



# Proceedings

**NADP Spring Meeting and Scientific Symposium**

## **Thinking Outside the Bucket: Innovation in a Changing Environment**

June 9-12, 2026

Madison, WI

Version: 6/4/2026



National Atmospheric Deposition Program

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# Meeting Information and Acknowledgements

## Locations

**June 9-12 Spring Meeting and Scientific Symposium** will be held at the Madison Concourse Hotel  
1 W Dayton St., Madison, WI 53703.

## Acknowledgements

The NADP Program Office would like to thank the following people for their support of and contributions to the 2026 Spring Meeting and Scientific Symposium:

Michael McHale, Scientific Symposium Chair

Dr. David A. Gay, Keynote Speaker

NADP Executive Committee

Ellis C. Cowling Student Travel Award Committee (Emmi Felker-Quinn, Tracy Dombek, and Katie Blaydes)

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 48+ years and will continue to do so for many years to come.

## Land Acknowledgement

The University of Wisconsin–Madison occupies ancestral Ho-Chunk land, a place their nation has called Teejop (day-JOPE) since time immemorial. In an 1832 treaty, the Ho-Chunk were forced to cede this territory. Decades of ethnic cleansing followed when both the federal and state government repeatedly, but unsuccessfully, sought to forcibly remove the Ho-Chunk from Wisconsin. This history of colonization informs our shared future of collaboration and innovation. Today, UW–Madison respects the inherent sovereignty of the Ho-Chunk Nation, along with the eleven other First Nations of Wisconsin.



## Message from the NADP Scientific Symposium Chair

I first learned about the NADP National Trends Network in the fall of 1994 as a graduate student beginning my research on nitrogen cycling at the Huntington Wildlife Forest in Newcomb, NY, the location of site NY20. My association with NADP has grown throughout my career from attending the science symposia, to becoming involved in committee work and now serving as the vice-chair of the Executive Committee. My work on atmospheric deposition and watershed response has consistently reinforced the value of long-term data in evaluating environmental change. Like many in the NADP community, I have come to appreciate that the strength of this program lies not only in its data, but in the people and partnerships that sustain it. From site operators collecting weekly samples in all conditions to the scientists and analysts interpreting those data, NADP is a truly collaborative scientific enterprise.

Over the past several decades, NADP has advanced our understanding of how emissions from energy production, agriculture, and other sources influence air, water, and ecosystems. These long-term records have documented important improvements in some areas while also highlighting emerging challenges, including shifts in emissions sources, evolving precipitation patterns, and changing deposition dynamics.

As our scientific questions continue to evolve, continued innovation is essential. The NADP network provides a critical foundation, offering consistent, high-quality measurements needed to detect trends, test new approaches, and inform decision-making. Building on this foundation requires creative thinking, new analytical tools, and strong collaboration across disciplines.

The theme of this year's symposium, **"Thinking Outside the Bucket: Innovation in a Changing Environment,"** reflects this need. The presentations highlight new methods, perspectives, and applications that expand how we use NADP data to better understand atmospheric deposition and its effects.

Thank you to all of the presenters and to the broader NADP community for your continued contributions. I especially want to thank the site operators without whom the networks would not exist, they do the hard work of producing the data that are the foundation of NADP. I look forward to the discussions and collaborations that will emerge from this symposium.

Mike McHale, U.S. Geological Survey

Vice-Chair of the Executive Committee



## Keynote Address

### What Wisdom? Lessons Learned from 1000 Mistakes at NADP

David A. Gay, PhD

Wednesday June 10, 2026, 8:45 AM



David Gay is the past Coordinator of the National Atmospheric Deposition Program at the Wisconsin State Laboratory of Hygiene at the University of Wisconsin - Madison.

Previously, he worked with NADP at the University of Illinois, Illinois State Water Survey, from 2003 to 2018.

He received his Ph. D. in Environmental Sciences, with a concentration in climatology of air pollution from the University of Virginia in 1996. He also holds a Master of Science in Environmental Sciences from Washington State University (1987), and a Bachelor of Science in Environmental Sciences from McNeese State University (1985).

He has worked in the air quality and environmental sciences area for over 35 years including previous positions with a consulting engineering firm (CH2M Hill, Inc.), on the faculty at the University of North Carolina - Charlotte, a self-employed business owner, and over 20 years as the Coordinator of NADP. He has also taught many environmental and atmospheric science classes. He currently conducts research in the areas of environmental deposition of mercury and ammonium, and is the author of many journal articles.



# Agenda

*Note all times are in CT*

## Technical and Science Committee Meetings


***Tuesday, June 9, 2026***

08:30 – 11:00	Joint Meeting Madison Ballroom
11:00 – 12:00	Education and Outreach Subcommittee (EOS) Meeting Madison Ballroom
12:00 – 13:30	Lunch (On your own)
13:30 – 15:15	Joint Meeting (Part 2) Madison Ballroom
15:15 – 15:30	Break
15:30 – 18:00	Executive Committee Meeting Madison Ballroom



## Scientific Symposium

 Indicates a student presentation


 Virtual: pre-recorded

### Wednesday, June 10, 2026

08:00 – 08:15	Welcome and logistics Madison Ballroom
	Opening of Symposium, Mike McHale, U.S. Geological Survey Welcome, Steve Strebels, EHD Director, Wisconsin State Laboratory of Hygiene
08:15 – 08:45	State of the NADP Address, Sarah Benish, Coordinator
08:45 – 09:40	Keynote Address: David Gay
09:40 – 10:00	Recognition Awards
10:00 – 10:20	Break

### Session 1: Linkages Between Emissions and Ecosystem Response


Chair: Kris Novak, EPA

10:20 - 10:40	Glenn Wolfe (NASA GSFC) - <i>FarmFlux: Connecting Agriculture, Atmospheric Composition, and Ecosystems</i>
10:40 - 11:00 	Linda Geiser (Oregon State University Department of Botany and Plant Pathology, Corvallis, Oregon, USA) - <i>Mapping Air Quality and Climate Vulnerabilities of Epiphytic Macrolichens Across North America</i>
11:00 - 11:20 	Ryleigh Adams (Oldfields School) - <i>It's more than just a Fancy Bucket</i>
11:20 - 11:40 	Krish Vijayaraghavan (Ramboll) - <i>Mitigating Community Concerns over Data Centers</i>
11:40 - 12:00 	Michael D Bell (National Park Service, Air Resources Division) - <i>New applications of critical loads of nitrogen and sulfur for herbaceous species enhance risk analyses of atmospheric deposition</i>
12:00 – 13:30	Lunch Break (on your own)



## Session 2: Aerosol Particles, Gases, and Air-Surface Exchange

Chairs: Jeff Collett, CSU

- 13:30 - 13:50  KarLee Zager (Bingham Research Center, Utah State University) - *Effects of Snow Type, Sunlight, and Temperature on Organic Compound Fluxes at the Air-Snow Interface*
- 13:50 - 14:10 Roxana Sierra (Texas A&M University - Corpus Christi) - *Ice Cores from High-Elevation Glaciers as Long-Term Archives of Atmospheric Deposition*
- 14:10 - 14:30 J. David Felix (University of North Carolina Wilmington) - *Linking Isotopes, Satellite Observations, and Aerosol Optical Properties to Constrain NO<sub>x</sub> Sources and Nitrate Formation in Coastal Urban PM<sub>2.5</sub>*
- 14:30 - 14:50 Stacy Knapp (Maine Dept. of Environmental Protection) - *Establishing Maine's Statewide Aeroallergen Monitoring Network: Methods, Challenges, and Early Insights*
- 14:50 - 15:10 Break

## Session 3: Atmospheric Deposition Monitoring and Modeling: Networks, Methods, and Innovative Data Analyses I

Chairs: Da Pan, Georgia Institute of Technology

- 15:10 - 15:30 Yongqiang Liu (USDA Forest Service) - *Temporal and regional patterns of wildfire-deposition relationships in the United States*
- 15:30 - 15:50 Ryan Fulgham (US EPA) - *Monitoring organic nitrogen in particulate matter across the US*
- 15:50 - 16:10  Stuart Weiss (Creekside Science) - *Spatial and temporal patterns of spring water nitrate discharge in a high deposition region*
- 16:10 - 16:30 Rodolfo Sosa Echeverría (Universidad Nacional Autónoma de México) - *The importance of international collaboration in wet atmospheric deposition and air quality*
- 16:30 - 16:50  Amelia Jiménez Alcántara (UNAM) - *Temporal variability of reactive nitrogen in wet atmospheric deposition: a comparative analysis across selected sites in Mexico and the United States*
- 16:50 - 17:10 Poster Lightning Session




18:30 – 20:30

**Poster Session – Capitol Ballroom B**

Sarah Nelson (Appalachian Mountain Club) - ***Dragonfly biosentinels link hydrologic extremes and mercury bioaccumulation in the Merrimack River Watershed***

Amy Christiansen (University of Missouri - Kansas City) - ***Nitrate Wet Deposition as a Constraint on NO<sub>x</sub> Emissions and Impacts on Modeled Secondary Pollutants***

 Paola Miramontes Gonzalez (University of New Hampshire) - ***From Canopy to Rain Chemistry: Vegetation Phenology as a Driver of Dissolved Organic Matter Wet Deposition***

Da Pan (Georgia Institute of Technology) - ***Understanding Land-Atmosphere Exchange of Reactive Nitrogen through Tiered and Machine Learning Assisted Monitoring***

Liam TrinhNguyen (NADP) - ***Combined Frequency and Time-Domain Analysis Reveals Persistent Annual and Semi-Annual Cycles in Wet and Dry Atmospheric Deposition Across the United States***

Christa Dahman (Wisconsin State Lab of Hygiene) - ***Assessment of trace metal backgrounds for National Trends Network collectors at site WI93 (Madison, WI)***

Ella Osby (NADP) - ***One-Week vs. Two-Week Sampling Interval Co-located Intercomparison Preliminary Results for the Mercury Deposition Network***

Jayde Alderman (WSP) - ***Assessing the Regional Impact of Biomass Burning on Air Quality in the Western United States (2010- 2023)***

Christopher Rogers (WSP USA Inc.) - ***Modernization of EPA's CASTNET***

Kevin Mishoe (WSP USA Inc.) - ***Addition of Particulate Matter Sensors at CASTNET Sites***

 Laure Wanyina (Oldfields School) - ***It's Not Just A Fancy Bucket - High school students establish NTN site MD91***



## Thursday June 11, 2026


08:30 – 08:40 Opening Remarks – Michael McHale, U.S. Geological Survey

### Session 4: Mercury Cycling, Deposition, and Bioaccumulation

Chairs: Tim Sharac, EPA

08:40 - 09:00 Seth Lyman (Bingham Research Center, Utah State University) - *Automated, dynamic, SI-traceable field calibration of atmospheric elemental and oxidized mercury*

09:00 - 09:20  Alexis Harper (Brigham Young University) - *Environmental Chamber Characterization for Quantifying Atmospheric Oxidants in Mercury Oxidation Mechanisms*  




09:20 - 09:40  José Alberto Rivas Fuentes (UNAM) - *Risk Assessment of Gaseous Elemental Mercury (GEM) in Ambient Air in Southern Mexico City and its Temporal Variability*

09:40 - 10:00  Lin Wu (SUNY-ESF) - *Understanding High Gaseous Elemental Mercury at Carlsbad Caverns National Park During CarCavAQS-21: Insights from Observations and CMAQ-newHg-Br v2 Simulations*


10:00 – 10:20 Break

### Session 5: Atmospheric Deposition Monitoring and Modeling: Networks, Methods, and Innovative Data Analyses II


Chairs: Jason Lynch, EPA

10:20 - 10:40  Saurabh Dhakad (Jawaharlal Nehru University) - *WetChemX: A Multi-Site Rainwater Chemistry Analysis Tool*  


10:40 - 11:00 Kristen O'Shea (Desert Research Institute) - *Using Climate Engine to Analyze and Visualize US EPA Total Deposition Layers Data*  


11:00 - 11:20 Daniel Persaud (York University) - *Understanding the Spatial Distribution of Trifluoroacetic Acid (TFA) in Precipitation Samples*  


11:20 - 11:40 Jeff Collett (Colorado State University) - *Evaluating methods for NADP phosphate wet deposition measurement*

11:40 - 12:00 Desneiges (Deni) Murray (Boston University) - *High Fidelity of Archived Wet Deposition Samples Across Solutes*  


12:00 – 13:30 Lunch Break (on your own)



## Session 6: State, Local and Tribal Concerns Connecting Air Quality to Atmospheric Deposition

Chairs: Mike McHale, USGS; Melissa Puchalski, EPA

13:45 – 14:50      Group Panel Discussion:  
Angie Dickens, LADCO  
Stacy Knapp, ME DEP  
Janice Lam Synder, Sacramento Metropolitan Air Quality Management District  
Yasi Hassanzadeh, NY Department of Environmental Conservation


14:50-15:10      Break

## Session 7: Pollutants & Contaminants and their Impacts on Human Health (e.g., PFAS, Black Carbon, etc.)

Chairs: Doug Burns, USGS

15:10 - 15:30      Alex Frie (Minnesota Sea Grant, University of Minnesota) - *PFAS in Great Lakes Region  
Precipitation: Insights from Two Years of Observations*

15:20 - 15:40      Douglas Burns (U.S. Geological Survey) - *Atmospheric Deposition of PFAS in Wet  
Deposition and Throughfall to an Urban Forest*

15:40 - 16:00       Quinn Whiting (University of Minnesota-Duluth) - *Finding the fluorine: Non-target  
analysis illuminates atmospheric PFAS deposition trends*

16:00 - 16:20       Ali Milani (UW-Madison) - *Tracking PFAS in rain and snow around the Lake Superior basin*

16:20 - 16:40      Miguel Bernardez (Minnesota Sea Grant, University of Minnesota) - *Attributing of wet-  
deposition of PFAS by tracking sources backwards in time*

16:40 - 17:00       Randy Tangang (University at Albany) - *Short Term Effects of Cold Weather Factors on  
Hospital Admissions for Subcategories of Autoimmune Diseases*



## Ellis B. Cowling Student Travel Award

The NADP Scientific Symposium has consistently welcomed undergraduate and graduate students to present their research through oral or poster presentations. Students benefit from discounted registration and are eligible for awards recognizing the best student presentations.

In 2024, the NADP Program Office, in collaboration with the Education and Outreach Subcommittee (EOS), introduced the Ellis B. Cowling Student Travel Award to help offset meeting attendance costs, including registration and lodging.

Funded by the NADP Foundation, established at the University of Wisconsin-Madison in 2019, this award provides honoraria to support student travel to the National Atmospheric Deposition Program Spring Meetings and Scientific Symposia. If you are interested in supporting student travel to future NADP Scientific Symposiums, consider contributing to the [NADP Foundation](#).

For more information on Dr. Ellis Cowling, visit: <https://nadp.slh.wisc.edu/news/in-memoriam-ellis-b-cowling-1932-2021/>.

This year's recipients are:

- Saurabh Dhakad                      Jawaharlal Nehru University – New Delhi, India
- Lin Wu                                      SUNY-ESF – Syracuse, NY
- Randy Tangang                      University at Albany – Albany, NY
- José Alberto Rivas Fuentes      Universidad Nacional Autónoma de Mexico – Mexico City, Mexico
- Amelia Jiménez Alcántara      Universidad Nacional Autónoma de Mexico – Mexico City, Mexico
- Quinn Whiting                      University of Minnesota-Duluth – Duluth, MN
- Laure Wanyina                      Oldfields School – Sparks Glencoe, MD
- Ryleigh Adams                      Oldfields School – Sparks Glencoe, MD



# 2025 NADP Site Operator Awards

## 40 Year Awards

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

## 30 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

## 15 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
NY96	Andrew Seal	Cedar Beach-Southold	Suffolk County Department of Health Services	MDN, NTN, AMoN	2010
TW01	Guey-Rong Sheu	Mt. Lulin	National Central University	AMNet	2010
WV04	Lisa Cochran	Babcock State Park	U.S. Geological Survey	NTN	2010



## 10 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
AK02	Mark Lukey	Juneau	National Park Service	NTN	2015
CO15	Eric Scherff	Sand Spring	Bureau of Land Management	NTN	2015
ID07	Mary Fauci	Nez Perce	WSP-U.S. Environmental Protection Agency	AMON	2015
KY29	Linnie Montgomery	Crockett	WSP-U.S. Environmental Protection Agency	AMON	2015
MA22	Nilotpal Ghosh	Boston University	Boston University	NTN	2015
MN02	Jennifer Malinski	Red Lake	Red Lake Band of Chippewa Nation	AMON, MLN	2015
MS30	Gail P. Thompson	Coffeeville	U.S. Geological Survey	NTN, AMoN	2015
MT05	Ed Eberhardy	Glacier National Park-Fire Weather Station	National Park Service	MDN, NTN	2015
ND11	Linda Clark	Woodworth	U.S. Geological Survey	NTN	2015
NY68	Dan DeChellis	Biscuit Brook	U.S. Geological Survey	MDN, NTN, MLN	2015
PA97	Linda Henry	Laurel Hill	WSP-U.S. Environmental Protection Agency	AMON	2015
SK27	John Smerek	Pinehouse	Environment and Climate Change Canada	MDN, AMoN	2015
WA19	Sharon Sarrantonio	North Cascades National Park-Marblemount Ranger Station	U.S. Geological Survey	NTN	2015



## 5 Year Awards

Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
AK01	Karl Olson	Poker Creek	USDA Forest Service	NTN	2020
AR09	Kelsey Anderson	Rambo Hill	USDA Agricultural Research Service	AMON	2020
AR15	Kelsey Anderson	LC Farms	USDA Agricultural Research Service	AMON	2020
AR27	Brad Austin	Fayetteville	U.S. Geological Survey	NTN	2020
CA44 and CA99	Jim Soldenwagner	Yosemite NP - Turtleback Dome/Hodgdon Meadow	National Park Service	AMON, NTN	2020
CA50	Dan Saylor	Sagehen Creek	U.S. Geological Survey	NTN	2020
CO08	Katie MacKnight	Four Mile Park	WSP-U.S. Environmental Protection Agency	NTN	2020
IN41	Niki DeArmond	Agronomy Center for Research and Extension	Purdue University	NTN	2020
KS32	Sara Kay Carrell	Lake Scott State Park	Kansas Department of Health and Environment	MDN	2020
MA08	Patrick Shea	Quabbin Reservoir	Northeast States for Coordinated Air Use Management	NTN	2020
MN18	Daren Lilja	Fernberg	Minnesota Pollution Control Agency/WSP-U.S. Environmental Protection Agency	MDN, NTN, AMoN	2020
MT98	Eleri Haney	Havre - Northern Agricultural Research Center	U.S. Geological Survey	NTN	2020
NE99	Matt Epley	North Platte Agricultural Experiment Station	U.S. Geological Survey	NTN	2020
NJ98	James Kukon	Washington Crossing CASTNET	WSP-U.S. Environmental Protection Agency	AMON	2020
NY01	Kevin Gagne	Alfred	U.S. Geological Survey	NTN	2020



Site Code	Operator Name	Site Name	Funding Agency	Networks	Start
OK06	Donny Le	Wichita Mountains NWR	Oklahoma Department of Environmental Quality	MDN	2020
TX43	Greg Ferguson	Cañonceta	Texas A&M University	NTN, AMoN	2020



# Abstracts

## Session 1: Linkages between Emissions and Ecosystem Response

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## FarmFlux: Connecting Agriculture, Atmospheric Composition, and Ecosystems

**Glenn Wolfe**<sup>1,\*</sup>, Emily Fischer<sup>2</sup>, and Jeff Geddes<sup>3</sup>

Gaseous emissions from agricultural activities affect atmospheric composition, with significant consequences for air quality, climate, stratospheric ozone, and ecosystem health. [FarmFlux](#) is a NASA airborne mission to quantify U.S. agricultural emissions and trace their Earth system impacts. In late 2026 and 2027, FarmFlux will equip two aircraft with *in situ* gas and particle instrumentation and acquire observations over croplands and animal feeding operations throughout the Midwest and Western U.S. Analysis with advanced techniques (mass balance, eddy covariance) will provide near-direct quantification of actual emission and deposition fluxes that can be used to understand environmental drivers, improve model parameterizations, and enhance the utility of satellite retrievals. This presentation will detail the motivation, objectives, techniques, and expected outcomes of FarmFlux.

<sup>1</sup> NASA Goddard Space Flight Center, Greenbelt, MD

<sup>2</sup> Colorado State University, Fort Collins, CO

<sup>3</sup> Boston University, Boston, MA

\* Corresponding author: [glenn.m.wolfe@nasa.gov](mailto:glenn.m.wolfe@nasa.gov)



## Mapping Air Quality and Climate Vulnerabilities of Epiphytic Macrolichens Across North America

**Linda H. Geiser**<sup>1,\*</sup>, Luis E. Velázquez Román<sup>2</sup>, Jessica Moses<sup>3</sup>, and Michael D. Bell<sup>4</sup>

Epiphytic macrolichens contribute to North American biodiversity, play integral ecological roles, and are useful biomonitors of environmental change. We wished to understand the risks posed to the distribution of 359 common epiphytic macrolichen bioindicators in North America from current levels of air pollution and future climate change. Our dataset consisted of 574,756 records from the Consortium of North American Lichen Herbaria and the USDA-Forest Service Lichens and Air Quality biomonitoring database collected between 1960 and 2024. To map current air pollution vulnerability, we calculated current critical load exceedances for acidity and nutrient nitrogen for each species historic range using 2021 data from the US Environmental Protection Agency Community Multiscale Air Quality v.5.4 and the North American Climate Integration and Diagnostics – Nitrogen Deposition v.1 models. To map climate variability, we used Random Forest, a machine learning method for presence-only data, to model the probability of species' detections under historical climates and distributions across the US, Canada, and Mexico, integrating 30- year normals for 11 climate variables from the University of British Columbia's ClimateNA. We then input future climate values under the IPCC AR6's Shared Socioeconomic Pathway 5 (+ 8.5 W/m<sup>2</sup> warming by 2100) and mapped species probabilities of occurrence in 2041-2070. Air pollution threats were greatest in the eastern US and urban corridors of the western US. Future climate conditions reduced median species-level probabilities of detection at their known sites by 15% (upper quartile 20%, range 0-93%) by 2041-2070, with rare species accounting for the largest decreases. Species richness declines can be expected across most of the US except the maritime PNW and highest elevations in the western mountains; the largest contiguous area of highest future species detection declines was the Great Lakes region. In contrast, future climates in southeastern Canada, the Yucatan Peninsula, and parts of southwestern Canada and Alaska suited more species and may offer refugia for species able to migrate there. Results can aid decision-making in air quality management and biodiversity conservation.

<sup>1</sup> Oregon State University Department of Botany and Plant Pathology, Corvallis, Oregon

<sup>2</sup> University of Puerto Rico at Río Piedras, Department of Biology, San Juan, Puerto Rico

<sup>3</sup> Oak Ridge Institute for Science & Education, US Department of Energy, Seattle, Washington

<sup>4</sup> Air Resources Division, Department of the Interior-National Park Service, Lakeview, Colorado

\* Corresponding author: [lgeiser2003@yahoo.com](mailto:lgeiser2003@yahoo.com)



## It's More Than Just a Fancy Bucket



**Ryleigh Adams**<sup>1</sup>, Laure Wanyina<sup>1</sup>, and Susan Foulks<sup>1,\*</sup>

The objective of this research is to determine whether varying levels of acid rain contribute to the development or worsening of skin conditions in school horses. In this project I will compare the acidity of precipitation with the growth and pH tolerance of *Dermatophilus congolensis* (rain rot) from our horse's skin. Rain rot, also known as rain scald or dermatophilosis, is a skin infection caused by a bacterium known as *Dermatophilus congolensis*. Rain rot is often found on the horse's topline, but it can also be found on numerous areas of the horse's body including their hind end, face, and legs after a humid or rainy day. Rain rot can be identified by crusty scabs, matted hair, hair loss, and bumps on the skin, most commonly on the back, hind end, and neck. The affected areas may be sensitive to the touch and appear red or irritated underneath the scabs. Living on the horse's skin, *D. congolensis* is mostly dormant but under wet conditions this bacterium can cause an inflammatory infection resulting in lesions along your horse's skin. These lesions cause small patches of raised bumps which are scabs containing clusters of your horse's hair. Removal of these scabs results in bald patches along the affected area. In severe cases the lesions and scabs may become large and affect multiple layers of skin. When this occurs the horse's use may be impacted until the infection clears.

<sup>1</sup> Oldfields School, Sparks Glencoe, MD

\* Corresponding author: [foulks@oldfieldsschool.org](mailto:foulks@oldfieldsschool.org)



## Mitigating Community Concerns Over Data Centers

**Krish Vijayaraghavan**<sup>1,\*</sup>

Due to the acceleration of AI usage, there has been an exponential growth in data center infrastructure development across the United States. This has resulted in increased concerns expressed by states and local communities over air quality, noise, water and ecosystem impacts. This presentation will discuss measures adopted by data centers to address these concerns.

<sup>1</sup> Ramboll

\* Corresponding author: [kvijay@ramboll.com](mailto:kvijay@ramboll.com)



## New Applications of Critical Loads of Nitrogen and Sulfur for Herbaceous Species Enhance Risk Analyses of Atmospheric Deposition

**Michael D. Bell**<sup>1,\*</sup>, Emmi Felker-Quinn<sup>1</sup>, Emma Censky<sup>2</sup>, Linda H. Geiser<sup>3</sup>, Jason A. Lynch<sup>4</sup>, and Christopher M. Clark<sup>5</sup>

Nitrogen and sulfur deposition can lead to eutrophication and acidification of soils that change competitive dynamics of herbaceous plant species. This leads to changes in individual plant species presence and shifts in community composition. Previous application of these critical loads has been limited to a small set of points that have limited occurrences in federal lands and a single raster that applies one community to the contiguous United States. This presentation will review two new methods and one new data product to help assign and communicate critical loads for declines in herbaceous species to federal lands.

The first new method uses species location data for the 198 herbaceous species with modeled critical load responses from the iNaturalist database to expand the number of observations used to apply CL to an area of interest. There were 876,873 observations within the contiguous United States, which was filtered to 571,323 observations when removing duplicates and limiting a species distribution to its environmental hull. These additional observations increased the number of NPS units with data from 206 to 261 and the number of USFS units with observations from 149 to 398. Additionally, it allows for a relative ranking of visitor interest in a species based on how observations are uploaded.

With the expansion of critical load data into new areas, it is important for users to understand the implications of species changes. To support this effort, the US Forest Service published a new report that provides information on the (1) distribution and conservation status, (2) species characteristics and habitat, (3) wildlife and livestock uses, (4) other ecosystem services, (5) traditional ecological knowledge, (6) responses to N and S deposition, climate, soil pH, including interactions, and (7) critical loads of each herbaceous species. The data will help users interpret the ecological importance of the species that have critical load exceedances and what other stressors may be impacting them.

The second method takes advantage of a new ecosystem classification product developed by NatureServe to apply regionally-developed critical loads for herbaceous community dynamics. The map displays the distribution of regional ecosystems for North America using the International Vegetation Classification (IVC) Group level. This allows for an accurate extrapolation of critical loads that were developed in a specific ecosystem and integration into our national critical load map. Importantly, this also allows for ecosystems that have shown to be resilient to deposition to be excluded from risk analyses.

<sup>1</sup> Air Resources Division, Department of the Interior-National Park Service, Lakeview, Colorado

<sup>2</sup> University of Colorado – Denver, Denver, CO

<sup>3</sup> Oregon State University Department of Botany and Plant Pathology, Corvallis, Oregon

<sup>4</sup> U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Atmospheric Programs, Washington, DC

<sup>5</sup> U.S. Environmental Protection Agency, Office of Research and Development, Center for Public Health and Environmental Assessment, Washington, DC

\* Corresponding author: [michael\\_d\\_bell@nps.gov](mailto:michael_d_bell@nps.gov)



## **Session 2: Aerosol Particles, Gases, and Air-Surface Exchange**

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**KarLee Zager<sup>1,\*</sup>**, Seth Lyman<sup>1</sup>, Trevor O'Neil<sup>1</sup>, Brant Holmes<sup>1</sup>, Kenzie Holmes<sup>1</sup>, and Tristan Coxson<sup>1</sup>

Snowpack serves as a complex participant in atmospheric chemistry, acting as a reservoir, photochemical reactor, and emission source for volatile organic compounds (VOCs). We hypothesize that snow-air VOC exchange varies by snow type and is influenced by ultraviolet (UV) exposure and temperature. To test this, we constructed a two-chamber cryogenic system using a modified chest freezer that allowed us to control UV exposure and temperature across samples of clean (remote-source) and dirty (oilfield-source) snow, each isolated in custom PTFE bags. Air samples were collected post-exposure using gas canisters and DNPH cartridges. These samples were then analyzed via GCMS and HPLC to quantify selected VOCs which were then summarized as groups of hydrocarbon subclasses.

Most hydrocarbon subclasses showed negligible relationships between temperature and emission rates ( $R^2 < 0.25$ ), except carbonyls, which exhibited a weak positive correlation ( $R^2 = 0.2756$ ) in the clean snow samples. Alcohols showed no clear emission trends in response to temperature, UVA, or UVB ( $R^2 < 0.25$ ). In contrast, alkenes exhibited strong positive correlations with increasing UV intensity, especially in clean snow samples: for UVA,  $R^2 = 0.8742$  (clean) and  $0.3301$  (dirty); for UVB,  $R^2 = 0.8541$  (clean) and  $0.3259$  (dirty). Interestingly, along with it being the only subclass to exhibit any response to temperature, carbonyls were also the only subclass to show a negative relationship with UV: for UVA,  $R^2 = 0.5589$  (dirty) and  $0.6351$  (clean); for UVB,  $R^2 = 0.6505$  (dirty) and  $0.5996$  (clean).

These results suggest that VOC flux at the snow-air interface is both compound and snow-type dependent. While UV exposure strongly influences alkene emission—particularly in clean snow—carbonyl emissions appear to be driven by temperature and suppressed by UV. This underscores the complexity of snowpack-atmosphere interactions and highlights the importance of environmental context in understanding atmospheric chemistry.

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## Ice Cores from High-Elevation Glaciers as Long-Term Archives of Atmospheric Deposition

**Roxana Sierra**<sup>1,\*</sup>

Glaciers preserve atmospheric species that are deposited as snow accumulates over time, creating invaluable records of past atmospheric conditions. Researchers extract ice cores from glaciers and analyze them to reconstruct historical deposition of aerosols. These records are essential for putting present-day changes into perspective and understanding the factors that drive them. In this presentation, I will summarize results from some of my published ice-core studies. Specifically, I will discuss the deposition history, emission sources, and influence of atmospheric circulation on the deposition of trace elements in a Tibetan ice core, as well as atmospheric black carbon and ammonium in an ice-core record from the Wrangell-St. Elias Mountain Range in Alaska.

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## Linking Isotopes, Satellite Observations, and Aerosol Optical Properties to Constrain NO<sub>x</sub> Sources and Nitrate Formation in Coastal Urban PM<sub>2.5</sub>

**J. David Felix**<sup>1,2,\*</sup>, Conner Guidry<sup>3</sup>, Abril Garcia Lunar<sup>1,2</sup>, and Allyson Girard<sup>1,2</sup>

Particulate matter (PM<sub>2.5</sub>) pollution is a major concern for human and environmental health in coastal urban airsheds shaped by both anthropogenic and natural emissions, and recent tightening of the U.S. PM<sub>2.5</sub> National Ambient Air Quality Standard (9.0 µg/m<sup>3</sup> annual mean, averaged over 3 years) has increased the need to better constrain emission sources and atmospheric formation pathways. Particulate nitrate (pNO<sub>3</sub><sup>-</sup>), a key component of PM<sub>2.5</sub> formed from NO<sub>x</sub>, represents an important target for mitigation efforts. This study integrates ground-based sampling, stable isotope analysis, satellite remote sensing techniques, and aerosol optical measurements to improve PM and NO<sub>x</sub> source apportionment and understanding of nitrate formation in a coastal urban environment approaching PM<sub>2.5</sub> nonattainment (Corpus Christi, Texas, USA). PM<sub>2.5</sub> samples were collected over two-week periods for one year using a medium volume particulate sampler and analyzed for the isotopic composition of nitrate (δ<sup>15</sup>N and δ<sup>18</sup>O). Isotope data was incorporated into a Bayesian mixing framework to differentiate among NO<sub>x</sub> emission sources, including industrial activities, vehicles, biomass burning, soils, and lightning. To better constrain intermittent sources (i.e., lightning, biomass burning), a complementary approach integrating lightning detection, fire and smoke mapping products, and air mass back trajectories was used to evaluate their influence on individual collection periods prior to application in the isotope-based mixing model. The oxygen isotopic composition of nitrate, atmospheric composition, fractionation scenarios, and mixing models were used to assess dominant atmospheric oxidation pathways contributing to pNO<sub>3</sub><sup>-</sup> formation. In parallel, aerosol optical properties measured using a Cimel Sun Photometer within NASA's AERONET network were used to classify aerosol types and evaluate source influences through cluster-based analysis and compared with nitrate source apportionment. The integration of these datasets enables cross-validation between chemical tracers, optical signatures, and atmospheric transport patterns, capturing both local emissions and regional transport dynamics to improve confidence in source attribution while resolving temporal variability in underlying processes. Results are being shared with state agencies and regional stakeholders to inform targeted mitigation strategies in coastal urban environments.

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## Establishing Maine's Statewide Aeroallergen Monitoring Network: Methods, Challenges, and Early Insights

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Aeroallergens such as pollen are an ongoing public health concern, triggering seasonal allergies, potentially worsening respiratory conditions like asthma, and reducing quality of life. Historically, there has been no publicly available aeroallergen data available for Maine to characterize exposure patterns and inform public health responses. To address this gap, a statewide aeroallergen monitoring network was established in Maine to collect these data needed to support public health and individual decision-making and reduce exposure and health impacts.

This presentation will describe the implementation of two monitoring methods deployed in Maine over a two-year period (2024-2025). The first method utilizes traditional microscopic identification, while the second employs emerging automated technologies for near real-time detection and classification. We will discuss the strengths and limitations of each approach, including considerations related to staffing, data processing, and maintenance, as well as the operational challenges encountered in sustaining a monitoring network in a rural, weather-variable state.

Results from two years of monitoring will be presented, highlighting temporal and spatial trends in aeroallergens across the state. Differences in seasonal timing, peak concentrations, and spatial variability will be examined. In addition, findings from a direct comparison of the two monitoring methods will be shared.

The presentation will also preview newly developed public-facing data tools designed to improve accessibility and usability of aeroallergen information for the general public. Finally, we will outline future goals for the program to better support public health decision-making.

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## **Session 3: Atmospheric Deposition Monitoring and Modeling: Networks, Methods, and Innovative Data Analyses I**

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## Temporal and regional patterns of wildfire–deposition relationships in the United States

Yongqiang Liu<sup>1,\*</sup> and Aaron Piña<sup>1</sup>

Wildfires emit a range of gases, including sulfur- and nitrogen-containing compounds, as well as particulate matter (PM) such as organic carbon and black carbon. These emissions can be transported long distances by wind and subsequently deposited onto soil and water surfaces. Both measurement and modeling studies indicate that smoke deposition can substantially contribute to total atmospheric deposition and can trigger rapid changes in ecosystem chemistry. However, wildfire occurrence, size, and intensity vary greatly across time and space, creating complex patterns in emissions and resulting depositions. This study characterizes the complexity by analyzing fire–deposition relationships and their temporal and regional patterns and differences between wet and dry depositions in the United States. The datasets used in this study included wildfires from the Monitoring Trends in Burn Severity (MTBS) program, wet depositions of eight parameters from the National Atmospheric Deposition Program (NADP) National Trends Network (NTN), and measurements of 12 parameters from the Interagency Monitoring of PROtected Visual Environments (IMPROVE) program which were used as proxies for dry depositions. Analyses of these datasets show that, despite generally opposite long-term trends over the past four decades in most U.S. Forest Service regions, years with intense wildfire activity often coincide with extreme values of chemical species, especially for dry depositions. Significant correlations with wildfires are observed for dry deposition species in nearly all regions and for certain wet deposition species in the western mountain regions. These correlations differ moderately between annual and fire-season averages but considerably across seasons. The seasons exhibiting the strongest correlations differ between wet and dry depositions and vary by region. Correlations are weak between wet and dry depositions, but strong among most wet deposition parameters in more than half regions and among dry deposition PM parameters in all regions. Overall, fire–deposition linkages are more pronounced for dry than wet deposition. These findings highlight the importance of accounting for wildfire-driven deposition variability and help improve understanding of uncertainties in NADP total deposition assessments.

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## Monitoring Organic Nitrogen in Particulate Matter Across the US

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Routine monitoring of atmospheric organic nitrogen (ON) is needed to better characterize spatiotemporal patterns and their drivers as well as provide data for more accurately assessing total atmospheric N deposition. This study evaluates an extension of the Clean Air Status and Trends Network (CASTNET) methodology to quantify water soluble total N (WSTN) and ON (WSON) in particulate matter (PM). Routine samples were collected for 12 months at a subset of 25 CASTNET sites. Results demonstrate that WSON in PM can be quantified using routine monitoring techniques. CASTNET storage and handling procedures represent a small (<5%) source of uncertainty with respect to potential changes in concentrations between sample collection and analysis. Field blanks were sufficiently low that a blank correction for WSON was not required and 75% of observations were above the method detection limit. Precision of WSON derived as the median absolute difference of field duplicates was 8.9% at a site representative of network-wide observations. Mean and median % contributions of WSON to WSTN were 15.3 and 13.3, respectively. On average,  $\text{NO}_3^-$  contributed about twice as much to WSTN than WSON and  $\text{NH}_4^+$  contributed about four times as much as WSON. WSON concentrations were highest in summer and lowest in winter. Concentrations of WSON in smoke-impacted samples were ~ 2X larger than non-impacted samples, as was the % contribution to WSTN (23.7% vs 12.8%). Establishing a method for routine monitoring of WSTN and WSON in precipitation for collocation with the method demonstrated here would rapidly advance understanding of ON deposition.

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## Spatial and Temporal Patterns of Spring Water Nitrate Discharge in a High Deposition Region

**Stuart Weiss<sup>1,\*</sup>**

Downwind of Silicon Valley, flower-filled grasslands on nutrient-poor soils weathered from serpentinite support the threatened Bay checkerspot butterfly and numerous imperiled plant taxa. This biodiversity hotspot is at risk from exotic annual grasses that vigorously invade under elevated N-deposition, which was the primary nexus for the Santa Clara Valley Habitat Plan, a regional Habitat Conservation/Natural Communities Conservation Plan approved in 2013. Tracking local and regional N-deposition for this plan is a challenge. Starting in 2016, samples of late dry-season (Sep.-Oct.) baseflow from springs revealed highly elevated nitrate, up to 5.5 ppm NO<sub>3</sub>-N, demonstrating high rates of leaching excess nitrate. Spatial patterns in 2016-2018 showed higher nitrate closer to urban Silicon Valley, and at low elevations closer to large highways and (often) below the inversion layer. In 2024, samples from 35 springs across a broader geographic range showed spatial gradients congruent with known pollution gradients and the elevation effect, allowing production of an interpolated map. Springs in the southwest part of the study area, outside the main pollution plume, have little or no nitrate. A 10-year time series (2016-2025) from 8 springs showed that the interannual ranges for sites were 0.3 to 1.1 ppm, compared with site means of 1.9 to 5.1 ppm. Much of that temporal variability could be explained by a positive effect of annual precipitation (Oct.- Sep.,  $p = 0.001$ ), with a residual downward trend of  $-0.016$  ppm/year ( $p = 0.016$ ). The hydrogeology of these springs indicates that the nitrate concentrations represent a 2-4 year average. Both TDEP and NO<sub>x</sub> measurements in San Jose show downward trends over this period, but of greater proportional magnitude in TDEP (11%) than the nitrate data (3% on average). This method is simple and inexpensive – 1 or 2 days of sample collection followed with analysis by a local certified laboratory and it provides invaluable spatial and temporal data on integrated N-deposition.

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## The Importance of International Collaboration in Wet Atmospheric Deposition and Air Quality

**Rodolfo Sosa Echeverría<sup>1,\*</sup>**, Pablo Sánchez Alvarez<sup>1</sup>, Ana Luisa Alarcón Jiménez<sup>1</sup>, Mónica Jaimes Palomera<sup>2</sup>, Amelia Jiménez Alcántara<sup>3</sup>, David Gay<sup>4</sup>, and John Walker<sup>5</sup>

Currently, addressing air pollution has undoubtedly proven more efficient by considering a comprehensive assessment of air quality and atmospheric deposition, in order to subsequently establish prevention, minimization, and control measures that benefit public health, as well as the protection of ecosystems and other receptors.

For more than a decade, the “Universidad Nacional Autónoma de México” (UNAM) and the National Atmospheric Deposition Program (NADP) have been collaborating on the evaluation of wet atmospheric deposition, air quality, and its interpretation in different regions, notably the Mexico City Metropolitan Area (MCMA) and the Gulf of Mexico Region.

For several decades, the MCMA has faced a challenge in terms of air pollution, currently experiencing poor air quality due to ozone and particulate matter, in addition to the problem of acid rain. This poses a significant health risk to more than 20 million inhabitants, and in the specific case of acid rain, there is a potential impact on ecosystems and materials. Since 2002, the Mexico City Government and the UNAM have collaborated continuously to operate the atmospheric deposition network. To date, several findings have been obtained, among which we can highlight the following: a) Despite the significant reduction in SO<sub>2</sub> emissions, resulting in improved air quality, the sulfate ion remains the largest component of acidifying cations (SO<sub>4</sub><sup>2-</sup>/NO<sub>3</sub><sup>-</sup> ratio of 1.5). b) Similarly, in the case of reactive nitrogen in wet atmospheric deposition, the NH<sub>4</sub><sup>+</sup>/NO<sub>3</sub><sup>-</sup> ratio is approximately 2.5, demonstrating a greater contribution of reactive nitrogen in its reduced form. c) In the Gulf of Mexico region, the highest value of the SO<sub>4</sub><sup>2-</sup>/NO<sub>3</sub><sup>-</sup> ratio, which is on the order of 4, has been found at the only sampling site in Mexico (La Mancha). d) It is important to establish monitoring stations in Mexico comparable to those that exist in the United States, such as the National Trends Network (NTN), Ammonia Monitoring Network (AMoN), Atmospheric Mercury Network (AMNet) and Mercury Deposition Network (MDN), among others.

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## Temporal Variability of Reactive Nitrogen in Wet Atmospheric Deposition: A Comparative Analysis Across Selected Sites in Mexico and the United States



**Amelia Jiménez Alcántara**<sup>1,\*</sup>, Rodolfo Sosa Echeverría<sup>2</sup>, Ana Luisa Alarcón Jiménez<sup>2</sup>, Gilberto Fuentes García<sup>3</sup>, David Gay<sup>4</sup>, and Pablo Sánchez Álvarez<sup>2</sup>

Reactive nitrogen (Nr) is a key component of the nitrogen cycle, whose balance has been significantly altered by anthropogenic activities that have increased its presence in the atmosphere over the past century. Gaseous compounds such as nitrogen oxides (NO<sub>x</sub>) and ammonia (NH<sub>3</sub>) are transformed into soluble species, including nitrate (NO<sub>3</sub><sup>-</sup>) and ammonium (NH<sub>4</sub><sup>+</sup>), which are subsequently removed through wet deposition. Excess Nr leads to adverse environmental impacts, including acidification, eutrophication, and disruptions of biogeochemical cycles.

In North America, monitoring networks such as the Mexico City Atmospheric Deposition Network (REDDA) and the National Trends Network (NTN) in the United States have generated long-term datasets; however, integrated comparative analyses across regions with different land-use types and emission contexts remain limited.

This study evaluates the spatial and temporal variability of oxidized and reduced Nr in wet deposition across selected regions in Mexico and the United States during the most recent available period (2015–2025). Datasets of concentration, deposition, and precipitation were integrated to identify regional patterns, assess intra- and interannual variability and trends, and quantify the NH<sub>4</sub><sup>+</sup>/NO<sub>3</sub><sup>-</sup> ratio as an indicator of the relative predominance of Nr forms.

Results reveal clear contrasts among cities. In the Mexico City Metropolitan Area (MCMA), the average NH<sub>4</sub><sup>+</sup>/NO<sub>3</sub><sup>-</sup> ratio was 2.52, indicating a strong predominance of ammonium; a similar pattern was observed in Denver (2.16). In contrast, Los Angeles and New York showed ratios close to unity (1.09 and 1.14), suggesting a more balanced contribution of both species, with a slight dominance of NH<sub>4</sub><sup>+</sup>.

These findings highlight the increasing relevance of reduced nitrogen in precipitation chemistry across urban regions of North America and underscore the need to strengthen NH<sub>3</sub> emission controls, a key precursor that has historically been less regulated than NO<sub>x</sub>. This comparative approach provides a basis for developing more comprehensive mitigation strategies.

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## Poster Session

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## Nitrate Wet Deposition as a Constraint on NO<sub>x</sub> Emissions and Impacts on Modeled Secondary Pollutants

Amy Christiansen<sup>1,\*</sup> and Toan Vo<sup>1</sup>

Nitrogen oxides (NO<sub>x</sub> = NO + NO<sub>2</sub>) play a critical role in regulating tropospheric chemistry, yet NO<sub>x</sub> emission estimates are subject to large uncertainties, casting doubt on our ability to accurately model secondary pollutants such as ozone and fine particulate matter (PM<sub>2.5</sub>). In previous work, we have established the use of nitrate wet deposition (NWD) fluxes as a reliable proxy for NO<sub>x</sub> emissions and trends. Using NWD observations and the chemical transport model GEOS-Chem, we found evidence of NO<sub>x</sub> overestimates in emissions inventories over the United States and Europe. Adjusting NO<sub>x</sub> emissions based on NWD fluxes over Europe improved model representation of surface ozone, reducing overestimates by 12%. In this work, we aim to expand our established method to new areas, seasons, and pollutants. Specifically, we constrain seasonal NO<sub>x</sub> emissions over the Midwestern United States (MWUS) using the National Atmospheric Deposition Program (NADP) NWD fluxes and GEOS-Chem. GEOS-Chem exhibits large biases in ozone and PM<sub>2.5</sub> concentrations on a seasonal basis. Over the MWUS, wintertime PM<sub>2.5</sub> and summertime ozone are overestimated by 35% and 52% on average, respectively. A common thread underlying model biases of both pollutants is uncertainty in NO<sub>x</sub> emissions, which are likely overestimated in this region. Our goal is to constrain seasonal NO<sub>x</sub> emissions to improve model representation of both ozone and PM<sub>2.5</sub>. Our preliminary results suggest that reducing summertime NO<sub>x</sub> emissions in the Community Emissions Data System (CEDS) inventory by 60% reduces model overestimates of summertime ozone by 49% across the MWUS. Reducing wintertime NO<sub>x</sub> emissions in CEDS by 40% reduces PM<sub>2.5</sub> overestimates by 8%. Future work includes exploring additional constraints on ammonia and sulfur dioxide emissions using ammonium and sulfate deposition to further improve representation of modeled PM<sub>2.5</sub> and its chemical speciation.

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## Modernization of EPA's CASTNET

**Christopher Rogers**<sup>1,\*</sup>, Kevin Mishoe<sup>2</sup>, Nathaniel Topie<sup>2</sup>, Jayde Alderman<sup>2</sup>, and Marcus Stewart<sup>2</sup>

In December 2024, EPA released a 3-year modernization plan for CASTNET. The plan, which is available at [https://www.epa.gov/system/files/documents/2025-01/castnet\\_modernization\\_plan\\_dec2024\\_final.pdf](https://www.epa.gov/system/files/documents/2025-01/castnet_modernization_plan_dec2024_final.pdf), lists the steps the program will take to respond to input from an external scientific review of CASTNET and address the evolving data needs of the EPA and the scientific community. The scientific review made several key recommendations among them to maintain long-term multipollutant monitoring at as many locations as possible, add PM<sub>2.5</sub> measurements using non-regulatory sensors, and continue to address spatial gaps in the Central United States. The review also recommended expanding Tribal partnerships to address gaps in data coverage and better understand environmental impacts to those communities.

The ultimate goal of the modernization effort is to establish a cost-effective, sustainable future for CASTNET. This involved difficult decisions about decommissioning select sites and ending certain measurements to enable the long-term viability of the network. The scientific review suggested criteria for evaluating existing sites, and these were used to perform a network assessment and determine which sites would be discontinued. Also, SO<sub>2</sub> measurements from the CASTNET filter pack were ended at most sites (EPA and NPS-sponsored), and continuous NO<sub>y</sub> measurements were ended with the exception of several special study sites and the NCore site at Bondville, IL.

During 2025 and early 2026, WSP has worked to begin implementation of the modernization plan. WSP has recommended and procured replacement, regulatory ozone analyzers and transfer standards for all EPA-sponsored sites. This equipment will begin deployment during the second half of 2026. We have acquired and deployed lower-cost PM sensors at all EPA and Indian River Lagoon (IRL) Council-sponsored CASTNET sites. WSP decommissioned seven CASTNET sites and transitioned two sites to ozone-only. We also worked on repairing existing infrastructure including several major shelter refurbishments. Since the fourth quarter of 2024, CASTNET has seen the addition of three sites (two with Tribal partners and one in conjunction with IRL Council) and the restart of a site in West Virginia whose operations had been suspended.

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## Understanding Land-Atmosphere Exchange of Reactive Nitrogen through Tiered and Machine Learning Assisted Monitoring

**Da Pan<sup>1,\*</sup>**

Atmospheric reactive nitrogen (Nr), including its reduced form ammonia (NH<sub>3</sub>) and oxidized forms (NO<sub>y</sub>), is a critical component of the Earth system that significantly impacts air quality, ecosystem health, and climate. While essential for agriculture, excess Nr is lost to the environment, initiating a cascade of detrimental effects, including the formation of ground-level ozone and fine particulate matter (PM<sub>2.5</sub>), ecosystem acidification, and biodiversity loss. As emissions of oxidized nitrogen decline, the role of agricultural ammonia in driving these impacts has grown, yet it remains the largest source of uncertainty in the U.S. nitrogen budget due to a lack of direct flux observation.

To address these significant knowledge gaps, we propose a novel Tiered and Machine Learning Assisted Monitoring (TMLAM) framework designed to provide comprehensive and cost-effective NH<sub>3</sub> flux data. The framework synergistically combines:

**Tier 1)** direct, high-fidelity eddy covariance flux measurements at a few "supersites" to develop and evaluate process models;

**Tier 2)** inferential modeling driven by low-cost sensors to expand spatial coverage into critical regions; and

**Tier 3)** upscaling using existing air quality monitoring networks and reanalysis data.

A key innovation of the TMLAM framework is a data-driven site selection strategy that moves beyond traditional ecoregions. We hypothesize that coherent regions for NH<sub>3</sub> land atmosphere exchange are defined by multivariate environmental drivers, including soil, vegetation, and atmospheric composition. Using unsupervised machine learning (K-means clustering) on principal components of high-resolution environmental data, we identify these "Nitrogen Exchange Similar Areas" (NESAs). This approach allows for strategic placement of Tier 1 sites in highly representative areas and Tier 2 sites at the boundaries between NESAs to characterize model uncertainty. This presentation will detail the TMLAM framework and the ML-based methodology for NESAs determination. In addition, we will discuss sensors suitable for each tier and recent advances in inferential modeling for Tier 2 sites. Finally, we will also evaluate and rank potential sites for the future implementation of TMLAM for NH<sub>3</sub> or Nr fluxes.

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## One-Week vs. Two-Week Sampling Interval Co-located Intercomparison Preliminary Results for the Mercury Deposition Network

**Ella Osby**<sup>1,\*</sup>, Christa Dahman Zaborske<sup>1</sup>, Richard Tanabe<sup>1</sup>, Nichole Miller<sup>1</sup>, and Sarah Benish<sup>1</sup>

The Mercury Deposition Network (MDN) is the only network providing a long-term record of total mercury (Hg) concentration and deposition in precipitation in the United States and Canada. In an effort to decrease expense thereby increasing the accessibility of joining the MDN program, the Program Office (PO) proposed the possibility of extending sampling periods from one-week to two-weeks. This change would allow the shipping cost of MDN coolers to be cut in half for a given year.

Starting in Summer 2025, three sites (TN11, WA04, and WI06) were able to participate in a collocated study between one- and two-week sampling to analyze if there exists any statistically significant difference in the precipitation volumes collected, and the reported Hg concentration measured in each sample. Both types of precipitation collectors provided supported by NADP, the Aerochem (ACM) collector, and the NCON collector, were tested during this study. The same collector types were used for both samples at each site; TN11 tested using ACM collectors, while WA04 and WI06 tested using NCON collectors. All factors other than sampling period, including during deployment and sample processing, were kept consistent between all samples.

Here we will present the results of this co-located intercomparison study by comparing the sample volume and Hg deposition of the two-week sample to that of the two one-week samples that correspond with that deployment time. Results are consistent in both sample volume and Hg deposition, showing that there exists no significant loss of sample volume due to evaporation over the two-week sampling period. Additionally, comparison of the volume corrected Hg deposition between the two sample periods do not show significant difference in analytical results.

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## Assessing the Regional Impact of Biomass Burning on Air Quality in the Western United States (2010- 2023)

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This study investigates the influence of biomass burning across the Western US, utilizing satellite data from NOAA's Hazard Mapping System (HMS) to monitor smoke activities from 2010 to 2023. Regression analysis of smoke frequency at 18 CASTNET and 57 IMPROVE western sites, revealed that 94.4% of CASTNET sites and 86.0% of IMPROVE sites exhibit significant upward trends in smoke activity, with the most robust signals observed in the "Light" smoke density category. Several mid-western sites for both CASTNET and IMPROVE showed increasing significance throughout all smoke density categories. Elevated levels of particulate chemistry and gaseous pollutants associated with biomass burning further highlight the regional air quality implications. To identify key elements affected by smoke events, multiple methods were used to create a ranking system. The ranking system used parameters from Spearman's correlation, Welch's Two Sample T Test, and logistic regression. The final mean rank value along with bootstrap derived confidence intervals were used to identify analytes most likely to be affected by smoke events. Results consistently illustrated that Potassium, Calcium, Magnesium, and Ammonium at CASTNET sites, along with PM 2.5, Organic Carbon, PM 10, Total Carbon, and Potassium at IMPROVE sites, serve as reliable indicators of biomass burning episodes. Overall, these findings highlight the escalating regional impact of biomass burning over the past decade, underscoring the importance of fire management and air quality mitigation strategies.

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## Winter Nitrate Formation at Mammoth Cave National Park - Regional Precursor Transport and Thermodynamic Partitioning

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Wintertime nitrate remains an important component of fine particulate matter (PM<sub>2.5</sub>) in many parts of the United States, despite long-term declines in NO<sub>x</sub> emissions. Here, we investigate the formation of particulate nitrate at Mammoth Cave National Park (MACA) using intensive field observations of PM<sub>2.5</sub> mass and composition and concentrations of gaseous ammonia and nitric acid collected from January 9 to February 10, 2025. Nitrate was the dominant PM<sub>2.5</sub> constituent during the study period and contributed most strongly during high-concentration episodes. Back-trajectory and residence time analyses showed that nitrate enhancements were associated primarily with transport from the north-central and upper Midwest regions, while sulfate-dominated conditions were linked to transport from the southeast.

Thermodynamic simulations with ISORROPIA-II, constrained by in situ observations, reproduced the observed aerosol composition well. Sensitivity analyses showed that PM<sub>2.5</sub> responded strongly to changes in total nitrate (TNO<sub>3</sub> = HNO<sub>3</sub> + NO<sub>3</sub><sup>-</sup>), but only weakly to changes in total ammonia (TNH<sub>x</sub> = NH<sub>3</sub> + NH<sub>4</sub><sup>+</sup>). With nitric acid availability acting as a frequent limiting factor, continued reductions in NO<sub>x</sub> emissions should be effective for mitigating wintertime PM<sub>2.5</sub> in the region.

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## Addition of Particulate Matter Sensors at CASTNET Sites

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During late 2024 and continuing through 2025, CASTNET added particulate matter (PM) monitoring capabilities as part of its modernization effort to all EPA-sponsored and IRL Council-sponsored CASTNET sites. Based on technical direction from EPA, WSP acquired and deployed QuantAQ MODULAIR and PurpleAir Flex sensors. QuantAQ and PurpleAir sensors are non-regulatory, lower cost, and low-maintenance instruments capable of providing high-temporal resolution measurements of PM<sub>2.5</sub> in real-time. These sensors deployed at rural CASTNET sites provide real-time information to communities that often lack other sources of air quality data, including locations impacted by wildfire smoke.

The continuous PM<sub>2.5</sub> concentration data from the PurpleAir sensors are included in the AirNow Fire & Smoke Map (<https://fire.airnow.gov/>) to fill in spatial gaps in the regulatory monitoring network. The map provides local air quality conditions (PM<sub>2.5</sub>) from regulatory monitors and non-regulatory sensors combined with fire locations and smoke plumes detected by satellites. The map is used as a resource to make informed decisions to protect community health during periods of poor air quality.

QuantAQ sensors deployed at CASTNET sites include two different models – PM-only (PM<sub>1</sub>, PM<sub>2.5</sub>, and PM<sub>10</sub>) and PM plus four gas-phase measurements (CO, NO, NO<sub>2</sub>, and ozone), with the gas measurements based on solid-state sensors. WSP has installed MODULAIR models with gas measurements at filter-pack only sites where FEM ozone measurements are not available. These sensors provide additional information about the spatial distribution of pollutants and are particularly effective in capturing data during non-routine sampling events like wildfires or rocket launches.

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## It's Not Just a Fancy Bucket - High School Students Establish NTN Site MD91



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In October of 2025 we (Laure Wanyina and Ryleigh Adams) applied for and became an NTN site. Prior to our approval, we began working with the samples we collected in our "fancy bucket" to study how our rain was able to enhance and inhibit the grown rain rot (*Dermatophilus congolensis*).

We used the NADP's online videos to study and learn the SOP for operating our site and have been sending samples every Tuesday since. Now that we are receiving chemical analysis back from our samples, we are expanding our in-house research on rain rot growth. This higher-level chemical testing allows us to expand our research beyond what we can do in our high school labs.

It may appear to be just a "fancy bucket" to our high school classmates, but it is allowing us to continue to study the impact of rain rot on our horses and become a part of this important national research network.

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## Dual FFT and ACF Analysis Reveals Persistent Annual and Semi-Annual Cycles in Both Wet and Dry Deposition Chemistry Across U.S. Monitoring Networks

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Atmospheric deposition refers to the transfer of pollutants from the atmosphere into the environment using either wet or dry deposition. The significance of monitoring the seasonality of atmospheric deposition cannot be overstated because it has direct implications on human health, crop yield, and aquatic environments. While the seasonality of deposition events has been widely reported for decades, their persistence over time, consistency in terms of both wet and dry deposition, and responses under non-stationary processes have not yet been fully quantified. In this study, we developed an automated scalable analysis approach with no stationarity assumptions, employing strict data quality control procedures, Box-Cox transformation based on segments, and frequency (FFT) and autocorrelation function (ACF) based approaches, applied to 128 high-quality data segments of the major ions across the USA measured by CASTNET and NADP/NTN. The developed approach allowed us to conduct a rigorous analysis comparing FFT with ACF, showing persistent annual and semi-annual cycles for a wide range of chemical species. Additionally, it was possible to detect fine phase differences between sites based on changes in the lag window used in ACF analysis, as well as map these cycles geographically through combination of ACF lags for different sites, detecting transport-driven seasonality in the Southeast and Midwest regions. Thus, it was shown that taking seasonality into account can significantly reduce biases in long-term trend detection, critical loads, and modeling of wet and dry deposition totals. The study demonstrates the importance of accounting for these cycles to diminish biases when assessing long-term trends, policy effects, and models of total deposition. All code used is available on GitHub.

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## Assessment of trace metal backgrounds for National Trends Network collectors at site WI93 (Madison, WI)

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Since 1978, the NADP's National Trends Network has monitored precipitation chemistry across the United States, analyzing samples for eight major ions and acidity. This vast network also has the potential to be used to monitor trace metals in precipitation that are of concern to human and environmental health, both to evaluate long-term trends and in response to acute threats (e.g., wildfires, industrial accidents). Determining which elements can be meaningfully detected in NTN samples requires an exposure study to estimate a network limit of detection based upon blank background.

Here, we present results for a set of six field blanks plus one precipitation sample, all collected in duplicate, from October to November 2025 at NTN site WI93 in Madison, Wisconsin. Each week, two blank samples were deployed in closed collectors and retrieved after seven days of continuous exposure to the sampler interior, one from each collector type (N-CON and Aerochem). No special precautions were taken to limit systemic exposure to metals during the deployment, collection, transportation, or filtering processes outside of standard NTN procedures. Filtered and unfiltered aliquots were collected into acid-washed 50 mL polypropylene containers and acidified to 2% v/v ultrapure nitric acid.

Samples were analyzed for a suite of 55 elements using a Thermo Element XR SF-ICP-MS located in the Trace Element Clean Laboratory in the Wisconsin State Laboratory of Hygiene. Results are consistent between the two NTN collectors. Limits of detection based upon blanks will be presented for dozens of elements. We note that there are observable differences between the unfiltered and filtered portions for some key elements, and that many elements of interest to human and environmental health are resolvable in precipitation samples relative to the blanks. Proposed conditions for a more focused pilot study will also be discussed.

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Atmospheric wet deposition of nutrients plays a critical role in the biogeochemical exchange between the atmosphere and terrestrial ecosystems. One component of atmospheric wet deposition is dissolved organic matter (DOM), comprised of both dissolved organic carbon (DOC) and dissolved organic nitrogen (DON), which originate from emission sources such as industrial and agricultural activity, biomass burning, and plant organic compounds. Current monitoring networks primarily analyze inorganic compounds in wet deposition, which leaves a key fraction of wet deposition compounds unreported. In the northern hemisphere, seasonality of DOM wet deposition has been shown to correlate with the growing season, however the role of vegetation phenology and potential plant emissions as a major driver of DOM wet deposition variability remains to be examined. Here we used archived samples (n = 836) from the National Atmospheric Deposition Program (NADP) collected in 2018 to develop a spatially distributed dataset of DOM wet deposition across eastern temperate forests. Monthly average deposition concentrations were combined with NASA Moderate Resolution Imaging Spectroradiometer (MODIS) vegetation indices and Daymet Daily Surface Weather data to examine the relationship between vegetation growth and potential precursor plant emissions to DOM wet deposition at 27 NADP sites. Results suggest that seasonal peaks in DOM wet deposition concentrations are linked to higher temperatures and active vegetation growth (i.e. increased vegetation cover and vegetation index metrics) during summer months. This result highlights the role of biogenic emission-deposition processes to drive the seasonal exchange of organic matter between the biosphere and atmosphere. Investigating the links between terrestrial phenology and DOM wet deposition clarifies the influence of vegetation-based emission sources on the timing and magnitude of DOM wet deposition. This study offers new insight into under-represented organic forms of nitrogen and carbon in deposition and improving our ability to predict bioavailable forms of nutrient inputs to ecosystems.

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## Dragonfly Biosentinels Link Hydrologic Extremes and Mercury Bioaccumulation in the Merrimack River Watershed

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Biosentinels have been used to indicate relative risk of mercury (Hg), a contaminant that has led to fish consumption advisories in all 50 states, tribes, and territories, to food webs across the US. Dragonfly larvae have been employed as biosentinels for Hg at the national scale, with good correspondence to fish, amphibian, and biogeochemical drivers. Although intra-annual variability in Hg concentrations in dragonflies is typically low relative to spatial variation, few studies have investigated the effects of extreme hydrologic events on Hg bioaccumulation. Regionally, the Northeastern US has experienced long-term atmospheric deposition of Hg from long-range transport, and has also seen the greatest increases in frequency of extreme precipitation events in the US. Such events can influence Hg via increases in dissolved organic carbon (DOC) mobilization, or potentially redistribution of legacy Hg from historic deposition or industrial pollution. The Merrimack River Watershed in New England was the earliest industrialized area in the US, with known in-watershed Hg releases including use of kyanized (Hg-treated) lumber in the 1800s to construct a canal and lock system, and the Nyanza Superfund site that used Hg in dye manufacturing through the 1970s. The Merrimack Watershed also includes remote, forested landscapes in its headwaters in the White Mountain National Forest (WMNF), NH. This project used dragonfly larvae, biosentinels for Hg in food webs, to investigate spatial patterns in Hg within the Merrimack River Watershed, with focus on both the industrialized areas within the watershed (Lowell and Lawrence, MA) and headwater areas in WMNF. Over five years of dragonfly collections, the watershed experienced extreme drought and wet years (e.g., July 2023 was the fourth wettest July since recordkeeping began for the Northeast; in 2025, New Hampshire had its highest coverage of extreme drought in the history of the U.S. Drought Monitor), providing hydrologic extremes that reveal how these climate-related events influence potential Hg changes in food webs. Although previous research has shown limited inter-annual variability in dragonfly Hg, such extreme hydrologic events did not occur in that study period. Thus, the current study offers the opportunity to refine our understanding of how these types of events could inform interpretation of long-term trends and underscores the need for long-term monitoring.

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## **Session 4: Mercury Cycling, Deposition, and Bioaccumulation**

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## Automated, Dynamic, SI-Traceable Field Calibration of Atmospheric Elemental and Oxidized Mercury

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Most atmospheric chemical measurements systems are routinely calibrated against traceable standards, and uncalibrated measurements are usually considered inferior, if not suspect. Atmospheric elemental mercury (Hg) measurements are typically calibrated by manual injection of Hg from a saturated vapor source, but manual injections are challenging, and competing vapor pressure equations differ by about 10%. Oxidized Hg measurements are almost never calibrated at all.

Efforts to develop Hg calibration methods have been undertaken for several decades, but no traceable, field-deployable method has yet been established other than elemental Hg manual injections. We have developed a permeation tube-based, field-ready calibration system that is able to output concentrations of elemental and oxidized Hg that are relevant to the ambient atmosphere (100 to 1,000 pg/m<sup>3</sup> for oxidized Hg; 0.5 to 10 ng/m<sup>3</sup> for elemental Hg) and demonstrated the functionality of this system in lab and field settings. The standard deviation of HgBr<sub>2</sub> output from the calibrator depends on the generated concentration, varying from 3% to 7% of the measured mean for concentrations from 310 to 550 pg/m<sup>3</sup>. Permeation rates of elemental mercury and mercury compounds used in the system are traceable to SI gravimetric standards. The system incorporates an inert dynamic dilution process that allows for rapid variation of the output concentration. Changing from one concentration to another requires an equilibration time of about 10 minutes, allowing for multi-point calibration of elemental and oxidized mercury. This automated system allows for routine, independent, SI-traceable checks on atmospheric Hg instrumentation in real field conditions.

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## Environmental Chamber Characterization for Quantifying Atmospheric Oxidants in Mercury Oxidation Mechanisms



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Elemental mercury (Hg<sup>0</sup>) is the predominant form of mercury in the atmosphere. Although relatively inert and not immediately toxic, its long atmospheric lifetime enables global transport. Once oxidized to more reactive species, Hg<sup>I</sup> and Hg<sup>II</sup>, mercury becomes more water-soluble and readily deposits onto surfaces, where it can enter ecosystems and convert into compounds such as methylmercury, which are highly toxic and bioaccumulative. These transformations pose serious risks to human and ecological health.

Computational studies have identified hydroxyl radicals (OH), ozone (O<sub>3</sub>), and halogen species, particularly bromine (Br), as key oxidants driving atmospheric mercury oxidation. However, direct experimental validation under controlled conditions remains limited.

To address this gap, we constructed a 35 m<sup>3</sup> polytetrafluoroethylene (PTFE) environmental chamber equipped with 200 UV-B and UV-C lamps to simulate atmospheric conditions. The chamber's large volume and optimized volume-to-surface-area ratio minimize wall-reaction artifacts that have complicated prior mercury kinetics studies. Prior to experimentation, characterization of the chamber, including flow rates, wall losses, and testing the UV irradiation system were completed. Elemental and oxidized mercury were measured using a dual channel Tekran system and a modified Reactive Mercury Active System (RMAS). Selected oxidants were measured according to their absorbance in different Broadband Cavity-Enhanced Absorbance Spectrometers (BBCEAS).

Currently, elemental mercury and selected oxidants are systematically being introduced into the chamber to investigate their individual and combined contributions to mercury oxidation. Promising preliminary results show that nitrous oxide (NO) can contribute to oxidizing Hg, even in dark conditions without photolysis, which was not previously predicted in computational models. While data has been collected on NO as a contributor to mercury oxidation, future studies will include introducing other chemical species, such as HONO, ozone, and bromine, to assess the effects of other oxidants in this larger atmospheric mechanism. By quantifying oxidation rates under controlled conditions, mechanistic understanding of atmospheric mercury transformation pathways will improve, thereby refining global models of mercury cycling and deposition.

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## Risk Assessment of Gaseous Elemental Mercury (GEM) in Ambient Air in Southern Mexico City and its Temporal Variability



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Atmospheric mercury is a pollutant of global concern due to its high toxicity, long atmospheric residence time (1-2 years), and persistence in environmental matrices, along with its adverse impact on ecosystems. In the atmosphere, the dominant species is gaseous elemental mercury (GEM,  $Hg^0$ ), which can persist for prolonged periods, enhancing its dispersion and increasing exposure to human populations and the environment. In urban areas, atmospheric mercury concentrations are influenced by a variety of anthropogenic and natural sources, as well as by meteorological processes and atmospheric reactivity that regulate its temporal variability.

The present study aims to assess the risk associated with the presence of GEM in ambient air in southern Mexico City by comparing reference values from different international organizations, as well as to characterize its temporal variability.

Based on concentrations recorded over a one-year period, an inhalation exposure risk assessment was conducted using reference values commonly applied in environmental risk assessment studies. Hazard quotients (HQ) were estimated using reference values from the U.S. Environmental Protection Agency (U.S. EPA), the Agency for Toxic Substances and Disease Registry (ATSDR), and the World Health Organization (WHO) (300 ng/m<sup>3</sup>), as well as the more stringent value proposed by the Office of Environmental Health Hazard Assessment (OEHHA) (30 ng/m<sup>3</sup>).

The results showed HQ values of 0.011 for U.S. EPA/ATSDR/WHO and 0.1 for OEHHA, indicating in all cases a low non-carcinogenic risk (HQ < 1) for the exposed population.

Preliminary results, along with ongoing analyses, allow the identification of temporal trends in GEM concentrations, thereby enhancing the understanding of mercury dynamics in urban environments such as Mexico City and providing scientific evidence to support the development of mitigation, control, and prevention strategies.

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## Understanding High Gaseous Elemental Mercury at Carlsbad Caverns National Park During CarCavAQS-21: Insights from Observations and CMAQ-newHg-Br v2 Simulations

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While mercury (Hg) pollution has been studied extensively in urban and highly polluted areas, work in Clean Air Act defined Class I areas, including National Parks in the United States (U.S.), remains limited. Measurement from the 2021 Carlsbad Caverns Air Quality Study (CarCavAQS-21) showed that Carlsbad Caverns National Park (CAVE), located in the southwestern U.S., experienced higher concentrations of gaseous elemental mercury (GEM) than most northeastern monitoring sites typically influenced by anthropogenic sources. One-month simulations (19 July – 19 August 2021), designed for the field intensive period, were conducted using CMAQ-newHg-Br v2 (Wu et al., 2024), which includes updated Hg redox chemistry and a theoretical gas-particle partitioning scheme. Our model simulations revealed significant contributions of transboundary transport from Mexico to ambient Hg concentrations at CAVE, reflected in episodic increases of up to 14% (27 ppqv) for GEM, 58% (1.2 ppqv) for gaseous oxidized mercury (GOM) and 88% (4.0 pg/m<sup>3</sup>) for particulate-bound mercury (PBM). In contrast, the direct impact of oil and natural gas (O&G) emissions from the Permian Basin – one of the most productive O&G regions in the U.S., on whose edge CAVE is located – was limited, accounting for <1% of total Hg emissions. However, their indirect effects via O<sub>3</sub>-driven oxidation of GEM could be non-negligible as a result of O<sub>3</sub> increases of 31% (~14 ppbv) on average. During three episodes of peak O&G influence, GOM and PBM increased by ~5% on average while GEM decreased slightly (0.2%). Gas-particle partitioning was found to play an important role in shaping the vertical distribution of PBM in the planetary boundary layer. These findings suggested that the southwestern U.S. may represent an underrecognized region of elevated GEM background concentrations and provided quantitative evidence that O&G emissions and transboundary transport from Mexico could together shape atmospheric Hg cycling in the region.

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**Session 5: Atmospheric Deposition Monitoring and Modeling: Networks, Methods, and Innovative Data Analyses II**

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**Saurabh Dhakad**<sup>1,\*</sup> and Umesh Chandra Kulshrestha<sup>1</sup>

Rainwater chemistry helps to understand atmospheric deposition, acid precipitation and long-range transport of the pollutants. Therefore, systematic analysis of rainwater chemistry is essential to understand the sources, transformation and environmental impacts of the pollutants through deposition. Despite its importance, there is a gap that there is no analytical platform to study large and multi-site rainwater chemistry data. The presence of this type of platform will increase the efficiency and reproducibility of precipitation chemistry studies. We present WetChemX, a R web application that addresses this gap. The framework is designed to process multi-site and multiparameter rain chemistry data (excel or CSV format). Along with unit conversion, it incorporates a quality assurance and quality control (QA/QC) procedure based on internationally established guidelines. There are 11 modules in the WetChemX which include descriptive statistical analysis with calculation of volume-weighted mean concentrations and wet deposition fluxes; validation of ionic balance together with consistency checks for pH and electrical conductivity; assessment of neutralization factors, fractional acidity, ammonium acidity index, and differentiation of sea-salt and non-sea-salt contributions; estimation of nitrogen deposition (different species); and sulphur-nitrogen balance. Additionally, acid-neutralization ratios and a newly developed “Patel plot” designed to visualise neutralization ratios in rain chemistry datasets. Multivariate analysis is supported through principal component analysis (PCA) with varimax or promax rotation, while spatial patterns can be explored using Inverse Distance Weighting (IDW) interpolation with optional shapefile boundary integration. By integrating these features into a single platform, WetChemX reduces the technical barriers associated with precipitation chemistry analysis and offers a transparent and reproducible computational framework that can support large-scale monitoring networks.

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## Using Climate Engine to Analyze and Visualize US EPA Total Deposition Layers Data

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Climate Engine is a set of tools developed by scientists from the Desert Research Institute, University of California Merced, and Google and is powered by Google Earth Engine. Climate Engine empowers users of all technical proficiencies to harness the power of cloud computing to analyze decades of Earth Observations data. Collectively, the Web App, API, and Reports are a powerful set of tools that bring together climate and remote sensing data to allow users to answer various environmental questions. This allows decision makers and researchers to spend less time wrangling data and more time deriving insights. With the addition of the US EPA Total Deposition Layers (TDep) to the Awesome GEE Community Catalog, Climate Engine now makes the gridded data available through its Web App and API, allowing users to generate anomaly, trend, and percentile maps as well as timeseries for specific areas of interest. This talk will share about Climate Engine and how to use the Climate Engine tools to access, analyze, and visualize the TDep data.

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## Understanding the Spatial Distribution of Trifluoroacetic Acid (TFA) in Precipitation Samples

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Trifluoroacetic acid is a highly persistent and water-soluble compound that is detected with increasing frequency and abundance environmental samples. This compound has an estimated environmental lifetime on the order of tens of thousands of years. This persistence has resulted in its widespread accumulation in different environmental media, leading to detection in global oceans, air, precipitation and human biological samples, including serum and urine. The concentrations measured for TFA are 1-2 orders of magnitude higher than those of other legacy per- and polyfluoroalkyl substances (PFAS) in several environmental media. While TFA is known to form in the atmosphere and deposition to be its primary loss process, the relative contributions of wet and dry deposition pathways require better constraint by observations.

Interest in TFA has intensified following regulatory shifts under the Montreal Protocol, which phased out chlorofluorocarbons (CFCs) and promoted the use of alternative refrigerants. Hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) were introduced as transitional replacements but are known precursors of TFA through atmospheric oxidation. More recently, the Kigali Amendment has driven the adoption of hydrofluoroolefins (HFOs), such as HFO-1234yf, which have short atmospheric lifetimes (~12 days) and degrade with near-quantitative yields of TFA. This shift in precursor chemistry is expected to enhance TFA formation and alter its spatial and temporal deposition patterns, even under comparable emission scenarios.

This study investigates the atmospheric deposition of TFA across multiple environments using a combination of total deposition collectors and custom-built automated wet deposition samplers. Sampling was conducted at three sites representing

urban, rural, and tropical regions: York University (Ontario, Canada), Lambton County (Ontario, Canada), and the University of Guyana (South America). Precipitation samples were analyzed via direct injection using ion chromatography–mass spectrometry (IC-MS), enabling sensitive and selective quantification of TFA.

TFA was consistently detected in precipitation across all sites, with datasets spanning one to six years. Observed concentrations indicate both spatial variability and temporal trends, reflecting differences in regional emissions, atmospheric transport, and meteorological conditions. In addition to wet deposition, this study evaluates the contribution of dry deposition to total TFA fluxes. Our findings suggest that dry deposition may represent a significant and previously underappreciated pathway contributing to TFA removal from the atmosphere and entry to surface ecosystems. These results highlight the need to better constrain atmospheric sources and deposition processes of TFA in the context of evolving refrigerant usage and their designed atmospheric degradation.

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## Evaluating Methods for NADP Phosphate Wet Deposition Measurement

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Phosphorus (P) is an essential nutrient for terrestrial and aquatic ecosystems. Important sources of P to the atmosphere include marine aerosols, wildfires, soil dust, and industrial activity. Atmospheric deposition of phosphate has received little attention in the United States despite its potential impacts on ecosystem health. Consequently, the NADP community is considering ways to pilot measurement of P wet deposition in weekly precipitation samples. Given potential microbial transformation of P in precipitation samples, use of SNIpIT (Sampler for Nitrogen and Phosphorus in Total) samplers charged with sulfuric acid has been a focus of method testing. Very low concentrations of P in measured samples stimulated testing of high sensitivity analytical methods. Following initial work by the NADP Central Analytical Lab, we pursued further tests to: (1) quantify blanks in prototype SNIpIT samplers, (2) select an analytical method with sufficient sensitivity to measure trace-level phosphate concentrations in precipitation samples, and (3) test for effects of sample acidification on P measurement.

Flow injection analysis was selected as an optimal method for quantifying phosphate ion. A Skalar SAN++ classic series automated wet chemistry analyzer was chosen for P measurement. The system adds reagents to the sample to form a light-absorbing complex that is measured at high sensitivity (MDL  $\sim 0.1 \mu\text{g P L}^{-1}$ ) using a long-path (50 cm) flow cell. Measurements of precipitation and snowpack samples collected in Colorado and Kentucky revealed P levels ranging from  $<1$  to approximately  $20 \mu\text{g P L}^{-1}$ . Initial SNIpIT sampler prototypes, constructed from PVC, were found to yield unacceptably high P blanks. New Delrin SNIpIT prototypes provided by the NADP Program Office yield consistent, low blank values below  $0.1 \mu\text{g P L}^{-1}$ . Preliminary SNIpIT sampling protocols call for pre-charging the sampler with sulfuric acid to yield a final collected sample pH  $< 2$  to limit microbial growth. Over-acidification (pH $<1.5$ ), however, interferes with color development and P quantification. This limits the optimal range of sample:acid volume, creating a challenge for a network with diverse and variable weekly precipitation amounts.

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## High Fidelity of Archived Wet Deposition Samples Across Solutes

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The National Atmospheric Deposition Program (NADP) archives National Trend Network (NTN) wet deposition samples from active monitoring sites for potential future research. Despite their potential value to the atmospheric and biogeochemical research communities, the physical archive is underutilized by researchers for additional analyses. This is due in part to questions regarding which chemical species are stable during storage duration, how storage conditions (e.g., frozen vs. refrigerated) affect sample integrity, and what quality assurance protocols should be applied to document sample quality. Establishing evidence-based criteria for archive sample quality would increase confidence in studies using archived samples and enable their use in novel research applications. In this study, we assess the fidelity of archived wet deposition samples across storage duration, storage method, and specific analytes using concentration-specific criteria that accounts for instrument detection limits and minimizes error inflation. We first compare results of chemical analyses of ammonium ( $\text{NH}_4^+$ ) and nitrate ( $\text{NO}_3^-$ ) performed at two laboratories (the NADP Analytical Lab (NAL) in Madison, WI and the University of New Hampshire) on archived samples collected in 2018 from 28 sites. Across 1,058 archived samples, 95 (9%) were classified as invalid for  $\text{NH}_4^+$  and 188 (18%) for  $\text{NO}_3^-$ , with only 18 samples (1.7%) deemed invalid for both solutes; most invalid samples occurred at low concentrations. We also examined the stability of NAL archived samples collected in 2019 from 102 sites and re-analyzed each year for a period of five years of storage under refrigerated and frozen conditions. Fridge storage resulted in 2.6× more invalid samples than freezer storage, affected a broader range of analytes, and in both treatments ammonium ( $\text{NH}_4^+$ ) was the dominant source of invalidity. Our results are encouraging, suggesting high fidelity of archived wet deposition samples across routine measured anions and cations, and cold storage types. By systematically quantifying sample stability across these dimensions, we provide foundational information to maximize the scientific utility of the NADP sample archive and similar environmental sample repositories worldwide.

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## **Session 6: State, Local and Tribal Concerns Connecting Air Quality to Atmospheric Deposition**

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## **Introduction**

This panel is intended to elevate state, local, and Tribal perspectives on how atmospheric deposition data are used—or could be used—to inform decisions related to:

- Air quality management
- Water quality and watershed protection
- Ecosystem health and restoration
- Public health

## **Panel Moderators**

**Mike McHale** – USGS

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## **Panel Participants**

**Angie Dickens**

Dr. Angie Dickens is the data scientist for the Lake Michigan Air Directors Consortium (LADCO), where she helps states understand the factors causing air pollution in the Great Lakes region, particularly ozone pollution. Prior to that, she worked as an air policy analyst with the Wisconsin Department of Natural Resources. She also served in the U.S. EPA's Office of Transportation and Air Quality as a science policy fellow and at Mount Holyoke College as an assistant professor of environmental chemistry. She has a Ph.D. from the University of Washington and a B.A. from Carleton College, both in chemistry.

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**Yasi Hassanzadeh**

Yasi Hassanzadeh is a Research Scientist with the New York State Department of Environmental Conservation Division of Air Resources. Her responsibilities include data management, QA/QA, and program support for New York's statewide ambient air quality network, and she is the lead for the program's deposition monitoring. Yasi started her career with NYSDEC in 2019 and has worked in Air Resources since 2022.

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**Stacy Knapp**



Now in her 12th year at the Maine Department of Environmental Protection, Stacy Knapp is the Director of the Division of Air Quality Assessment in the Air Bureau. In this role she and her team are primarily responsible for ambient air monitoring, air quality forecasting, and air toxics assessment. Stacy holds a Bachelor of Science in biology from St. Lawrence University as well as both a Master of Business Administration and a Master of Science in environmental health and engineering from Gannon University.

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### **Janice Lam Snyder**

Janice Lam Snyder is the Director of Community Air Protection for the Sacramento Metropolitan Air Quality Management District, where she leads federal, state, and community-level air quality programs, including the development of State Implementation Plans (SIPs), emissions inventories, air quality monitoring, rule development, and community engagement. She began her career at UC Davis' Crocker Nuclear Laboratory, developing analytical methods for air pollution samples, and now helps translate air quality science into regional policy and local action. Janice served as Principal Investigator for EPA grant-funded studies on woodsmoke and air toxics in local communities, as well as a separate study on mobile-source air toxics. With more than 20 years of experience in air quality and environmental policy, she has worked extensively on air monitoring, wildfire smoke and exceptional events analysis, wood smoke reduction, and community-based research. She holds a B.S. in Applied Physics from UC Davis and an M.S. in Environmental Planning and Management from Johns Hopkins University.

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## **Session 7: Pollutants & Contaminants and their Impacts on Human Health (e.g., PFAS, Black Carbon, etc.)**

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**Quinn Whiting**<sup>1</sup>, Alexander Frie<sup>1</sup>\*, Samantha McClung<sup>2</sup>, Bridget Ulrich<sup>3</sup>, Martin Schafer<sup>4</sup>, Emily Sellers<sup>4</sup>, Iris Bloede<sup>4</sup>, Jared Kunick<sup>4</sup>, and Elizabeth O'Gorman<sup>4</sup>

Per- and polyfluoroalkyl substances (PFAS) have been detected globally in wet deposition samples suggesting that the atmosphere is one mechanism for global transport of this persistent class of chemicals. Currently, long-term monitoring studies (i.e., years) of precipitation samples for PFAS are minimal. As part of the National Atmospheric Deposition Program-National Trends Network (NADP-NTN) PFAS weekly wet deposition samples were collected across 5 sites in Minnesota and Michigan. Targeted analysis of 33 PFAS was conducted on weekly samples to obtain high resolution temporal trends. Additionally, total extractable organic fluorine (EOF) was used to obtain a “total fluorine” contamination level on monthly composite samples. Target PFAS were found to explain ~2-5% of EOF, suggesting a substantial “fluorine-gap”. To investigate other fluorinated species contributing to EOF, an open-source non-target analysis (NTA) workflow was created to identify novel, emerging, and other organic-fluorine containing pollutants. This approach identified ~1200 fluorinated features, ~60% were low confidence (unequivocal molecular formula), ~35% were medium confidence (tentative structure), and ~5% were high confidence features (confirmed with analytical standards). Semi-quantification of probable fluorine containing features increased the explained fluorine by an order of magnitude, reaching ~20-60% of EOF. Features contributing to the additional explained fluorine include agrochemicals, pharmaceuticals, traditional PFAS not screened for in the target method, and unique PFAS precursors and transformation products. The 2-year monitoring duration enabled temporal trends to be investigated across targeted PFAS and NTA features, with estimated concentrations of the sum of fluorine containing features increasing in the spring and summer while decreasing in the winter. Temporal patterns support the use of long-term monitoring to determine the overall input of atmospheric deposition, as sampling for shorter periods (days-months) may under- or over-estimate annual loading.

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## Atmospheric Deposition of PFAS in Wet Deposition and Throughfall to an Urban Forest

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Wet atmospheric deposition and throughfall samples were collected weekly and analyzed for 33 per- and polyfluoralkyl substances (PFAS) during April through November 2023 within an old growth forest in the New York Botanical Garden. The median total PFAS concentration in throughfall during the study period was 7.43 ng/L, 5.7 times greater than the median total PFAS concentration in wet deposition. The median total atmospheric deposition of PFAS in throughfall was 21.74 ng/m<sup>2</sup>/d, 3.4 times greater than wet deposition highlighting the dominance of dry deposition of PFAS over wet deposition to this urban forest. Perfluorobutanoic acid (PFBA) had the highest concentration among the PFASs, and carboxylates (PFCAs) were the dominant group in both forms of atmospheric deposition. Short chain PFASs were dominant in wet deposition and throughfall, though to a lesser extent in throughfall. Precipitation amount was significantly and inversely correlated with several of the PFASs in wet deposition, and this relationship was stronger in throughfall consistent with atmospheric scavenging and particle wash-off as processes affecting atmospheric PFAS deposition. Several major ions in wet deposition and throughfall, most notably Ca<sup>2+</sup>, were significantly and positively correlated with several of the PFASs, providing additional evidence that atmospheric scavenging and particle wash-off are important processes affecting atmospheric deposition to the study forest. These results indicate that dry deposition of PFAS as reflected in throughfall is the dominant form of atmospheric deposition to this urban forest. Further studies are warranted to examine the role of throughfall in other forested settings.

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## PFAS in Great Lakes Region Precipitation: Insights from Two Years of Observations

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Wet deposition transfers per- and polyfluoroalkyl substances (PFAS) from the atmosphere to the Earth's surface. This introductory pathway is particularly important in remote areas and for lakes with water budgets dominated by over-lake precipitation, such as Lake Superior. Despite this, the sources, atmospheric controls, and seasonal and compositional variability of PFAS in wet deposition remain poorly constrained. To investigate this variability in the Great Lakes region, 33 PFAS compounds were measured continuously via weekly integrated sampling at five National Atmospheric Deposition Program National Trends Network (NADP-NTN) sites in Minnesota and Michigan from summer 2023 to summer 2025.

These observations found ubiquitous PFAS contamination of precipitation, with at least one PFAS species detected in 100% of the samples and the sum of PFAS concentrations ranging from 0.05 to 10.4 ng/L. Perfluorocarboxylic acids (PFCAs) dominated the PFAS mass in wet deposition, representing 80% of the measured PFAS mass flux. Perfluoroheptanoic acid (PFHpA) was the most commonly detected species, detected in 99% of samples. Although PFCAs dominated the observed PFAS mass, other families, including GenX, perfluoroalkane sulfonic acids (PFASAs), and perfluoroalkane sulfonamides (FASAs), were detected regularly but more sporadically, indicating event- or source-driven changes in atmospheric composition for these species. These observations underscore the importance of atmospheric deposition as a significant source of PFAS in the Great Lakes region, highlighting the need to constrain its magnitude and controls.

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## Tracking PFAS in Rain and Snow Around the Lake Superior Basin



**Alissia M. Milani**<sup>1,\*</sup>, Kaitlyn J. Gruber<sup>2</sup>, Martin Shafer<sup>3</sup>, and Christina K. Remucal<sup>1,2,4</sup>

Atmospheric transport and transformation of per- and polyfluoroalkyl substances (PFAS) are major mechanisms driving the global distribution of these toxic chemicals. Both wet (i.e., rain and snow) and dry atmospheric deposition may represent major input pathways of PFAS to many aquatic and terrestrial environments, especially in otherwise pristine natural systems. Lake Superior, the largest of the Great Lakes, is likely one such system with limited PFAS point sources and large meteoric loadings. Lake Superior also serves as a drinking water source to more than 10 million people, thus it is critical to understand how rain or snow may contribute to PFAS accumulation in Lake Superior, a lake with a very long hydraulic residence time of nearly 200 years. However, as in many locations, the atmospheric sources and loading of PFAS to the Upper Great Lakes are poorly characterized and constrained. Therefore, this research seeks to interpret spatial trends of PFAS in wet deposition with potential sources using statistical analyses and back-trajectory modeling. In collaboration with the National Atmospheric Deposition Program, wet deposition samples were collected on a weekly basis from nine sites around the US side of Lake Superior between 2022 and 2024. These samples were analyzed for 33 PFAS compounds in five major classes by solid-phase extraction, isotope dilution, liquid chromatography-tandem mass spectrometry (LC-MS/MS). Perfluorocarboxylic acids (PFCAs) were the most frequently detected class and accounted for 75.8% to 96.6% of targeted PFAS by mass. The abundance of PFCAs may partially result from atmospheric transformation of volatile precursor PFAS. However, the overall distribution of PFAS classes varied between sites, which may be driven by their proximity to potential point sources. Chemistry data from the NADP's National Trends Network will be leveraged to better understand potential pollutant sources impacting wet deposition. Advancing our understanding of sources, transformation, and deposition of PFAS in precipitation can inform future research, drive policy development, and ultimately mitigate human exposure to these contaminants.

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## Attributing of Wet-Deposition of PFAS by Tracking Sources Backwards in Time

**Miguel Bernardez<sup>1,\*</sup>**, Alexander Frie<sup>1</sup>, Bridget Ulrich<sup>2</sup>, Martin Schafer<sup>3</sup>, Quinn Whiting<sup>1</sup>, Samantha McClung<sup>4</sup>, Emily Sellers<sup>3</sup>, Iris Bloede<sup>3</sup>, Jared Kunick<sup>3</sup>, and Elizabeth O'Gorman<sup>3</sup>

Wet deposition of Per- and poly-fluoroalkyl substances (PFAS) is widespread and a pathway for contamination of both land and water systems. Source attribution for wet deposited PFAS is challenging, in part because of the complexity of atmospheric transport of PFAS and the event-based nature of wet deposition. To address this challenge, we have developed a novel approach to directly investigate the impact of air-mass history on PFAS composition. This approach uses the Stochastic Time-Inverted Lagrangian Transport (STILT) Model to track the air masses corresponding to wet deposition periods backward in time for a specific sampling period. Back trajectory footprints are then combined with PFAS concentration data over a large number of samples using the concentration-weighted trajectory approach to identify possible hotspots associated with higher PFAS. Here, we apply this approach to two years of PFAS concentration observations from five National Atmospheric Deposition Program-National Trends Network (NADP-NTN) sites in Minnesota and Michigan. This analysis enables investigation of how source region varies for different PFAS species, seasons, and rain types, providing new insights into the sources of and controls on PFAS in wet deposition.

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## Short Term Effects of Cold Weather Factors on Hospital Admissions for Subcategories of Autoimmune Diseases



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Wet deposition of Per- and poly-fluoroalkyl substances (PFAS) is widespread and a pathway for contamination of both land and water systems. Source attribution for wet deposited PFAS is challenging, in part because of the complexity of atmospheric transport of PFAS and the event-based nature of wet deposition. To address this challenge, we have developed a novel approach to directly investigate the impact of air-mass history on PFAS composition. This approach uses the Stochastic Time-Inverted Lagrangian Transport (STILT) Model to track the air masses corresponding to wet deposition periods backward in time for a specific sampling period. Back trajectory footprints are then combined with PFAS concentration data over a large number of samples using the concentration-weighted trajectory approach to identify possible hotspots associated with higher PFAS. Here, we apply this approach to two years of PFAS concentration observations from five National Atmospheric Deposition Program-National Trends Network (NADP-NTN) sites in Minnesota and Michigan. This analysis enables investigation of how source region varies for different PFAS species, seasons, and rain types, providing new insights into the sources of and controls on PFAS in wet deposition.

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