996
NY06	Bronx	New York State Department of Environmental Conservation	1/9/2008
NY20	Huntington Wildlife	New 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 (NEORSD)	Northeast Ohio Regional Sewer District (NEORSD)	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

MDN

Site ID	Site Name	Site Sponsor	Start Date
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
WI06	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

NADP Program Office
Wisconsin State Laboratory of Hygiene
University of Wisconsin-Madison
465 Henry Mall
Madison, WI 53706
http://nadp.slh.wisc.edu