



**2013 Annual Meeting and Scientific Symposium**

**Western U.S. Monitoring and Analysis:  
Progress and Current Issues**

**October 8-11, 2013**

**Park City, UT**



National Atmospheric Deposition Program

# Schedule at a Glance

	Tuesday October 8	Wednesday October 9	Thursday October 10	Friday October 11
7:30	Registration	Registration	Registration	
8:00		Opening	Opening Remarks	Registration
8:15		Annual State of NADP	Session 5 (6 speakers)	
8:30	Joint Subcommittee Meeting	Session 1 (4 speakers)		
8:45				
9:00				
9:15				
9:30				
9:45	Subcommittee Meetings (4)	Break	Break	N-Flux Workshop (1 speaker)
10:00				
10:15				
10:30				
10:45				
11:00	Lunch on your own	Lunch on your own	Lunch on your own	Break
11:15				
11:30				
11:45				
12:00				
12:15	Joint Subcommittee meeting	Session 2 (3 speakers)	Session 7 (7 speakers)	Buffet Lunch (Speaker)
12:30				
1:00				
1:15				
1:30				
1:45	Break	Session 3 (3 speakers)		N-Flux Workshop (2 speakers)
2:00				
2:15				
2:30				
2:45				
3:00	Executive Committee Meeting	Break	Break	N-Flux Workshop (2 speakers)
3:15				
3:30				
3:45				
4:00				
4:15	Break	Session 3 (2 speakers)	Session 8 Keynote Speaker (4 speakers)	
4:30				
4:45				
5:00				
5:15				
5:30		Break	Break	Close
6:00				
6:30				
7:00				
8:00				
9:00		Poster Session and Reception	Optional Field Trip	

**NADP 2013  
Technical Committee Meeting**

October 8-11, 2013  
Park City, UT

**Scientific Symposium Chair**  
Christopher M. Rogers  
AMEC Environment & Infrastructure

**PROCEEDINGS**

Prepared by

**Lisa A. Volk  
NADP Program Office  
Illinois State Water Survey  
Prairie Research Institute  
University of Illinois  
2204 Griffith Drive  
Champaign, IL 61820**

**October 2013**

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## **NADP Scientific Symposium Agenda**

**NADP Annual Meeting and Scientific Symposium  
Park City, UT  
October 8-11, 2013**

<b>Tuesday, October 8, 2013</b>		<b>Room Location</b>
Open All Day	Registration Desk	Foyer A
8:30 a.m.–10:00 a.m.	Joint Subcommittee Meeting	Prospector 4
10:00 a.m.–12:00 noon	Subcommittee Meetings Network Operations Data Management & Analysis Ecological Response and Outreach Critical Loads	Prospector 4 Silver Mine Room B Silver Mine Room A Prospector 3
12:00 noon- 1:30 p.m.	Lunch - On your own	
1:30 p.m. - 3:30 p.m.	Joint Subcommittee Meeting	Prospector 4
3:30 p.m. - 3:45 p.m.	Break	Foyer C
3:45 p.m. - 6:00 p.m.	Executive Committee Meeting	Prospector 2-3

<b>Wednesday, October 9, 2013</b>		<b>Room Location</b>
Open All Day	Registration/Office	Foyer A
8:00 a.m. -8:35 a.m.	<b>Welcome, Program Gffice Report Awards and Announcements</b> Christopher Rogers: NADP Vice Chair, Symposium Chair AMEC E & I David Gay: NADP Coordinator Andy Johnson: NADP Chair Maine DEP, Bureau of Air Quality	Prospector 3-4

**Wednesday, October 9, 2013**

**Room Location**

Prospector 3-4

<b>Technical Session 1:</b>	<b>IMPROVE</b> Session Chair: Scott Copeland USDA Forest Service
8:35 a.m. – 9:05 a.m.	<b>Overview and description of IMPROVE</b> Charles E. McDade, Crocker Nuclear Laboratory, University of California, Davis
9:05 a.m. – 9:25 a.m.	<b>Trends in remote and rural speciated particulate concentrations from the IMPROVE network (1989-2011).</b> Jenny L. Hand, CIRA, Colorado State University
9:25 a.m. - 9:45 a.m.	<b>The Regional Haze Rule Reasonable Progress Report Project for 116 Western Class I Areas</b> Cassie Archuleta, Air Resource Specialists
9:45 a.m. – 10:05 a.m.	<b>Reanalysis of a 15-year archive of IMPROVE samples</b> Nicole P. Hyslop, Crocker Nuclear Laboratory, University of California
10:05 a.m. – 10:20 a.m.	Break
10:20 a.m. – 10:40 a.m.	<b>Determination of Organic Material to Organic Carbon (OM/OC) Ratios by FT-IR Spectroscopy at Select Sites in the IMPROVE Network</b> Ann M. Dillner, University of California
10:40 a.m. – 11:00 a.m.	<b>Resources available to the IMPROVE data user</b> Warren H. White, Crocker Nuclear Laboratory, University of California
<b>Technical Session 2:</b>	<b>Western U.S. Issues</b> Session Chair: Ellen Porter National Park Service
11:00 a.m. – 11:20 a.m.	<b>From passive samplers to estimates of nitrogen deposition in arid and semi-arid areas of the western United States</b> Andrzej Bytnerowicz, USDA, Forest Service

Wednesday, October 9, 2013		Room Location
		Prospector 3-4
11:20 a.m.–11:40 a.m.	<b>Fire Contribution to Reduced Gaseous Nitrogen Species at Grand Teton National Park</b> W.C. Malm, CIRA, Colorado State University	
11:40 a.m.-12:00 p.m.	<b>Organic Nitrogen in the Snowpack throughout the United States Rocky Mountains</b> B.A Schichtel, National Park Service	
12:00 p.m. – 1:00 p.m.	<b>Lunch on your own</b>	
<b>Technical Session 2:</b>	<b>Western U.S. Issues (continued)</b> Session Chair: Ellen Porter National Park Service	
1:00 p.m. – 1:20 p.m.	<b>Adapting and applying the integrated biogeochemical model ForSAFE-Veg at a subalpine site – processes and prospects</b> S. Belyazid, Belyazid Consulting & Communication	
1:20 p.m. – 1:40 p.m.	<b>Impact of Nitrogenous Air Pollutants on Vegetation Communities Across the Snake River Plains</b> Michael D. Bell, University of California, Riverside	
1:40 p.m. – 2:00 p.m.	<b>Atmospheric N in the Alberta Oil Sands, Canada</b> Sagar Krupa, University of Minnesota	
<b>Technical Session 3:</b>	<b>Critical Loads</b> Session Chair: Jason Lynch, U.S. EPA	
2:00 p.m. – 2:20 p.m.	<b>Critical Loads of Atmospheric N Deposition for the Protection of Plant Biodiversity in the Western United States in the Context of Oil and Gas Development and a Changing Climate</b> T.J. Sullivan, E&S Environmental Chemistry, Inc.	
2:20 p.m. – 2:40 p.m.	<b>Strategic plan to establish and implement nitrogen critical loads and target loads for national forests and national parks in the Pacific Northwest, USA</b> Tonnie Cummings, National Park Service	

Wednesday, October 9, 2013		Room Location
		Prospector 3-4
2:40 p.m. – 3:00 p.m.	<b>Monitoring Critical Levels of Ozone in Remote Rocky Mountain Ecosystems and Exceedances of the National Ambient Air Quality Standard</b> Robert C. Musselman, U.S. Forest Service	
3:00 p.m. – 3:15 p.m.	Break	
<b>Technical Session 3:</b>	<b>Critical Loads (continued)</b> Session Chair: Jason Lynch U.S. EPA	
3:15 p.m. – 3:35 p.m.	<b>A Hybrid Approach For Estimating Total Nitrogen And Sulfur Deposition In The United States</b> G. G. Lear, U.S. EPA	
3:35 p.m. – 3:55 p.m.	<b>Sources and sinks of reactive nitrogen in the Canadian landscape</b> Thomas Clair, Wood Buffalo Environmental Association	
<b>Technical Session 4:</b>	<b>Atmospheric Modeling</b> Session Chair: Bret Schichtel National Park Service	
3:55 p.m. – 4:15 p.m.	<b>Simulating Total Nitrogen Deposition at Western National Parks with the WestJumpAQMS Modeling Platform</b> Mike Barna, National Park Service	
4:15 p.m. – 4:35 p.m.	<b>Evaluation of CMAQ air-surface exchange and WRF energy balance algorithms against flux measurements</b> Jesse Bash, U.S. EPA	
4:35 p.m. - 4:55 p.m.	<b>The influence on CMAQ modeled wet and dry deposition of advances in the CMAQ systems for meteorology and emissions</b> Robin Dennis, U.S. EPA	
4:55 p.m. – 5:15 p.m.	<b>Comparison of organic nitrogen from CMAQ with measured values using a revised CB05 chemical mechanism</b> Donna Schwede, U.S. EPA	
5:15p.m. - 5:35 p.m.	<b>Evaluation of bi-directional ammonia exchange in GEOS-chem using in-situ observations</b> Liye (Juliet) Zhu, University of Colorado at Boulder	

Wednesday, October 9, 2013	Room Location
5:35 p.m. – 6:30 p.m.	Break
6:30 p.m. – 9:00 p.m.	Poster Session and Reception Prospector 1-2
Thursday, October 10, 2013	Room Location
Open All Day	Registration/Office Registration/Office
Thursday, October 10, 2013	Room Location
	Prospector 3-4
8:00 a.m. – 8:05 a.m.	<b>Opening remarks, announcements and overview of Day 2</b> Chris Rogers, NADP Vice Chair, AMEC E & I
<b>Technical Session 5:</b>	<b>Mercury and Trace Metals</b> Session Chair: David Schmeltz U.S. EPA
8:05 a.m. - 8:25 a.m.	<b>Measurements of Mercury and Ancillary Species at NOAA's Mauna Loa Observatory</b> Winston T. Luke, NOAA Air Resources Laboratory
8:25 a.m. – 8:45 a.m.	<b>Hg isotopes in gaseous and particulate atmospheric mercury species above a coastal suburban environment (Pensacola, Florida, USA)</b> Arnout ter Schure, Electric Power Research Institute
8:45 a.m. – 9:05 a.m.	<b>Dry Deposition of Atmospheric Mercury to the Great Salt Lake</b> Kevin D. Perry, University of Utah
9:05 a.m. – 9:25 a.m.	<b>Seasonal Variation of Atmospheric Deposition of Trace Metal in Urban Central New York</b> Nicholas B. Glick, Syracuse University
9:25 a.m. – 9:45 a.m.	<b>A Great Lakes Atmospheric Mercury Monitoring Network</b> Martin R. Risch, U.S. Geological Survey
9:45 a.m. – 10:05 a.m.	<b>Air Mercury Speciation Accuracy and Calibration</b> Eric M. Prestbo, Tekran Research and Development
10:05 a.m. – 10:20 a.m.	Break

Thursday, October 10, 2013	Room Location
	Prospector 3-4
<b>Technical Session 6:</b>	<b>Nitrogen Emissions and Deposition</b> Session Chair: Donna Schwede U.S. EPA
10:20 a.m. – 10:40 a.m.	<b>Ammonia Emissions State of the Science</b> Viney P. Aneja, North Carolina State University
10:40 a.m. – 11:00 a.m.	<b>Assessing the Sensitivity of Agricultural Systems to Atmospheric N Deposition</b> Ellen Cooter, U.S. EPA NERL/AMAD
11:00 a.m. – 11:20 a.m.	<b>Surface-Atmosphere Exchange of Ammonia in a Non-fertilized Grassland and its Implications for PM<sub>2.5</sub></b> Gregory R. Wentworth, University of Toronto
11:20 a.m. – 11:40 a.m.	<b>Atmospheric nitrogen deposition across China</b> X.J. Liu, China Agricultural University
11:40 a.m. – 12:00 p.m.	<b>First steps toward the establishment of a Nitrogen Cycling network in Latin America (Nnet)</b> Ariel F. Stein, ERT, Inc. & Air Resources Laboratory (ARL), NOAA
12:00 p.m. – 1:00 p.m.	Lunch on your own
<b>Technical Session 7:</b>	<b>Networks, Measurements, and New Techniques for Atmospheric Monitoring</b> Session Chair: Tom Butler Cornell University
1:00 p.m. – 1:20 p.m.	<b>Wet deposition in the Mexico City Metropolitan Zone</b> Humberto Bravo, Universidad Nacional Autónoma de México And <b>Wet deposition in the Coast of the Gulf of Mexico</b> Rodolfo Sosa E, Universidad Nacional Autónoma de México
1:20 p.m. – 1:40 p.m.	<b>Quality Assurance and Data Management in the World Meteorological Organization Global Atmosphere Watch Precipitation Chemistry Program</b> Richard Artz, NOAA Air Resources Laboratory

Thursday, October 10, 2013

Room Location

Prospector 3-4

1:40 p.m. - 2:00 p.m. **Measurements and Modeling of Atmosphere-Snowpack Exchange of Ozone and Nitrogen Oxides at Summit, Greenland**  
Keenan A. Murray, Michigan Technological University

2:00 p.m. - 2:20 p.m. **A Winter Ozone Monitoring Network in Utah's Uintah Basin**  
Seth Lyman, Utah State University

2:20 p.m. - 2:40 p.m. **Field Performance Evaluation of the Monitor for AeRosols and GAses in ambient air (MARGA)**  
Greg M. Beachley, U.S. EPA

2:40 p.m. - 3:00 p.m. **Seasonal variation of speciated nitrogen and sulfur fluxes above a grass field**  
Ian C. Rumsey, U.S. EPA

3:00 p.m. - 3:20 p.m. **Continued Development and Validation of Inexpensive Flux-Measurement Tools**  
Berkeley Almand, University of Colorado

3:20 p.m. - 3:35 p.m. Break

**Technical Session 8: Nitrogen Flux Workshop Kickoff**  
Session Chair: John Walker  
U.S. EPA

3:35 p.m. - 4:35 p.m. **KEYNOTE: The state of the science on nitrogen deposition budgets and their use in critical loads assessments in Europe**  
David Fowler, CEH Edinburgh UK

4:35 p.m. - 4:55 p.m. **NO<sub>2</sub> and O<sub>3</sub> deposition to intensively managed grassland - Findings, characterization and parameterization from a multi-year dynamic chamber study**  
Veronika Wolfi, Agroscope Reckenholz-Tänikon Research Station, Zurich, Switzerland

4:55 p.m. - 5:15 p.m. **Reactive nitrogen oxides fluxes above two mid-latitude North American mixed hardwood forests**  
Jeffrey Geddes, University of Toronto & now at Dalhousie University

Thursday, October 10, 2013

Room Location

Prospector 3-4

5:15 p.m. - 5:35 p.m. **An Investigation of Anthropogenic Influences on Fluxes of Organic Nitrates from a Temperate Deciduous Forest in East Tennessee**  
Rick D. Saylor, NOAA Air Resources Laboratory

5:35 p.m. Closing Comments

6:30 p.m. - 8:00 p.m. Optional Field Trip  
Swaner EcoCenter

Friday, October 11, 2013

Room Location

8:00 a.m. - 9:00 a.m. **Registration/Office** Foyer A

Friday, October 11, 2013

Room Location

Prospector 4

8:30 a.m. - 9:30 a.m. **Development of total nitrogen deposition budgets for U.S. critical loads assessments**  
John T. Walker, U.S. EPA

9:30 a.m. - 10:30 a.m. **Reactive nitrogen deposition in the United States: the increasing importance of ammonia**  
Jeffrey L. Collett, Jr., Colorado State University

10:30 a.m. - 10:45 a.m. Break

10:45 a.m. - 11:45 a.m. **Observations of fluxes and gradients of NO<sub>x</sub> and Peroxynitrates: Disentangling Chemical and Physical Mechanisms of Atmosphere-Biosphere Exchange of Oxidized N**  
Ronald C. Cohen, Departments of Chemistry and of Earth and Planetary Science, UC Berkeley

11:45 a.m. - 12:30 p.m. Lunch Buffet Provided

12:00 p.m. - 12:30 p.m. **Lunchtime Talk: Continuous Measurements of NO<sub>y</sub> and NO<sub>y</sub> Components during the Southeast Atmospheric Study, June 1-July 15, 2013**  
Eric S. Edgerton, Atmospheric Research & Analysis, Inc.

Friday, October 11, 2013

Room Location

Prospector 4

12:30 p.m. – 1:30 p.m.	<b>Application of common and new techniques for measuring air-surface exchange of reactive nitrogen</b> Christof Ammann, Agroscope Reckenholz-Tänikon Research Station, Zurich, Switzerland
1:30 p.m. – 2:30 p.m.	<b>Land - atmosphere ammonia exchange: Do we have the necessary information to contribute to a common conceptual framework for modelling biosphere atmosphere exchanges of gases and aerosols</b> R.-S. Massad, INRA-AgroParisTech Environnement et Grandes Cultures
2:30 p.m. – 2:45 p.m.	Break
2:45 p.m. - 3:45 p.m.	<b>Constraints on air quality model budgets of the sources and sinks of reactive trace gases</b> Daven K. Henze, University of Colorado, Boulder
3:45 p.m. – 4:45 p.m.	<b>Preferential Canopy Uptake of Nitrate and Consequences for Deposition Monitoring in Forests of the Pacific Northwest, USA</b> Mark E. Fenn, USDA Forest Service
4:45 p.m.	<b>CLOSE</b>

## **2013 NADP SITE OPERATOR AWARDS**



NATIONAL ATMOSPHERIC DEPOSITION PROGRAM OPERATOR AWARDS

5 YEAR AWARDS

Site	Operator Name	Site Name	Wet Start	Agency
AK02 - NTN	Adelaide Johnson	Juneau	06/21/04	U.S. Forest Service
CO99 - MDN	Paul Bohmann	Mesa Verde NP - Chapin Mesa Mesa Verde NP - Chapin Mesa	12/26/01 04/28/81	National Park Service-ARD U.S. Geological Survey
ND08 - NTN	Janna Robinson	Icelandic State Park	10/25/83	U.S. Geological Survey
NE15 - MDN	Tom Lowman	Mead	06/26/07	Nebraska DEQ
NTN		Mead	07/25/78	University of Nebraska
SD08 - NTN	David Gay	Cottonwood	10/11/83	U.S. Geological Survey
WY06 - NTN	Ted Porvoll	Pinedale	01/26/82	BLM

10 Year Awards

Site	Operator Name	Site Name	Wet Start	Agency
MIS1 - NTN	Dense Dickson	Unionville	01/26/99	U.S. EPA-Clean Air Markets
MS19 - NTN	Grace Norman	Newton	11/11/86	NOAA-ARL
WA99 - NTN	Rebecca Lotgren	Mount Ramer NP - Lakoma Woods	10/26/99	National Park Service-ARD
WY00 - NTN	John Kortmacher	Snowy Range	04/22/86	U.S. Forest Service
WY95 - NTN		Brooklyn Lake	09/22/92	U.S. Forest Service

15 Year Awards

Site	Operator Name	Site Name	Wet Start	Agency
ME96 - NTN	Don Prince	Casco Bay - Wolfe's Neck Farm	01/06/98	U.S. EPA/Maine DEP
MDN		Casco Bay - Wolfe's Neck Farm	01/06/98	U.S. EPA/Maine DEP
MO03 - NTN	Kevin Hosman	Ashland Wildlife Area	10/20/81	U.S. Geological Survey
NM08 - NTN	Linda Madron	Mayhill	01/24/84	U.S. Geological Survey

Site	Operator Name	Site Name	Wet Start	Agency
MD13-NTN	Michael Newell	Wye	03/08/83	University of Maryland-State Agricultural Experiment Station
IL18-NTN	David Lindgren	Shabbona	05/26/81	University of Illinois-State Agricultural Experiment Station

30 Year Awards

Site	Operator Name	Site Name	Wet Start	Agency
TX16-NTN	Robert Moen	Sonora	06/26/84	U.S. Geological Survey

25 Year Awards

PA15-NTN	Robert Ziegler	Penn State	06/07/83	NOAA-ARL
PA42-NTN	Kevin Homer	Leading Ridge	04/25/79	Pennsylvania State University

20 Year Awards

Site	Operator Name	Site Name	Wet Start	Agency
PA15-NTN	Robert Ziegler	Penn State	06/07/83	NOAA-ARL
PA15-NTN	AIRMON	Penn State	10/06/92	NOAA-ARL

**TECHNICAL SESSION 1:  
IMPROVE**

*Session Chair: Scott Copeland,  
USDA Forest Service*

## Overview and description of IMPROVE

Charles E. McDade

The Interagency Monitoring of Protected Visual Environments (IMPROVE) network tracks the concentration and chemical composition of haze aerosols at about 170 locations in mostly rural locations throughout the United States. IMPROVE began collecting samples in 1988 with a network of about 30 sites. A major expansion around 2000 brought the network to its current size.

IMPROVE collects 24 h samples of particulate matter with aerodynamic diameters less than 2.5  $\mu\text{m}$  ( $\text{PM}_{2.5}$ ) and less than 10  $\mu\text{m}$  ( $\text{PM}_{10}$ ) at a frequency of every third day. Four samples are collected on each sample day:  $\text{PM}_{2.5}$  on polytetrafluoroethylene (PTFE) filters,  $\text{PM}_{2.5}$  on nylon filters,  $\text{PM}_{2.5}$  on quartz filters, and  $\text{PM}_{10}$  on PTFE filters. The PTFE  $\text{PM}_{2.5}$  samples are weighed and then analyzed for elements by x-ray fluorescence (XRF) and light absorption ( $F_{\text{abs}}$ ). The quartz  $\text{PM}_{2.5}$  samples are analyzed by thermal optical reflectance (TOR) analysis for carbon and the  $\text{PM}_{2.5}$  nylon samples are analyzed by ion chromatography for the major anions. The PTFE  $\text{PM}_{10}$  samples are weighed.

The IMPROVE aerosol sampling network is managed by Crocker Nuclear Laboratory at the University of California at Davis (UC Davis), which also conducts the gravimetric, elemental, and light absorption analyses. Carbon analysis is conducted at the Desert Research Institute of the University of Nevada, and ion analysis is conducted at Research Triangle Institute. Each site is serviced by a local operator, often a park ranger or firefighter. The local operator visits the site once a week to change the filters and to record sampling parameters.

Data are processed and validated at UC Davis and are delivered to the Cooperative Institute for Research in the Atmosphere (CIRA). The final ambient concentration data are available for open, public downloading on this website: <http://views.cira.colostate.edu/fed/>.

IMPROVE data are widely used by researchers, regulators, and policy-makers. Regional Haze Rule (RHR) analysts are among the principal users of IMPROVE data. The RHR, enacted in 1999, was issued to improve visibility in Class I areas across the country, such as National Parks and wilderness areas. IMPROVE data are used to track long-term progress in achieving the RHR goals.

Charles E. McDade, Crocker Nuclear Laboratory, University of California, Davis, CA 95616, [cemcdade@ucdavis.edu](mailto:cemcdade@ucdavis.edu), (530) 752-7119

## Trends in remote and rural speciated particulate concentrations from the IMPROVE network (1989-2011)

Jenny L. Hand, Bret A. Schichtel and William C. Malm

The Interagency Monitoring of Protected Visual Environments (IMPROVE) network has monitored speciated aerosol concentrations at remote and rural sites across the United States since 1988. One of the main objectives of the program is to document trends for assessing progress towards national visibility goals in national parks and visibility-protected federal class I areas. To meet this objective, daily samples (24-hr) are collected every third day and analyses are performed to determine concentrations of particulate anions (e.g., sulfate, nitrate), organic and light absorbing carbon, elemental concentrations, and  $\text{PM}_{2.5}$  and  $\text{PM}_{10}$  gravimetric mass. To evaluate changes in these species over the past two decades, trends were computed at approximately 50 long-term (1989-2011) and 150 short-term (2000-2011) sites. In particular, we focused on monthly, seasonal, and annual mean trends for sulfate ion, nitrate ion, and mineral dust concentrations. Results of statistically significant short- and long-term trends suggest that concentrations of most species have decreased across the country, although concentrations of some species have actually increased during specific seasons. For example, since 2000 sulfate concentrations have increased at many sites in the West in spring, and both sulfate and nitrate concentrations have increased at sites in the central and northern Great Plains in winter. Mineral dust has increased across the west in spring and the Midwest in fall. Trends in EPA's National Emission Inventory  $\text{SO}_2$  and  $\text{NO}_x$  emissions suggest that for sulfate and nitrate, influences other than regulated emissions appear to be influencing rural concentrations in the West, which has implications for the effectiveness of current emission mitigation strategies in meeting goals for improving air quality, especially in the West.

Jenny L. Hand  
CIRA, Colorado State University, Fort Collins, CO 80523, [jlhand@colostate.edu](mailto:jlhand@colostate.edu)

Bret A. Schichtel  
National Park Service, Air Resource Division, CIRA, Colorado State University, Fort Collins, CO 80523, [Bret.Schichtel@colostate.edu](mailto:Bret.Schichtel@colostate.edu)

William C. Malm  
CIRA, Colorado State University, Fort Collins, CO 80523, [wc.Malm@colostate.edu](mailto:wc.Malm@colostate.edu)

## The Regional Haze Rule Reasonable Progress Report Project for 116 Western Class I Areas

Cassie Archuleta<sup>1</sup>, Emily Vanden Hoek<sup>1</sup>, Joe Adlhoch<sup>1</sup>, and Tom Moore<sup>2</sup>

Data from the International Monitoring of Protected Visual Environments (IMPROVE) program supports the EPA's Regional Haze Rule (RHR), which protects visibility in 156 federal Class I areas (CIAs), including national parks and wilderness areas. The RHR mandates that State's create implementation plans designed to reduce man-made emissions affecting these CIAs towards goals of natural conditions, or conditions without any man-made influences, by 2064. Over the long-term period of RHR haze planning (nominally 60 years) each State is required to periodically assess the rate of visibility improvement for each CIA in that state. The first of these progress assessment reports are due at various dates in the 2013-15 timeframe, depending on respective submittal dates for each state's initial implementation plans.

The Western Regional Air Partnership (WRAP), on behalf of the 15 western state members in the WRAP region, has recently completed a project designed to provide the technical basis for use by States to develop the first of their individual reasonable progress reports for the 116 Class I federal areas located in the WRAP region. The final project report includes summaries of monitoring and emissions data, including comparisons between baseline averages and first progress period averages, and trends in monitored data. This presentation will summarize the goals of this project, and presents example data summaries and results. The final project report is available at <http://www.wrapair2.org/RHRPR.aspx>.

<sup>1</sup> Air Resource Specialists, Inc. (ARS), 1901 Sharp Point Drive, Suite E, Fort Collins, CO 80525

<sup>2</sup> Western Regional Air Partnership, CIRA, CSU, 1375 Campus Delivery, Fort Collins, CO 80523

**Principle Contact:** Cassie Archuleta, Project Scientist, Air Resource Specialists, Inc., Fort Collins, CO 80525, 970-484-7941, FAX-484-3423, [carchuleta@air-resource.com](mailto:carchuleta@air-resource.com)

## Reanalysis of a 15-year archive of IMPROVE samples

Nicole P. Hyslop<sup>1</sup>, Krystyna Trzepla<sup>1</sup>, and Warren H. White<sup>1</sup>

The IMPROVE (Interagency Monitoring of PROtected Visual Environments) network monitors aerosol concentrations at about 170 rural or remote sites throughout the United States. Twenty-four-hour filter samples of fine particulate matter (PM<sub>2.5</sub>) are collected every third day and analyzed for elements, ions, carbon, and total mass. About 30 of these sites have operated continuously since 1988, and the sustained data record (<http://views.cira.colostate.edu/web/>) offers a unique window on regional aerosol trends through a period of changing anthropogenic and natural emissions.

For the elemental measurements, the same sampling conditions have been maintained throughout the program. All elemental analyses have been performed by Crocker Nuclear Laboratory at the University of California in Davis, and all original sample filters collected since 1995 are archived on campus. The suite of reported elements has remained constant, but the analytical methods employed for their determination have evolved. For example, the elements Na – Mn were determined by PIXE through November 2001, by XRF analysis in a He-flushed atmosphere from December 2001 through December 2004, and by XRF analysis in vacuum since January 2005. In addition to these fundamental changes, incompletely-documented operational factors such as detector performance and calibration details have introduced variations in the measurements.

Because the past analytical methods were all non-destructive, the archived filters can be re-analyzed with the current analytical systems and protocols. The 15-year sample archives from Great Smoky Mountains National Park, Mount Rainier National Park, and Point Reyes National Seashore were recently selected to generate such analytically homogeneous data series. For each site, the complete historical series of consistently collected samples was processed in a single analytical batch. The agreement between the new analyses and original determinations varies with element and analytical era.

<sup>1</sup>Crocker Nuclear Laboratory, University of California, Davis, CA 95616, email: [nmhyslop@ucdavis.edu](mailto:nmhyslop@ucdavis.edu), phone: (530) 754-8979

## Determination of Organic Material to Organic Carbon (OM/OC) Ratios by FT-IR Spectroscopy at Select Sites in the IMPROVE Network

Ann M. Dillner and Travis C. Ruthenburg, University of California, Davis, CA

Organic carbon (OC) in PM<sub>2.5</sub> (particulate matter (PM) with an aerodynamic diameter  $\leq 2.5$   $\mu\text{m}$ ) filter samples is typically quantified using a thermal optical technique for samples collected on quartz filters. After correcting the OC mass for gas phase adsorption, mass of organic matter (OM) in PM<sub>2.5</sub> is estimated by multiplying OC by a fixed factor that typically ranges from 1.4 to 1.8. In this work, we develop a non-destructive, Fourier Transform-Infrared spectroscopic (FT-IR) technique to measure OM in PM<sub>2.5</sub> samples collected on PTFE filters (polytetrafluoroethylene, commonly called "teflon filters"). PTFE filters are used for gravimetric, light absorption and elemental analysis in the IMPROVE network and the non-destructive FT-IR technique does not interfere with those analyses. Gas phase adsorption onto PTFE filters is negligible so no sampling artifact correction is needed. FT-IR measures absorption by organic functional groups, which are comprised of carbon bonded to oxygen, hydrogen and other elements. To calibrate the method, we developed laboratory standards of atmospherically relevant organic compounds collected on PTFE filters and measured their absorption using a standard FT-IR instrument. A multivariate calibration based on the laboratory standards was used to quantify organic functional groups, including alkane CH, alcohol OH, carboxylic acid OH, and carbonyl. These four functional groups are likely to represent the preponderance of organic mass in most ambient aerosol samples. OM is estimated using a weighted sum of all functional groups and OC is estimated using a weighted sum of the alkane CH and carbonyl functional groups. The precision of the OM measurement is 7% and the minimum detection limit is 0.15  $\mu\text{g}/\text{m}^3$  for an IMPROVE sample.

The method was employed to estimate OM, OC, OM/OC and organic functional groups in one year of routinely collected filter samples at seven IMPROVE sites. In the IMPROVE network protocol, OC is measured using a thermal optical reflectance method and OM is estimated using an OM/OC ratio of 1.8. Using the FT-IR technique developed here, the median OM/OC ratio for the seven sites was 1.67 and the 25<sup>th</sup> and 75<sup>th</sup> percentiles were 1.53 and 1.86. Phoenix, AZ had the lowest median value of 1.55 and Mesa Verde, CO had the highest of 1.83. For most sites, the highest median OM/OC ratio occurred in fall while the lowest occurred in winter or spring. The FT-IR measured sample, site and seasonal OM/OC ratios indicate that a single estimate of OM/OC does not represent the observed variability in OM/OC. Additionally, the mass of functional groups vary by sample, site and season.

Principal Contact: Ann M. Dillner, Associate Research Scientist, University of California, 1 Shields Ave., Davis, CA 95616, 530-752-0509, 530-752-4107, [amdillner@ucdavis.edu](mailto:amdillner@ucdavis.edu)

## Resources available to the IMPROVE data user

Warren H. White<sup>1</sup>

The Interagency Monitoring of Protected Visual Environments (IMPROVE) network tracks the concentration and chemical composition of haze aerosols at about 170 locations throughout the United States. Data are and documentation provided on-line at <http://views.cira.colostate.edu/fed/>, where users can download species concentrations, together with sample-specific uncertainties, detection limits, data flags, and other supporting information.

Sample- and species-specific measurement parameters do not always capture everything that is known about data quality. Improved analytical methods may yield data whose greater accuracy can be distinguished only in large-scale or inter-species comparisons, for example. Alternatively, data may exhibit patterns in time or space that do not correspond to plausible atmospheric signals. If no rationale can be identified for correcting or invalidating the underlying measurement sets, there is then a network-level uncertainty that is not reflected in the uncertainties reported with individual samples. (Even when a correction can be identified, users may prefer to recognize and accept the resulting discontinuity rather than retrospectively adjust data that have already undergone widespread analysis.) Anomalous data are sometimes identifiable as legitimate measurements of exceptional events in the real world.

IMPROVE offers higher-order information with an open-ended collection of data advisories, available at [http://vista.cira.colostate.edu/improve/Data/QA\\_OC/Advisory.htm](http://vista.cira.colostate.edu/improve/Data/QA_OC/Advisory.htm). These advisories follow a standard format giving the species, sites, and sampling periods involved, the phenomenon at issue, and a recommended course of action for users of the data, accompanied by a succinct account of the technical basis and supporting evidence. This presentation reviews these advisories and their intended use.

<sup>1</sup>Warren H. White, Crocker Nuclear Laboratory, University of California, One Shields Avenue, Davis, CA 95616, 530-752-1213, [whwhite@ucdavis.edu](mailto:whwhite@ucdavis.edu)

**TECHNICAL SESSION 2:  
WESTERN U.S. ISSUES**

*Session Chair: Ellen Porter,  
National Park Service*

## From passive samplers to estimates of nitrogen deposition in arid and semi-arid areas of the western United States

Andrzej Bytnerowicz<sup>1</sup>, Witold Fraczek<sup>2</sup>, Robert Johnson<sup>3</sup>, Darrel Jenerette<sup>3,4</sup>, Edith Allen<sup>3,4</sup> and Mark Fenn<sup>1</sup>

Passive samplers have been used for determinations of concentrations of nitrogenous (N) air pollutants such as nitrogen oxides (NO<sub>x</sub>), nitrogen dioxide (NO<sub>2</sub>), ammonia (NH<sub>3</sub>), and nitric acid vapor (HNO<sub>3</sub>). Their use has allowed for an improved understanding of the distribution of concentrations of these pollutants in topographically complex landscapes, such as in mountainous areas. A USDA Forest Service team in collaboration with various partners conducted numerous monitoring campaigns to determine concentrations of NH<sub>3</sub>, NO, NO<sub>2</sub> and HNO<sub>3</sub> in remote areas of the western United States and Canada. These results aided by geostatistical methodologies (ArcGIS Geostatistical Analyst, ESRI, USA) allowed us to generate pollution distribution maps in the Sierra Nevada Mountains (including Sequoia & Kings Canyon National Parks and the Lake Tahoe Basin), the White Mountains, the San Bernardino Mountains, Joshua Tree National Park, wildland-urban areas of southern California and the Athabasca Oil Sands Region in northern Alberta, Canada. Examples of such maps and information on spatial and temporal changes of reduced vs. oxidized forms on N pollutants as well as total inorganic gaseous reactive nitrogen (Nr) species will be presented and will focus on southern California and the Sierra Nevada Mountains. We will also provide an outline of a GIS-based inferential method for estimation of N deposition especially designed for arid and semi-arid areas. This methodology is based on measurements of gaseous concentrations of N air pollutants obtained with passive samplers, empirical values of surface deposition velocity for NH<sub>3</sub> and HNO<sub>3</sub>; empirically and literature-based values of stomatal conductance for NH<sub>3</sub>, NO<sub>2</sub> and HNO<sub>3</sub>; satellite information on leaf area index (LAI); and detailed information on landscape cover. Results obtained with this methodology will be illustrated for the San Bernardino Mountains of southern California for 2002-2006. Information on N deposition distribution helps to estimate exceedances of N deposition critical loads for better understanding of potential threats of N air pollution to ecosystem health and services.

<sup>1</sup>USDA, Forest Service, Pacific Southwest Research Station, Riverside, California, 92507; <sup>2</sup>Environmental Systems Research Institute, Redlands, California 92373; <sup>3</sup>Center for Conservation Biology, <sup>4</sup>Department of Botany and Plant Sciences, University of California, Riverside, California 92521.

## Fire Contribution to Reduced Gaseous Nitrogen Species at Grand Teton National Park

W.C. Malm<sup>1</sup>, A.J. Prenni<sup>2</sup>, E.J.T. Levin<sup>2</sup>, K.B. Benedict<sup>2,3</sup>, A.P. Sullivan<sup>2</sup>, M. Schurman<sup>2</sup>, K.A. Gebhart<sup>4</sup>, D.E. Day<sup>1</sup>, C.M. Carrico<sup>5</sup>, B.A. Schichtel<sup>4</sup>, J.L. Collett Jr.<sup>2</sup>, and S.M. Kreidenweis<sup>2</sup>

Grand Teton National Park (GTNP) contains sensitive high elevation ecosystems that are sensitive to additional increments of nitrogen beyond natural background levels. The park is located in proximity to large agricultural and concentrated animal feeding operations (CAFO), both sources of reactive nitrogen emissions (N<sub>r</sub>) and it is also impacted by wildfire emissions which are known sources of N<sub>r</sub>. The nitrogen compounds include both oxidized and reduced nitrogen. The Grand Teton Reactive Nitrogen Deposition Study (GrandTReNDS) was conducted in spring-summer 2011, with the objectives of better understanding sources of reactive nitrogen impacting GTNP as well as identifying the concentration levels of various species that impact the park. As part of the measurement program a sampling strategy was designed to estimate gas phase reduced organic nitrogen compounds, species which have not been routinely measured in long-term monitoring networks or during special studies. Of specific interest is reduced organic nitrogen species other than ammonia, referred to here as RNH<sub>x</sub>. Surprisingly, smoke aerosol contains significant amounts of RNH<sub>x</sub> as well as ammonia. Nearly all the RNH<sub>x</sub> was associated with fire emissions and about 16% of the measured ammonia was fire related. Therefore, combining fire related ammonia and RNH<sub>x</sub> concentrations, it is estimated that fire emissions made up about 44% of total reduced measured nitrogen concentrations. Ammonia concentrations, other than fire, made up about 84% of measured concentrations.

<sup>1</sup>Cooperative Institute for Research in the Atmosphere, Fort Collins, CO

<sup>2</sup>Department of Atmospheric Science, Colorado State University, Campus Delivery 1371, Fort Collins, CO

<sup>3</sup>Now at U.C., Davis

<sup>4</sup>National Park Service, Cooperative Institute for Research in the Atmosphere, Fort Collins, CO

<sup>5</sup>AECOM, Fort Collins, CO



## Organic Nitrogen in the Snowpack throughout the United States Rocky Mountains

Schichtel, B.A.<sup>1</sup>, K.B. Benedict<sup>2</sup>, G. P. Ingersoll<sup>3</sup>, Y. Desyaterik<sup>4</sup>, K. Morris<sup>4</sup>, and J.L. Collett Jr.<sup>5</sup>

Excess reactive nitrogen (Nr) deposition is occurring in sensitive ecosystems in the Rocky Mountains. In some high alpine lakes in Rocky Mountain national park and the Greater Yellowstone Area, this deposition has passed critical thresholds and is causing biogeochemical changes. Nr deposition is monitored by the National Atmospheric Deposition Program National Trends Network (NADP/NTN) and Clean Air Status and Trends (CASTNET) network that measure inorganic nitrate and ammonium. The NADP Ammonia Monitoring Network (NADP/AMoN) began measuring ammonia gas in 2010 at over 50 sites across the U.S. Missing Nr components from these networks include organic nitrogen (ON). Special monitoring studies at Rocky Mountain and Grand Teton national parks found significant contributions of wet ON deposition and high ambient concentrations of ON gas that could contribute to Nr deposition. However the spatial extent of the contribution of ON to Nr deposition is not known. Every year the U.S. Geological Survey collects snowpack samples at over 50 sites throughout the United States Rocky Mountains. Similar to the NADP, these samples are analyzed for the inorganic ionic composition, including oxidized and reduced nitrogen compounds. A benefit of the snowpack samples is that they contain contributions from both dry and wet deposition, but the multi-month long sample collection period provides opportunities for chemical and biological processing of the deposited Nr. To better understand the contribution of ON to the Nr deposition, the 2012 and 2013 snowpack samples were also analyzed for total nitrogen from which ON was estimated. It was found that 10-60% of the Nr in the 2012 samples was ON. ON was poorly correlated with inorganic oxidized and reduced N indicating different sources responsible for the ON or possibly different atmospheric/snowpack rates of processing.

<sup>1</sup>National Park Service, Cooperative Institute for Research in the Atmosphere, Fort Collins, CO; 970-491-8581; bret.schichtel@colostate.edu

<sup>2</sup>Department of Land, Air & Water Resource, University of California, Davis, CA

<sup>3</sup> U.S. Geological Survey, Rocky Mountain Region, Colorado Water Science Center, Denver, CO

<sup>4</sup>National Park Service, Air Resources Division, Lakewood, CO

<sup>5</sup>Atmospheric Science Department, Colorado State University, Fort Collins, CO 80523

## Adapting and applying the integrated biogeochemical model ForSAFE-Veg at a subalpine site – processes and prospects

S. Belyazid, T.C. McDonnell, T.J. Sullivan, W. Bowman, H. Sverdrup, E. Porter

The ForSAFE-Veg model was originally developed to simulate the integrated response of forest ecosystems to simultaneous changes in atmospheric deposition, climate change and land use. Within the framework of the United Nations' Convention on Long-Range Transboundary Air Pollution, the model was used to develop a method for estimating dynamically calculated critical loads of nitrogen deposition with the change in ground vegetation communities as an end point. This method was adapted to model plant biodiversity at a subalpine site of Loch Vale in the US Rocky Mountains.

To be able to simulate the ecosystem type at Loch Vale, the model was adapted in a number of ways that allowed us to explore the possibility of expanding its applicability from forest stands to a tree line site. We allowed for the calibration of a limited number of model parameters and initial values, as well as the modification of the key processes of nutrient uptake and decomposition.

Despite the current model limitations, the simulated outputs for soil and soil solution chemistry together with the composition of the ground vegetation community compared satisfactorily with measured data at Loch Vale. The model showed that the expected effects of climate change alone will surpass those expected from N deposition, and that that combination of both may lead to the decline or loss of key plant species.

The model application at Loch Vale confirms the potential to expand the model outside of forest ecosystems, while stressing the necessity and advantages of calibrating the model, particularly the vegetation response niches required for the vegetation community module Veg. The current study made use of the model in its current version, implying a range of limitations stemming from the fact that it is primarily developed for forest ecosystems. Yet, the potential for expanding into ecosystems where trees are not dominant or even absent is shown to be substantial. The model needs to be further developed to fully integrate the ground vegetation in the biogeochemical cycle.

Dr. Salim Belyazid

Director

Belyazid Consulting & Communication AB

Österportsgatan 5C

211 28 Malmö, Sweden

Assistant professor

Centre for Environment and Climate Research, Lund university

Sölvegatan 37

223 62 Lund, Sweden Tel: 0046-761657639

email: [salim@belyazid.com](mailto:salim@belyazid.com)

## Impact of Nitrogenous Air Pollutants on Vegetation Communities Across the Snake River Plains

Michael D. Bell<sup>1</sup>, Edith B. Allen<sup>1,2</sup>, Andrzej Bytnerowicz<sup>3</sup>, Mark E. Fenn<sup>3</sup>

Anthropogenic nitrogen (N) emissions have been increasing in the Snake River Plains of southern Idaho due largely to agricultural sources, especially confined animal feeding operations (CAFO) and fertilizer use and production. This sagebrush steppe community is being invaded by *Bromus tectorum* and other exotic plants which can increase the size and frequency of wildfires. This experiment measured atmospheric concentrations and bulk deposition of reactive N species at 10 sites within Craters of the Moon National Monument and Reserve (CRMO), Hagerman Fossil Beds National Monument (HAFO), Minidoka National Historic Site, and City of Rocks National Reserve (CIRO). Vegetation transects across the study area were used to determine if there is a correlation between increased nitrogen deposition and the structure of the vegetation community.

The dominant form of atmospheric N in passively collected samples was NH<sub>3</sub> (1.33 – 15.3 µg m<sup>-3</sup>), with the highest values recorded in summer near urban areas with adjacent CAFOs. Peak HNO<sub>3</sub> values (0.83 – 1.32 µg m<sup>-3</sup>) were also measured in summer with the highest values measured in the city of Pocatello near a fertilizer plant. NO<sub>x</sub> concentrations peaked in winter (5.04 – 10.8 ppb) with the highest concentrations near agricultural zones. At low deposition sites, the bulk deposition of NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup> were similar, but at high total N deposition sites, NH<sub>4</sub><sup>+</sup> was the dominant form of N. To correct for contamination from birds in bulk deposition samplers at some sites, atmospheric concentrations were regressed with uncontaminated bulk deposition sites to calculate N deposition rates. On average, measured deposition values exceeded CMAQ-modeled values by 75%, leading to calculated values over 11 kg ha<sup>-1</sup> yr<sup>-1</sup> at HAFO, the site with highest N deposition. Based on measured and calculated N deposition values of 3 to 11 kg N ha<sup>-1</sup> yr<sup>-1</sup> from CIRO, CRMO, and HAFO, there was an increase in exotic grass cover from 4% in low deposition areas to 62% under high deposition. At these same sites there was a concomitant decrease in native shrub and bunch grass cover as N deposition increased.

An increase in cover of invasive plants decreases the quality of the rangeland for grazing, wildlife, and biodiversity conservation, while increasing the likelihood of large fire events. Additional vegetation surveys and N deposition measurements are needed to establish a critical load for N impacts of invasion of the Snake River Plains, with consideration for variable grazing histories and precipitation regimes.

<sup>1</sup>Center for Conservation Biology, <sup>2</sup>Department of Botany and Plant Sciences, University of California, Riverside, California 92521 and <sup>3</sup>U.S.D.A. Forest Service, Pacific Southwest Research Station, Riverside, California, 92507.

Contact information: michael.bell@email.ucr.edu / Tel: 909-815-3388

## Atmospheric N in the Alberta Oil Sands, Canada

Sagar Krupa and Kevin Percy

The Alberta Oil Sands contain the third largest oil reserve in the world and contribute daily production to North American energy needs. Of the three oil sands deposits, the Athabasca Oil Sands Region (AOSR) is the largest. Production there is currently 1.8 M bpd and is expected to reach 3.5 M bpd by 2020. Bitumen (oil that is too solid to flow) is extracted by open pit mining (20% of the reserve) or by drilling (80% of the reserve). Upgrading of the bitumen occurs on site or downstream. In addition to the stationary point source air emissions, of concern are the fugitive dust from mining, overburden deposits, tailing pond dykes, 400 ton mine heavy haulers, and forest fires. Total anthropogenic N emissions (total 310 T/d) in the AOSR were: (a) industrial stacks 211T, (b) mine fleets 75T; and (c) non-industrial sources 24T. Spatial patterns of N were characterized as feasible in this remote region by integrating: (a) continuous air monitoring; (b) passive air sampling; (c) through the accumulation of total N and stable Pb isotope tracers (206, 207 and 208 ratios) in an epiphytic lichen bio-indicator; and (d) regional dispersion modeling.

Atmospheric concentrations of N (NO<sub>x</sub>, NH<sub>3</sub>) and N in particulate matter (PM) are being measured at 18 sites. The highest hourly NO<sub>2</sub> values ranged from 52.1 ppb at a community station, and 141 ppb at an industry site. The 99th percentile values ranged from 11.4 ppb to 42 ppb. Annual average NH<sub>3</sub> concentrations were 0.07 ppb and 0.01 ppb. Maximum one-hour NH<sub>3</sub> concentrations in 2012 were 64 ppb and 34 ppb. Both these values were above the 99th percentile. In the limited, partial summer time precipitation samples, NO<sub>3</sub> concentrations ranged from 0.5 to 9 ppm, and NH<sub>4</sub> from 0.1 to 2 ppm. Due to logistics (access to distant sites only by an helicopter), the continuous monitoring sites were located close to the source cluster, and likely did not allow measurements of effective atmospheric plume scavenging. Total N in the bio-indicator lichen showed 1.2% by tissue dry weight within the first 10-15 km from the sources and declined rapidly to 0.7%, reaching plateau-linearity all the way to >100 km. Several crustal elements and the stable Pb isotopes showed the same pattern (coarse particle deposition). At distant sites where trace elements, such as Zn appeared to be more important, possible fine particle deposition was detected.

Spatial patterns of total N deposition modeled with CALPUFF indicated the primary influence of NO<sub>x</sub> sources were within a nominal 20 km radius where the deposition was greater than 4 kg N/ha/yr (20kg N/ha/yr maximum). The influence of the sources decreased from 4 kg/ha/yr at 20 km, to about 2 kg N/ha/yr at 50 km. At 100 km, the deposition converged to the background value of about 1.8 kg N/ha/yr. In order to understand these overall results, application of receptor models *PMF and Unmix* showed that (a) combustion contributed 19 to 23%, (b) fugitive tailing sand 19 to 25%, (c) oil sand processing 11 to 15%, (d) mobile sources and lime stone 15 to 17% and (e) others (general anthropogenic, e.g., urban) 28% to the total elemental concentrations in the lichen.

Sagar Krupa, University of Minnesota, St. Paul, MN, USA (krupa001@umn.edu) and Kevin Percy, Wood Buffalo Environmental Association (WBEA), Fort McMurray, Alberta, Canada (kpercy@wbea.org).

**TECHNICAL SESSION 3:  
CRITICAL LOADS**

*Session Chair: Jason Lynch,  
U.S. EPA*

## Critical Loads of Atmospheric N Deposition for the Protection of Plant Biodiversity in the Western United States in the Context of Oil and Gas Development and a Changing Climate

T.J. Sullivan<sup>1</sup>, T.C. McDonnell<sup>1</sup>, S. Belyazid<sup>2</sup>, H. Sverdrup<sup>3</sup>, W. Bowman<sup>4</sup>, E. Porter<sup>5</sup>

We integrate results from empirical critical load (CL) estimates for protecting vegetation diversity, vegetation maps, and estimates of nitrogen oxide (NO<sub>x</sub>) emissions and deposition to evaluate the likelihood that reactive N CLs are exceeded in National Park Service Class I areas and to assess the relative importance of oil and gas (O&G) emissions to NO<sub>x</sub> emissions in counties near parks. Our focus is on selected national park units in the southwestern United States and the Northern Great Plains networks.

Based on lower limits of reported CL ranges, terrestrial resources in most study parks were either in exceedance of the CL or received ambient (year 2008) total wet plus dry N deposition within 1 or 2 kg N/ha/yr of the CL. Thus, nutrient sensitive terrestrial resources in some of these parks may be experiencing adverse impacts associated with CL exceedance.

Of the parks evaluated, estimated CL exceedances were most pronounced in Mesa Verde, Black Canyon of the Gunnison, and Saguaro national parks. Large portions of Grand Canyon, Arches, Badlands, Theodore Roosevelt, and Wind Cave national parks and Colorado and Dinosaur national monuments received N deposition in 2008 that was within 1 kg N/ha/yr of the CL.

Although O&G development appears to be a quantitatively important component of the oxidized N emissions in many areas, the data summarized here do not fully capture the extent of the O&G contribution to oxidized N emissions in these areas. This is because other sources are important in some areas and additional O&G development has occurred since 2008. It will be important to continue to track O&G NO<sub>x</sub> emissions. In addition, analyses are needed to evaluate the relative contributions of both oxidized and reduced N emissions to deposition and CL exceedances in these, and perhaps other, national park units.

Potential effects of CL exceedance and climate change were evaluated for one highly sensitive vegetation community in the subalpine zone of Rocky Mountain National Park. The ForSAFE-Veg model was used for evaluating past and future terrestrial plant biodiversity at a subalpine site. Model results were generated from a matrix of climate and N deposition scenarios. Changes in climate and N deposition since 1900 resulted in pronounced changes in plant species cover. Simulated tree sapling coverage increased by more than 25%, graminoid response was mixed, and forbs generally decreased in abundance in the simulations. Results suggested that the ground vegetation at the study site has already undergone a change relative to estimated background N deposition. Future increases in temperature are forecasted to have further impact on plant community composition, exacerbating expected changes in response to N deposition alone.

<sup>1</sup> E&S Environmental Chemistry, Inc., P.O. Box 609, Corvallis, OR 97339; 541 758-5777; [tim.sullivan@esenvironmental.com](mailto:tim.sullivan@esenvironmental.com)

<sup>1</sup> Belyazid Consulting & Communication AB, Stationsvägen 13, 517 34 Bollebygd, Sweden; [salim@belyazid.com](mailto:salim@belyazid.com)

<sup>1</sup> Biogeochemistry and Systems Analysis, Chemical Engineering, Lund University, SE-221 00 Lund, Sweden; [Harald.Sverdrup@chemeng.lth.se](mailto:Harald.Sverdrup@chemeng.lth.se)

<sup>1</sup> Ecology and Evolutionary Biology, University of Colorado, Boulder, CO; Bill Bowman, [William.Bowman@Colorado.edu](mailto:William.Bowman@Colorado.edu); 303 492-2557

<sup>1</sup> National Park Service, Air Resources Division, PO Box 25287, Denver, Colorado 80225-0287; 303 969 2617; [ellen\\_porter@nps.gov](mailto:ellen_porter@nps.gov)

## Strategic plan to establish and implement nitrogen critical loads and target loads for national forests and national parks in the Pacific Northwest, USA

Tonnie Cummings, Tamara Blett, Linda Geiser, Rick Graw, Jill McMurray, Steve Perakis, Ellen Porter and Regina Rochefort

The Clean Air Act and agency policies provide the basis for the National Park Service and the U.S. Forest Service to work with regulatory agencies and others to protect the air quality and air pollution-sensitive resources of national parks and national forests. A workgroup comprised of National Park Service, U.S. Forest Service and U.S. Geological Survey scientists has developed a five-year strategic plan to establish and implement nitrogen critical loads and target loads for areas managed by the National Park Service and the U.S. Forest Service in the states of Idaho, Oregon and Washington. The plan includes publication of a “state of knowledge” report that describes known and potential ecological effects of nitrogen in the Pacific Northwest and prioritizes data needs, development of nitrogen critical and target loads specific to Pacific Northwest ecosystems, preparation of GIS maps showing areas that exceed the nitrogen critical and target loads, and implementation of critical and target loads through National Park Service and U.S. Forest Service planning and policy mechanisms. Ultimately, the National Park Service and the U.S. Forest Service intend to collaborate with local, state and federal regulatory agencies to obtain emission reductions from sources that contribute to critical and target load exceedances in national parks and national forests.

### Author affiliations and contact information:

Tonnie Cummings, National Park Service, 601 E. Reserve St., Vancouver, WA 98661, 360-816-6201, [tonnie\\_cummings@nps.gov](mailto:tonnie_cummings@nps.gov)

Tamara Blett, National Park Service, P.O. Box 25287, Denver, CO 80225, 303-969-2011, [tamara\\_blett@nps.gov](mailto:tamara_blett@nps.gov)

Linda Geiser, U.S. Forest Service, P.O. Box 1148, Corvallis, OR 97339, 541-231-9452, [lgeiser@fs.fed.us](mailto:lgeiser@fs.fed.us)

Rick Graw, U.S. Forest Service, P.O. Box 3623, Portland, OR 97208, 503-808-2918, [rgraw@fs.fed.us](mailto:rgraw@fs.fed.us)

Jill McMurray, U.S. Forest Service, P.O. Box 130, Bozeman, MT 59711, 406-587-6892, [jammurray@fs.fed.us](mailto:jammurray@fs.fed.us)

Steve Perakis, U.S. Geological Survey, 3200 SW Jefferson Way, Corvallis, OR 97331, 541-750-0991, [sperakis@usgs.gov](mailto:sperakis@usgs.gov)

Ellen Porter, National Park Service, P.O. Box 25287, Denver, CO 80225, 303-969-2617, [ellen\\_porter@nps.gov](mailto:ellen_porter@nps.gov)

Regina Rochefort, National Park Service, 810 State Route 20, Sedro-Woolley, WA 98284, 360-854-7202, [regina\\_rochefort@nps.gov](mailto:regina_rochefort@nps.gov)

## Monitoring Critical Levels of Ozone in Remote Rocky Mountain Ecosystems and Exceedances of the National Ambient Air Quality Standard

Robert C. Musselman and John L. Korfmacher

Research has shown that ozone (O<sub>3</sub>) parameters that closely relate to vegetation response are cumulative throughout the growing season, preferentially weight the higher concentrations, and include time periods when stomata are open to allow uptake into plant tissue. Critical levels of O<sub>3</sub> used in the European Union to determine vegetation response have utilized these parameters by using an exposure-based metric and more recently incorporating flux-based metrics that requires data on stomatal conductance of individual plant species. The U.S. National Ambient Air Quality Standard (NAAQS) for O<sub>3</sub> has always used concentration based metrics derived from hourly O<sub>3</sub> data, and not the vegetation related exposure metrics. The Clean Air Act does not allow the NAAQS to utilize flux-based vegetation parameters in their exceedance metric, and although exposure based metrics are allowed they have not been used. The U.S. EPA has recently suggested strengthening the concentration based primary O<sub>3</sub> NAAQS metric to 70 ppb for the 4<sup>th</sup> highest 8-hr average, and for the first time adding a separate exposure based metric secondary O<sub>3</sub> standard using the 3-month W126 of 13 ppm-hrs. The proposed new secondary standard is designed to protect forest trees in rural ecosystems. Monitoring O<sub>3</sub> in remote high elevation rural mountain ecosystems is problematic since these areas are often inaccessible in winter and electric power is unavailable. We have developed a portable O<sub>3</sub> monitoring system to collect O<sub>3</sub> data in these remote regions. Data collected in remote high elevation areas of the Southern Rocky Mountain have shown that many of these sites have O<sub>3</sub> concentrations that exceed both the strengthened primary and the proposed new secondary NAAQS. Exceedance levels were caused by mixing ratios that favor persistence of O<sub>3</sub>, particularly at night; high number of mid-level O<sub>3</sub> concentrations; stratospheric intrusion of O<sub>3</sub>; and precursors from energy development.

Robert C. Musselman (970-498-1239, [rmusselman@fs.fed.us](mailto:rmusselman@fs.fed.us) or [bobm@colostate.edu](mailto:bobm@colostate.edu))  
and John L. Korfmacher (970-498-1052, [jkorfmacher@fs.fed.us](mailto:jkorfmacher@fs.fed.us))

US Forest Service, Rocky Mountain Research Station, 240 West Prospect Road, Fort Collins, CO 80526

## A Hybrid Approach for Estimating Total Nitrogen And Sulfur Deposition In The United States

G G Lear and D B Schwede

Atmospheric deposition of sulfur and nitrogen can lead to the decline of ecosystems through acidification and excess eutrophication which lead to effects such as decreases in forest growth, loss of species diversity, shifts in the geographical distribution of species, and increases in harmful algal blooms. In the U.S., strategies for improving ecosystem health often require estimation of the total atmospheric deposition as well as components of the total deposition as input to the analyses. Obtaining estimates of total deposition of sulfur and nitrogen is a challenge in the U.S. due to the difficulty in measuring dry deposition. While modeling of dry deposition is done at sites in the Clean Air Status and Trends Network (CASTNET), these values cannot be spatially interpolated due to the complexity of the deposition fields. Additionally, several important species such as NO<sub>2</sub>, N<sub>2</sub>O<sub>5</sub>, HONO, PANs and alkyl nitrates, which contribute to the nitrogen budget, are not routinely measured at network sites. In response to this need, we developed a methodology for developing spatially continuous estimates of total deposition for the US using an approach that uses information from existing monitoring networks and the Community Multiscale Air Quality (CMAQ) model. The methodology gives precedence to measurements and supplements with modeled data as needed to provide a complete budget. We provide a description of the data sets and methodology used to develop estimates of total deposition as well as a discussion of the outputs derived from this technique. Results are available for download at <http://ftp.epa.gov/castnet/tdep>

G G Lear (U.S. Environmental Protection Agency, Office of Atmospheric Programs)

D B Schwede (U.S. Environmental Protection Agency, Office of Research and Development)

## Sources and sinks of reactive nitrogen in the Canadian landscape

Thomas Clair<sup>1</sup>, Nathan Pelletier<sup>2</sup>, Shabtai Bittman<sup>3</sup>, Ian Dennis<sup>4</sup>, David Niemi<sup>4</sup>, Michael Moran<sup>4</sup>, Robert Vet<sup>4</sup>, Adrian Leip<sup>2</sup>, Paul Arp<sup>5</sup>, Shannon Sterling<sup>6</sup>

Canada is a large country with a small population density. Much of its population, agriculture and industry is concentrated near its southern border with the United States, with which there is a significant exchange of atmospheric N. The country is a large exporter of fertilizer, food, hydrocarbons and wood. Using a combination of measured and modeled values, we produced a reactive N budget for Canada, which estimated not only trans-boundary exchanges, but also within-country fluxes. We stratified the Canadian landscape into natural forest, agricultural, urban/industrial, water and atmosphere and estimated fluxes into and out of each of these units. Our results show that natural forest N fluxes in Canada are in balance, that agricultural systems are gaining N in soils, and that there are flows in urban/industrial sectors which we need to identify in order to better understand the fate of reactive N in the country.

<sup>1</sup> Wood Buffalo Environmental Association, Fort McMurray, AB, Canada, [tclair@wbea.org](mailto:tclair@wbea.org), ph 708 972 9516, <sup>2</sup> European Union, Joint Research Centre, <sup>3</sup> Agriculture and Agrifood Canada, <sup>4</sup> Environment Canada, <sup>5</sup> University of New Brunswick, <sup>6</sup> Dalhousie University

**TECHNICAL SESSION 4:  
ATMOSPHERIC MODELING**

*Session Chair: Bret Schichtel,  
National Park Service*

## Simulating Total Nitrogen Deposition at Western National Parks with the WestJumpAQMS Modeling Platform

Mike Barna<sup>1</sup>, Tom Moore<sup>2</sup>, Tammy Thompson<sup>3</sup>, Kristi Gebhart<sup>1</sup> and Bret Schichtel<sup>1</sup>

The western U.S. contains many national parks that are sensitive to elevated nitrogen deposition, with several parks already estimated to be above critical load thresholds for certain nitrogen-sensitive plant communities at  $3 \text{ kg N ha}^{-1} \text{ yr}^{-1}$  (e.g., Black Canyon of the Gunnison National Park, Mesa Verde National Park), and many others within  $1 \text{ kg N ha}^{-1} \text{ yr}^{-1}$  of this value (e.g., Dinosaur National Monument). To investigate the broad spectrum of nitrogen-containing compounds that contribute to the nitrogen deposition budget at western U.S. national parks, the chemical transport model CAMx (Comprehensive Air Quality with Extensions) was applied. Inputs for CAMx were provided by the West-wide Jump-start Air Quality Modeling Study (WestJumpAQMS). A key component of WestJumpAQMS is the refinement of many of the sources that contribute to nitrogen emissions, including revised estimates for ammonia from livestock operations and fertilizer application, as well as updates to nitrogen oxides from oil and gas development, mobile sources, and large point sources such as coal-fired power plants. Fire emissions were updated to better capture their significant and episodic role as a source of both oxidized and reduced nitrogen. Biogenic emissions were also refined, with new estimates for volatile compounds such as isoprene that can form organic nitrates, as well as revisions to soil nitrogen oxide. This study presents simulated wet and dry nitrogen deposition at a 12 km horizontal resolution for selected national parks in the western U.S. for 2008. All nitrogen-containing compounds within CAMx's chemical mechanism are evaluated, including the reduced nitrogen species of ammonia ( $\text{NH}_3$ ) and particulate ammonium ( $\text{NH}_4^+$ ), and the oxidized species of nitric acid ( $\text{HNO}_3$ ), particulate nitrate ( $\text{NO}_3^-$ ), peroxyacetyl nitrate (PAN), nitrogen oxides ( $\text{NO}_x$ ), organic nitrates, and 'nighttime' species such as dinitrogen pentoxide ( $\text{N}_2\text{O}_5$ ) and nitrate radical ( $\text{NO}_3$ ). Predicted deposition values are compared to wet and dry deposition measurements at available NADP (National Atmospheric Deposition Program) and CASTNet (Clean Air Speciation and Trends Network) sites. Dry deposition velocities predicted by the older Wesely and newer Zhang models are also compared.

<sup>1</sup>National Park Service – Fort Collins, CO

<sup>2</sup>Western Regional Air Partnership – Fort Collins, CO

<sup>3</sup>Colorado State University – Fort Collins, CO

Contact info for Mike Barna:  
970-491-8692  
mike\_barna@nps.gov

## Evaluation of CMAQ air-surface exchange and WRF energy balance algorithms against flux measurements

Jesse Bash, John Walker, Ian Rumsey, Donna Schwede

The atmosphere-biosphere exchange of trace gases in chemical transport models is a critical process that influences atmospheric chemistry, particulate matter formation and deposition of pollutants and nutrients to ecosystems. Typically these processes are evaluated for a single species at a time using data from short term flux measurement campaigns due to the lack of routine network observations. Recent advances in instrumentation allow for the flux measurement of multiple trace gases. A box model of Community Multiscale Air Quality (CMAQ) chemical transport model dry deposition and bidirectional exchange and the Weather Research Forecast (WRF) meteorological model energy balance algorithms has been developed for field scale model algorithm evaluation and development. This model can simultaneously estimate multiple pollutant air-surface exchange and latent, sensible, and soil heat fluxes. All modeled fluxes use a common resistance framework to constrain the modeled processes. This model was applied to flux measurements of  $\text{HNO}_3$ ,  $\text{SO}_2$ ,  $\text{NH}_3$ , and latent, sensible and soil heat taken at a grassland site at Duke Forest, NC. An evaluation of model deposition and energy balance algorithms and potential improvements to vegetative resistance parameters will be presented.

Contact:  
Jesse Bash  
U.S. EPA  
Tel: 919-541-0862  
Email: bash.jesse@epa.gov  
NERL Atmospheric Modeling and Analysis Division  
MD: E243-02  
Research Triangle Park, NC 27711



## The influence on CMAQ modeled wet and dry deposition of advances in the CMAQ systems for meteorology and emissions

Robin Dennis, Jesse Bash, Kristen Foley, Rob Gilliam, Rob Pinder

Process level improvements in the CMAQ system have been made to WRF, national emissions, and CMAQ. These include a different convective precipitation option in WRF, the addition of lightning NO production, a mechanistically based diurnal emissions profile for animal NH<sub>3</sub> emissions, and inclusion of bidirectional NH<sub>3</sub> exchange in CMAQ. These process changes are briefly introduced. Then an incremental study that was conducted to quantify the impact of these changes on modeled total nitrogen deposition and ambient aerosol concentrations is described. Evaluation results are presented to quantify the resulting changes on model fields by evaluating model versions against aerosol and wet deposition observations. Preliminary results are that: 1) using the WRF Kain-Fritsch sub-grid convection parameterization with a new convective trigger reduces the bias (over prediction) in the summertime convective precipitation, reducing the summertime wet deposition bias; 2) the inclusion of NO produced from lightning reduces the summertime and annual bias (under prediction) in wet nitrate deposition; 3) the new meteorologically driven diurnal profile of confined animal NH<sub>3</sub> emissions reduces the PM<sub>2.5</sub> bias and error in the fall (over prediction); and 4) the inclusion of bidirectional NH<sub>3</sub> exchange reduces the spring and fall PM<sub>2.5</sub> bias (over prediction) and the annual ammonium wet deposition bias (under prediction).

U.S. Environmental Protection Agency, National Exposure Research Laboratory,  
Atmospheric Modeling and Analysis Division

Contact:  
Robin Dennis  
U.S. EPA  
Tel: 919-541-2870  
Email: dennis.rob@epa.gov  
NERL Atmospheric Modeling and Analysis Division  
MD: E243-02  
Research Triangle Park, NC 27711

## Comparison of organic nitrogen from CMAQ with measured values using a revised CB05 chemical mechanism

Donna B. Schwede, Deborah J. Luecken, John T. Walker, George A. Pouliot

Organic nitrogen is an important contributor to the total atmospheric nitrogen deposition. However, our understanding of the sources and composition of organic nitrogen is limited. In this study, we examine potential sources of uncertainty and error in the calculations of organic nitrate in air quality models. Treatment of organic nitrogen in regional air quality models is very limited due to gaps in the emissions inventory and the chemical mechanisms. Traditionally, chemical mechanisms developed for regional air quality models have focused on ozone chemistry and therefore organic nitrogen compounds such as urea are often speciated as VOCs rather than explicit nitrogen species. Additionally, organic nitrate compounds are lumped together to improve model runtime even though chemical properties may be quite variable. The chemical mechanism (CB05TUCL) was revised to include better consideration of the multifunctional character of organic nitrates, including increases in aqueous solubility and gas-phase reaction rates. These revisions also included recycling of organic nitrate and NO<sub>x</sub> in the gas-phase reactions of organic nitrates. The assumptions made in these derivations are tested out in a series of sensitivity studies in which CMAQ predictions are compared to measurements of total organic nitrogen concentrations in precipitation at a site in Bondville, IL. The results of these studies provide insights on how to best represent a complex ensemble of chemical species in an air quality model and motivate further model and emissions inventory development.

Contact:  
Donna Schwede  
U.S. EPA  
Tel: 919-541-3255  
Email: Schwede.donna@epa.gov  
NERL Atmospheric Modeling and Analysis Division  
MD: E243-04  
Research Triangle Park, NC 27711

## Evaluation of bi-directional ammonia exchange in GEOS-chem using in-situ observations

Authors: Liye (Juliet) Zhu<sup>1</sup>, Daven Henze<sup>1</sup>, Jesse Bash<sup>2</sup>, Karen Cady-Pereira<sup>3</sup>, Mark Shephard<sup>4,5</sup>, Gill-Ran Jeong<sup>6</sup>, Robert Pinder<sup>2</sup>, Mingzhao Luo<sup>7</sup>

Ammonia is an important species in atmosphere which contributes to air pollution, climate change and environmental health. Ammonia emissions are known to be primarily from agricultural sources, however there is persistent uncertainty in the magnitudes and seasonal trends of these sources. In most current air quality models, the inventories are based on the assumption of unidirectional ammonia emissions from the soil and vegetation canopies. However, the ammonia air-surface exchange is known as bi-directional. Therefore, we investigate the impact of implementing the ammonia bi-directional exchange to the GEOS-Chem chemical transport model. We also update the diurnal variability of the ammonia livestock emissions in the GEOS-Chem emission inventories. The coupled bi-directional exchange model with new diurnal variation of ammonia emissions is evaluated by comparing the modeled surface ammonia, aerosol ammonium and nitrate, and reduced nitrogen wet deposition to the independent surface measurements AMoN, NTN, and IMPROVE.

<sup>1</sup> Department of Mechanical Engineering, University of Colorado at Boulder, Boulder, CO.

<sup>2</sup> US EPA, Research Triangle Park, NC.

<sup>3</sup> Atmospheric and Environmental Research Inc. Lexington, MA.

<sup>4</sup> Atmospheric and Climate Application, Inc., East Gwillimbury, Ontario, CANADA.

<sup>5</sup> Environment Canada, Toronto, Ontario, CANADA

<sup>6</sup> Korea Institute of Atmospheric Prediction Systems (KIAPS), Seoul, Republic of Korea.

<sup>7</sup> Jet Propulsion Laboratory, Los Angeles, CA.

E-mail: [Liye.Zhu@Colorado.edu](mailto:Liye.Zhu@Colorado.edu)

Mail:  
CU Mechanical Engineering Dept  
1111 Engineering Drive ECME 114  
Boulder, CO 80309

Phone: 303-492-7077

**TECHNICAL SESSION 5:  
MERCURY AND TRACE METALS**

*Session Chair: David Schmeltz,  
U.S. EPA*

## Measurements of Mercury and Ancillary Species at NOAA's Mauna Loa Observatory

Winston T. Luke, Paul Kelley, Xinrong Ren, Mark Cohen (NOAA Air Resources Laboratory, College Park, MD); Aidan Colton, Nash Kobayashi, Darryl Kuniyuki, David Nardini (NOAA Earth Systems Research Laboratory, Hilo, HI)

In January 2011 NOAA's Air Resources Laboratory assumed oversight of speciated atmospheric mercury measurements at the Mauna Loa Observatory (MLO), and the site joined NADP's Atmospheric Mercury Network (AMNet). MLO is one of six NOAA baseline monitoring stations for the study of the background global atmosphere, and is located at an elevation of 3,397 m on the northern slope of the Mauna Loa volcano on the Big Island of Hawaii. A single Tekran speciation system measures gaseous elemental mercury (GEM), gaseous oxidized mercury (GOM), and particulate-bound mercury (PBM) with nominal 1-hr resolution. Since 2011, measurements of ozone (O<sub>3</sub>), sulfur dioxide (SO<sub>2</sub>), and carbon monoxide (CO) were added, and the collection of aerosols for <sup>7</sup>Be analysis was instituted.

The site is an ideal high-altitude location from which to monitor the global background atmosphere. Free atmospheric flow at the elevation of MLO is typically from the east and northeast (trade wind circulation), with local upslope (daytime: 0800-2000 HST) flow mainly from the east through northwest and downslope (nighttime: 2000-0800 HST) flow from the southeast through southwest superimposed on the larger-scale flows. Results of the mercury measurement program to date will be presented, and interpreted with respect to atmospheric circulation and dynamics, long range transport, and mesoscale flows. Relationships between and among mercury compounds and other trace gas and aerosol species, as well as physical meteorological parameters, will be examined to infer key aspects of the atmospheric mercury cycle in the lower and middle free troposphere. Finally, mercury measurement challenges at MLO will be presented and discussed.

## Hg isotopes in gaseous and particulate atmospheric mercury species above a coastal suburban environment (Pensacola, Florida, USA)

Arnout ter Schure<sup>b,\*</sup>, Vincent Perrot<sup>a</sup>, Virginia Eller<sup>a</sup>, Vincent J.M. Salters<sup>a</sup> and William M. Landing<sup>a,c</sup>

The fate of mercury in the atmosphere is controlled by multiple physical, (photo)chemical and meteorological processes. Assessing Hg cycling in the atmosphere via the use of its stable isotopes remains complicated due to the high reactivity of this element and the Hg isotope fractionation that has thus far been reported. In this study we measured the Hg isotopic composition of gaseous elemental Hg (Hg<sup>0</sup><sub>(g)</sub>, GEM), reactive gaseous Hg (Hg<sup>II</sup><sub>(g)</sub>, RGM) and particulate aerosol Hg (Hg<sup>II</sup><sub>(p)</sub>) in the atmosphere above a coastal area located near the city of Pensacola, Florida. Gold-coated quartz sand traps (1 LPM) were used to collect total gaseous Hg. Aerosol Hg was collected on pre-baked quartz fiber (Whatman QMA) filters deployed in a Tisch Environmental high-volume aerosol sampler (~1100 LPM). Reactive gaseous Hg was collected on a QMA filter that had been soaked in a KCl solution (then dried and pre-baked) that was deployed underneath the aerosol QMA filter. These sampling methods collected from 1 to 30 ng of the different atmospheric Hg species after 1 to 3 days of deployment during the summer 2012. Both mass-dependent (MDF) and mass-independent (MIF) signatures of GEM were significantly different than those of Hg(II) species. GEM, which represented more than 99% of the total Hg at this site, displayed positive  $\delta^{202}\text{Hg}$  values (0.7 to 1.2‰, average  $1.0 \pm 0.2\text{‰}$ , n=14) whereas both RGM and Hg(p) had negative  $\delta^{202}\text{Hg}$  values (-2.4 to -0.1‰,  $-0.7 \pm 0.4\text{‰}$ , n=34). On the other hand, GEM (n=14) had slightly negative  $\Delta^{199}\text{Hg}$  and  $\Delta^{200}\text{Hg}$  average values ( $-0.26 \pm 0.09\text{‰}$  and  $-0.07 \pm 0.03\text{‰}$ , respectively) whereas Hg(p) (n=17) exhibited slightly positive values ( $0.33 \pm 0.13\text{‰}$  and  $0.10 \pm 0.04\text{‰}$ , respectively). RGM displayed no significant MIF ( $\Delta^{199}\text{Hg} = 0.02 \pm 0.14\text{‰}$  and  $\Delta^{200}\text{Hg} = -0.02 \pm 0.10\text{‰}$ , respectively) of both even and odd isotopes. We suggest that both oxidation and reduction processes are responsible for the observed patterns in the isotopic composition of RGM and Hg(p). This suggests that preferential scavenging of RGM and Hg(p) (rather than GEM) in wet and dry deposition may result in significant variability in the isotopic fractionation of Hg that is deposited in coastal environments as a function of seasonal and sporadic changes in air mass trajectories and atmospheric physico-chemistry.

<sup>a</sup>High Magnetic Field Laboratory, Geochemistry department, Florida State University, 1800 East Paul Dirac Drive, Tallahassee, 32310, FL, USA

<sup>b</sup>Electric Power Research Institute, 3420 Hillview Avenue | Palo Alto, CA 94304

<sup>c</sup>Department of Earth, Ocean, and Atmospheric Science, Florida State University, Tallahassee, FL, 32306, USA

\* PRESENTING AUTHOR

## Dry Deposition of Atmospheric Mercury to the Great Salt Lake

Kevin D. Perry<sup>1</sup>, Joel R. Lisonbee<sup>2</sup>, Eric R. Pardyjak<sup>3</sup>

The Great Salt Lake (GSL) in the western United States has been identified as the most mercury-laden body of water in the United States with a median water mercury concentration of 42 ng L<sup>-1</sup>. When Hg enters an aquatic ecosystem it can be converted to methylmercury which bioaccumulates up the food chain. Methylmercury contamination has resulted in many consumption advisories for game fish in lakes and rivers throughout the Intermountain West. In 2005, the Utah Department of Health and the Fish and Wildlife Service placed a similar consumption advisory on waterfowl on the GSL. The primary goal of this study is to identify the pathway of greatest influx of Hg pollution to the GSL to give insight toward the source and an eventual solution to the Hg pollution problem.

Speciated atmospheric mercury measurements were collected at the UT96 field site on the eastern shore of the GSL from July 1, 2009 to June 30, 2012. The atmospheric mercury concentrations, along with high-frequency atmospheric turbulence measurements, were used as input to a resistance-in-series dry deposition model (based on *Wesley and Hicks 1977*). The dry deposition flux of mercury was determined from the modeled dry deposition velocity and the measured concentrations. This dry deposition flux was compared to the wet deposition flux measured by the National Deposition Network and the riverine influx measured by the USGS. Over this three-year study an average of 10.5 g m<sup>-2</sup> of Hg was deposited into the GSL by dry deposition from the atmosphere.

Dry deposition of mercury into the GSL is the most significant pathway of mercury into the GSL, accounting for 57.5% of all the Hg deposited in the lake. Wet deposition accounts for 33% and riverine influx accounts for only 9.5%. The measurements of mercury from wet deposition, riverine influx, and the output from this dry deposition resistance-in-series model collectively account for a flux of about 23.6 μg m<sup>-2</sup> yr<sup>-1</sup> of mercury. Multiplying by the average surface area of the lake during the measurement period would suggest about 108.5 kg of mercury is deposited into the GSL each year

<sup>1</sup>Department of Atmospheric Sciences, University of Utah,  
801-581-6138, [kevin.perry@utah.edu](mailto:kevin.perry@utah.edu)

<sup>2</sup>Darwin Climate Service Centre, Australian Bureau of Meteorology,  
61 (08) 8920-3813 [j.lisonbee@bom.gov.au](mailto:j.lisonbee@bom.gov.au)

<sup>3</sup>Department of Mechanical Engineering, University of Utah,  
801-585-6414, [pardyjak@eng.utah.edu](mailto:pardyjak@eng.utah.edu)

## Seasonal Variation of Atmospheric Deposition of Trace Metal in Urban Central New York

Nicholas B. Glick<sup>1</sup>, Charles T. Driscoll<sup>1</sup>, Mario Montesdeoca<sup>1</sup>, Aimee Clinkhammer<sup>2</sup>  
Dimitar Todorov<sup>3</sup>

Little is known about atmospheric deposition in urban settings. A study was conducted to examine the deposition of trace metal in urban Syracuse, NY at the Syracuse Center of Excellence. Concentrations of 10 trace metals (Al, Mn, Cu, Zn, As, Sr, Pb, Se, Cr, Cd) were analyzed in wet and bulk precipitation collected after every significant rainfall (greater than 2.54 mm) from 3/9/11 to 3/7/13. We evaluated seasonal patterns of trace metal deposition and calculated annual fluxes. Concentrations of several of the trace metals varied between the summer (April-September) and the winter (October-March). Lead, zinc, arsenic, strontium and manganese exhibited high concentrations in the winter, followed by low concentrations during the summer. Possible mechanisms for this pattern include fossil fuel combustion in the winter, as well as the salting of major highways which run near the sampling site. In contrast, copper and aluminum concentrations were high in the summer and very low in the winter. Possible mechanisms for this pattern include increased road dust, and construction activities. The Department of Environmental Conservation analyzes trace metals at Morrisania (South Bronx) and Rochester, NY. The seasonal patterns of nickel, arsenic, lead and manganese from these two DEC sites follow similar patterns to Syracuse, NY.

<sup>1</sup>Department of Civil and Environmental Engineering, Syracuse University, Syracuse,  
NY 13244  
[nbglick@syr.edu](mailto:nbglick@syr.edu), [ctdrisco@syr.edu](mailto:ctdrisco@syr.edu), [mmontesd@syr.edu](mailto:mmontesd@syr.edu)

<sup>2</sup>Syracuse Center of Excellence  
Syracuse, NY 13244  
[aclinkhammer@syracusecoe.org](mailto:aclinkhammer@syracusecoe.org)

<sup>3</sup>Utica College, Department of Construction Management  
Utica, NY 13502  
[ditorov@utica.edu](mailto:ditorov@utica.edu)

## A Great Lakes Atmospheric Mercury Monitoring Network

Martin R. Risch<sup>1</sup>, Donna M. Kenski<sup>2</sup>, and David A. Gay<sup>3</sup>

As many as 51 mercury (Hg) wet-deposition-monitoring sites from 4 networks operated in 8 USA states and Ontario, Canada in the Great Lakes Region from 1996-2010. By 2013, 39 percent of those sites were no longer in operation and approximately half the geographic area of the Region was represented by a single Hg-monitoring site. In response, a Great Lakes Atmospheric Mercury Monitoring (GLAMM) network has been proposed as a framework for regional collaboration in Hg-deposition monitoring. The purpose of the GLAMM network is to detect changes in regional atmospheric Hg deposition related to decreases in Hg emissions. An optimized design for the network was determined to be a minimum of 21 sites in a representative and approximately uniform geographic distribution. A majority of the active and historic Hg-monitoring sites in the Great Lakes Region are part of the National Atmospheric Deposition Program (NADP) Mercury Deposition Network (MDN) in North America and the GLAMM network is planned to be part of the MDN.

To determine an optimized network design, active and historic Hg-monitoring sites in the Great Lakes Region were rated based on 21 factors that included characteristics of the monitoring locations and available Hg data. Monitoring sites were rated according to the number of Hg emissions sources and annual Hg emissions in a geographic polygon centered on each site. Also, monitoring locations were evaluated for proximity to areas with high annual Hg emissions and areas with high average weekly Hg wet deposition. Site ratings considered locations in protected natural areas, urban areas, and Great Lakes watersheds. Hg-monitoring data for the sites were compared based on the magnitude of long-term averages for weekly Hg concentrations in precipitation and weekly Hg-wet deposition, and on significant temporal trends in Hg concentrations and Hg deposition. A cluster analysis method was used to group sites with similar variability in their Hg data in order to identify sites that were unique for explaining Hg data variability in the Region. In a statistical analysis, meaningful correlations in the wet deposition of Hg and sulfate were shown for co-located NADP Hg-monitoring and acid-rain monitoring sites in the Region. This finding indicated that efficiency in regional Hg monitoring can be improved by adding new Hg monitoring to existing NADP acid-rain monitoring sites.

Implementation of the GLAMM network design will require Hg-wet-deposition monitoring to be: (a) continued at 12 MDN sites active in 2013 and (b) restarted or added at 9 NADP sites where it is absent in 2013. Ongoing discussions between the USA states in the Great Lakes Region, the Lake Michigan Air Directors Consortium (a regional planning entity), the NADP, the U.S. Environmental Protection Agency, and the U.S. Geological Survey are aimed at funding and coordinating the GLAMM network.

## Air Mercury Speciation Accuracy and Calibration

Eric M. Prestbo, Tekran Research and Development

Development and use of methods to measure atmospheric mercury speciation date back to the early 1980s. A major advancement occurred in the late 1990s when an automated, continuous system to measure gaseous oxidized mercury (GOM), particulate-bound mercury (PBM) and gaseous elemental mercury (GEM) was made available to researchers. The air mercury speciation system (Tekran Models 2537, 1130, 1135) was initially challenged by the USEPA and over the years by many research groups in field and lab studies, both with good results. The application of the air mercury speciation system resulted in observations that continued to build assurance that the mercury speciation system was generating high quality results. Examples of these will be presented, such as observation of high GOM values in point-source emission plumes, higher PBM during winter months, increased GOM during polar GEM depletion events and highly elevated GOM concentrations in stable free tropospheric air. The air mercury speciation system detector (Tekran 2537) is routinely calibrated with a traceable GEM source to establish accuracy. Although there have been hundreds of high quality publications of atmospheric mercury speciation, one critical limitation has been the lack of traceable GOM and PBM standards at the picogram/m<sup>3</sup> (pg/m<sup>3</sup>) level. Recent studies have once again highlighted the need for field-deployable atmospheric mercury speciation standards to further improve estimates of accuracy. A brief review of attempts to develop standard GOM sources for air mercury speciation systems will be presented with an emphasis on the challenges of transport, stability and traceability. Lastly, a conceptual proposal for an automated GOM source for routine standard additions at the pg/m<sup>3</sup> level will be shown.

<sup>1</sup>Martin R. Risch, Research Hydrologist, U.S. Geological Survey, 5957 Lakeside Blvd. Indianapolis, IN 46278,

(317) 600-2763, [mrrisch@usgs.gov](mailto:mrrisch@usgs.gov)

<sup>2</sup>Donna M. Kenski, Ph.D., Data Analyst, Lake Michigan Air Directors Consortium, 9501 W. Devon Ave., Suite 701 Rosemont, IL 60018, (847) 720-7883, [kenski@ladco.org](mailto:kenski@ladco.org)

<sup>3</sup>David A. Gay, Ph.D., Coordinator, National Atmospheric Deposition Program, Illinois State Water Survey, Prairie Research Institute University of Illinois at Urbana-Champaign 2204 Griffith Dr.

Champaign, IL 61820-7495,  
(217) 244-0462, [dgay@illinois.edu](mailto:dgay@illinois.edu)

**TECHNICAL SESSION 6:**  
**NITROGEN EMISSIONS AND DEPOSITION**

*Session Chair: Donna Schwede,  
U.S. EPA*

## Ammonia Emissions State of the Science

Viney P. Aneja\* and William Battye\*\*

Biologically active, photochemically reactive, and radiatively active nitrogen compounds in the atmosphere, hydrosphere, and biosphere are collectively referred to as reactive nitrogen. Recent studies suggest that human activities accelerate the production of reactive nitrogen on a global scale. Increased nitrogen emissions may lead to environmental impacts including photochemical air pollution, reduced visibility, changes in biodiversity, and stratospheric ozone depletion. Ammonia (NH<sub>3</sub>) is the most reduced and abundant form of reactive nitrogen in the atmosphere. In the last 50 years, emissions of NH<sub>3</sub> have significantly increased as a result of intensive agricultural management and greater livestock production. Globally, domestic animals are the largest source [32x10<sup>12</sup> g NH<sub>3</sub>-N (ammonia-nitrogen) yr<sup>-1</sup>] of atmospheric NH<sub>3</sub>, comprising approximately 40% of natural and anthropogenic emissions combined. Additionally, synthetic fertilizers and agricultural crops together contribute 9x10<sup>12</sup> g NH<sub>3</sub>-N yr<sup>-1</sup> (12% of total emissions). This paper presents a discussion of the ammonia emissions inventory based on emission factor, process based modeling, Carnegie-Mellon Model, and inverse modeling approaches. Ammonia emissions are compared and contrasted with all the criteria pollutants in the US and Europe. In addition, best management practices are explored as the scientific community attempts to maximize the beneficial use of reactive nitrogen while simultaneously minimizing negative environmental impacts.

Viney P. Aneja\* and William Battye\*\*  
Department of Marine, Earth, and Atmospheric Sciences  
North Carolina State University  
Raleigh, NC 27695-8208, U.S.A.

\*Corresponding Author

\*\*EC/R Inc., Chapel Hill, NC 27514

## Assessing the Sensitivity of Agricultural Systems to Atmospheric N Deposition

Ellen Cooter

The estimation of air quality program benefits becomes increasingly important in difficult economic times. It is, however, difficult to anticipate every unintended consequence of these programs. For instance, there is now anecdotal evidence that farm managers are moving to new N fertilizer forms containing added sulphur sourced from industrial scrubbers. They are doing this to make up for decreased atmospheric sulphur deposition resulting from recent implementation of stricter SO<sub>x</sub> and NO<sub>x</sub> emission regulations. To date there have not been similar reports regarding the need for supplemental N applications but, in the past, the agricultural community has been critical of program analyses that neglect potential benefits of atmospheric N deposition for commercial crop production. The advent of the coupled agricultural management/CMAQ modeling system released in 2012 facilitates the generation of quantitative estimates of simulation uncertainty attributable to deposition inputs as well as potential production and biogeochemical benefits (as well as “dis-benefits”) derived from atmospheric deposition. In particular, the USDA Environmental Policy Integrated Climate (EPIC) model, the agricultural engine of the linked agricultural management/CMAQ system, allows us to explore the sensitivity of agricultural soil nitrogen status to alternative deposition scenarios. The EPIC biogeochemical model is run for legume and non-legume crops under alternative deposition scenarios including; no deposition, EPIC default deposition (wet deposition only), unidirectional CMAQ deposition and “first guess” bidirectional CMAQ estimates. The sensitivity of EPIC ammonia fertilizer application rate and timing as well as soil N status indicators such as N-fixation and denitrification rates, biomass production, N-uptake, yield and patterns of surface and subsurface N losses will be examined. Benefits and “dis-benefits” will be summarized to support or refute the hypothesis of the importance of N-deposition to agricultural production systems.

Ellen Cooter, USEPA/NERL/AMAD  
Phone: 919-541-1334  
Mail drop E243-02,  
Research Triangle Park, NC 27711  
[Cooter.ellen@epa.gov](mailto:Cooter.ellen@epa.gov)



Surface-Atmosphere Exchange of Ammonia in a Non-fertilized Grassland and its Implications for PM<sub>2.5</sub>Gregory R. Wentworth<sup>1</sup>, Phillip Gregoire<sup>1</sup>, Alex Tevlin<sup>1</sup>, Jennifer G. Murphy<sup>1</sup>X.J. Liu<sup>1,\*</sup>, Y. Zhang<sup>1</sup>, W.X. Han<sup>1</sup>, A. H. Tang<sup>1</sup>, J. L. Shen<sup>1</sup>, X. S. Luo<sup>1</sup>, Z. L. Cui<sup>1</sup>, P. Vitousek<sup>2</sup>, J. W. Erisman<sup>3</sup>, K. Goulding<sup>4</sup>, P. Christie<sup>1,5</sup>, A. Fangmeier<sup>6</sup>, F. S. Zhang<sup>1</sup>

Abstract: A growing body of evidence suggests that the surface-atmosphere exchange of ammonia (NH<sub>3</sub>) occurs in a bidirectional fashion governed by a compensation point (i.e. the atmospheric mixing ratio where flux changes direction). The compensation point represents an equilibrium between atmospheric NH<sub>3</sub> and dissolved NH<sub>4</sub><sup>+</sup> in soil water and/or plant tissues. Direct measurement of the compensation point is not trivial, due to its dependence on surface temperature, pH and the nitrogen distribution in the system. In particular, previous studies on bidirectional flux have been hindered by a lack of direct measurements of compensation point values and poor temporal characterization of surface nitrogen pools. Furthermore, few studies have explored bidirectional exchange in non-fertilized grasslands. An accurate understanding of the factors governing bidirectional flux is required in order for air quality models to accurately predict trace gas mixing ratios, aerosol composition and spatial patterns of nitrogen deposition.

To address these issues, a field study was conducted in southwestern Ontario during the summer of 2012 to simultaneously measure the atmospheric and surface components of this framework and provide observational constraints that test our understanding of the bi-directional exchange of NH<sub>3</sub>. An Ambient Ion Monitor Ion Chromatograph (AIM-IC) was used to quantify the water-soluble trace gases (NH<sub>3</sub>, SO<sub>2</sub>, HNO<sub>3</sub>, HCl, and HONO) as well as water-soluble ions in PM<sub>2.5</sub> with hourly time resolution. Similar IC methods were used in an offline fashion to periodically measure soil ammonium, nitrite and nitrate composition. Soil temperature and moisture were measured continuously with hourly time resolution. Using interpolated data for soil composition, diurnal and seasonal trends in the compensation point could be evaluated. The surface atmosphere exchange of NH<sub>3</sub> was calculated using an estimated exchange velocity, measured gas phase ammonia concentration and estimated compensation point. Back trajectories calculated throughout the campaign show that NH<sub>3</sub> is the only atmospheric constituent that does not exhibit a directional bias implying NH<sub>3</sub> concentrations are efficiently modulated by bidirectional exchange. In addition, there is evidence that dew evaporation contributes to a frequently observed yet unexplained morning spike of NH<sub>3</sub>. Challenges in quantifying inorganic nitrogen speciation in soils are also discussed.

Gregory R. Wentworth<sup>1</sup>, Phillip Gregoire<sup>1</sup>, Alex Tevlin<sup>1</sup>, Jennifer G. Murphy<sup>1</sup>  
<sup>1</sup>Department of Chemistry, University of Toronto, 80 St. George St., Toronto, ON, M5S 3H6, Canada  
 Telephone: +1-(416)-946-3011  
 E-mail: [greg.wentworth@utoronto.ca](mailto:greg.wentworth@utoronto.ca)

China is currently experiencing intense air pollution caused in large part by anthropogenic reactive nitrogen (N) emissions. These emissions result in the downwind deposition of atmospheric N in terrestrial and aquatic ecosystems, with consequence of acid rain, smog, eutrophication and loss of biodiversity, associated with human and ecosystem health, greenhouse gas balances and biological diversity. However, we have limited information on the magnitude and impact of this deposition in China. Here we used nationwide data sets on bulk N deposition, plant foliar N and crop N uptake (from unfertilized soils) to evaluate N deposition dynamics and effects across China from 1980 to 2010. Annual bulk N deposition increased by approximately 8 kg N ha<sup>-1</sup> (p<0.001) or 60% from the 1980s (13.2 kg N ha<sup>-1</sup>) to the 2000s (21.1 kg N ha<sup>-1</sup>), an accelerating trend compared with historical records. Nitrogen deposition is greatest in industrialized and agriculturally intensified regions; here, rates of deposition are as high as the peak levels of deposition in northwestern Europe in the 1980s, prior to the introduction of N emission mitigation measures there. NH<sub>4</sub>-N was dominant in deposition but most of the increase was from NO<sub>3</sub>-N deposition, consistent with decreased ratios of NH<sub>3</sub> to NO<sub>x</sub> emissions since 1980. Besides bulk/wet N deposition, we also found that dry N deposition (2.4-82.0 kg N ha<sup>-1</sup> yr<sup>-1</sup>, measured only in the 2000s), based on the inferential method, contributed to more than half of the total N deposition in China. Evidence from significantly increased foliar N in natural vegetations and N uptake from long-term unfertilized croplands support the enhanced N deposition over China. The increase in foliar N was 5.9 mg N g<sup>-1</sup> (P < 0.001) from the 1980s to 2000s while the increase in N uptake by maize, wheat and rice averaged 11.3 kg N ha<sup>-1</sup> (P < 0.05) during the same period. China is facing an ongoing challenge to lower N emissions, N deposition, and their negative impacts on human and ecosystem health and the climate.

Key words: Air pollution; reduced N; oxidized N, wet and dry deposition; ecological impact

<sup>1</sup> College of Resources and Environmental Sciences, China Agricultural University, No.2 Yuanmingyuan Xilu, Beijing 100193, China

<sup>2</sup> Department of Biology, Stanford University, Stanford, CA 94305, USA

<sup>3</sup> VU University Amsterdam, 1081 HV Amsterdam; and Louis Bolk Institute, the Netherlands

<sup>4</sup> Department of Soil Science, Rothamsted Research, Harpenden, Herts, AL5 2JQ, UK

<sup>5</sup> Agri-Environment Branch, Agri-Food and Biosciences Institute, Belfast BT9 5PX, UK

<sup>6</sup> Institute of Landscape and Plant Ecology, University of Hohenheim, 70593 Stuttgart, Germany

\* Corresponding author: [liu310@cau.edu.cn](mailto:liu310@cau.edu.cn) (X.J. Liu)

## First steps toward the establishment of a Nitrogen Cycling network in Latin America (Nnet)

Ariel F. Stein<sup>1,2</sup>, Jean Ometto<sup>3</sup>, Cristina Forti<sup>3</sup>, and Richard Artz<sup>2</sup>

Nitrogen is a key element for life on Earth, strongly associated with ecosystem function and many human activities, and significantly perturbed from natural background conditions over much of the planet. The lack of information, however, on the nitrogen cycle in Latin America is a serious impediment to our ability to evaluate current conditions and predict future impacts as human activity continues to alter nitrogen reservoirs and impact cycling on regional and global scales. Empirical measurements of nitrogen atmospheric deposition and other important aspects of nitrogen cycling are extremely scarce in Latin America, severely restricting the successful application of global and regional circulation models in this region.

We are in the process of developing a broad integrative network of research stations and outreach programs across multiple eco-regions and socioeconomic backgrounds in Latin America, with the formation of the Nitrogen Cycling in Latin America; Drivers, Impacts and Vulnerabilities network (Nnet). Our goal is to examine human impacts in natural and modified ecosystems across a wide range of climates, ranging from direct measurements to regional modeling exercises, aspiring to a greater understanding of how nitrogen excess or shortage affects ecosystem processes and biodiversity. With a common framework of experimental design and sample collection in sites distributed along extensive regional precipitation gradients, we expect to provide original, innovative, and integrative results related to ecosystem function and nitrogen dynamics. In several study sites distributed in the region defined according to physiographic and socio-economic attributes, the following inputs and outputs of nitrogen will be reviewed and analyzed: (i) inputs: Natural and cultivation induced biological nitrogen fixation, fertilizer use, and atmospheric deposition; (ii) Outputs: Net exports of agricultural products at the regional level and estimates at local scale of gaseous emissions from land use (fertilizer volatilization, biogenic soil emissions and burning), export of nitrogen to groundwater and surface waste (domestic, agricultural and industrial) and via nitrification and denitrification. Generation of regional-scale products based on this local-scale information will require an intense level of effort to model regional-level nitrogen atmospheric deposition, and to frame a network of sampling sites and to frame a network of sampling sites that eventually will become more permanent contributors to the global networking community. Our work aims to constrain regional atmospheric chemistry and transport models, which will in turn feed global models, leading to the enhancement of our understanding of the global nitrogen cycle.

In this presentation we will focus on the development of the Nnet wet deposition network. We will show some preliminary results from a station in central Argentina where the NADP weekly sampling protocol was adapted for local application. A description of the site setting and challenges encountered to implement a workable protocol will be presented. We will also discuss future plans for network expansion and the establishment of an Nnet Central Analytical Laboratory at INPE in Brazil.

<sup>1</sup> ERT, Inc (ariel.stein@noaa.gov)

<sup>2</sup> Air Resources Laboratory (ARL), NOAA

<sup>3</sup> Instituto Nacional de Pesquisas Espaciais (INPE), Brazil

**TECHNICAL SESSION 7:  
NETWORKS, MEASUREMENTS, AND NEW  
TECHNIQUES FOR ATMOSPHERIC  
MONITORING**

*Session Chair: Tom Butler,  
Cornell University*

## Wet deposition in the Mexico City Metropolitan Zone

Humberto Bravo A., Rodolfo Sosa E., María del Carmen Torres B., Ana Luisa Alarcón J., Pablo Sánchez A.

This work covers a period of sampling and analysis of wet deposition of the consecutive years 2003 to 2009. The present research identified and evaluated the chemical composition of wet deposition of 2665 samples collected. Eventually, all the stations in the Mexico City Metropolitan Zone (MCMZ), present acidity characteristic (pH lower than 5.6) the behavior of the values of acidity, increased from the North to the South region in the MCMZ; potential values increased from the North to the South, the annual pH values volume weighted to "PAR and "LOM", sampling stations were 4.15 and 4.26 respectively to 2006. The pH values decreased from 2003 to 2006; year 2007 to 2009 had a tendency to increase.

The physicochemical parameters of pH and conductivity were evaluated, both in the field and in the laboratory; the concentration of soluble ions  $\text{Na}^+$ ,  $\text{NH}_4^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$  and  $\text{Cl}^-$ , with the ions  $\text{SO}_4^{2-}$  and  $\text{NO}_3^-$ , the most abundant (50% to 60% compared to anions and 30% to 40% compared to the total mass).

Distributions of  $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$  and  $\text{Cl}^-$ , in kilograms (kg) per hectare, increased from the stations located in the Southwest, reaching maximum values of 47.39 Kg / ha(2007), 49.37 Kg / ha(2008) and 17.69 Kg / ha(2006) respectively.

In an effort to maintain control programs and quality assurance in the analysis of samples, the laboratory of SCA-CCA-UNAM is part of the Global Atmosphere Watch Precipitation Chemistry Program of the World Meteorological Organization since 2009.

It is recommended that Latin American countries for sampling and analysis follow the strict protocols, so that the results obtained will be comparable at the international level.

Sección de Contaminación Ambiental, Centro de Ciencias de la Atmósfera, Universidad Nacional Autónoma de México. Circuito Exterior, Ciudad Universitaria. México, D.F. C.P. 04510. México.

## Wet deposition in the Coast of the Gulf of Mexico

Rodolfo Sosa E., Humberto Bravo A., Ana Luisa Alarcón J., María del Carmen Torres B., Pablo Sánchez A., Monica Jaimes P.

In the Gulf of Mexico, the coast has a rich variety of natural resources, such as a wide range of agriculture, cattle farming, fishing, tourism and industrial activities. According to the latest National Mexican emissions inventory, the state of Veracruz (which lies in the gulf coast area), ranks respectively in second and third place in terms of sulphur dioxide and nitrogen oxide emission. This is mainly driven by activities carried out within and outside the coastal zone (for example, the oil industry), which makes this region an interesting destination for this study analyzing the wet deposition.

Since 2002, four stations were installed, in order to evaluate both dry and wet deposition in the State of Veracruz at the following locations: the San Juan de Ulúa Fortress, the Archaeological Site of "El Tajín", the Universidad Veracruzana in the City of Veracruz, and the Instituto de Ecología, A.C. in "La Mancha". The last one is still operating with a strict quality assurance and analytical quality control. The protocol has been followed and made this station a prototype for studies of atmospheric deposition in the Gulf of Mexico. The pH levels found in rainwater show a strong presence of the phenomenon of acid rain in the study area, with pH values in a range of 3.8 to 5.6.

Sección de Contaminación Ambiental, Centro de Ciencias de la Atmósfera, Universidad Nacional Autónoma de México. Circuito Exterior, C.U., México, D.F., C.P. 04510.

## Quality Assurance and Data Management in the World Meteorological Organization Global Atmosphere Watch Precipitation Chemistry Program

Richard Artz<sup>1</sup>, Van Bowersox<sup>2</sup>, Robert Vet<sup>3</sup>

The World Meteorological Organization (WMO) Global Atmosphere Watch (GAW) program is a partnership involving the members of the WMO, contributing networks, and collaborating organizations and bodies, which provides reliable scientific data and information on the chemical composition of the atmosphere, its natural and anthropogenic change, and helps to improve the understanding of interactions between the atmosphere, the oceans, and the biosphere. Precipitation chemistry is one of the GAW focal areas.

For approximately the past fifteen years, the GAW precipitation chemistry program has been driven by a Science Advisory Group (SAG) consisting of a small group of scientists representing the world's established monitoring networks, and interested emerging countries. The SAG seeks to harmonize measurement standards and methodologies in support of scientific assessments and modeling studies and to make data widely available. The SAG oversees a quality assurance center as well as the official data center. The Quality Assurance/Science Activity Centre – Americas seeks to document and help improve the quality of precipitation chemistry measurements from around the world. It conducts semi-annual laboratory intercomparison studies and presents graphical and tabular results of past studies. The World Data Center for Precipitation Chemistry receives, archives, and makes available precipitation chemistry data and complementary information from stations around the world and links to the web sites of major regional and national programs.

This presentation will provide an overview of the GAW precipitation chemistry program quality assurance and data archival functions.

1. NOAA Air Resources Laboratory, College Park, MD
2. Illinois State Water Survey, Champaign, IL, retired
3. Environment Canada, Downsview, Ontario, Canada

## Measurements and Modeling of Atmosphere-Snowpack Exchange of Ozone and Nitrogen Oxides at Summit, Greenland

Keenan A. Murray<sup>1</sup>, Louisa J. Kramer<sup>2</sup>, Claudia Toro<sup>2</sup>, Brie A. Van Dam<sup>3</sup>, Brian Seok<sup>3</sup>, Detlev Helmig<sup>3</sup>, Laurens Ganzeveld<sup>4</sup>, Paul V. Doskey<sup>2\*</sup>, and Richard E. Honrath<sup>2†</sup>

Snowpack is a reservoir for reactive nitrogen gases. Nitrogen oxides (NO<sub>x</sub>) are generated in the interstitial air of sunlit snowpack through photolysis of nitrate (NO<sub>3</sub>) in snow. Ozone (O<sub>3</sub>) scavenged by snowpack might react with nitrite (NO<sub>2</sub>) in snow and represent an additional source of NO<sub>x</sub> in interstitial air. Gradients in NO<sub>x</sub> mixing ratios between snowpack interstitial air and the Arctic boundary layer regulate transfer of NO<sub>x</sub> to/from snowpack and affect the O<sub>3</sub> budget and climate at high latitude. We collected meteorological and chemical data at Summit, Greenland to investigate production of NO<sub>x</sub> in snowpack over glacial ice. Semi-continuous measurements of NO, NO<sub>2</sub>, and O<sub>3</sub> mixing ratios were made at several depths in snowpack interstitial air and at 2 levels above the snow surface. A one-dimensional, process-scale model of atmosphere-snowpack exchange was developed to simulate profiles of NO<sub>x</sub> and O<sub>3</sub> in the Arctic boundary layer and in snowpack interstitial air. The model includes detailed representations of snowpack chemical and physical processes and the physical and chemical dynamics of the overlying atmosphere that drive atmosphere-snowpack exchange. A more highly parameterized version of the process-scale model is incorporated into a global-scale model to assess impacts of cryosphere-atmosphere exchange on the Arctic O<sub>3</sub> budget.

<sup>1</sup>Department of Civil and Environmental Engineering, Michigan Technological University, Houghton, MI, USA

<sup>2</sup>Atmospheric Sciences Program, Michigan Technological University, Houghton, MI, USA

<sup>3</sup>Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO, USA

<sup>4</sup>Wageningen University and Research Center, Wageningen, Netherlands

†Deceased.

\*Corresponding Author. pvdoskey@mtu.edu 906-487-2745

## A Winter Ozone Monitoring Network in Utah's Uintah Basin

Seth Lyman

While Utah's Uintah Basin typically experiences criteria pollutant concentrations below the Environmental Protection Agency's National Ambient Air Quality Standards (NAAQS), specific meteorological conditions during some winters allow ozone to build up over a broad area of the Basin. Conditions conducive to ozone formation include extensive snow cover, strong temperature inversions, and light winds. The Uintah Basin supports a vibrant oil and natural gas extraction industry, and it is likely that  $\text{NO}_x$  and hydrocarbons emitted during oil and gas extraction, along with emissions from other sources, contribute to ozone production during inversion episodes.

For three years Utah State University (USU) has operated a network of 10-20 stations that monitor ozone, meteorology, and ozone precursors around the Uintah Basin. 10 more air quality stations are operated by other groups, resulting in a dense monitoring network that allows for a detailed understanding of causes of wintertime ozone pollution in the Basin. For example, volatile organic compound (VOC) concentrations in the Basin are strongly correlated with proximity to oil and gas wells ( $R^2 = 0.92$ ), and VOC speciation is dependent on the type of wells (oil or gas) in the area. In contrast, ozone is most strongly correlated with elevation ( $R^2 = 0.60$ ), though proximity to oil and gas production is also important (combined  $R^2$  value of 0.78 with elevation and proximity to wells as independent variables). Spatial relationships of ozone and precursors with compressors, gas plants, coal-fired power plants, population, traffic, meteorological phenomena, and other parameters have also been investigated. This monitoring network has allowed for detailed observation of the buildup and distribution of ozone and precursors under inversion conditions and dispersion of ozone plumes as storms flush polluted air from the Basin. Data from this network are being incorporated into regulatory and research-grade meteorological and air quality models, including models under development at USU.

Bingham Entrepreneurship and Energy Research Center  
Office of Commercialization and Regional Development  
Utah State University  
320 N. Aggie Blvd.  
Vernal, UT 84078  
435-722-1740  
[seth.lyman@usu.edu](mailto:seth.lyman@usu.edu)

## Field Performance Evaluation of the Monitor for AeRosols and GAses in ambient air (MARGA)

Greg M. Beachley<sup>a</sup>, Gary Lear<sup>a</sup>, Melissa Puchalski<sup>a</sup>, Ian C. Rumsey<sup>b</sup>, John.T. Walker<sup>b</sup>

In an effort to supplement its long-standing Clean Air Status and Trends Network (CASTNET) filter pack measurements of weekly integrated atmospheric concentrations of pollutants, the US EPA has evaluated the performance capabilities of duplicate Monitor for AeRosols and GAses (MARGA) systems at the Beltsville, MD (BEL116) site. The MARGA system measures hourly (semi-continuous) ambient concentrations of soluble gases ( $\text{SO}_2$ ,  $\text{HNO}_3$ ,  $\text{NH}_3$ ) and aerosols ( $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$ ,  $\text{NH}_4^+$ ) which can be used to better characterize atmospheric deposition processes that contribute to ecosystem exposure to nitrogen and sulfur compounds.

MARGA performance has been verified through the US EPA's Environmental Technology Verification (ETV) program and further evaluated in a study detailing modified procedures to correct for any limitations or artifacts.

To date, much of the study devoted to these instruments has been with regard to their capacity and performance in an intensive research environment where meticulous time and attention can be devoted to observation, maintenance, and correction procedures. This communication outlines field implementation of the MARGAs at the BEL116, MD site over 3 seasons of the past year, including collocation of duplicate systems with hourly trace gas measurements ( $\text{SO}_2$  and  $\text{NO}_y$ ), and time integrated sampling methods historically present at CASTNET sites (e.g. filterpack, AMoN samplers). This will provide better insight as to the contribution of episodic pollution events from both local and regional sources and diurnal variations have on the integrated measurements as well as identify any unknown biases or sampling artifacts associated with the existing methods. The measured ambient concentration data will also be compared with historical CMAQ predicted concentration values as a function of season and time as a tool to investigate the efficacy of the model and potentially identify any artifacts or biases, particularly autocorrelation of deposition velocities and concentrations that may exist.

<sup>a</sup> Clean Air Markets Division, U.S. Environmental Protection Agency, Washington, DC 20460, U.S.A  
202-343-9621  
[beachley.gregory@epa.gov](mailto:beachley.gregory@epa.gov)

<sup>b</sup> Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711, U.S.A

## Seasonal variation of speciated nitrogen and sulfur fluxes above a grass field

Ian C. Rumsey\*, John T. Walker

Development of robust air-surface exchange algorithms requires observational datasets that capture the full range of variability in surface conditions, meteorology, and atmospheric chemistry that drive surface-atmosphere fluxes. For development of total nitrogen and sulfur deposition budgets, simultaneous measurement of multiple species is a further requirement. New on-line measurement techniques, such as the Monitor for AeRosols and GAses in ambient air (MARGA) 2S, afford the opportunity for long-term multi-species flux measurements. The MARGA is an on-line ion chromatography system that measures water-soluble gases and aerosols at an hourly temporal resolution. Air-surface exchange fluxes of gases ( $\text{NH}_3$ ,  $\text{HNO}_3$ , HONO, and  $\text{SO}_2$ ) and aerosols ( $\text{NH}_4^+$ ,  $\text{NO}_3^-$ , and  $\text{SO}_4^{2-}$ ) were calculated by measuring concentrations at two different heights using a modified MARGA 2S and by employing the aerodynamic gradient method. The presentation summarizes the performance of the MARGA as a gradient system and describes preliminary measurements of nitrogen and sulfur compound fluxes above a grass field during 2012 and 2013 with a focus on seasonal flux variation. The air-surface exchange fluxes are also evaluated with respect to diurnal variations and the influence of meteorological conditions and surface characteristics. The uncertainty of the fluxes is determined by calculating the concentration gradient and transfer velocity precision. The relative contribution of individual nitrogen compounds to the total flux of  $\text{NH}_3 + \text{HNO}_3 + \text{HONO} + \text{NH}_4^+ + \text{NO}_3^-$  is examined with respect to seasonal variations.

Office of Research and Development, U.S. Environmental Protection Agency,  
Research Triangle Park, NC 27711, U.S.A

\* Corresponding author  
Email: rumsey.ian@epa.gov  
Telephone: (919) 541-4746  
Fax: (919) 541-7885

## Continued Development and Validation of Inexpensive Flux-Measurement Tools

Berkeley Almand<sup>1</sup>, Nicolas Masson<sup>1</sup>, Lauren Hafford<sup>1</sup>, Corey Miller<sup>1</sup>, Eladio Knipping<sup>2</sup>,  
John Walker<sup>3</sup>, Michael Hannigan<sup>1</sup>

Measurements of  $\text{NO}_x$  and  $\text{SO}_x$  dry deposition are needed to assess the effectiveness of the secondary National Ambient Air Quality Standards (NAAQS). Given the large spatio-temporal variability in air-surface exchange rates of reactive compounds, there is an urgent need for low-cost, easily deployable systems for measuring dry deposition. Our research effort addresses this need through the creation of a robust, inexpensive, and continuous multiple-species gas-flux monitoring system, which can provide data for a variety of relevant atmospheric pollutants. This tool enables exploration of the spatial variability of fluxes, as the expense of building multiple flux chambers is similar to that of a single eddy-covariance tower. Additionally, flux chambers are mobile, which permits them to be moved around a site or even shared between multiple sites.

We designed and built a prototype flux chamber and completed preliminary testing, which demonstrated that the chamber was capable of measuring  $\text{O}_3$  and  $\text{CO}_2$  fluxes. After evaluating the limitations of the first-generation chamber, we used computational fluid dynamics modeling to minimize wall losses for the second-generation design. We also built a “blank” chamber, with a plexiglass bottom that prevents deposition to vegetation, to accompany each flux chamber. This enables the calculation of real-time wall losses. Every chamber is equipped with low-cost metal-oxide ozone and  $\text{NO}_2$  sensors. In the future, electrochemical  $\text{NO}_x$  sensors will also be installed. A total of 5 pairs of chambers were constructed, and the total cost of each pair, including the sensors mentioned above, is below \$3500.

To validate the performance of these chambers, we collocated them with an EPA flux tower at a grassland field site in the Blackwood Division of the Duke Forest. The EPA measures a variety of fluxes at this site, and provided high-quality eddy-covariance measurements of  $\text{O}_3$ ,  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ , and  $\text{NO}_x$  for comparison, as well as an assortment of relevant meteorological variables. Measurements of  $\text{O}_3$ ,  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ , and  $\text{NO}_x$  fluxes were performed by attaching high-quality concentration monitors to the flux chambers, which enabled us to validate their accuracy independently of the performance of the low-cost sensors. Preliminary data analysis indicates that chamber measurements for  $\text{O}_3$  flux agree with eddy-covariance measurements under some meteorological conditions, but accuracy is affected by wind speed and  $\text{H}_2\text{O}$  flux. Preliminary data also indicate that the chambers are capable of resolving  $\text{NO}_x$  deposition. Comparison to eddy covariance  $\text{NO}_x$  fluxes is forthcoming.

<sup>1</sup>University of Colorado, 427 UCB, Boulder, CO, 80309

<sup>2</sup>Electric Power Research Institute, 2000 L Street NW Suite 805, Washington, DC 20036

<sup>3</sup>US Environmental Protection Agency, 109 T.W. Alexander Drive, RTP, NC 27711

**Principal Contact:** Berkeley Almand, PhD Student, University of Colorado, 427 UCB, 1111 Engineering Drive, Boulder, CO, 80309, Phone: (303) 807-7668, Fax: (303) 492-3498, berkeleyalmand@gmail.com

**TECHNICAL SESSION 8:**  
**NITROGEN FLUX WORKSHOP KICKOFF**

*Session Chair: John T. Walker,*  
*U.S. EPA*



## The state of the science on nitrogen deposition budgets and their use in critical loads assessments in Europe

David Fowler, Ron Smith, Marsailidh Twigg and Daniela Famulari

The deposition of reactive nitrogen compounds to terrestrial ecosystems may lead to changes in the diversity of the flora, freshwater eutrophication, acidification and enhanced emissions of N<sub>2</sub>O and NO. To protect ecosystems from the effects of excess N r deposition the Critical Loads concept has been used extensively in Europe to identify areas at risk of these effects. Estimates of Nr deposition are generally provided by regional atmospheric dispersion, transport and deposition models, but seldom are the uncertainties in estimates of deposition quantified. In this presentation, current understanding of nitrogen deposition processes and uncertainties in the estimates are reviewed.

The science of nitrogen deposition estimates is complicated by the number and form of nitrogen compounds contributing to surface –atmosphere exchange processes and the difficulty in measuring each of the processes. The compounds involved in surface – atmosphere exchange include the gases, NO, NO<sub>2</sub>, NHO<sub>3</sub>, NH<sub>3</sub> and HONO, the particulate NO<sub>3</sub> and NH<sub>4</sub> and wet deposited NH<sub>4</sub>and NO<sub>3</sub>. Organic nitrogen also contributes to Nr deposition and will be discussed as a specific issue as the current understanding of organic nitrogen in the atmosphere is very limited and no emission inventories are available to simulate the process.

The measurement and interpretation of flux measurements of Nr compounds is discussed, as there remain important uncertainties in the mechanistic understanding of sources and sinks of some of the Nr compounds, notably HONO and the organic Nr. Even for NO<sub>2</sub>, where the available literature suggests a simple process of uptake through stomata and no other significant deposition sink at the surface, the chemical conversion of NO within plant canopies obscures many field measurements.

CEH Edinburgh UK

[dfowler@ceh.ac.uk](mailto:dfowler@ceh.ac.uk)

## NO<sub>2</sub> and O<sub>3</sub> deposition to intensively managed grassland - Findings, characterization and parameterization from a multi-year dynamic chamber study

Wolff, V.<sup>1</sup>; Flechard, C.R.<sup>2</sup>; Spirig, C.<sup>3</sup>; Neftel, A.<sup>1</sup>; Ammann, C.<sup>1</sup>

### Motivation

Though nitrogen dioxide (NO<sub>2</sub>) is an important player in the deposition of reactive nitrogen, only few flux measurements are reported in literature and deposition pathways are poorly understood, especially on the ecosystem level. Accordingly, inferential models only comprise very simple deposition schemes for NO<sub>2</sub>, usually linking its deposition to stomatal uptake (Flechard et al., 2011).

Using dynamic chamber measurements (Pape et al. 2009) of the NO-NO<sub>2</sub>-O<sub>3</sub> triad at an intensively managed grassland site (Oensingen in the Swiss central plateau, 7°44'E, 47°17'N, 450 m a.s.l.), we aim at (a) an integrative interpretation of the chamber fluxes in respect to ambient exchange processes, accounting for chemical interactions within the NO-NO<sub>2</sub>-O<sub>3</sub> triad, (b) the investigation of NO<sub>2</sub> and O<sub>3</sub> deposition pathways, e.g. stomatal vs. non-stomatal uptake, and (c) formulating an empirical parameterization for NO<sub>2</sub> deposition based on the in-situ flux measurements.

### Preliminary results and outlook

While O<sub>3</sub> deposition shows consistent deposition patterns with regular diurnal cycles and  $R_c$  values between around 100 sm<sup>-1</sup> during daytime and above 600 sm<sup>-1</sup> during night, the proximity to the highway and consequent instationarity of NO<sub>2</sub> concentration lead to a highly noisy chamber flux signal for NO<sub>2</sub>. Daytime stomatal resistance was estimated from eddy covariance H<sub>2</sub>O fluxes and adjusted for the reduced molecular diffusivities of O<sub>3</sub> and NO<sub>2</sub>. Both O<sub>3</sub> and NO<sub>2</sub> deposition processes cannot be explained by the stomatal resistance alone. In periods without the influence of fertilization, NO<sub>2</sub> was found to be the dominant reactive nitrogen compound at the site. In such conditions the NO<sub>2</sub> deposition derived from chamber flux measurements compare well to total reactive nitrogen exchange fluxes (Ammann et al., 2012). The residual non-stomatal resistances are related to meteorological parameters with the aim of a suitable parameterization of  $R_c(O_3)$  and  $R_c(NO_2)$  for our site.

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- 1) Agroscope Research Station, Zurich, Switzerland
- 2) Soils, Agro- and Hydro-Systems (SAS Unit), INRA, Rennes Cedex, France
- 3) Swiss Federal Office of Meteorology and Climatology MeteoSwiss, Zürich, Switzerland

Mail : [veronika.wolff@agroscope.admin.ch](mailto:veronika.wolff@agroscope.admin.ch); Phone : +41 44 377 7513

## Reactive nitrogen oxides fluxes above two mid-latitude North American mixed hardwood forests

Jeffrey Geddes<sup>1,2</sup> and Jennifer Murphy<sup>1</sup>

While precipitation sampling networks allow us to quantify wet deposition inputs, dry deposition must often be inferred from atmospheric mixing ratios using a dry deposition model with parameterized deposition velocities. Dry deposition of the sum of reactive nitrogen oxides ("NO<sub>y</sub>") in forested environments has been directly observed by eddy covariance at only a handful of sites across the globe. The results presented here add to this small body of work.

NO<sub>x</sub> and NO<sub>y</sub> mixing ratios and fluxes were measured above two North American mid-latitude mixed hardwood forests. Observations were made in central Ontario at Haliburton Forest and Wildlife Reserve (HFWR) from July 20 to October 13, 2011, and in northern Michigan at the University of Michigan Biological Station's PROPHET tower from July 24 to August 14, 2012. Campaign average NO<sub>y</sub> mixing ratios at both locations were around 1.5 ppb, with average NO<sub>x</sub> mixing ratios between 0.7-0.8 ppb.

NO<sub>y</sub> fluxes were predominantly of deposition at both sites. The mean flux was higher at PROPHET than at HFWR ( $-4.2 \pm 7.5$  and  $-1.8 \pm 4.9$  ng N m<sup>-2</sup> s<sup>-1</sup> respectively), but both sites showed the same average relationship between NO<sub>y</sub> deposition and NO<sub>y</sub> mixing ratios (campaign average deposition velocity of  $0.58 \pm 0.06$  cm s<sup>-1</sup> and  $0.54 \pm 0.02$  cm s<sup>-1</sup> respectively). Diurnal averaged NO<sub>y</sub> fluxes showed highest deposition during the day time at both sites, but with maximum deposition at PROPHET occurring several hours later compared to HFWR. Diurnal average NO<sub>x</sub> fluxes show evidence that above the canopy, apparent deposition of NO is largely counteracted by apparent emission of NO<sub>2</sub> and the net NO<sub>x</sub> flux is close to zero. Wind direction plays a role in NO<sub>y</sub> deposition, with both locations showing clear influence from source regions that enhance deposition compared to unpolluted conditions. The total NO<sub>y</sub> dry deposition budget could be estimated and compared with wet deposition observations at both locations. It was found that dry deposition contributed 0.34 mg N m<sup>-2</sup> and 0.14 mg N m<sup>-2</sup> per day on average throughout the campaigns at PROPHET and HFWR, representing 48% and 22% of total deposition of oxidized nitrogen at each site respectively.

<sup>1</sup> University of Toronto, Department of Chemistry, 80 St. George Street, Toronto, ON, M5S 3H6

<sup>2</sup> Now at Dalhousie University, Department of Physics and Atmospheric Science

Phone: 416-946-3011

Email: [jmurphy@chem.utoronto.ca](mailto:jmurphy@chem.utoronto.ca)

## An Investigation of Anthropogenic Influences on Fluxes of Organic Nitrates from a Temperate Deciduous Forest in East Tennessee

Rick D. Saylor

Forests are a dominant source of biogenic volatile organic compound (BVOC) emissions into the earth's atmosphere and play an important role in ozone photochemistry and the formation of secondary organic aerosol (SOA). To arrive at a better scientific understanding of the complex chemical and physical processes of forest-atmosphere exchange and provide a platform for robust analysis of field measurements of these processes, a process-level, one-dimensional, multiphase model of the atmospheric chemistry and physics of forest canopies is being developed. The initial gas-phase version of the model, the Atmospheric Chemistry and Canopy Exchange Simulation System (ACCESS) currently includes processes accounting for the emission of biogenic volatile organic compounds (BVOCs) from the canopy, turbulent vertical transport within and above the canopy and throughout the height of the planetary boundary layer, near explicit chemical reactions, mixing with the background atmosphere and bi-directional exchange between the atmosphere and the canopy and the forest floor.

The Walker Branch Watershed (WBW) is a dedicated ecosystem research area on the U. S. Department of Energy's Oak Ridge Reservation in east Tennessee. A flux tower located within the watershed (35°57'30"N, 84°17'15"W; 365 m above mean sea level) and 10 km southwest of Oak Ridge, Tennessee, served as a focal point for BVOC chemical flux measurements from the forest canopy in 1999. At the time of the measurements, the forest stand was approximately 50 years old, the overstory canopy height was 26 m, and the whole canopy leaf area index was 6.0 m<sup>2</sup> leaf/m<sup>2</sup> ground area. In this presentation, the ACCESS model will be briefly described and results from its application to the WBW forest canopy will be presented, emphasizing fluxes of organic nitrates produced from the interaction of emitted BVOCs and nearby anthropogenic sources of nitrogen oxides (NO<sub>x</sub>). Results from sensitivity studies will be presented to demonstrate the role of anthropogenic influences on organic nitrate fluxes from a temperate deciduous forest canopy.

NOAA Air Resources Laboratory  
Atmospheric Turbulence and Diffusion Division  
Oak Ridge, TN 37830  
email: [Rick.Saylor@noaa.gov](mailto:Rick.Saylor@noaa.gov)  
office: (865) 576-0116

## **NITROGEN FLUX WORKSHOP**

## Development of total nitrogen deposition budgets for U.S. critical loads assessments

John T. Walker<sup>1\*</sup>, Robin Dennis<sup>2</sup>, Donna Schwede<sup>2</sup>, Gary Lear<sup>3</sup>, Jesse Bash<sup>2</sup>, Kristen M. Foley<sup>2</sup>, Brett Schichtel<sup>4</sup>, Jeff Collett<sup>5</sup>, Mike Barna<sup>1</sup>, William Malm<sup>6</sup>, Kristi Morris<sup>7</sup>, Christopher Lehmann<sup>8</sup>, Tom Butler<sup>9</sup>, Tara Greaver<sup>10</sup>

Atmospheric deposition is a pathway of the nitrogen (N) cascade by which reactive N emitted from anthropogenic and biogenic sources is returned to the earth's surface by wet and dry air-surface exchange processes. For many terrestrial and aquatic ecosystems, atmospheric deposition represents the primary exogenous N source and therefore plays an important role in system productivity and biogeochemical cycling. The atmospheric reactive N pool consists of oxidized and reduced compounds, both organic and inorganic, which are incorporated into precipitation (wet deposition) and deposit directly to the surface as particles and gases (dry deposition). While N is a key nutrient, long-term ecosystem inputs in excess of biosphere demand may lead to changes in vegetation and microbial species composition, decreased resistance of vegetation to pests and climate variability, soil acidification, eutrophication, and other stressors. The concept of a "critical nitrogen load", below which harmful effects are not expected to occur, has been developed as a policy tool for protecting ecosystems from excessive N deposition. Widely used in Europe since the 1980s, federal agencies in the U.S. are now employing critical loads (CL) approaches to protect key ecosystems and research in support of this effort is advancing.

Estimates of total N deposition are often required for calculation of the CL itself. Additionally, speciation of the N deposition budget is necessary to quantify the relative contribution of individual compounds to the total N load and thereby accurately quantify the fraction of the budget that is subject to regulatory control. Speciated N deposition budgets are therefore required to develop the most effective and cost efficient strategies for meeting target deposition loads identified through CL assessments. While much progress has been made in developing measurement and modeling approaches for quantifying atmospheric N deposition, most CL assessments in the U.S. currently rely on budgets that are to some extent incomplete (e.g., do not include some compounds such as organics) or contain deposition estimates for some important compounds that are highly uncertain. The purpose of this study is to examine the state of the science with respect to development of total N deposition budgets for the U.S. We begin by summarizing current approaches for constructing deposition budgets, including chemical transport models, measurement networks, and recent intensive field studies. Site specific case studies are presented in which speciated budgets developed from each approach, and combinations thereof, are compared. Key uncertainties of the budgets are discussed, including the implications for ecosystem protection and policy effectiveness. Finally, recommendations for near- and long-term monitoring and process oriented research needed to improve current methods for developing total deposition budgets are put forth.

<sup>1</sup>U.S. EPA, Office of Research and Development, National Risk Management Research Laboratory, Durham, NC 27711. <sup>2</sup>U.S. EPA, Office of Research and Development, National Exposure Research Laboratory, Durham, NC 27711. <sup>3</sup>U.S. EPA, Office of Air and Radiation, Clean Air Markets Division, Washington, DC 20460. <sup>4</sup>National Park Service, Colorado State University, Fort Collins, CO 80523. <sup>5</sup>Colorado State University, Department of Atmospheric Science, Fort Collins, CO 80523. <sup>6</sup>Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, CO 80523

<sup>7</sup>National Park Service, Air Resources Division, Denver, CO 80225. <sup>8</sup>National Atmospheric Deposition Program, Illinois State Water Survey, University of Illinois at Urbana-Champaign, Champaign, IL 61820. <sup>9</sup>Cary Institute of Ecosystem Studies, Millbrook, NY 12545. <sup>10</sup>U.S. EPA, Office of Research and Development, National Center for Environmental Assessments, Durham, NC 27711

\* Corresponding author, Email: [walker.johnt@epa.gov](mailto:walker.johnt@epa.gov), Telephone: (919) 541-2288

## Reactive nitrogen deposition in the United States: the increasing importance of ammonia

Jeffrey L. Collett, Jr.<sup>1</sup>, Yi Li<sup>1</sup>, and Bret A. Schichtel<sup>2</sup>

While initial interests in U.S. wet deposition focused largely on sulfate content and acidity, increasing attention has been paid in recent years to scavenging and deposition of reactive nitrogen compounds. NADP wet deposition measurements have a long history of measuring both oxidized and reduced forms of inorganic nitrogen: nitrate and ammonium. While some networks measure concentrations and/or deposition of gaseous nitric acid and fine particle nitrate, less is known historically about atmospheric concentrations or dry deposition of gaseous ammonia and fine particulate ammonium. Over the past three decades, NADP wet deposition data indicate that ammonium has become a relatively larger component of inorganic nitrogen wet deposition. Since the 1980s many regions of the country have shifted from nitrate-dominated wet inorganic nitrogen deposition to a situation where ammonium is the majority contributor. We will review this change in the NADP wet deposition data record. We will also examine available observations of gaseous ammonia and nitric acid and fine particulate ammonium and nitrate to see whether the shift in wet deposition contributions is closely tied to the relative abundance of oxidized and reduced inorganic nitrogen in the atmosphere. Finally, we will use available records to assess the relative importance of dry deposition of oxidized and reduced inorganic reactive nitrogen in select regions of the country.

<sup>1</sup>Atmospheric Science Department, Colorado State University, Fort Collins, CO 80523; 970-491-8697; [collett@atmos.colostate.edu](mailto:collett@atmos.colostate.edu)

<sup>2</sup>National Park Service, Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, CO 80523

**Observations of fluxes and gradients of NO<sub>x</sub> and Peroxynitrates:  
Disentangling Chemical and Physical Mechanisms of Atmosphere-  
Biosphere Exchange of Oxidized N**

Professor Ronald C. Cohen

**Abstract**

Recent laboratory and field studies have highlighted the absence of observational evidence for many commonly held assumptions about atmosphere-biosphere exchange of the oxides of nitrogen, including “canopy reduction factors,” “compensation points,” and the assumption that deposition is dominated by the inorganic nitrate. In this talk I will first describe conclusions from our own field work indicating that within canopy chemistry has important consequences for N exchange rates of NO, NO<sub>2</sub> and peroxy nitrates and that these species are important players in the total budget for N exchange. Then I will discuss prospects for improved in situ field studies, analyses of satellite observations and novel laboratory studies that would help address the prevalence of conflicting mechanisms present in current models of atmosphere-biosphere exchange of N.

**Authors and Contact info:**

Professor Ronald C. Cohen  
Departments of Chemistry and of Earth and Planetary Science  
UC Berkeley  
Latimer Hall  
Berkeley, CA 94720-1460

Phone: (510) 642-2735  
[rccohen@berkeley.edu](mailto:rccohen@berkeley.edu)

**Continuous Measurements of NO<sub>y</sub> and NO<sub>y</sub> Components during the  
Southeast Atmospheric Study, June 1-July 15, 2013**

Eric S. Edgerton

Atmospheric dry deposition of oxidized nitrogen species (collectively known as NO<sub>y</sub>) is a complex function of chemistry and physics, including physical form (gas or aerosol), diffusivity, solubility and reactivity of individual species. Thus, information on individual components of NO<sub>y</sub> is needed to develop and/or constrain deposition estimates. This presentation will describe observations of NO<sub>y</sub> and its major components at a rural site in the southeastern US during the summer of 2013. Hourly and 5-minute average measurements of NO<sub>y</sub>, NO, NO<sub>2</sub>, HNO<sub>3</sub>, fine particulate nitrate (pNO<sub>3</sub>), total peroxy nitrates (tPANs) and total alkyl nitrates (tANs) were performed at the SEARCH Centreville, AL site during the multi-agency SAS/SOAS/SENEX campaign (June 1-July 15, 2013). All components were quantified via NO-O<sub>3</sub> chemiluminescence: NO directly, NO<sub>y</sub> via conversion to NO on 350C Mo, NO<sub>2</sub> via blue LED photolysis, HNO<sub>3</sub> via denuder difference, pNO<sub>3</sub> via denuder-filter difference, tPANs and tANs via thermal-photolytic conversion at 160C and 380C, respectively. Results show that the sum of components accounts for 98 +/- 11% of NO<sub>y</sub> (mean = 1250 +/- 810 parts per trillion) over the course of the study and that NO<sub>x</sub> (NO<sub>2</sub> + NO) and NO<sub>z</sub> (others) each account for almost exactly 50% of NO<sub>y</sub>. HNO<sub>3</sub>, tPANs, tANs and pNO<sub>3</sub> account for 12%, 10%, 21% and 4% of NO<sub>y</sub>, respectively. Each of the measured components has a more or less unique diurnal pattern. NO<sub>x</sub> accounts for >75% of NO<sub>y</sub> during nighttime hours and is exclusively NO<sub>2</sub> overnight, while HNO<sub>3</sub>, NO<sub>2</sub>, tPANs and tANs each account for roughly 25% of NO<sub>y</sub> during midday. HNO<sub>3</sub> concentrations generally peak around 1600 local standard time (LST), while tPANs and tANs generally peak around 0900-1200 LST. pNO<sub>3</sub> concentrations peak within +/- 2 hours of sunrise and are effectively zero from 1000-1600 LST. Inspection of time series data provides interesting clues to the physical-chemical characteristics of tPANs and tANs (recognizing, of course, that these are classes of compounds rather than individual compounds). For example, tPAN and tAN concentrations are very slightly affected by rainfall events, whereas HNO<sub>3</sub> and pNO<sub>3</sub> concentrations are rapidly reduced to zero or near zero. Similarly, nighttime concentrations of tPANs and tANs decline much more slowly than HNO<sub>3</sub>. These observations suggest that tPANs and tANs have substantially different (slower) wet and dry removal rates than HNO<sub>3</sub>, which, in turn, may provide useful information for estimating NO<sub>y</sub> deposition.

Eric S. Edgerton: Atmospheric Research & Analysis, Inc.; 410 Midenhall Way, Cary, NC, 27513; 919.522.8565; [eedgerton@atmospheric-research.com](mailto:eedgerton@atmospheric-research.com)

## Application of common and new techniques for measuring air-surface exchange of reactive nitrogen

Ammann, C., Wolff, V., Sintermann, J., Neftel, A.

For ecosystems, the availability of (reactive) nitrogen is one of the key limiting factors for the productivity and the competition success of individual species, thereby influencing the biodiversity and the exchange of greenhouse gases. Thus the quantification of the reactive nitrogen ( $N_r$ ) exchange is essential for the interpretation of ecosystem behavior. Since the  $N_r$  exchange includes various inorganic as well as organic compounds that can undergo fast chemical reactions and have differing chemical and physical characteristics, a variety of detection techniques is usually necessary to measure all relevant compounds.

For dry deposition monitoring purposes, weekly or monthly integrating methods using denuders, filter packs, passive sampler or bulk sampler techniques may often be sufficient, but they depend on assumptions and generic parameterizations. In order to investigate specific surface exchange processes and improve the mechanistic parameterization schemes in models, direct measurement methods with high temporal resolution (one hour or better) are necessary. A number of online detection methods (incl. chemiluminescence, fluorescence, laser absorption, electrochemical techniques, online ion chromatography, mass spectroscopy etc.) have been developed or optimized for nitrogenous compounds in recent years.

For the observation of deposition processes or bi-directional exchange, micrometeorological methods are preferable since they do not modify the environmental conditions of the ecosystem and are less prone to wall effects than chamber methods. We show different applications of micrometeorological flux measurement systems for  $N_r$  compounds and discuss their advantages and disadvantages. Gas-phase chemiluminescence detectors for NO were used for eddy covariance (EC) flux measurements. In combination with inlet converters ('blue-light' converter for  $NO_2$ , gold catalyst converter for  $NO$ , and total  $N_r$  converter) this system allowed to measure lumped fluxes of a group or the total sum of  $N_r$  compounds. Specific EC flux measurements for the highly soluble and adsorbing  $NH_3$  required the use of a strongly heated ( $>100^\circ C$ ) inlet tube. For all these EC systems the damping of high-frequency fluctuations in the inlet system is potentially problematic and needs to be quantified.

If no fast response detector is available, the gradient or relaxed eddy accumulation method can be a valuable alternative (e.g. for the  $NH_3$ - $HNO_3$ - $NH_4NO_3$  triad). They need only slow but still very accurate detection of two inlet lines. Thus a careful assessment of error sources (especially biases between the inlets) is very important. For NO and  $NO_2$  exhibiting fast gas-phase reaction within the canopy and in the surface layer (with chemical time scale similar to the turbulent transport time scale), micrometeorological measurements above the canopy may be less suitable to investigate the respective source/sink processes, because the fluxes often show a strong vertical divergence. In such cases, the use of (dynamic) chamber and cuvette systems is often a necessary complement or alternative.

Agroscope, Federal Research Station, Zurich, Switzerland  
e-mail: christof.ammann@agroscope.admin.ch; phone: +41-44-377-7503

## Land - atmosphere ammonia exchange: Do we have the necessary information to contribute to a common conceptual framework for modelling biosphere atmosphere exchanges of gases and aerosols

R.-S. Massad<sup>1</sup>, C. Flechard<sup>2</sup>, B. Loubet<sup>1</sup>, and E. Personne<sup>1</sup>

When considering biosphere – atmosphere exchange of trace gases and volatile aerosols, significant advances have been made in recent years both from an experimental and modeling point of view and on several scales, going from organ to plant to plot and to the landscape level. This was particularly stimulated by the availability of new datasets generated from technological improvements. Recent research advances thus allow us, not only to identify major mechanisms and factors affecting the exchange of trace gases and volatile aerosols between the biosphere and the atmosphere, but also to recognize several gaps in the methodologies currently used in accounting for emissions and deposition in landscape and global scale models. We can therefore aim at better quantifying the contribution of terrestrial surfaces to atmospheric pollution and the global green house gas balance. Surface/atmosphere exchange models are necessary to compute the temporal and spatial patterns of emissions and deposition at the soil, plant, field, landscape, regional and global scales. Developing a common modelling framework for air-surface exchange of reactive gases and particles was one of the main objectives of a Workshop co-organized by the COST action ABBA and the EU-FP7 project ECLAIRE. Ammonia exchange between the land surface and the atmosphere was one of the focuses of the workshop. Models of surface/atmosphere  $NH_3$  exchange have been both developed and applied for a number of purposes and at a large range of spatial scales ranging from the leaf or plant, the canopy or ecosystem, the landscape, to the national/regional level and to the globe. The basic processes controlling surface/atmosphere  $NH_3$  exchange are relatively well understood, at least qualitatively. A wide range of factors are important, including: thermodynamics, meteorology, surface and air column heterogeneous chemistry, plant physiology and N uptake, ecosystem N cycling, compensation points, nitrogen inputs via fertilization and atmospheric deposition, leaf litter decomposition, SOM and soil microbial turnover, soil properties. There has been a gradual increase in the complexity of surface/atmosphere  $NH_3$  exchange models, from simple steady-state resistance models to dynamic, multiple layer, multiple sink/source, multiple chemical species exchange models. This reflects both the improvement in process understanding and the increasing availability of flux datasets, which are needed to parameterize models. Modelling and measuring the leaf-level processes that drive bi-directional air-surface exchange of N remains a challenge and a key issue for improving the predictive capability of existing models at the field scale.

<sup>1</sup> INRA, UMR1091 INRA-AgroParisTech Environnement et Grandes Cultures, 78850 Thiverval-Grignon, France

<sup>2</sup> INRA, Agrocampus Ouest, UMR1069 Sol Agro-hydrosystème Spatialisation, 35042 Rennes, France

## Constraints on air quality model budgets of the sources and sinks of reactive trace gases

Daven K. Henze

One of the most valuable diagnostics from air quality models is spatially and seasonally detailed estimates of chemical deposition. These modeling tools enable us to estimate the impacts of emissions controls on acid deposition, or to predict how future emissions might govern reactive nitrogen deposition. Measurements of deposition present a valuable means of benchmarking the models' budget for specific tracers, and enforced consistency between predicted and observed deposition is often used to adjust model emissions. We will present some regional and global scale estimates of the roles of different reactive nitrogen species, their deposition in specific regions, and the constraints that measured deposition places on their sources. Further, since deposition is still fundamentally a notoriously difficult process to simulate reliably in air quality models, we will also consider the extent to which in situ or remote sensing measurements can compliment deposition observations for constraining both sources and sinks.

## Preferential Canopy Uptake of Nitrate and Consequences for Deposition Monitoring in Forests of the Pacific Northwest, USA

Mark E. Fenn, Christopher S. Ross, and Susan L. Schilling

Throughfall deposition of N and S was measured in three national parks in Washington State and compared to NADP wet deposition. Throughfall deposition of  $\text{NO}_3$  in the three parks was 80-90% lower than wet deposition of  $\text{NO}_3$ . In contrast,  $\text{NH}_4$  deposition in throughfall was 1.5 – 2.8 times greater in throughfall. This strong preferential canopy uptake of wet-deposited  $\text{NO}_3$  has now been reported for 38 stands in the Pacific Northwest region of the United States, 21 of which are newly reported data. The phenomenon sometimes occurs in other regions, but appears to be ubiquitous in the Pacific Northwest, and it complicates the interpretation of throughfall monitoring data. In more polluted sites (e.g., throughfall N deposition > ca. 3-4 kg/ha/yr) elevated levels of washoff of dry-deposited  $\text{NO}_3$  from the canopy obscures detection of canopy consumption of  $\text{NO}_3$ . In the three parks simulated annual  $\text{NH}_4$  deposition (CMAQ model) was 2.1 times greater than measured throughfall deposition of  $\text{NH}_4$ ; simulated  $\text{NO}_3$  deposition was 15.6 times greater than throughfall deposition of  $\text{NO}_3$ . Preferential canopy consumption of  $\text{NO}_3$  was not observed in relatively low deposition forest sites in California, including Yosemite National Park and in the northern Sierra Nevada. The hypothesized mechanism for the preferential canopy  $\text{NO}_3$  uptake in the Pacific Northwest is the result of  $\text{NO}_3$  uptake by moistened stems, branches and bark. Total (wet + dry) inorganic N deposition was calculated for the three parks using sulfur deposition measurements from ion exchange resin throughfall collectors and wet deposition S/N ratios. It was assumed that S/N ratios are equivalent in throughfall and wet deposition and that throughfall S deposition fluxes approximate total S deposition inputs. Support for this approach of estimating total inorganic N deposition from throughfall data will be presented.

Department of Mechanical Engineering, University of Colorado, Boulder, Colorado  
80309, United States  
Email: Daven.Henze@colorado.edu

USDA Forest Service, 4955 Canyon Crest Dr., Pacific Southwest Research Station,  
Riverside, California, 92507 USA; [mfenn@fs.fed.us](mailto:mfenn@fs.fed.us) Tel. 951-680-1565

**POSTER SESSION**

IN ALPHABETICAL ORDER BY AUTHOR



## Investigation of Potential In-Canopy Vegetative Uptake of Ozone and other Gases at Maine's Howland Research Forest

Greg M. Beachley<sup>a</sup>, Christopher Rogers<sup>b</sup>, Kevin Mishoe<sup>c</sup>

### Abstract:

From September 2011 to April 2013, the Clean Air Status and Trends Network (CASTNET) conducted a collaborative effort with Ameriflux to investigate atmospheric to vegetative exchanges of ozone and sulfur and nitrogen species at the Howland Research Forest Ameriflux site in Maine. The forest is comprised of mature, lowland evergreen trees aged 40 to 160 years with a local canopy height of 20 m. Measurements taken at the site consisted of hourly ambient ozone concentrations sampled at eight levels throughout and above the evergreen canopy and weekly integrated ambient concentrations of gases and particles from CASTNET filter packs located above and below the canopy. Design for the ozone system centered on the use of a single ozone analyzer and site transfer standard in conjunction with a solenoid system to allow for all eight levels to be measured with a residence time > 20 s using the same analyzer. Daily quality assurance and analyzer performance showed no evidence of line loss.

Hourly ozone data shows evidence of episodic, nighttime negative concentration gradients with decreasing sampling heights that may indicate potential deposition and scavenging mechanisms occurring within the canopy. These losses were statistically compared with atmospheric stability and moisture parameters to identify potential drivers of vegetative uptake and discern from existing gradients due to poor mixing within the canopy. Loss events, defined when measured ozone concentration at the canopy floor is < 50% of the above canopy concentration, appear stability dependent and rarely occur at low wind speeds and small temperature differences at the above and below canopy levels. Loss events also occur at relative humidity levels higher than 60%. Weekly-integrated ambient concentrations measured with the filterpack support these observations, having below canopy concentrations of approximately 60% and 64% of above-canopy concentrations for sulfur dioxide and total nitrate (including gaseous nitric acid), respectively. Above and below-canopy concentrations for concentrations of particulate matter components (i.e. total ammonium and sulfate) show much less difference, which may be indicative of slower deposition rates than those of the gaseous species.

<sup>a</sup> Clean Air Markets Division, U.S. Environmental Protection Agency, Washington, DC 20460, U.S.A

<sup>b</sup> AMEC Inc., Jacksonville, FL

<sup>c</sup> AMEC Inc., Newberry, FL

## Nitrogen Deposition: Trends and Impacts in the Greater Yellowstone Area

Tamara Blett<sup>1</sup> and Terry Svalberg<sup>2</sup>

Air quality and ecosystem monitoring and research indicate that anthropogenic nitrogen pollution is beginning to alter sensitive ecosystems in the Greater Yellowstone Area (GYA). Some GYA lakes may be at the early stages of eutrophication (nitrate concentrations are at levels where algal species may increase), and some lakes are beginning to acidify (lose acid neutralizing capacity). Lake sediment cores show increasing influences of anthropogenic nitrogen and degraded lichen communities are present in areas of higher nitrogen deposition. Although the ecosystems changes are subtle, an increasing weight of evidence points to declining health in aquatic and terrestrial ecosystems in the GYA. Deposition and ambient air monitors also indicate that nitrogen compounds in air, rain, and snow are increasing in several areas of the GYA. Critical loads indicating thresholds of change for chemical and biological endpoints have been developed to show the levels of nitrogen specifically impacting different ecosystem components in the GYA. Critical loads in the GYA can: (1) Help National Park and National Forest land managers set goals to protect and improve resource conditions and (2) Serve as benchmarks identifying areas and pollutants for which State and Regional Plans to improve air quality would be most effective.

1. National Park Service, Air Resources Division, PO Box 25287, Lakewood, CO 80225. 303-969-2011. [Tamara\\_blett@nps.gov](mailto:Tamara_blett@nps.gov)
2. USDA Forest Service, Pinedale Ranger District, 29 East Fremont Lake Rd. P.O. Box 220 Pinedale, WY 82941. 307-367-4326. [tsvalberg@fs.fed.us](mailto:tsvalberg@fs.fed.us)

## Liming to Accelerate the Recovery of Acidified Ecosystems: A Case Study in the Adirondack Mountains of New York

Douglas A. Burns, Karen Riva Murray, Gregory B. Lawrence,  
Charles T. Driscoll, Cliff E. Kraft & Daniel C. Josephson

The Adirondack region of New York State is sensitive to acidic deposition, and widespread effects on aquatic and terrestrial ecosystems in this region have been demonstrated. As of the mid-1980s, about 25% of Adirondack lakes had become too acidic ( $ANC < 0$  meq/L,  $pH < 5.0$ ) to support a healthy fish community, and brook trout were believed to have been extirpated from many lakes. Since that time, precipitation acidity has decreased greatly as the Clean Air Act and its amendments were implemented and emissions of  $SO_2$  and other acid precursors declined. Precipitation pH at Huntington Wildlife Station, for example, has increased from about 4.3 in the mid-1980s to 5.0 in 2011, an 80% decline in acidity. As a result of decreased acid deposition, lakes in the Adirondacks have begun to recover; widespread decreases in  $SO_4^{2-}$  and Al concentrations along with increases in pH and ANC have been reported. Notably, some lakes with ANC values near or below zero have now improved to above zero indicating conditions more favorable for a diverse aquatic biological community. Declines in lake acidity thus far have been less than those of atmospheric deposition, and limited biological data suggest a slow recovery to a pre-acidification community, hindered in part by the slow pace of soil recovery from base cation loss. We are studying the effects of stream and watershed liming in several tributaries to Honnedaga Lake in the southwestern Adirondacks as a means of accelerating aquatic and terrestrial ecosystem recovery. This lake was acidified to summer pH values  $< 5.2$  in the 1960s through the 1980s, but recent values have risen to about 5.5, a threshold accompanied by decreases in Al concentrations. The lake and its tributaries contain a heritage strain of brook trout whose numbers were greatly diminished as acidification progressed. While the population density of these trout has increased in recent years in parallel with improvements in water quality, numbers remain low due to the sluggish recovery. Liming is being studied as a method for improving brook trout recruitment in key lake tributaries with an aim of providing guidance for future liming activities that may improve fisheries management in the Adirondack region. Unintended consequences of liming such as potential increases in Hg bioaccumulation are also being studied in this ecosystem. Recent results from this study will be discussed.

Douglas A. Burns, U.S. Geological Survey, 425 Jordan Rd., Troy, NY 12180, 518-285-5662, daburns@usgs.gov

Karen Riva Murray, U.S. Geological Survey, Troy, NY

Gregory B. Lawrence, U.S. Geological Survey, Troy, NY

Charles T. Driscoll, College of Engineering and Computer Science, Syracuse Univ., Syracuse, NY

Cliff E. Kraft, Dept. of Natural Resources, Cornell Univ., Ithaca, NY

Daniel C. Josephson, Dept. of Natural Resources, Cornell Univ., Old Forge, NY

## Atmospheric ammonia measurements at low concentration sites in the northeastern USA: implications for nitrogen deposition and comparison with CMAQ estimates

Tom Butler<sup>\*1,2</sup>, Roxanne Marino<sup>2</sup>, Donna Schwede<sup>3</sup>, Robert Howarth<sup>2</sup>, Jed Sparks<sup>2</sup> & Kim Sparks<sup>2</sup>

Long-term monitoring sites for atmospheric deposition have only recently begun to measure  $NH_3$  gas. We evaluate the importance of ammonia deposition at two headwater areas of the Susquehanna River, that are remote from major sources of ammonia emissions: Connecticut Hill (CTH) in central NY State and the Kane Experimental Forest (KEF) in NW Pennsylvania.

We used Ogawa passive samplers to measure ammonia concentrations during all seasons over several years for CTH, and mainly in 2009 for KEF. Chamber calibration studies and field comparisons with annular denuders for ammonia validated the use of these passive samplers over a range of temperatures and humidities observed in the field. Seasonal  $NH_3$  concentration trends were consistent for these, and another forested site near CTH. The annual mean concentrations were twice as high at CTH than at KEF:  $0.48$  vs  $0.24 \mu g NH_3 m^{-3}$ . For CTH, this value is very close to the estimate from the CMAQ model, while at KEF the mean of our measured values was 2.5-fold higher than the CMAQ estimate.

Concentration and deposition velocity ( $V_d$ ) can be correlated and ignoring this correlation when using average values to determine flux can result in errors. Monthly *concentration-weighted*  $V_d$ 's, based on hourly CMAQ concentrations and hourly  $V_d$ 's, and applied to mean monthly CMAQ concentrations, produce nearly the same depositions based on the sum of hourly depositions, thus compensating for the correlation effect. Using our ammonia concentration data and these monthly concentration-weighted  $V_d$ 's, we estimate dry gaseous  $NH_3$  deposition as  $2.0$  and  $1.4 kg N ha^{-1} yr^{-1}$  at CTH and KEF, respectively. Approximately 70% of this deposition occurs between April and September.

CTH and KEF CMAQ estimates of all modeled N deposition species are compared with total deposition estimates incorporating CASTNET, NADP and passive sampler data, where available (hybrid approach). CMAQ and the hybrid approach yield deposition values of  $9.7$  and  $9.5$ , respectively for CTH, and  $10.1$  and  $9.2 kg N/ha-yr$ , respectively for KEF. Approximately 85% of these depositions are from dry  $HNO_3$  and  $NH_3$ , and wet  $NO_3^-$  and  $NH_4^+$ . The hybrid approach, based on measured concentrations, yields lower depositions for  $HNO_3$  and higher  $NH_3$  depositions. Wet  $NH_4^+$  deposition is 20% to 25% higher than CMAQ estimates, and wet  $NO_3^-$  are nearly equal for both approaches. CMAQ estimates of wet organic N deposition for these sites, appear to be too low by  $\sim 0.5$  to  $1.0 kg N/ha-yr$ , compared to literature values.

\*corresponding author ([tjb2@cornell.edu](mailto:tjb2@cornell.edu); 607 255-3580); <sup>1</sup>Cary Institute of Ecosystem Studies, Millbrook, NY; <sup>2</sup>Ecology & Evolutionary Biology, Cornell University, Ithaca, NY; <sup>3</sup>Atmospheric Modeling and Analysis Division, National Exposure Research Lab, US EPA, RTP, NC

## Spatial distribution of ecologically relevant atmospheric compounds in native Sonoran Desert protected areas within and surrounding Phoenix, Arizona

Elizabeth M. Cook<sup>1\*</sup> and Sharon J. Hall<sup>1</sup>

Urban air quality is expected to have significant impacts on protected lands both within the urban boundary and the surrounding native ecosystem. Atmospheric reactive nitrogen (N) compounds, ozone (O<sub>3</sub>) and carbon dioxide (CO<sub>2</sub>) are elevated near human dominated ecosystems and individually act as a resource or stressor to ecosystems, but their co-occurring distribution and ecological effects in protected lands is uncertain. Local urban air quality monitoring programs routinely measure O<sub>3</sub> and nitrogen oxides (NO<sub>x</sub>) to meet human health regulations, but the spatial resolution is often restricted to residential areas. In contrast, ecologically important compounds such as ground-level CO<sub>2</sub> and highly reactive N compounds are not monitored in either cities or remote protected lands. We compared the spatial distribution of atmospheric nitric acid (HNO<sub>3</sub>), ammonia (NH<sub>3</sub>), NO<sub>x</sub>, O<sub>3</sub>, and CO<sub>2</sub> concentrations in native Sonoran Desert parks within and surrounding Phoenix, Arizona. Using a spatially extensive design, we monitored reactive N and O<sub>3</sub> with co-located passive samplers and CO<sub>2</sub> with three portable infrared gas analyzers in 10 protected open space parks. Additionally, using a 1500 meter transect within one large desert open space within the city, we examined reactive N and O<sub>3</sub> concentrations along a gradient from the exterior to the interior of the park.

Concentrations of reactive N are higher in desert open space parks within the city compared to the surrounding desert. For example, HNO<sub>3</sub> concentrations were not significantly different between four desert parks within the city (5.1 +/- 0.23 ug/m<sup>3</sup>), but together, they were higher than HNO<sub>3</sub> concentrations in surrounding desert parks east (3.4 +/- 0.4 ug/m<sup>3</sup>) or west (3.2 +/- 0.3 ug/m<sup>3</sup>) of the metropolitan region. Along the interior park transect, HNO<sub>3</sub> concentrations were up to 60% lower within the park (2.7 +/- 1.0 ug/m<sup>3</sup>) than at the outer urban edge (4.7 ug/m<sup>3</sup>). These results suggest that the interior of large open, protected spaces may experience minimal pollutant loading, similar to surrounding desert areas. Accounting for diurnal variation, atmospheric CO<sub>2</sub> concentrations varied surprisingly little among locations, remaining consistently elevated near 380–400 ppm. This study is the first to identify the distinct spatial pattern of co-occurring, ecologically important urban pollutants within protected lands. To preserve the integrity of key ecosystem services for people, 50-75% of whom live in cities, our findings highlight the need for air quality monitoring at multiple spatial scales, including an expanded repertoire of compounds that are known to affect ecosystem structure and functioning.

<sup>1</sup> School of Life Sciences, Arizona State University, Tempe, Arizona

\*Elizabeth Cook: School of Life Sciences, PO Box 874601, Arizona State University, Tempe, Arizona, 85287-4601, Elizabeth.M.Cook@asu.edu, Phone: 617.549.9145

## An automated system to monitor total mercury in MDN precipitation collectors

Joel Creswell<sup>1</sup>, Erik Haugaard<sup>1</sup>, Mark Johnson<sup>1</sup>, Steve Gunther<sup>1,2</sup>, Jeremy Divis<sup>1</sup>, Colin Davies<sup>1</sup>

Mercury Deposition Network precipitation collectors are currently sampled weekly and samples are shipped to the Mercury Analytical Laboratory for analysis. This system has been rigorously tested and has produced years' worth of reliable data, but has several downsides including a delay between sample collection and the availability of results, weekly time resolution (not individual rain events), and the expense of sending field personnel to the site and shipping samples. Brooks Rand Instruments is developing an automated mercury monitor to address some of the downsides of the current MDN protocol. This instrument will collect samples directly from a modified precipitation collector and will analyze them for total mercury unattended in the field. The instrument will be capable of analyzing at intervals determined by precipitation volume, or be started remotely by a site operator. It will provide results in real time and these will be accessible from anywhere via the internet. Increasing the time resolution of MDN data has benefits for data users, who will gain the ability to monitor individual rain events or even multiple samples within each rain event. Decreasing the cost of generating total mercury data has benefits for site operators, many of whom struggle with tightening state budgets.

Our poster presentation will include conceptual renderings of the instrument and will demonstrate how it will interface with a modified MDN precipitation collector. We will also present a plan for testing and evaluating the instrument following NADP guidelines.

**Authors:** Joel Creswell (joel@brooksrandinc.com)<sup>1</sup>, Erik Haugaard (erik@brooksrandinc.com)<sup>1</sup>, Mark Johnson (mark@brooksrandinc.com)<sup>1</sup>, Steve Gunther (sgunther@nceelabs.com)<sup>1,2</sup>, Jeremy Divis (jeremy@brooksrandinc.com)<sup>1</sup>, Colin Davies (colin@brooksrandinc.com)<sup>1</sup>

**Institutional Affiliations:** <sup>1</sup>Brooks Rand Instruments, 4415 6<sup>th</sup> Ave NW, Seattle, WA 98107, 206-596-8477; <sup>2</sup>Now at NCEE Labs, 4740 Discovery Drive, Lincoln, NE 68521, 402-323-6233

## Laboratory Quality Assurance Method and Characterization of Ogawa Passive Samplers for SO<sub>2</sub> and NO<sub>2</sub> Measurements

Tracy L. Dombek\*, Prakash Doraiswamy, Eva Hardison, Larry Michael, Jeff Nichol, and Eric Poitras RTI International, Research Triangle Park, NC

Passive sampling devices are advantageous for measurement of gaseous pollutants because they are relatively inexpensive, require no power, and can be deployed virtually anywhere for monitoring. Passive samplers are also very useful in evaluating hot-spots and to examine the spatial pattern of pollutant distribution for applications such as identifying locations for continuous monitoring as well as supplement long-term regional monitoring.

RTI has been performing analysis of passive samples for ammonia, sulfur dioxide, nitrogen dioxide, NO<sub>x</sub>, and ozone for numerous government and commercial clients since 1998. While excellent results have been obtained with Ogawa NO<sub>2</sub>/NO<sub>x</sub> and O<sub>3</sub> passive samplers as compared to continuous monitors operating in tandem, the use of SO<sub>2</sub> passive samplers sometimes produces questionable results, especially for exposure durations of one day or less. In these cases, the SO<sub>2</sub> blank (unexposed) sampler shows a higher SO<sub>4</sub><sup>-2</sup> loading than the exposed passive samplers, resulting in a negative calculated atmospheric SO<sub>2</sub> concentration when a blank correction is applied.

The purpose of this research project is to characterize the performance of Ogawa passive samplers and develop a method which will provide quality assurance for Ogawa passive samplers. Here, we generate known concentrations of SO<sub>2</sub> and NO<sub>2</sub> gases from certified EPA Protocol gas cylinders and expose the passive samplers under controlled conditions in an enclosed sampling train. The sampling system is also capable of varying temperature and relative humidity, thereby enabling examination of the performance over a range of environmental conditions. We will present preliminary results from this study on the performance of Ogawa samplers under defined laboratory conditions. The intent of the study is to: (1) reveal any interference that may result in blank samples showing higher SO<sub>2</sub> loadings than exposed samples and (2) provide an improved understanding of the influence of environmental parameters on their performance for both SO<sub>2</sub> and NO<sub>2</sub>.

\*Tracy L. Dombek, presenting author  
Environmental Chemistry Division  
RTI International  
3040 Cornwallis Road Research Triangle Park, NC 27709-2194  
919 541-5934 [tdombek@rti.org](mailto:tdombek@rti.org)

## A bi-directional exchange model of ammonia (SurfAtm-NH<sub>3</sub>) used as a tool in order to investigate the main compartments at the field scale for ammonia source and sink after slurry application over a growing wheat

Personne Erwan, Tardy Florence., Decuq Céline, Générumont Sophie, Durand Brigitte, Fanucci Olivier, Gueudet Jean-Christophe, Lauransot Michel, Mascher Nicolas, Masson Sylvie, and Loubet Benjamin.

The current NH<sub>3</sub> bi-directional exchange models have significantly improved estimates of emission and deposition fluxes over the ecosystems. The SurfAtm-NH<sub>3</sub> model is a coupled model for energy balance, and exchange of NH<sub>3</sub>, at the field scale. It is based on a resistive scheme similar for energy and NH<sub>3</sub> exchanges. It distinguishes three compartments for the exchanges with the atmosphere: soil, stomatal and cuticular pathway. This model is used here to interpret the results of a measurement campaign for a wheat crop in 2012, after manure application. Physico-chemical measurements were carried out and were used to calculate the potential emissions of the three compartments (and their dynamics with time). The integration of these measured emission potentials in the model were used to test various scenarios to determine the source of NH<sub>3</sub> from the ground. Tests were conducted on ground resistance by searching for predictors of the strong soil/manure contribution of the NH<sub>3</sub> emission the first few days after manure application. The results suggested to distinguish three different periods after the manure application, *i*/ a period of one day when the NH<sub>3</sub> emission comes directly from the ground surface without transfer resistance from the soil surface, indicating that there were no manure infiltration into the soil, *ii*/ a two-week period during which the source comes mainly from NH<sub>3</sub> slurry which were gradually infiltrated into the soil and the last period, three weeks after the application of manure, during which the emission from the ground can be considered negligible. For the latter period, the NH<sub>3</sub> fluxes were mainly deposition which depends on the exchanges with the leaves (stomatal and cuticular deposition). Regarding the intermediate period during which the soil were a NH<sub>3</sub> pool for emission, if the main source is identified, the factors regulating this issue appear complex. In fact, soil resistance for NH<sub>3</sub> transfer seems to be dependent on the soil evaporation.

UMR 1091 Environnement et Grandes Cultures, INRA-AgroParisTech, , 78850 Thiverval-Grignon, France.

Corresponding authors : [erwan.personne@agroparistech.fr](mailto:erwan.personne@agroparistech.fr)  
Tel : +33 1 30 81 55 70

## Soil flux of methane and other hydrocarbons in an oil and gas field

Jordan Evans

The explosive growth of oil and gas production in the United States has focused public and regulatory attention on environmental impacts of hydrocarbon extraction, including air quality and climate impacts. EPA and others have acknowledged that current air emissions factors and inventories for many oil and gas-related source categories are inadequate or lacking entirely. One potentially important emissions source is leakage of natural gas from wellbores and other soil seepage. This phenomenon has long been recognized to occur, but no attempt has been made to quantify emission rates of gas leaked from wellbores to the atmosphere.

Soil gas measurements carried out by USGS over the last several years in Utah's oil and gas fields have shown that, while concentrations of methane in soils near wells are typically low, soil gas near some wells contains more than 10% methane. In summer 2013 we carried out a campaign to measure the emission rate of methane and other hydrocarbons from soils near wells in two oil and gas fields in Utah. We also measured at varying distances from wellheads to determine the change in emission rate with distance from well heads, and we measured emissions at non-well sites in the same area to determine background emission rates. Methane emission rates at some wells exceeded  $3 \text{ g m}^{-2} \text{ h}^{-1}$ , while emission rates at other wells were similar to background levels, and a correlation was observed between soil gas methane concentrations and methane emission rates from the soil. We used these data to estimate total methane and hydrocarbon emission rates from these two fields.

Jordan Evans  
[evansjord@gmail.com](mailto:evansjord@gmail.com)

## 10 Years of Trend Data for the Sapelo Island National Estuarine Research Reserve SINERR (GA 33) Latitude 31.3961 Longitude -81.2811 & the National Weather Service Data collected by the University of Georgia Marine Institute Station 097808 Latitude 31.3972 Longitude -81.2811

Aimee Gaddis

In December 1976 the Sapelo Island National Estuarine Research Reserve (SINERR) was designated to establish and provide opportunities for long-term research, education and interpretation in an ecologies typical Carolinian biogeographic region and incorporates a coastline characterized by expanses of tidal salt marshes protected by a chain of barrier islands. SINERR joined the NADP in November 2002. The GA 33 station has been collecting data for 10 years. In close proximity to the GA33 NADP station is the University of Georgia Marine Institute National Weather Service station 097808 that began in 1964. This poster will compare the last 10 years of rain fall data collected at these two stations.

Affiliation: Sapelo Island National Estuarine Research Reserve and the Georgia Department of Nature Resources Wildlife Management Program  
Author: Aimee Gaddis  
Phone Number: 912-485-2251  
Mailing Address: P.O. Box 15, Sapelo Island, Georgia 31327  
E-mail Address: [Aimee.Gaddis@dnr.state.ga.us](mailto:Aimee.Gaddis@dnr.state.ga.us)

## NTN Sample Dilution

Nina Gartman<sup>1</sup>, Mark Rhodes<sup>1</sup>, Christopher Lehmann<sup>1</sup>, and Tracy Dombek<sup>2</sup>

The National Atmospheric Deposition Program's National Trends Network (NADP/NTN) analyzes weekly precipitation samples for free acidity, specific conductance, calcium, magnesium, sodium, potassium, sulfate, nitrate, chloride, ammonium, orthophosphate and bromide. Historically, approximately 3% of NTN samples each year have sufficient volume to measure only pH, or pH and conductivity. An additional 3% of the samples are classified as wet-dilute (WD) samples. WD samples are diluted in order to have sufficient volume to measure the full suite of NTN analytes. A study was conducted by personnel from the Central Analytical Laboratory (i.e., the NTN laboratory) and the NADP Program Office to assess the uncertainty that is introduced as a result of sample dilution. Results from this study suggest that possible changes in NTN protocol may help minimize the uncertainty in the measurements.

## Preliminary Back Trajectory Analysis of Reactive Nitrogen Measured during the 2011 GrandTREnds Study at Grand Teton National Park, WY

Kristi A. Gebhart<sup>1</sup>, Anthony J. Prenni<sup>2</sup>, Michael G. Barna<sup>1</sup>, Bret A. Schichtel<sup>1</sup>, William C. Malm<sup>3</sup>, Ezra J.T. Levin<sup>2</sup>, Katherine B. Benedict<sup>4</sup>, Amy P. Sullivan<sup>2</sup>, Jeffrey L. Collett Jr.<sup>2</sup>, Tammy Thompson<sup>3</sup>, Derek Day<sup>3</sup>

Grand Teton National Park (GTNP), Wyoming includes natural areas sensitive to excess nitrogen deposition and it is near nitrogen sources including agricultural activities in Idaho's Snake River Valley to the west and oil and gas extraction in the Upper Green River Basin to the east. The Grand Teton Reactive Nitrogen Deposition Study (GrandTREnds) was conducted in 2011 to better understand potential sources of reactive nitrogen influencing the region.

The core measurement site was located at an elevation of 2722 m near GTNP, at Grand Targhee Ski Resort. The resort is in Targhee National Forest on the western slope of the Teton Mountains, and falls within the Greater Yellowstone Ecosystem. Most measurements at the core site began in late July and continued until September 22, 2011.

Air mass back-trajectories were calculated with the Hybrid Single-Particle Lagrangian Integrated Trajectory Model (HYSPPLIT) with input from the 12-km North American Mesoscale Forecast System (NAM12). Statistical analyses of these trajectories provide insight regarding the source regions that impacted the core site during the study period. These analyses show that, on average, airmasses arrived predominantly from the west, including from the Snake River Valley, and from the southwest, including northern Utah. Airmasses from throughout the region, including western Wyoming, also impacted the site at various times throughout the study.

During a period when measured concentrations indicated biomass burning impacts at the core site, trajectories suggested airmasses reached the site after passing through multiple areas with active fires in Wyoming, Idaho, and Montana as detected from satellite. Also, concentrations of oxidized nitrogen at the core site appear to be at least partially driven by a mountain-valley flow pattern with daytime up valley flows primarily from the southwest and nighttime downslope flows mostly from the southeast at the core site.

<sup>1</sup>National Park Service, Air Resources Division, CIRA, Colorado State University, Fort Collins, CO

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

<sup>3</sup>Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University, Fort Collins, CO

<sup>4</sup>University of California at Davis, Davis, CA

Contact info for Kristi Gebhart:  
970-491-3684  
[kristi\\_gebhart@nps.gov](mailto:kristi_gebhart@nps.gov)

<sup>1</sup>Illinois State Water Survey/Prairie Research Institute, Champaign, Illinois

<sup>2</sup>Research Triangle Institute, Research Triangle Park, North Carolina

## Climate controls on the fate of anthropogenic nitrogen additions in hot desert ecosystems

D.P. Huber\*<sup>1</sup>, K.A. Lohse<sup>1</sup> and S.J. Hall<sup>2</sup>

**Abstract:** Rapid urbanization in dryland regions is increasing nitrogen (N) emissions and deposition yet the fate of this N is poorly constrained. Long-term experimental N additions have shown no significant aboveground shrub response whereas herbaceous cover has responded positively when accompanied by average or above average winter rains. Retention of N in surface soils receiving long-term N additions has not been able to explain the fate of N additions. Here we show significant storage of anthropogenic N in deep soils (average 84% of applied N) and strong climate controls on retention of N. Under-plant storage of applied ammonium declined with small increase in precipitation ( $r^2=0.99$ ,  $P=0.08$ ) whereas retention of nitrate increased dramatically across the same gradient ( $r^2=0.99$ ,  $P=0.03$ ). A simple model coupling ammonium oxidation kinetics to soil water potential in Hydrus 1-D explained much of the excess residual nitrate found in N plots; wind or water redistribution from inter-plant spaces to under-shrubs may also be responsible. Soil N storage in inter-plant spaces showed no correlation with precipitation or temperature. Our findings suggest subtle changes in precipitation predicted over the next several decades may have important consequences for the fate of anthropogenic N in desert ecosystems. This work highlights the critical nature of understanding N retention processes in dryland systems and the need for future research efforts.

D.P. Huber\*<sup>1</sup>, K.A. Lohse<sup>1</sup> and S.J. Hall<sup>2</sup>.

<sup>1</sup>Department of Biological Sciences, Idaho State University, 921 S. 8<sup>th</sup> Ave. Stop 8007, Pocatello ID 83201-8007; <sup>2</sup>School of Life Sciences, Arizona State University, PO Box 874501, Tempe AZ 85287-4501.

\*David P. Huber  
(970) 420-7708  
Department of Biological Sciences  
Idaho State University  
921 S 8<sup>th</sup> Ave. Stop 8007  
Pocatello, ID 83209-8007  
[hubedavi@isu.edu](mailto:hubedavi@isu.edu)

## Data Quality Explorations Using Duplicate Measurements

Nicole P. Hyslop<sup>1</sup> and Warren H. White<sup>1</sup>

The Interagency Monitoring of Protected Visual Environments (IMPROVE) program is a cooperative measurement effort in the United States designed to characterize current visibility and aerosol conditions in scenic areas (primarily National Parks and Forests) and to identify chemical species and emission sources responsible for existing man-made visibility impairment. In 2003 and 2004, the IMPROVE network began operating collocated samplers at several sites to evaluate the measurement quality.

Environmental measurements are subject to uncontrolled natural variations that are difficult to reproduce in the laboratory. Collocated measurements are the most direct and comprehensive approach to characterizing measurement quality because the observed differences reflect the actual measurement performance under the natural environmental variability. Collocated data have been used extensively to estimate measurement precision but these rich data sets can be used to explore several additional data characteristics. This presentation uses collocated measurements from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network to explore relationships between measurement precision and concentration, the existing model of precision, measurement error distributions, detection limits, and relationships among measurement errors in different species.

<sup>1</sup> Crocker Nuclear Laboratory, University of California, One Shields Ave., Davis, CA 95616, E-mail: [nmhyslop@ucdavis.edu](mailto:nmhyslop@ucdavis.edu), phone: 530-754-8979.

## THE EVOLUTION OF THE CLEAN AIR STATUS AND TRENDS NETWORK (CASTNET) 1986 TO CURRENT

Selma Isil<sup>1</sup>, Christopher Rogers<sup>2</sup>

The Clean Air Status and Trends Network (CASTNET) initially evolved from the National Dry Deposition Network (NDDN), which was established in late 1986 by EPA for the purposes of providing the National Acid Precipitation and Assessment Program (NAPAP) with estimates of dry deposition flux to use in model evaluation, determining spatial patterns of dry deposition, and relating deposition to ecological effects. In 1990, Congress amended the Clean Air Act (CAA) requiring emission reductions in sulfur and nitrogen oxides. A national monitoring network was mandated as part of these amendments in order to determine the effectiveness of the required emission reductions. EPA therefore established CASTNET in mid-1991, the data from which would be used to define the spatial distribution of pollutant and to detect and quantify trends in pollutants.

By the mid-nineties CASTNET consisted of approximately 50 sites with the majority located in the eastern U.S. Each site collected continuous ozone and meteorological data and measured weekly concentrations of sulfate and nitrate species as well as other various cations of interest using a filter pack system. CASTNET also featured visibility and mountain acid deposition related sub-networks. In 1994, the National Park Service (NPS) began its participation by sponsoring CASTNET sites in national parks, most of which were located in the western U.S.

Over the past decade, CASTNET has conducted numerous special studies including examining filter pack sampling artifacts and testing methods for measuring NH<sub>3</sub>. In 2011, CASTNET initiated a new collaboration with the AmeriFlux Network at Howland, Maine. Also in 2011, EPA completed the upgrade of CASTNET ozone measurements at EPA-sponsored sites to make them compliant with 40CFR Part 58 requirements and began delivering ozone data from EPA-sponsored sites to the EPA Air Quality System (AQS). NPS-sponsored CASTNET sites have always been considered 40CFR Part 58 compliant for ozone.

In 2012, CASTNET added the Bureau of Land Management (BLM) as a sponsor with the addition of four new sites in Wyoming (a fifth BLM-sponsored site was added in 2013). Other network expansion during 2012 included three new sites in the Adirondacks, National Core (NCore) Monitoring Network instrumentation at the Bondville, IL site, and conducting continuous trace-level gas analyses at several sites. Currently, CASTNET features measurements conducted at 88 locations.

<sup>1</sup> AMEC Environment & Infrastructure, Inc., 404 SW 140<sup>th</sup> Terr., Newberry, FL 32669, 352-333-6607, [ssisil@mactec.com](mailto:ssisil@mactec.com)

<sup>2</sup> AMEC Environment & Infrastructure, Inc., 3901 Carmichael Ave., Jacksonville, FL 32207, 904.391.3744, [cmrogers@mactec.com](mailto:cmrogers@mactec.com)

## Biological Sensors for Atmospheric Nitrogen Deposition

Amanda James, James Sickman, and Mark Fenn

The Integrated Total Nitrogen Input (ITNI) method is a technique for evaluating nitrogen deposition by utilizing plants as collection interfaces. The ITNI method employs a plant-liquid-sand system (PLS system) in which a plant is hydroponically grown in silica sand and labeled with <sup>15</sup>N tracer while growing in a greenhouse. After plants are labeled, they are deployed into the environment where the <sup>15</sup>N tracer in the plant tissues is diluted as a result of atmospheric nitrogen deposition input via gaseous, leaf and root uptake. At the end of the sampling period, all components of the plant and system are harvested and analyzed on a mass spectrometer to determine the degree of dilution of the tracer. The <sup>15</sup>N values obtained will be incorporated into a mass balance equation that accounts for the total deposition occurring on the PLS system surfaces and yields the total nitrogen uptake from the atmosphere. In this study, we will employ Coastal Sage Scrub (CSS) species, a declining native California plant assemblage, to determine total nitrogen deposition occurring in the Inland Empire of Southern California. Traditional nitrogen deposition collection devices such as throughfall and passive gaseous collectors will be co-located with the ITNI PLS systems to compare and assess the accuracy of such traditional collectors. We will also be simultaneously deploying prominent invasive species to determine, by rate of isotope dilution, if nitrogen deposition is assimilated more readily in invasives than natives. This will explore the notion that increased nitrogen deposition rates to CSS assemblages in turn encourage invasive species proliferation and subsequent displacement of native CSS species. Preliminary data shows that nitrogen mass balance in the ITNI systems may be compromised due to NO<sub>x</sub> flux, which we hope to investigate using a NO<sub>x</sub> box apparatus, as opposed to “microbial activity,” suggested by previous investigators using the ITNI method.

Authors: Amanda James, James Sickman, and Mark Fenn  
Affiliation: University of California Riverside: Environmental Sciences Department and US Forest Service: Pacific Southwest Research Station of Riverside, California

951-310-1544, 900 University Ave., Riverside, CA 92521, [acobb001@ucr.edu](mailto:acobb001@ucr.edu)



## Using $\delta^{15}\text{N}$ and passive air samplers to identify gradients of nitrogen deposition from a coal-fired power plant

Julie A. Kenkel, Kevin R. Hultine, Steven Sesnie, Thomas D. Sisk & Nancy C. Johnson

In the western U.S., current atmospheric reactive nitrogen (N) deposition is nearly 20 times that of pre-industrial levels. In areas with naturally occurring low N levels, any increase in N deposition can facilitate severe ecosystem alterations resulting in biodiversity loss and ecosystem decline. Long-range transport of atmospheric N pollution from point sources such as coal-fired power plants may elicit detectable shifts in nutrient cycling regimes in protected areas across the Southwest such as the Paria Plateau, in northeastern Arizona, USA. The atmospheric point source emission model, CALPUFF, predicts atmospheric N deposition across the Paria Plateau from the nearby coal-fired power plant, the Navajo Generating Station (NGS), to range from  $< 0.01$ -  $> 0.5 \text{ kg N ha}^{-1}\text{yr}^{-1}$ ; however, the terrestrial impacts across the predicted N deposition range are not known. This study examines air, soil, and vegetation along a distance gradient from the NGS. Atmospheric NO<sub>x</sub>, soil N, pinyon pine allometry and  $\delta^{15}\text{N}$  content of both soils and pinyon pine were collected across the plateau at a distance gradient from the NGS.

We found distance from the NGS explained over 80% of the variation in measured atmospheric NO<sub>x</sub> across the Paria Plateau ( $r^2 = 0.86$ ). We also found correlations between soils and vegetation and CALPUFF predicted N deposition. Both soil and foliar  $\delta^{15}\text{N}$  signatures were more positive in areas that received higher levels of N deposition (+3.00 ‰ to +10.32 ‰ and -3.1 ‰ to +9.7 ‰, for soil and foliar samples, respectively). The more positive  $\delta^{15}\text{N}$  signatures correspond to known ranges of  $\delta^{15}\text{N}$  signatures emitted from coal-fired power plants; this supports the use of isotopic signatures to provide insights into pollution sources and pathways in the environment. Also, pinyon pine allometric variables including branch volume/ needle area (cm) and branch volume/needle mass ( $\text{cm}^3/\text{g}$ ) showed indications of increased needle production in areas of higher NGS-derived N deposition. Our results suggest a correlation between atmospheric, soil, and vegetation nutrients and CALPUFF predicted N deposition patterns from the NGS. Identifying indicators of N deposition at the ground level bridges atmospheric models with shifts in terrestrial nutrient patterns to then begin to understand the impact of N enrichment in the ecologically sensitive semi-arid Southwest.

Julie A. Kenkel, School of Earth Science and Environmental Sustainability, Northern Arizona University, Flagstaff, AZ; jkenkel@gmail.com; (918) 740.2537.  
Kevin R. Hultine, Desert Botanical Garden, Phoenix, AZ, kevin.hultine@dbg.org, (480) 481-8195.  
Steven Sesnie, U.S. Fish and Wildlife Service, Spatial Ecologist Regional Office, Albuquerque, NM; Steven\_Sesnie@fws.org; (505) 248- 6631.  
Thomas D. Sisk, School of Earth Sciences and Environmental Sustainability, Northern Arizona University, Flagstaff, AZ; thomas.sisk@nau.edu; (928)523-7183.  
Nancy C. Johnson, Department of Biological Sciences, Northern Arizona University, Flagstaff, AZ; nancy.johnson@nau.edu; (928) 523-6473.

## Low-Power Instrumentation for Ozone Data Collection at Remote Sites

John L. Korfmacher and Robert C. Musselman

### Abstract:

The US Environmental Protection Agency (USEPA) has proposed lowering the 8-hour ozone standard from 75 to 70 ppb, and a new metric, W126, may be used in the future to evaluate ozone effects on vegetation. New continuous data collection requirements may be associated with the new standards, including remote-site monitoring. The US Forest Service, Rocky Mountain Research Station has developed hardware and procedures for deploying low-power ozone analyzers in remote locations. These stand-alone installations are automated, solar-powered, and pack-transportable. In this poster, we describe three versions of the installation with 3- and 4-season capability, ranging in cost from \$7960 to \$14,600. We include some observations of the instrument's operating characteristics, considerations for field deployment. Supplemental materials including engineering diagrams, sample datalogger programs, and parts lists with cost estimates will be available upon publication in late 2013.

### Authors:

John L. Korfmacher and Robert C. Musselman  
US Forest Service, Rocky Mountain Research Station  
Fort Collins, CO 80526 USA

John L. Korfmacher  
Physical Scientist  
USFS – Rocky Mountain Research Station  
240 W. Prospect Rd.  
Fort Collins, CO 80526 USA  
970.498.1052 ofc  
970.420.9890 cell  
jkorfmacher@fs.fed.us

**The National Atmospheric Deposition Program/Ammonia Monitoring Network (NADP/AMoN): Five Years of Trends**

Lehmann, Christopher<sup>a</sup>; Kerschner, Brian<sup>a</sup>; Gartman, Nina<sup>a</sup>; Green, Lee<sup>a</sup>; Gay, David<sup>a</sup>; Puchalski, Melissa<sup>b</sup>

The NADP's Ammonia Monitoring Network (AMoN) was established in October 2007 to routinely measure ammonia gas using cost-efficient passive type air samplers. The purpose of AMoN is to provide land managers, air quality modelers, ecologists, and policymakers critical data to assess the long-term trends in ambient NH<sub>3</sub> concentrations and deposition of reduced nitrogen species; validate atmospheric models; better estimate total nitrogen inputs to ecosystems; assess changes in atmospheric chemistry due to sulfur and nitrogen dioxide reductions; and assess compliance with fine particulate (PM<sub>2.5</sub>) standards.

The NADP/AMoN uses Radiello™ type passive samplers, which are deployed continuously over 2 week periods at each site at a standardized height (~2m). Triplicate samples and travel blanks are deployed randomly as an indicator of data quality. All site operators comply with the Standard Operating Procedures (SOPs), using only sampling materials provided by the NADP/AMoN. Further information about AMoN methods is available at <http://nadp.isws.illinois.edu/AMoN>.

Five-year (winter 2008 - fall 2012) AMoN trends were evaluated using the Seasonal Kendall Trend (SKT) test in the EnvironmentalStats version 2.0 package of S-PLUS 8.0. Statistical significance levels were set at  $p \leq 0.10$  for trend and at  $p > 0.10$  for seasonal homogeneity, indicating 90% confidence of trend existence. The trend slope magnitude was determined by the Sen's median estimator. Two-week deployments were aggregated into seasonal averages, as defined by the midpoint of the two-week period (i.e., December – February = meteorological winter, March – May = spring, etc.) Meteorological seasons were included in the trend analysis if they had a minimum of 9.75 weeks (i.e., 75%) valid data. All sites were included that had a minimum of 5 years' data, which comprised 14 sites.

Mean atmospheric NH<sub>3</sub> concentrations (2007 – 2012) at the 14 sites ranged from 0.32 – 3.42 µg/m<sup>3</sup>. Statistically-significant trends were determined at 8 of the 14 sites evaluated, and the overall magnitude of the trend ranged from 0.03 – 0.31 µg/m<sup>3</sup>-yr. All trends were increasing in magnitude, and statistically consistent across seasons.

<sup>a</sup> National Atmospheric Deposition Program, Illinois State Water Survey, University of Illinois at Urbana-Champaign; 2204 Griffith Dr., Champaign, IL 61820; [nadpca@isws.illinois.edu](mailto:nadpca@isws.illinois.edu)

<sup>b</sup> Clean Air Markets Division, U.S. EPA, 1200 Pennsylvania Ave. NW, Washington, D.C., (202) 343-9882, [puchalski\\_melissa@epa.gov](mailto:puchalski_melissa@epa.gov)

**TEMPORAL CHANGES IN pH, NON-SEA SALT SULFATE, NITRATE CONCENTRATIONS, SULFATE: SODIUM AND NITRATE:SODIUM RATIOS ASSOCIATED WITH CHANGES ANTHROPOGENIC EMISSIONS IN THE PENSACOLA BAY REGION**

Alexander Maestre, Jane M. Caffrey, William M. Landing, Nishanth Krishnamurthy, Arnout Ter Schure

Anthropogenic sulfur dioxide, nitrogen oxides and mercury emissions can lead to enhanced atmospheric deposition of these constituents and associated negative environmental impacts. Atmospheric wet deposition of mercury (Hg), trace metals, and the major ions nitrate (NO<sub>3</sub><sup>-</sup>), chloride (Cl<sup>-</sup>), sodium, and sulfate (SO<sub>4</sub>), etc. have been made in Pensacola, FL, USA from November 1, 2004 to December 31, 2012. Event based rain samples were collected at three inland sites since in 2004 and one marine background site since 2009. Over the last 7 years, local industries have completed multiple environmental projects that aim to reduce the emissions of chlorides, mercury, and sulfur to the environment. Examples of these projects include the installation of a flue gas Desulfurization System by a coal-fired power plant, Plant Crist. Our analyses indicate that there are statistical significant differences in the pH of wet samples collected in summer and winter compared with samples collected in spring and fall. We examine the effect of near regional sources (i.e. nearby coal power plants, cement plants, ocean) and their effect on rainwater pH, and major ion concentrations as well as ratios of Hg:Na, SO<sub>4</sub>:Na and NO<sub>3</sub>:Na. While there were no trends in mercury concentrations, both non sea salt sulfate and nitrate concentrations significantly declined over the seven year period. Ratios of Hg:Na did not change while SO<sub>4</sub>:Na and NO<sub>3</sub>:Na declined over this period. Nearby stations of the National Atmospheric Deposition Program showed a similar response.

\*Alexander Maestre School of Engineering, Department of Civil, Construction, and Environmental Engineering, University of Alabama, Box 870205, Tuscaloosa, Alabama 35487-0205, [aam30@students.uwf.edu](mailto:aam30@students.uwf.edu), 850-291-8443  
Jane M. Caffrey Center for Environmental Diagnostics and Bioremediation, University of West Florida, Pensacola, FL 32514, [jcaffrey@uwf.edu](mailto:jcaffrey@uwf.edu), 850-857-6089  
William M. Landing, Department of Earth, Ocean, and Atmospheric Science, Florida State University, 117 N. Woodward Ave., P.O. Box 3064320, Tallahassee, FL 32306-4320, [wlanding@fsu.edu](mailto:wlanding@fsu.edu), 850-644-6037  
Nishanth Krishnamurthy Department of Earth, Ocean, and Atmospheric Science, Florida State University, 117 N. Woodward Ave., P.O. Box 3064320, Tallahassee, FL 32306-4320, [nk08d@my.fsu.edu](mailto:nk08d@my.fsu.edu)  
Arnout Ter Schure Electric Power Research Institute, 3420 Hillview Avenue, Palo Alto, CA 94304, [aterschu@epri.com](mailto:aterschu@epri.com), 650-855-2281

## Effect of power-plant emission reductions on the Mount Zirkel Wilderness Area in northwestern Colorado

M. Alisa Mast<sup>1</sup> and Daniel Ely<sup>2</sup>

This study evaluates the effect of emission reductions at two coal-fired power plants in northwestern Colorado on a nearby wilderness area. Control equipment was installed at both plants during 1999-2004 to reduce SO<sub>2</sub> and NO<sub>x</sub> emissions. One challenge was separating the effects of local from regional emissions, which also declined during the study period. The long-term data sets examined confirm that emission reductions had a beneficial effect on air and water quality in the wilderness. Despite a 75% reduction in SO<sub>2</sub> emissions, sulfate aerosols measured in the wilderness decreased by only 20%. Because the site is relatively close to the power plants (<75 km), the slow rate of conversion of SO<sub>2</sub> to sulfate, particularly under conditions of low relative humidity, might account for this less than one-to-one response. On the clearest days, emissions controls appeared to improve visibility by about 1 deciview, which is a small but perceptible improvement. On the haziest days, however, there was little improvement perhaps reflecting the dominance of regional haze and other components of visibility degradation particularly organic carbon and dust. Sulfate and acidity in atmospheric deposition decreased by 50% near the southern end of the wilderness of which 60% was attributed to power-plant controls and the remainder to reductions in regional sources. Lake-water sulfate responded rapidly to trends in deposition declining at 28 lakes monitored in and near the wilderness. Although little change in acid-base status was observed, few of the lakes appear to be at risk from chronic or episodic acidification.

M. Alisa Mast<sup>1</sup> and Daniel Ely<sup>2</sup>

<sup>1</sup>U.S. Geological Survey, Colorado Water Science Center, Denver, CO 80225 (email: mamast@usgs.gov)

<sup>2</sup>Daniel Ely LLC, Lafayette, CO, 80026

## Using Epiphytic Lichens to Monitor Nitrogen Deposition Near Natural Gas Drilling Operations in The Wind River Range, WY, USA

Jill A. McMurray, Dave W. Roberts, Mark E. Fenn, Linda H. Geiser, Sarah Jovan

Rapid expansion of natural gas drilling in Sublette County, Wyoming (1999-present) has raised concerns about the potential ecological effects of enhanced atmospheric nitrogen (N) deposition to the Wind River Range (WRR) including the Class I Bridger Wilderness. We sampled annual throughfall (TF) N deposition and lichen thalli N concentrations under forest canopies in four different drainages of the WRR. Measurements of TF N deposition and N concentrations in lichen thalli were highest at plots closest to drilling operations (< 30 km). N concentrations in lichens decreased exponentially with distance from drilling activity. Highest TF N deposition, 4.1 kg ha<sup>-1</sup> year<sup>-1</sup>, coincided with clear evidence of damage to lichen thalli. This deposition value is above estimated preindustrial deposition conditions (0.9 kg N ha<sup>-1</sup> year<sup>-1</sup>) and regional critical loads (a deposition value below which ecosystem harm is prevented) of N deposition for sensitive ecosystem components. N concentrations in *Usnea lapponica* were strongly correlated (r = 0.96) with TF N deposition, demonstrating that elemental analysis of lichen material can be used to estimate TF N deposition. N concentrations below 1.35% in *U. lapponica* and 1.12% in *Letharia vulpina* were associated with 0.9 kg N ha<sup>-1</sup> year<sup>-1</sup>. Additional lichen sampling in the Bridger Wilderness is recommended to further quantify and monitor spatial patterns of N deposition and to define areas of elevated N deposition.

Jill A. McMurray  
U.S. Forest Service, Northern and Intermountain Region  
Air Resources Management Program  
Bozeman, MT 59711 USA  
e-mail: [jamcmurray@fs.fed.us](mailto:jamcmurray@fs.fed.us) phone: 406-223-8735

David W. Roberts  
Department of Ecology, Montana State University,  
Bozeman, MT 59717 USA

Mark E. Fenn  
US Forest Service, Pacific Southwest Research Station,  
Riverside, CA 92507 USA

Linda H. Geiser  
U.S. Forest Service, Pacific Northwest Region Air  
Resources Management Program,  
Corvallis, OR, USA

Sarah Jovan  
US Forest Service, Pacific Northwest Research Station,  
Portland, OR 97205 USA

## Spatial and Temporal Patterns of Wet and Dry Deposition of Mercury in Western North America

Kristi Morris<sup>1</sup>, Alisa Mast<sup>2</sup>, George Ingersoll<sup>2</sup>, Genine Wright<sup>3</sup>, Mae Gustin<sup>3</sup>, Chris Eckley<sup>4</sup>, Dave Schmeltz<sup>5</sup>, David Gay<sup>6</sup>, Alexandra Steffen<sup>7</sup>, Leiming Zhang<sup>7</sup>, Pierrette Blanchard<sup>7</sup>, Peter Weiss-Penzias<sup>8</sup>, Dan Jaffe<sup>9</sup>, Jill Webster<sup>10</sup>, and Mark Sather<sup>11</sup>

The Western North America Mercury Synthesis (WNAMS) is a collaborative effort to integrate information on mercury (Hg) emissions, transport and deposition, as well as methyl mercury (MeHg) production, bioaccumulation, and risk across the Western U.S., Canada, and Mexico. This paper evaluates the spatial and temporal patterns of wet, dry, and total Hg deposition over this region. Quantifying the atmospheric input of Hg to ecosystems is important in understanding how Hg and MeHg cycle through the environment resulting in risks to fish, wildlife, and humans. Understanding the spatial and temporal patterns of atmospheric Hg and deposition provides insight on the transport and fate of Hg emissions from source areas and types in Western North America. Characterizing deposition to this extensive region is difficult because (1) measurements of Hg deposition by the U.S. National Atmospheric Deposition Program are limited in time and space, and (2) the elevation and precipitation gradients are extreme, ranging from rainforests to mountains to deserts. The data sets presented here focus on Hg wet deposition. Other work to be incorporated into the assessment includes measurements of bulk Hg deposition, throughfall, atmospheric Hg concentrations, and fog, and data from passive samplers and surrogate surfaces. Temporal patterns will be presented and these spatially limited observations will be compared with global and regional atmospheric Hg models to examine the degree of consistency and to understand spatial patterns. The use of multiple data sets will allow us to compare deposition estimates obtained from different methodologies.

<sup>1</sup>National Park Service-Air Resources Division, PO Box 25287, Denver CO, 303-987-6941, kristi\_morris@nps.gov;

<sup>2</sup>US Geological Survey, Rocky Mountain Region, Colorado Water Science Center;

<sup>3</sup>University of Nevada, Reno;

<sup>4</sup>US Environmental Protection Agency (US EPA)-Region 10;

<sup>5</sup>US EPA-Clean Air Markets Division;

<sup>6</sup>NADP Program Office, Program Coordinator;

<sup>7</sup>Environment Canada;

<sup>8</sup>University of California, Santa Cruz;

<sup>9</sup>University of Washington, Bothell;

<sup>10</sup>US Fish and Wildlife Service-Air Quality Branch;

<sup>11</sup>US EPA-Region 6, Air Quality Analysis Section.

## Atmospheric Mercury Network (AMNet): For Estimates of Dry Deposition of Mercury

Mark L. Olson, David Gay, Tom Bergerhouse, Eric M. Prestbo, & David Schmeltz

The NADP Atmospheric Mercury Network (AMNet) is a collaborative effort involving many federal, state, and tribal agencies, academic researchers, and industry partners across North America and Taiwan. AMNet officially began operation in January 2009, and now has over 90 site years of observations for Gaseous Elemental Mercury (GEM), Gaseous Oxidized Mercury (GOM), and Particulate-bound Mercury (PBM<sub>2.5</sub>). The NADP's role is to organize individual monitoring groups into a homogeneous monitoring effort, implement consistent standard operating procedures and provide final quality assured data. The end result is a data base of comparable atmospheric mercury speciation measurements coordinated by the AMNet Site Liaison. The AMNet mercury data provided on the NADP web site is available for use by scientists, modelers, government agencies and educators. In collaboration with Environment Canada, AMNet will estimate short-term rates of dry deposition of the three mercury fractions. This data, in combination with wet deposition rates from associated Mercury Deposition Network (MDN) sites, can be used to approximate "total" mercury deposition (wet plus dry) at individual locations.

Mark L. Olson, NADP, University of Illinois

David Gay, NADP, University of Illinois

Tom Bergerhouse, University of Illinois

Eric M. Prestbo, Tekran Research & Development

David Schmeltz, U.S. EPA

## SubCommittee on Urban Atmospheric Monitoring (SCUAM)

Richard V. Pouyat<sup>1</sup>, Thomas Whitlow<sup>2</sup> and Pamela Templer<sup>3</sup>

Urban landscapes and their environments typically exhibit higher concentrations and depositional fluxes of atmospheric chemicals than rural environments. Most atmospheric pollutants originate from the combustion of fossil fuels, industrial emissions, and wear products from vehicles, all of which are associated with cities.

These include nitrogen oxides, sulfur oxides, heavy metals, and numerous organic chemicals. In addition, urban landscapes have unique source-sink relationships of pollutants at various scales, which make it difficult to predict their spatial-temporal depositional and accumulation patterns and thus the potential for human exposure and ecosystem impacts. We formed the ad-hoc Subcommittee on Urban Atmospheric Monitoring (SCUAM) to address the monitoring and assessment of urban atmospheric environments. Our primary goals include 1) assemble a database of people and entities interested in atmospheric monitoring in urban areas, 2) expand the existing NADP network into urban areas, 3) design a "passive" sampler network that augments the expanded networks to quantify the spatial and temporal heterogeneity of urban atmospheric environments, and 4) integrate citizen science participation in the network. We plan also to present recent research findings of urban environmental measurements.

<sup>1</sup>USDA Forest Service, Washington, DC, <sup>2</sup>Cornell University, Ithaca, NY, and <sup>3</sup>Boston University, Boston, MA

Richard V. Pouyat, [rpouyat@fs.fed.us](mailto:rpouyat@fs.fed.us), 703-605-5286  
National Program Leader Bioclimatology  
USDA Forest Service R&D  
Environmental Sciences Research Staff  
1601 North Kent Str., RPC-4  
Arlington, VA 22209

## MDN and NTN Training Webinars

Jeffrey Pribble, Jason Karlstrom, Brian Kerschner

The National Atmospheric Deposition Program (NADP) in collaboration with the Central Analytical Laboratory (CAL) and the Mercury Analytical Laboratory (HAL) is currently streaming monthly, interactive, and educational webinars with the goal of efficiently training NADP site personnel, and operators. In addition to attending live webinar events, users can access archived webinar videos and procedure documents through the training website, thus giving them the opportunity to experience the training using audiovisual examples from each session. This material is available online at <http://go.illinois.edu/NADPTraining>. This poster will give a brief introduction to online training, covering equipment troubleshooting, and sample processing.

**Jeffrey Pribble**, (217) 265-5257, [Pribble@illinois.edu](mailto:Pribble@illinois.edu)  
**Brian Kerschner**, (217) 244-6417, [bmkersch@illinois.edu](mailto:bmkersch@illinois.edu)  
Central Analytical Laboratory  
Illinois State Water Survey  
2204 Griffith Drive  
Champaign, IL 61820

**Jason Karlstrom**, (425) 686-3573, [jasonk@frontiergs.com](mailto:jasonk@frontiergs.com)  
Mercury Analytical Laboratory  
Eurofins Frontier Global Sciences, Inc.  
11720 North Creek Parkway N, Suite 400  
Bothell, WA 98011

## Mercury Speciation at A Suburban Site in the Mid-Atlantic United States: Seasonal and Diurnal Variations and Source-Receptor Correlationship

Xinrong Ren<sup>1,2,\*</sup>, Winston T. Luke<sup>1</sup>, Paul Kelley<sup>1</sup>, Mark Cohen<sup>1</sup>, Daniel Tong<sup>1,2</sup>, Richard Artz<sup>1</sup>, Mark L. Olson<sup>3</sup>, David Schmeltz<sup>4</sup>

**Abstract** Factors influencing diurnal, seasonal and inter-annual variability in mercury speciation over Mid-Atlantic US were investigated using multi-year measurements from 2007 to 2012 conducted at a suburban site in Beltsville, Maryland. Average concentrations and standard deviations were  $1.43 \pm 0.31 \text{ ng m}^{-3}$  for gaseous elemental mercury (GEM),  $5.0 \pm 39.7 \text{ pg m}^{-3}$  for gaseous oxidized mercury (GOM), and  $8.5 \pm 66.7 \text{ pg m}^{-3}$  for particulate bound mercury (PBM). Diurnal variation of GEM shows a slight peak in GEM concentration in the morning, likely due to rush hour traffic. Seasonal variation of GEM shows lower levels in fall. Both diurnal variations of GOM and PBM show peaks in the afternoon likely due to photochemical oxidation of GEM. Seasonally, PBM measurements exhibit higher levels in winter and spring and lower levels in summer, while GOM measurements show high levels in early summer and late fall and low levels in winter. Despite significant emission reduction of  $\text{SO}_2$  and  $\text{NO}_x$  in the nearby power plants since 2009/2010, there were not significant reduction in GEM, GOM and PBM, indicating that long range transport or the global mercury pool dominates the mercury concentrations at this suburban site in the Mid-Atlantic United States

<sup>1</sup>Air Resources Laboratory, National Oceanic and Atmospheric Administration, College Park, Maryland, USA

<sup>2</sup>Cooperative Institute for Climate and Satellites, University of Maryland, College Park, Maryland, USA

<sup>3</sup>Illinois State Water Survey, University of Illinois at Urbana-Champaign, Champaign, Illinois, USA

<sup>4</sup>Clean Air Markets Division, Environmental Protection Agency, Washington, District of Columbia, USA

\*Correspondence to: X. Ren ([Xinrong.Ren@noaa.gov](mailto:Xinrong.Ren@noaa.gov))

## The National Atmospheric Deposition Program Litterfall Mercury Monitoring Initiative

By Martin R. Risch<sup>1</sup>

The National Atmospheric Deposition Program (NADP) started the Litterfall Mercury Monitoring Initiative in 2012 to complement the Mercury Deposition Network (MDN) monitoring for mercury in precipitation and the Atmospheric Mercury Network (AMNet) monitoring for mercury in air. The litterfall monitoring program enables a NADP site sponsor to get measurements that approximate a large part of the mercury dry deposition in a forest landscape. Annual samples of litterfall are collected with passive samplers in a forest study plot near the NADP site. The samples are analyzed for mercury and litterfall mercury deposition is computed. The litterfall data can be used to examine ranges of mercury dry deposition, to estimate combined wet and dry mercury deposition, and to evaluate models of mercury deposition. The Initiative includes a 5-year transition program partially supported by the U.S. Geological Survey. The transition program provides a network of sites to obtain annual litterfall mercury data and includes a process for evaluating network operations.

A network of 14 monitoring sites in 10 states in the eastern USA completed data collection in autumn (September through December) 2012. Annual litterfall mercury deposition at these sites averaged 9.2 micrograms per square meter per year ( $\mu\text{g/m}^2/\text{yr}$ ) and ranged from 1.9 to 17.2  $\mu\text{g/m}^2/\text{yr}$ . By comparison, annual mercury wet deposition from the MDN monitoring at these sites averaged 9.5  $\mu\text{g/m}^2/\text{yr}$  and ranged from 6.3 to 13.7  $\mu\text{g/m}^2/\text{yr}$ . For wet and dry deposition combined, the average dry deposition was 46.1 percent and ranged from 20.2 to 70.5 percent. Mercury concentrations in litterfall samples averaged 3.7 times higher than the volume-weighted average annual mercury concentrations in precipitation.

Eight of the 2012 litterfall mercury monitoring network sites were part of a 3-year pilot study of litterfall mercury deposition at 23 MDN sites in 15 states from 2007–2009. The difference between the 2012 annual litterfall mercury deposition and the 2007–2009 average deposition at these 8 sites was 0.8  $\mu\text{g/m}^2/\text{yr}$ . Differences between 2007–2009 and 2012 at individual sites ranged from a 3.1  $\mu\text{g/m}^2/\text{yr}$  decrease to a 0.8  $\mu\text{g/m}^2/\text{yr}$  increase. In 2012 and previous years, the highest litterfall mercury deposition values were recorded at sites in deciduous forests of predominant oak-hickory forest type, while the lowest values were at sites in deciduous or mixed deciduous forests of predominant aspen-maple forest type.

<sup>1</sup>Martin R. Risch, Research Hydrologist, U.S. Geological Survey, 5957 Lakeside Blvd. Indianapolis, IN 46278, (317) 600-2763, [mrrisch@usgs.gov](mailto:mrrisch@usgs.gov)

## Atmospheric Deposition Comparisons Between Photochemical Grid Model Estimates and Measurements in the Western U.S.

Tiffany Samuelson<sup>1</sup>, Zion Wang<sup>1</sup>, Courtney Taylor<sup>1</sup> & Marco Rodriguez<sup>1</sup>

Recent studies have highlighted the discrepancies between measured and model-predicted estimates of nitrogen and sulfur deposition fluxes using various models including photochemical grid models (PGMs). These modeling discrepancies, importantly, could lead to an inaccurate assessment of the impacts of atmospheric deposition, especially on sensitive ecosystems. This analysis focuses on the comparison of PGM estimated atmospheric deposition fluxes to measured data products from the National Atmospheric Deposition Program National Trends Network (NADP/NTN) and Clean Air Status and Trends Network (CASTNET) in the Western U.S. Atmospheric deposition in the Western U.S. is often dominated by nitrogen deposition that has demonstrated an increasing trend in recent years; furthermore, deposition in the Western U.S. is characterized by low deposition levels, relative to the Eastern U.S., with localized hotspots downwind of urban areas and agro-industrial activities. Atmospheric deposition measurements, however, are sparse throughout the region. In unmonitored areas, modeled values are an important source of deposition estimates.

In this work, modeled wet and dry deposition fluxes are derived from a PGM, the Comprehensive Air Quality Model with extensions (CAMx). For comparison with NADP/NTN data products, modeled wet atmospheric deposition contributions from ammonium (NH<sub>4</sub><sup>+</sup>), nitrate (NO<sub>3</sub><sup>-</sup>), and sulfate (SO<sub>4</sub><sup>2-</sup>) are considered. For comparison with CASTNET data products, modeled dry atmospheric deposition contributions from gas and particle-phase species, including NH<sub>4</sub><sup>+</sup>, NO<sub>3</sub><sup>-</sup>, nitric acid (HNO<sub>3</sub>), SO<sub>4</sub><sup>2-</sup>, and sulfur dioxide (SO<sub>2</sub>), are considered. Model performance is evaluated by comparing the speciated, wet, and dry deposition values to NADP/NTN and CASTNET data products. Further comparisons were made in evaluating the model's ability to reproduce spatial and temporal deposition features over the Western U.S. Additionally, the modeled, speciated nitrogen budget is analyzed including the aforementioned monitored deposition components and additional unmonitored deposition components such as ammonia (NH<sub>3</sub>), nitric oxide (NO), nitrogen dioxide (NO<sub>2</sub>), dinitrogen pentoxide (N<sub>2</sub>O<sub>5</sub>), nitrous acid (HONO), peroxyacetyl nitrate (PAN), and organic nitrogen. An emphasis was placed on model evaluations of atmospheric deposition in Class I areas, sensitive Class II areas, and high elevation sensitive lakes. These analyses are intended to inform the development of more extensive and inclusive nitrogen deposition monitoring.

Tiffany Samuelson<sup>1</sup>, Tiffany.Samuelson@aecom.com

Zion Wang<sup>1</sup>, Zion.Wang@aecom.com

Courtney Taylor<sup>1</sup>, Courtney.Taylor@aecom.com

Marco Rodriguez<sup>1</sup>, Marco.Rodriguez@aecom.com

<sup>1</sup> AECOM Inc., (970) 493-8878, 1601 Prospect Parkway, Fort Collins, CO 80525

## On a Revised Formulation for the Multi-Layer Model (MLM) for Inferring Dry Deposition to Vegetated Surfaces: Impact on Inferred HNO<sub>3</sub> Dry Deposition

Rick D. Saylor<sup>1</sup>, Glenn M. Wolfe<sup>2</sup>, Tilden P. Meyers<sup>1</sup> and Bruce B. Hicks<sup>3</sup>

The Multilayer Model (MLM) has been used for many years to infer dry deposition fluxes from measured trace species concentrations and standard meteorological measurements for national networks in the U. S., including the U. S. Environmental Protection Agency's Clean Air Status and Trends Network (CASTNet). MLM utilizes a resistance analogy approach to calculate deposition velocities appropriate for whole vegetative canopies, while employing a multilayer integration within the canopy to account for vertically varying meteorology, canopy morphology and radiative transfer. However, the MLM formulation, as it was originally presented and as it has been subsequently employed contains a non-physical representation related to the leaf-level quasi-laminar boundary layer resistance, which affects the calculation of the total canopy resistance. In this presentation, the non-physical representation of the canopy resistance as originally formulated in MLM is presented and analyzed and a revised, physically consistent, formulation is suggested as a replacement. The revised canopy resistance formulation results in HNO<sub>3</sub> deposition velocities that are reduced by as much as 38% during mid-day as compared to values generated by the original formulation. Inferred deposition velocities for SO<sub>2</sub> and O<sub>3</sub> are not significantly altered by the change in formulation (< 3%); however, it is shown that any trace gaseous species with large effective Henry's law coefficients (> 10<sup>4</sup>-10<sup>5</sup> M atm<sup>-1</sup>) or high vegetative surface reactivity and consequently small cuticular and mesophyll resistances have smaller calculated deposition velocities with the revised formulation than are generated by the original formulation. Inferred deposition loadings of oxidized and total nitrogen from CASTNet data may be reduced by 10-20% and 5-10%, respectively, for the Eastern U. S. when employing the revised formulation of MLM as compared to the original formulation.

<sup>1</sup> NOAA Air Resources Laboratory, Atmospheric Turbulence and Diffusion Division, Oak Ridge, TN 37830 (Rick.Saylor@noaa.gov; 865-576-0116)

<sup>2</sup> Atmospheric Chemistry and Dynamics Laboratory, NASA Goddard Space Flight Center and Joint Center for Earth Systems Technology, University of Maryland Baltimore County, Baltimore, MD 21250

<sup>3</sup> Metcorps, Norris, TN 37828

## Assessing the use of diatom-based critical loads of nitrogen deposition in lakes from three National Parks in Washington State

Richard W. Sheibley<sup>1,\*</sup>, Mihaela Enache<sup>2,3</sup>, Peter W. Swarzenski<sup>4</sup>, James R. Foreman<sup>1</sup>, and Patrick W. Moran<sup>1</sup>

### Abstract

Increased nitrogen (N) deposition has been identified as a critical issue in high-elevation lakes in the western United States. High-elevation lakes are particularly sensitive to these increases because they are naturally oligotrophic systems. We measured atmospheric deposition, lake water quality, and historical diatom assemblages for 10 lakes in National Parks in Washington. Our study lakes were ultra-oligotrophic with NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup> concentrations often at or below detection limits with low specific conductance (<100 μS/cm), and acid neutralizing capacities (<400 μeq/L). Rates of summer total inorganic N deposition at all our sites ranged from 0.6 to 2.4 kg N/ha-yr and were variable both within and across the parks. Diatom assemblages showed no sign of N enrichment for most of our lakes. However, a sediment core from Hoh Lake (Olympic National Park) displayed a shift to increased relative abundances of *Asterionella formosa* and *Fragilaria tenera* beginning in the 1969-1975 timeframe. These diatom species are known to be indicative of N enrichment and allowed for the development of an empirical critical load of N deposition, or threshold level, where changes in diatom communities were observed. We used modeled precipitation for Hoh Lake and annual inorganic nitrogen precipitation concentrations from a nearby National Atmospheric Deposition Program station, to calculate elevation-corrected N deposition for 1980-2009 at Hoh Lake. An exponential fit to this data was hindcasted to the 1969-1975 time period and we estimate a critical load of 1.0 to 1.2 kg N/ha-yr for wet deposition for this lake. This is lower, although comparable, to critical loads determined for the Rockies and Sierra Nevada mountains (1.4-1.5 kg N/ha-yr).

## Characterizations of atmospheric mercury deposition on a free tropospheric mountain-top site in Taiwan

Guey-Rong Sheu<sup>\*1</sup>, Da-Wei Lin<sup>1</sup>, Neng-Huei Lin<sup>1</sup>, Leiming Zhang<sup>2</sup>, Shu-Ting Liang<sup>3</sup>, Yi-Hui Hsieh<sup>3</sup>

Taiwan is located downwind of the East Asian continent, which is the largest anthropogenic mercury (Hg) source region globally. Speciated atmospheric mercury (Hg) has been measured since mid-April 2006 and weekly rainwater samples have been collected for total Hg analyses since early 2009 at the Lulin Atmospheric Background Station (LABS; 120.87°E, 23.47°N, 2862 m a.s.l.) in central Taiwan. Here we report and characterize the wet and dry deposition of Hg on LABS in 2010. Dry deposition was estimated based on a model calculation. In 2010, the annual rainfall at LABS was 3173.2 mm with a total of 36 weekly rainwater samples being collected for Hg analysis. Sample Hg concentrations ranged from 4.1 to 24.9 ng L<sup>-1</sup>, with an annual volume-weighted mean Hg concentration of 9.6 ng L<sup>-1</sup>. Seasonal VWM concentrations were 7.3, 12.7, 8.6, and 6.6 ng L<sup>-1</sup>, whereas seasonal wet deposition fluxes were 4.8, 20.8, 5.8, and 1.4 μg m<sup>-2</sup>, for spring, summer, fall, and winter, respectively. Seasonal wet deposition flux was higher in summer primarily as a result of elevated amount of rainfall and to a lesser extent, higher rainwater Hg concentration. The high summertime rainwater Hg concentration hints the importance of Hg<sup>0</sup> oxidation and/or scavenging of upper-altitude Hg(II) by deep convection. The annual wet deposition flux was 32.8 μg m<sup>-2</sup>. On the other hand, the estimated annual dry deposition flux was 26.2 μg m<sup>-2</sup>, with a contribution of 20.8 μg m<sup>-2</sup> from GEM and of 5.4 μg m<sup>-2</sup> from RGM. Dry deposition of PHg was negligible. Wet deposition dominated in summer/fall, but dry deposition dominated in spring/winter. Nonetheless, overall wet deposition was more important than dry deposition at this subtropical free tropospheric mountain-top site because of abundant rainfall, which is different from sites in North America where dry deposition is expected to be higher than wet deposition. Compared with the 2010 values (15.7-63.4 μg m<sup>-2</sup>) for sites of the Taiwan Wet Hg Deposition Network, the Hg wet deposition flux at LABS is about 52% of the highest value.

<sup>1</sup>Department of Atmospheric Sciences, National Central University, Taiwan

<sup>2</sup>Environment Canada

<sup>3</sup>Taiwan Environmental Protection Administration

\*+886-3-4227151 ext. 65514

\*grsheu@atm.ncu.edu.tw

<sup>1</sup>US Geological Survey, Tacoma, WA 98402; <sup>2</sup>Academy of Natural Sciences, Philadelphia at Drexel University, Philadelphia, PA 19103; <sup>3</sup>current address: NJ Department of Environmental Protection, Trenton, NJ 08625, <sup>4</sup>US Geological Survey, Santa Cruz, CA

\*corresponding author: [sheibley@usgs.gov](mailto:sheibley@usgs.gov); 253-552-1611, 253-552-1581(f)



## **Trends in aerosol acidity and constraints on past ammonia derived from 20 years of Canadian Air and Precipitation Monitoring Network (CAPMoN) data.**

Alex Tevlin, Jennifer Murphy

Aerosol acidity is important for its role in influencing particulate chemistry, as well as in moderating the impact of particulate matter in terms of both human and ecosystem health. Because if this it is important to understand trends in aerosol acidity and the factors that drive them. As the primary atmospheric base, gas phase ammonia plays an important role in controlling particle acidity, however the long term gas phase data needed to understand ammonia trends is generally lacking. Using 20 years of particulate data from the Canadian Air and Precipitation Monitoring Network (CAPMoN), spatial and temporal trends in aerosol strong acidity were investigated at 8 geographically diverse sites. Statistically significant decreases in strong acidity were observed at all sites, as well as a clear seasonal periodicity which differed between sites. Sites closer to anthropogenic influence showed summer maxima, while more remote sites had greater strong acidity during winter, a contrast which can be understood in terms of the relative importance of different inorganic species as drivers of aerosol acidity. Combining this particulate information with precipitation and gas-phase data from these same sites, the possibility of constraining past ammonia concentrations was investigated, using the thermodynamic Aerosol Inorganic Model (AIM) to calculate the ammonia concentrations necessary to replicate available gas and particulate data. This estimate could contribute to our understanding of ammonia trends and their influence on aerosol acidity despite the scarcity of long term measurements.

University of Toronto  
80 St George Street  
Toronto, ON M5S 3H6  
(416)-946-3011  
atevlin@chem.utoronto.ca  
jmurphy@chem.utoronto.ca

## **Accurate Representation of Ammonia in Rocky Mountain National Park: Investigating Diurnal Concentration Profiles**

Tammy M. Thompson<sup>1\*</sup>, Michael G. Barna<sup>2</sup>, Kristi A. Gebhart<sup>2</sup>, William C. Malm<sup>1</sup>, Bret A. Schichtel<sup>2</sup>

We investigate a discrepancy between summertime diurnal patterns of modeled ground level ammonia concentrations and ammonia measurements taken in Rocky Mountain National Park as part of the Rocky Mountain Atmospheric Nitrogen and Sulfur (RoMANS) II study. Obtaining correct modeled representation of ammonia deposition first requires accurate representation of ambient concentrations. We run a year-long CAMx episode with 2009 meteorology and 2009 emissions inventories at 36, 12, and 4 km resolution, and find that modeled concentrations of ammonia at the core site in RMNP peak in late evening (on average around 11 P.M.) as evaluated using a 4 km nested grid domain. This nighttime peak of ammonia concentrations has been reported previously in studies when co-located measurement data was not available. In those cases, mixing height variability was often used to explain the result. However, in the case of RoMANS, hourly measurements are available and these measurements report a mid-day peak. Modeled daily average concentrations are within 6% of the measured values on average at the Rocky Mountain core site during the summer months (and within 15% annually), therefore showing good agreement for that metric. In contrast, chemical transport models utilizing different modeling episode inputs consistently predict nighttime maximum ammonia concentrations at Rocky Mountain National Park and in surrounding areas despite measurements that consistently provide evidence of daytime maximum values. Source apportionment air quality modeling tools are used to identify the contributing ammonia sources to this site on an hourly basis. Process analysis is used to identify the contributions of all physical and chemical processes to ammonia concentrations also on an hourly basis. Using these data and information on the relative uncertainty of contributing factors, we design sensitivity runs to test the influence of select sources and processes on the modeled diurnal profile of ammonia with the goal of identifying areas that need further study in order to improve the model representation of ammonia concentrations and deposition.

<sup>1</sup>Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, Colorado, 80523-1375

<sup>2</sup>National Park Service, Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, Colorado, 80523-1375

\*Corresponding Author: [Tammy.Thompson@colostate.edu](mailto:Tammy.Thompson@colostate.edu), 970-491-3679

## Bias in modeled bi-directional NH<sub>3</sub> fluxes associated with temporal averaging of atmospheric NH<sub>3</sub> concentrations

John T. Walker<sup>1\*</sup> and Melissa Puchalski<sup>2</sup>

Direct measurements of NH<sub>3</sub> air-surface exchange are expensive, labor intensive, and require detailed supporting measurements of soil, vegetation, and atmospheric chemistry for interpretation and model parameterization. It is therefore often necessary to infer fluxes by combining measurements of atmospheric concentrations, meteorology, and surface chemistry within a suitable air-surface exchange model. Two-week integrated NH<sub>3</sub> air concentrations are currently measured using passive diffusion samplers at ≈ 60 sites within the U.S. as part of the NADP's Ammonia Monitoring Network (AMoN). Ideally, these measurements could be used to estimate NH<sub>3</sub> fluxes in a manner similar to CASTNET, in which dry deposition is estimated by combining measured or averaged historical hourly meteorological measurements with measured weekly integrated air concentrations. Estimation of site specific NH<sub>3</sub> fluxes from AMoN data and other time-integrated monitoring data will require identification of a suitable air-surface exchange model, collection of necessary supporting data to parameterize the model, and evaluation model performance. Errors resulting from the inability of the model to accurately simulate the flux and the use of time-integrated data, rather than hourly data, to drive the model may significantly affect the accuracy of the modeled flux. The use of time-integrated (temporally averaged) air concentrations may produce errors in the modeled NH<sub>3</sub> flux due to biases in the air concentration at the hourly time scale, which directly bias the flux, and covariance between the atmospheric concentration and other variables that drive the flux. This study investigates temporal averaging of the NH<sub>3</sub> air concentration as a source of error in modeled fluxes using a series of simulations in which temporally aggregated fluxes (seasonal and annual) derived from hourly versus time-integrated air concentrations are compared for a range of atmospheric and surface conditions.

<sup>1</sup>U.S. EPA, Office of Research and Development, Research Triangle Park, NC 27711, U.S.A

<sup>2</sup>U.S. EPA, Office of Air Programs, Clean Air Markets Division, Washington, DC 20460, U.S.A.

\* Corresponding author  
Email: walker.johnt@epa.gov  
Telephone: (919) 541-2288  
Fax: (919) 541-7885

## Statistical Comparison of OTT Pluvio-2 and Belfort 5-780 Weekly Precipitation Records

Gregory A. Wetherbee<sup>1</sup>, Mark F. Rhodes<sup>2</sup>, and Amy S. Ludtke<sup>3</sup>

Replacement of Belfort 5-780 (Belfort) precipitation gages with OTT Pluvio-2 (OTT) gages at National Atmospheric Deposition Program (NADP) sites could cause shifts in long-term precipitation-depth records. Data collected from co-located Belfort and OTT gages at 31 NADP sites from January 3, 2011-June 18, 2013, were reduced to 724 weekly precipitation-depth pairs. Data were removed when one gage had an incomplete or erroneous record. Weeks with zero precipitation for both gages represent 21 percent of the data. The median OTT-minus-Belfort depth difference is 0.01 inches over the range 0-4.77 inches (OTT) weekly precipitation.

Seasonal distribution of data was approximately consistent; weeks with frozen precipitation comprised 12 percent of the data. Therefore, this comparison is biased towards liquid precipitation.

Bias among gages was confirmed using the Wilcoxon signed rank test ( $p < 2.2 \times 10^{-16}$ ) for the entire data set. Records from the gages were highly correlated (Kendall's Tau: 0.90,  $p < 2.2 \times 10^{-16}$ ). Weekly precipitation-depth differences were compared on a monthly basis using the Kruskal-Wallis rank sum test, which indicated bias between gages for at least one month of the year ( $p = 0.100$ ). The largest monthly mean difference was 0.077 inches for 71 paired measurements during May 2011-13.

Linear regression predicted weekly OTT precipitation depths from weekly Belfort precipitation depths as:

$$\text{OTT Predicted Precipitation (inches)} = 1.019 \times \text{Belfort Precipitation (inches)} + 0.020 \quad (\text{Eq. 1}),$$

where the slope and y-intercept are significant at the  $\alpha = 0.05$  and  $\alpha = 0.001$  significance levels, respectively. An adjusted R-squared of 0.96 was calculated for this model. Autocorrelation was ruled out (Durbin-Watson test,  $p < 2.2 \times 10^{-16}$ ), and normality of residuals was confirmed (Shapiro-Wilk,  $p < 2.2 \times 10^{-16}$ ). Log transformation of the data did not improve model suitability.

The model presented in Eq. 1 may be used to adjust historical, Belfort-measured, weekly precipitation depths for sites that have been upgraded with an OTT gage. The adjustment implied by the model is approximately +2 percent. Bias was not evaluated on a site-specific basis.

<sup>1</sup>Use of trade of firm names herein is for identification purposes only and does not constitute endorsement by the U.S. Government.

<sup>1</sup> USGS/Branch of Quality Systems, Denver, Colorado

<sup>2</sup> Illinois State Water Survey, Champaign, Illinois

<sup>3</sup> USGS, Office of Water Quality, Denver, Colorado

## Trends in gypsiferous aerosol downwind of White Sands, New Mexico

Warren H. White<sup>1</sup>, Krystyna Trzepla<sup>2</sup>, Sinan Yatkin<sup>3</sup>, Thomas E. Gill<sup>4</sup> and Lixin Jin<sup>5</sup>

White Sands National Monument preserves a major portion of the world's largest gypsum dunefield. The field sits in a topographic sink, the 60km-wide Tularosa Basin, bounded by the San Andres Mountains to the west and the Sacramento Mountains to the east. Prevailing winds carry evaporite minerals from the ephemeral Lake Lucero into and beyond the dune system. Since January 2002, the U.S. Forest Service has operated an IMPROVE sampler about 160 km away at White Mountain in the lee of the Sacramento Mountains.

In recent years a spring pulse of sulfate aerosol has appeared at White Mountain, eclipsing the regional summer peak attributed to atmospheric reactions of sulfur dioxide emissions. A significant fraction of this spring sulfate appears to represent gypsum and other evaporites from White Sands, with clearly increased concentrations of calcium, strontium, and chloride. Concentrations have increased in recent years, during a drought following a period of above-average precipitation. The gypsiferous material is particularly rich in strontium, with Sr/Ca ratios well above those usually seen in gypsum.

This paper examines the routine PM<sub>2.5</sub> composition data available from White Mountain and other regional IMPROVE sites, supplemented by some elemental analysis of collocated PM<sub>10</sub> samples. The ambient data are compared with chemical analyses of surface samples from White Sands, satellite observations of dust plumes, and available meteorological records.

## Measurement of light absorption in the IMPROVE aerosol monitoring network

Warren H. White<sup>1</sup>

The IMPROVE network (Interagency Monitoring of Protected Visual Environments) has collected 24h PM<sub>2.5</sub> samples on PTFE filters since 1988, at a sustained frequency of twice a week or every third day. The network now includes about 170 sites, 70 having operated continuously since 1995. The PTFE PM<sub>2.5</sub> samples are weighed for total mass, analyzed by XRF for elemental concentrations, and analyzed for light absorption. Light absorption is measured at 633 nm with the U.C. Davis Hybrid Integrating Plate/Sphere (HIPS) system.

HIPS directs a diffused laser beam at the back side of the filter, recording both back-scattered and transmitted light intensity. Backscatter from the "clean" side of the filter is collected with an integrating sphere, and transmission through the filter and sample deposit is collected with an integrating plate. The backscatter is used to estimate the transmission of the unexposed ("clean") filter; the ratio of that reference to the observed transmission then yields a measure of absorption by the deposited sample. Because it employs the same sample used for XRF analysis, HIPS delivers an absorption measurement that is accompanied by relevant information on chemical composition. The measurement is also somewhat unfamiliar, as the thin membrane filters optimal for XRF are quite unlike the optically thick fiber filters widely used in aethelometers and other dedicated real-time monitors.

Previous analyses have exposed deficiencies in the calibration historically used to report absorption data from HIPS. This paper summarizes recent work to place the calibration of HIPS on a sounder foundation. Improved long-term stability is demonstrated for historical data reprocessed with the new calibration, together with an improved relationship of absorption to carbon fractions and fine soil dust.

<sup>1</sup>Warren H. White, Crocker Nuclear Laboratory, University of California, One Shields Avenue, Davis, CA 95616, 530-752-1213, [whwhite@ucdavis.edu](mailto:whwhite@ucdavis.edu)

<sup>2</sup>Krystyna Trzepla, University of California, Davis, CA 95616, [ktrzeplanabaglo@ucdavis.edu](mailto:ktrzeplanabaglo@ucdavis.edu)

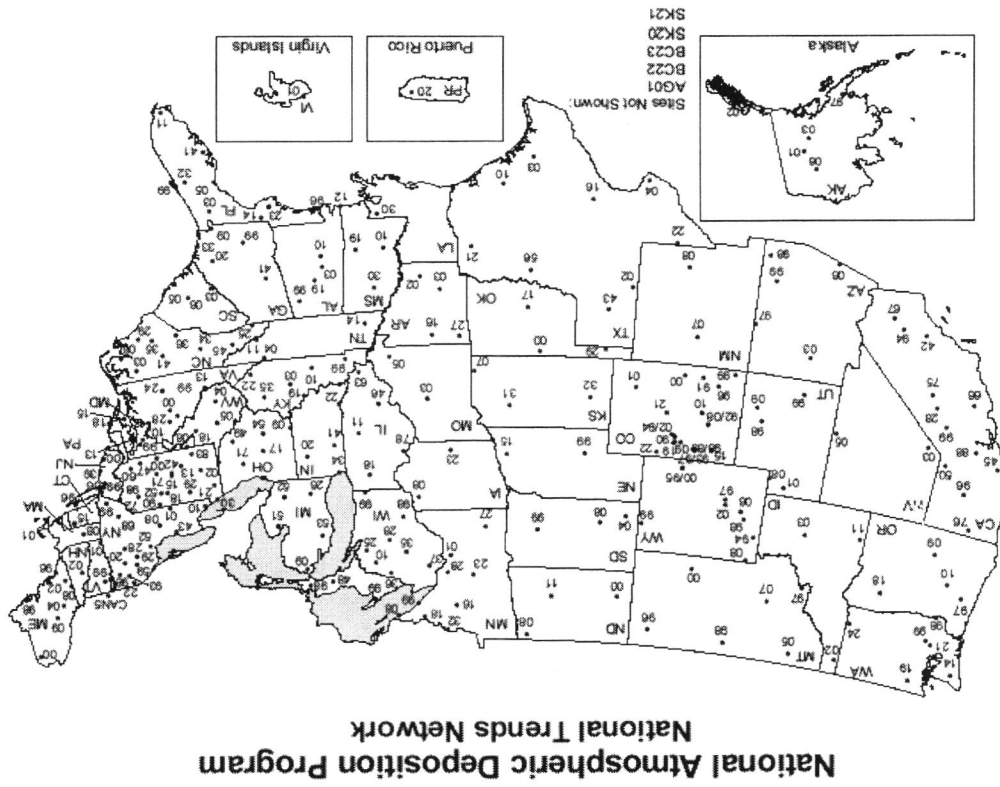
<sup>3</sup>Sinan Yatkin, University of California, Davis, CA 95616, [syatkin@ucdavis.edu](mailto:syatkin@ucdavis.edu)

<sup>4</sup>Thomas E. Gill, University of Texas, El Paso, TX 79968, [tegill@utep.edu](mailto:tegill@utep.edu)

<sup>5</sup>Lixin Jin, University of Texas, El Paso, TX 79968, [jin2@utep.edu](mailto:jin2@utep.edu)

<sup>1</sup>Warren H. White, Crocker Nuclear Laboratory, University of California, One Shields Avenue, Davis, CA 95616, 530-752-1213, [whwhite@ucdavis.edu](mailto:whwhite@ucdavis.edu)

NTN Map and Site Listings



**National Atmospheric Deposition Program/National Trends Network Sites**

**July 31, 2013**

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<b>State/Province Site Code</b>	<b>Site Name</b>	<b>Collocation</b>	<b>Sponsoring Agency</b>	<b>Start Date</b>
<b>Alabama</b>				
AL03	Centerville	MDN	Atmospheric Research & Analysis, Inc.	2/11
AL10	Black Belt Research & Extension Center		US Geological Survey	08/83
AL19	Birmingham	AMNet/MDN	Atmospheric Research & Analysis, Inc.	12/12
AL99	Sand Mountain Research & Extension Center	AMoN	Tennessee Valley Authority	10/84
<b>Alaska</b>				
AK01	Poker Creek		USDA Forest Service	12/92
AK02	Juneau		USDA Forest Service	06/04
AK03	Denali NP - Mount McKinley		National Park Service - Air Resources Division	06/80
AK06	Gates of the Arctic NP - Bettles	MDN	US Bureau of Land Management	11/08
AK97	Katmai National Park - King Salmon		National Park Service - Air Resources Division	11/09
<b>Argentina</b>				
AG01	Laurenti-MAR	NTN	PROMAR- Centro de Zoologia Aplicada UNC	10/11
<b>Arizona</b>				
AZ03	Grand Canyon NP - Hopi Point		National Park Service - Air Resources Division	08/81
AZ06	Organ Pipe Cactus NM		National Park Service - Air Resources Division	04/80
AZ97	Petrified Forest NP-Rainbow Forest		National Park Service - Air Resources Division	12/02
AZ98	Chiricahua	AMoN	US Environmental Protection Agency-CAMD	02/99
AZ99	Oliver Knoll		US Geological Survey	08/81

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<b>State/Province Site Code</b>	<b>Site Name</b>	<b>Collocation</b>	<b>Sponsoring Agency</b>	<b>Start Date</b>
<b>Arkansas</b>				
AR02	Warren 2WSW		US Geological Survey	05/82
AR03	Caddo Valley	AMoN	US Geological Survey	12/83
AR16	Buffalo NR - Buffalo Point		National Park Service - Air Resources Division	07/82
AR27	Fayetteville		US Geological Survey	05/80
<b>California</b>				
CA28	Kings River Experimental Watershed		USDA Forest Service	04/07
CA42	Tanbark Flat		USDA Forest Service	01/82
CA45	Hopland		US Geological Survey	10/79
CA50	Sagehen Creek		US Geological Survey	11/01
CA66	Pinnacles NM - Bear Valley		National Park Service - Air Resources Division	11/99
CA67	Joshua Tree NP - Black Rock	AMoN	National Park Service - Air Resources Division	09/00
CA75	Sequoia NP - Giant Forest	MDN	National Park Service - Air Resources Division	07/80
CA76	Montague		US Geological Survey	06/85
CA88	Davis		US Geological Survey	09/78
CA94	Converse Flats	MDN	USDA Forest Service	05/06
CA96	Lassen Volcanic NP - Manzanita Lake		National Park Service - Air Resources Division	06/00
CA99	Yosemite NP - Hodgdon Meadow		National Park Service - Air Resources Division	12/81

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>Colorado</b>				
CO00	Alamosa		US Geological Survey	04/80
CO01	Las Animas Fish Hatchery		US Geological Survey	10/83
CO02	Niwot Saddle		NSF-Institute of Arctic & Alpine Research/University of CO	06/84
CO08	Four Mile Park		US Environmental Protection Agency-CAMD	12/87
CO09	Kawaneechee Meadow		Grand County Water Information Network	07/12
CO10	Gothic		US Environmental Protection Agency-CAMD	02/99
CO15	Sand Spring		US Bureau of Land Management	03/79
CO19	Rocky Mountain NP - Beaver Meadows		National Park Service - Air Resources Division	05/80
CO21	Manitou		USDA Forest Service	10/78
CO22	Pawnee		Colorado Department of Public Health & Environment	05/79
CO89	Rocky Mountain National Park-Loch Vale		National Park Service - Air Resources Division	09/09
CO90	Niwot Ridge-Southeast		NSF-Institute of Arctic & Alpine Research/University of CO	01/06
CO91	Wolf Creek Pass		USDA Forest Service	05/92
CO92	Sunlight Peak		US Environmental Protection Agency-CAMD	01/88
CO93	Buffalo Pass - Dry Lake		USDA Forest Service	10/86
CO94	Sugarloaf		US Environmental Protection Agency-CAMD	11/86
CO96	Molas Pass	MDN	USDA Forest Service	07/86
CO97	Buffalo Pass - Summit Lake	MDN	USDA Forest Service	02/84
CO98	Rocky Mountain NP - Loch Vale	AMoN	USGS/Colorado State University	08/83
CO99	Mesa Verde NP - Chapin Mesa	MDN	US Geological Survey	04/81

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>Connecticut</b>				
CT15	Abington	AMoN	US Environmental Protection Agency-CAMD	01/99
<b>Florida</b>				
FL03	Bradford Forest		US Environmental Protection Agency-CAMD	10/78
FL05	Chassahowitzka NWR	MDN	US Fish & Wildlife Service - Air Quality Branch	08/96
FL11	Everglades NP - Research Center	MDN/AMoN	National Park Service - Air Resources Division	06/80
FL14	Quincy		US Geological Survey	03/84
FL23	Sumatra		US Environmental Protection Agency-CAMD	01/99
FL32	Orlando		Seminole County Public Works Department	12/05
FL41	Verna Well Field		US Geological Survey	08/83
FL96	Pensacola	AMNet/MDN	Atmospheric Research & Analysis, Inc.	01/13
FL99	Kennedy Space Center		NASA/Innovative Health Applications, LLC	08/83
<b>Georgia</b>				
GA09	Okefenokee NWR	MDN	US Fish & Wildlife Service - Air Quality Branch	06/97
GA20	Bellville		US Environmental Protection Agency-CAMD	04/83
GA33	Sapelo Island	MDN	NSF/UGA, & GA Dept of Natural Resources	11/02
GA41	Georgia Station	AMoN	Atmospheric Research & Analysis, Inc.	10/78
GA99	Chula		US Geological Survey	02/94
<b>Idaho</b>				
ID02	Priest River Experimental Forest		USDA Forest Service	12/02
ID03	Craters of the Moon NM	AMoN	National Park Service - Air Resources Division	08/80
ID11	Reynolds Creek		US Geological Survey	11/83

State/Province	Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>Illinois</b>					
	IL11	Bondville	AIRMoN/ MDN/AMoN	US Environmental Protection Agency-CAMD	02/79
	IL18	Shabbona		SAES-University of Illinois	05/81
	IL46	Alhambra	AMoN	US Environmental Protection Agency-CAMD	01/99
	IL63	Dixon Springs Agricultural Center		SAES-University of Illinois	01/79
	IL78	Monmouth		US Geological Survey	01/85
<b>Indiana</b>					
	IN20	Roush Lake		US Geological Survey	08/83
	IN22	Southwest Purdue Agriculture Center	AMoN	US Geological Survey	09/84
	IN34	Indiana Dunes NL		National Park Service - Air Resources Division	07/80
	IN41	Agronomy Center for Research and Extension		SAES-Purdue University	07/82
<b>Iowa</b>					
	IA08	Big Springs Fish Hatchery		US Geological Survey	08/84
	IA23	McNay Memorial Research Center		US Geological Survey	09/84
<b>Kansas</b>					
	KS07	Farlington Fish Hatchery		US Geological Survey	03/84
	KS31	Konza Prairie	AMoN	SAES-Kansas State University	08/82
	KS32	Lake Scott State Park	MDN	US Geological Survey	03/84

State/Province	Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>Kentucky</b>					
	KY03	Mackville	AMoN	US Geological Survey	11/83
	KY10	Mammoth Cave NP-Houchin Meadow	MDN	National Park Service - Air Resources Division	08/02
	KY19	Seneca Park		US Geological Survey	10/03
	KY22	Lilley Cornett Woods		US Geological Survey	09/83
	KY35	Clark State Fish Hatchery		US Geological Survey	08/83
	KY99	Mulberry Flats		TVA/Murray State University	12/94
<b>Louisiana</b>					
	LA30	Southeast Research Station		US Geological Survey	01/83
<b>Maine</b>					
	ME00	Caribou	MDN	EPA/Maine Dept of Environmental Protection	04/80
	ME02	Bridgton	MDN	EPA/Maine Dept of Environmental Protection	09/80
	ME04	Carrabassett Valley	MDN	US Environmental Protection Agency - CAMD	03/02
	ME08	Gilead		US Geological Survey	09/99
	ME09	Greenville Station	MDN	EPA/Maine Dept of Environmental Protection	11/79
	ME96	Casco Bay - Wolfe's Neck Farm	MDN	EPA/Maine Dept of Environmental Protection	01/98
	ME98	Acadia NP - McFarland Hill	MDN	National Park Service - Air Resources Division	11/81

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State/Province	Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>Maryland</b>					
	MD08	Piney Reservoir	MDN/AMNet/ AMoN	Maryland Department of Natural Resources	06/04
	MD13	Wye		SAES-University of Maryland	03/83
	MD15	Smith Island		NOAA-Air Resources Lab	06/04
	MD18	Assateague Island NS - Woodcock		Maryland Department of Natural Resources	09/00
	MD99	Beltsville	MDN/AMNet AMoN	Maryland Department of Natural Resources	06/04
<b>Massachusetts</b>					
	MA01	North Atlantic Coastal Lab	MDN	National Park Service - Air Resources Division	12/81
	MA08	Quabbin Reservoir		Northeast States for Coordinated Air Use Management	03/82
<b>Michigan</b>					
	MI09	Douglas Lake		SAES-Michigan State University	07/79
	MI26	Kellogg Biological Station		SAES-Michigan State University	06/79
	MI48	Seney NWR - Headquarters	MDN	US Fish & Wildlife Service - Air Quality Branch	11/00
	MI51	Unionville		US Environmental Protection Agency-CAMD	01/99
	MI52	Ann Arbor		US Environmental Protection Agency-CAMD	01/99
	MI53	Wellston		USDA Forest Service	10/78
	MI98	Raco		US Environmental Protection Agency-CAMD	05/84
	MI99	Chassell		USDA Forest Service	02/83

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State/Province	Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>Minnesota</b>					
	MN01	Cedar Creek		Minnesota Pollution Control Agency	12/96
	MN08	Hovland		Minnesota Pollution Control Agency	12/96
	MN16	Marcell Experimental Forest	MDN	USDA Forest Service	07/78
	MN18	Fernberg	MDN/AMoN	US Environmental Protection Agency-CAMD	11/80
	MN23	Camp Ripley	MDN	US Geological Survey	10/83
	MN27	Lamberton	MDN	Minnesota Pollution Control Agency	01/79
	MN28	Grindstone Lake		Minnesota Pollution Control Agency	12/96
	MN32	Voyageurs NP - Sullivan Bay		National Park Service - Air Resources Division	05/00
	MN99	Wolf Ridge		Minnesota Pollution Control Agency	12/96
<b>Mississippi</b>					
	MS10	Clinton		US Geological Survey	07/84
	MS12	Grand Bay NERR	MDN/AMNet	NOAA-Air Resources Lab	03/10
	MS19	Newton		NOAA-Air Resources Lab	11/86
	MS30	Coffeenville		Tennessee Valley Authority	07/84
<b>Missouri</b>					
	MO03	Ashland Wildlife Area	MDN	US Geological Survey	10/81
	MO05	University Forest		US Geological Survey	10/81



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State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>Montana</b>				
MT00	Little Bighorn Battlefield NM		US Geological Survey	07/84
MT05	Glacier NP - Fire Weather Station	MDN	National Park Service - Air Resources Division	06/80
MT07	Clancy		US Geological Survey	01/84
MT96	Poplar River		EPA/Fort Peck Tribes	12/99
MT97	Lost Trail Pass		USDA Forest Service	09/90
MT98	Havre - Northern Agricultural Research Center		US Geological Survey	07/85
<b>Nebraska</b>				
NE15	Mead	MDN	SAES-University of Nebraska	07/78
NE99	North Platte Agricultural Experiment Station		US Geological Survey	09/85
<b>Nevada</b>				
NV03	Smith Valley		US Geological Survey	08/85
NV05	Great Basin NP - Lehman Caves		National Park Service - Air Resources Division	01/85
<b>New Hampshire</b>				
NH02	Hubbard Brook	AMoN	USDA Forest Service	07/78
<b>New Jersey</b>				
NJ00	Edwin B Forsythe NWR		US Fish & Wildlife Service - Air Quality Branch	10/98
NJ39	Cattus Island County Park		US Environmental Protection Agency - CAMD	12/12
NJ99	Washington Crossing		US Environmental Protection Agency - CAMD	08/81

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State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>New Mexico</b>				
NM07	Bandelier NM		National Park Service-Air Resources Division	06/82
NM08	Mayhill		US Geological Survey	01/84
<b>New York</b>				
NY01	Alfred		US Geological Survey	08/04
NY06	Bronx	AMNet/MDN	NYSERDA	01/13
NY08	Aurora Research Farm		USDA/Cornell University	04/79
NY10	Chautauqua		US Geological Survey	06/80
NY20	Huntington Wildlife	MDN/AMNet/ AMoN	NYSERDA	10/78
NY22	Akwesasne Mohawk - Fort Covington		US Environmental Protection Agency - CAMD	08/99
NY28	Piseco Lake		NYSERDA	12/12
NY29	Moss Lake		US Geological Survey	07/03
NY43	Rochester	MDN	NYSERDA	04/13
NY52	Bennett Bridge		US Environmental Protection Agency-CAMD	06/80
NY59	Wanakena		NYSERDA	01/13
NY68	Biscuit Brook	MDN	US Geological Survey	10/83
NY93	Paul Smith's		NYSERDA	01/13
NY96	Cedar Beach, Southold		EPA/Suffolk Dept of Health Service-Peconic Estuary Program	11/03
NY98	Whiteface Mountain	AMoN	US Geological Survey	07/84
NY99	West Point		US Geological Survey	09/83

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>North Carolina</b>				
NC03	Lewiston		North Carolina State University	10/78
NC06	Beaufort	AMoN	US Environmental Protection Agency-CAMD	01/99
NC25	Coweeta	AMoN	USDA Forest Service	07/78
NC29	Hofmann Forest		North Carolina State University	07/02
NC34	Piedmont Research Station		North Carolina State University	10/78
NC35	Clinton Crops Research Station		North Carolina State University	10/78
NC36	Jordan Creek		US Geological Survey	10/83
NC41	Finley Farms		North Carolina State University	10/78
NC45	Mount Mitchell		US Environmental Protection Agency-CAMD/NCSU	11/85
<b>North Dakota</b>				
ND00	Theodore Roosevelt NP-Painted Canyon		National Park Service-Air Resources Division	01/01
ND08	Icelandic State Park		US Geological Survey	10/83
ND11	Woodworth		US Geological Survey	11/83
<b>Ohio</b>				
OH09	Oxford		US Geological Survey	08/84
OH17	Delaware		USDA Forest Service	10/78
OH49	Caldwell		US Geological Survey	09/78
OH54	Deer Creek State Park	AMoN	US Environmental Protection Agency-CAMD	01/99
OH71	Wooster		US Geological Survey	09/78

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>Oklahoma</b>				
OK00	Salt Plains NWR		US Geological Survey	12/83
OK17	Kessler Farm Field Laboratory		NOAA-Air Resources Lab	03/83
OK29	Goodwell Research Station		US Geological Survey	01/85
<b>Oregon</b>				
OR09	Silver Lake Ranger Station		US Geological Survey	08/83
OR10	H J Andrews Experimental Forest		USDA Forest Service	05/80
OR18	Starkey Experimental Forest		US Geological Survey	03/84
OR97	Hyslop Farm		US Environmental Protection Agency-CAMD	04/83
<b>Pennsylvania</b>				
PA00	Arendtsville	MDN/AMoN	US Environmental Protection Agency-CAMD	01/99
PA02	Crooked Creek Lake		Pennsylvania State University	07/11
PA13	Allegheny Portage Railroad National Historic Site	MDN	Pennsylvania State University	07/11
PA15	Penn State	AIRMoN	NOAA-Air Resources Lab/PA Game Commission	06/83
PA18	Young Woman's Creek		US Geological Survey	04/99
PA21	Goddard State Park	MDN	Pennsylvania State University	07/11
PA29	Kane Experimental Forest	MDN/AMoN	USDA Forest Service	07/78
PA30	Erie	MDN	Pennsylvania State University	07/11
PA42	Leading Ridge	MDN	SAES-Pennsylvania State University	04/79
PA47	Millersville	MDN	Pennsylvania Department of Environmental Protection	11/02
PA52	Little Pine State Park	MDN	Pennsylvania State University	07/11
PA60	Valley Forge	MDN	Pennsylvania State University	07/11

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
PA71	Little Buffalo State Park		Pennsylvania State University	07/11
PA72	Milford	MDN	USDA Forest Service	12/83
PA83	Laurel Hill State Park		Pennsylvania State University	07/11
PA90	Hills Creek State Park	MDN	Pennsylvania State University	07/11
PA98	Frances Slocum State Park		Pennsylvania State University	07/11
<b>Puerto Rico</b>				
PR20	El Verde		USDA Forest Service	02/85
<b>South Carolina</b>				
SC03	Savannah River	MDN	Savannah River Nuclear Solution	12/11
SC05	Cape Romain NWR	MDN/AMoN	US Fish & Wildlife Service - Air Quality Branch	11/00
SC06	Santee NWR		US Geological Survey	07/84
<b>South Dakota</b>				
SD04	Wind Cave National Park-Elk Mountain		National Park Service - Air Resources Division	11/02
SD08	Cottonwood		US Geological Survey	10/83
SD99	Huron Well Field		US Geological Survey	11/83
<b>Tennessee</b>				
TN04	Speedwell		US Environmental Protection Agency-CAMD	01/99
TN11	Great Smoky Mountain NP - Elkmont	MDN	National Park Service - Air Resources Division	08/80
TN14	Hatchie NWR		Tennessee Valley Authority	10/84
<b>Texas</b>				
TX02	Muleshoe NWR		US Geological Survey	06/85
TX03	Beeville		US Geological Survey	02/84

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
TX04	Big Bend NP - K-Bar		National Park Service - Air Resources Division	04/80
TX10	Attwater Prairie Chicken NWR		US Geological Survey	07/84
TX16	Sonora		US Geological Survey	06/84
TX21	Longview	MDN	Texas Commission on Environmental Quality	06/82
TX22	Guadalupe Mountains NP-Frijole Ranger Stn		US Geological Survey	06/84
TX43	Cañonceta	AMoN	Texas A&M University/Texas Agrilife Research	07/07
TX56	LBJ National Grasslands		US Geological Survey	09/83
<b>Utah</b>				
UT01	Logan	AMoN	US Geological Survey	12/83
UT09	Canyonlands NP - Island in the Sky		National Park Service - Air Resources Division	11/97
UT98	Green River		US Geological Survey	04/85
UT99	Bryce Canyon NP - Repeater Hill		National Park Service - Air Resources Division	01/85
<b>Vermont</b>				
VT01	Bennington		US Geological Survey	04/81
VT99	Underhill	AMNet MDN/AMoN	US Geological Survey	06/84
<b>Virgin Islands</b>				
VI01	Virgin Islands NP - Lind Point		National Park Service - Air Resources Division	04/98
<b>Virginia</b>				
VA00	Charlottesville		US Geological Survey	10/84
VA13	Horton's Station		Tennessee Valley Authority	07/78
VA24	Prince Edward	AMoN	US Environmental Protection Agency-CAMD	01/99
VA28	Shenandoah NP - Big Meadows	MDN	National Park Service - Air Resources Division	05/81

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
VA99	Natural Bridge Station		USDA Forest Service - Air Program	07/02
<b>Washington</b>				
WA14	Olympic NP - Hoh Ranger Station		National Park Service - Air Resources Division	05/80
WA19	North Cascades NP-Marblemount Ranger Stn		US Geological Survey	02/84
WA21	La Grande		US Environmental Protection Agency-CAMD	04/84
WA24	Palouse Conservation Farm		US Geological Survey	08/85
WA98	Columbia River Gorge		USDA Forest Service - Pacific Northwest Region	05/02
WA99	Mount Rainier NP - Tahoma Woods	AMoN	National Park Service - Air Resources Division	10/99
<b>West Virginia</b>				
WV04	Babcock State Park		US Geological Survey	09/83
WV05	Cedar Creek State Park		US Environmental Protection Agency-CAMD	01/99
WV18	Parsons	AMoN	USDA Forest Service	07/78
<b>Wisconsin</b>				
W109	Popple River	MDN	Wisconsin Department of Natural Resources	12/86
W110	Potawatomi	MDN	EPA/Forest County Potawatomi Community	06/05
W125	Suring		Wisconsin Department of Natural Resources	01/85
W128	Lake Dubay		Wisconsin Department of Natural Resources	06/82

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
W135	Perkinstown	AMoN	US Environmental Protection Agency-CAMD	01/99
W136	Trout Lake	MDN	Wisconsin Department of Natural Resources	01/80
W137	Spooner		Wisconsin Department of Natural Resources	06/80
W198	Wildcat Mountain		Wisconsin Department of Natural Resources	08/89
W199	Lake Geneva	MDN	Wisconsin Department of Natural Resources	06/84
<b>Wyoming</b>				
WY00	Snowy Range		USDA Forest Service	04/86
WY02	Sinks Canyon		Bureau of Land Management	08/84
WY06	Pinedale		Bureau of Land Management	01/82
WY08	Yellowstone NP - Tower Falls	MDN	National Park Service - Air Resources Division	06/80
WY94	Grand Tetons National Park	AMoN	State of Wyoming DEQ	09/11
WY95	Brooklyn Lake	AMoN	USDA Forest Service	09/92
WY97	South Pass City		USDA Forest Service/Bridger Teton NF	04/85
WY98	Gypsum Creek		USDA Forest Service/Bridger Teton NF	12/84
WY99	Newcastle		Bureau of Land Management	08/81
<b>Canada</b>				
BC22	Haul Road Station		Rio Tinto	09/12
BC23	Lakelse Lake		Rio Tinto	03/13
CAN5	Frelighsburg		US Geological Survey	10/01
SK20	Cactus Lake		Saskatchewan Ministry of Environment	02/12
SK21	Hudson Bay		Saskatchewan Ministry of Environment	04/12

AIRMoN Map and Site Listings

**National Atmospheric Deposition Program  
Atmospheric Integrated Research Monitoring Network**



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

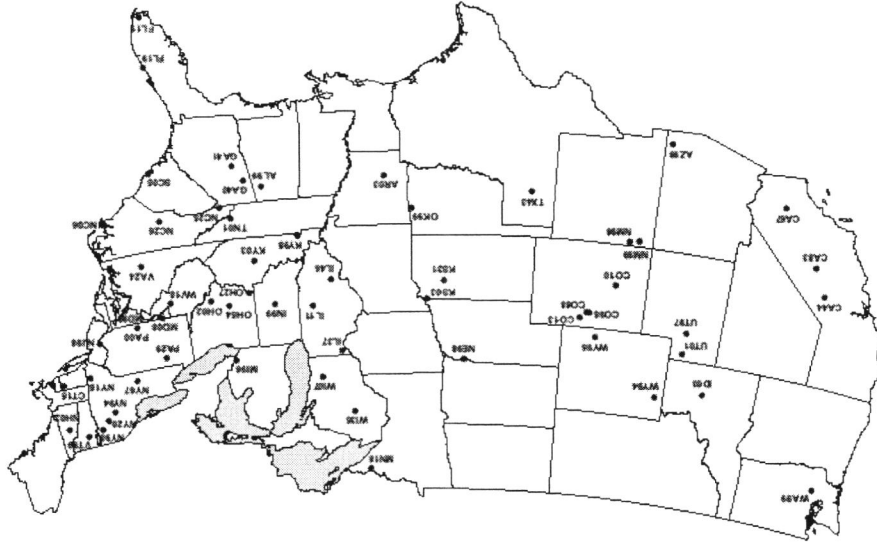
July 31, 2013

<b>State</b>	<b>Site Code</b>	<b>Site Name</b>	<b>Collocation</b>	<b>Sponsoring Agency</b>	<b>Start Date</b>
<b>Delaware</b>					
	DE02	Lewes		NOAA-Air Resources Laboratory	09/92
<b>Illinois</b>					
	IL11	Bondville	MDN/NTN/AMoN	NOAA-Air Resources Laboratory	10/92
<b>New York</b>					
	NY67	Cornell University	AMoN	NOAA-Air Resources Laboratory	09/92
<b>Pennsylvania</b>					
	PA15	Penn State	NTN	NOAA-Air Resources Laboratory	10/92
<b>Tennessee</b>					
	TN00	Walker Branch Watershed		NOAA-Air Resources Laboratory	09/92
<b>West Virginia</b>					
	WV99	Canaan Valley Institute		NOAA-Air Resources Laboratory	06/00

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AMoN Map and Site Listings



National Ammonia Monitoring Network  
National Atmospheric Deposition Program

**National Atmospheric Deposition Program/Ammonia Monitoring Network Sites**

**July 31, 2013**

<b>State/Province</b>	<b>Site Code</b>	<b>Site Name</b>	<b>Collocation</b>	<b>Sponsoring Agency</b>	<b>Start Date</b>
<b>Alabama</b>					
	AL99	Sand Mountain Research & Ext. Center	NTN	US Environmental Protection Agency - CAMD	03/11
<b>Arizona</b>					
	AZ98	Chiricahua	NTN	National Park Service - Air Resources Division	03/11
<b>Arkansas</b>					
	AR03	Caddo Valley	NTN	US Environmental Protection Agency - CAMD	03/11
<b>California</b>					
	CA44	Yosemite NP- Turtleback Dome		National Park Service - Air Resources Division	03/11
	CA67	Joshua Tree NP - Black Rock	NTN	National Park Service - Air Resources Division	03/11
	CA83	Sequoia NP-Ash Mountain		National Park Service - Air Resources Division	03/11
<b>Colorado</b>					
	CO10	Gothic	NTN	US Environmental Protection Agency - CAMD	09/12
	CO13	Fort Collins	MDN	US Environmental Protection Agency - CAMD	11/07
	CO88	Rocky Mountain NP- Longs Peak		National Park Service - Air Resources Division	05/11
	CO98	Rocky Mountain NP - Loch Vale	NTN	National Park Service - Air Resources Division	05/11
<b>Connecticut</b>					
	CT15	Abington	NTN	US Environmental Protection Agency - CAMD	03/11
<b>Florida</b>					
	FL11	Everglades NP - Research Center	NTN/MDN	National Park Service - Air Resources Division	03/11
	FL19	Indian River		US Environmental Protection Agency - CAMD	04/11

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<b>State/Province</b>	<b>Site Code</b>	<b>Site Name</b>	<b>Collocation</b>	<b>Sponsoring Agency</b>	<b>Start Date</b>
<b>Georgia</b>					
	GA40	Yorkville	AMNet/MDN	Atmospheric Research & Analysis	12/11
	GA41	Georgia Station	NTN	US Environmental Protection Agency - CAMD	06/11
<b>Idaho</b>					
	ID03	Craters of the Moon NM	NTN	National Park Service - Air Resources Division	06/10
<b>Illinois</b>					
	IL11	Bondville	AIRMoN/MDN /NTN	US Environmental Protection Agency - CAMD	10/07
	IL37	Stockton		US Environmental Protection Agency - CAMD	04/11
	IL46	Alhambra	NTN	US Environmental Protection Agency - CAMD	03/11
<b>Indiana</b>					
	IN99	Indianapolis		US Environmental Protection Agency - CAMD	10/07
<b>Kansas</b>					
	KS03	Reserve	MDN	Sac and Fox Nation of Missouri	10/11
	KS31	Konza Prairie	NTN	US Environmental Protection Agency - CAMD	03/11
<b>Kentucky</b>					
	KY03	Mackville	NTN	US Environmental Protection Agency - CAMD	03/11
	KY98	Cadiz		US Environmental Protection Agency - CAMD	03/11

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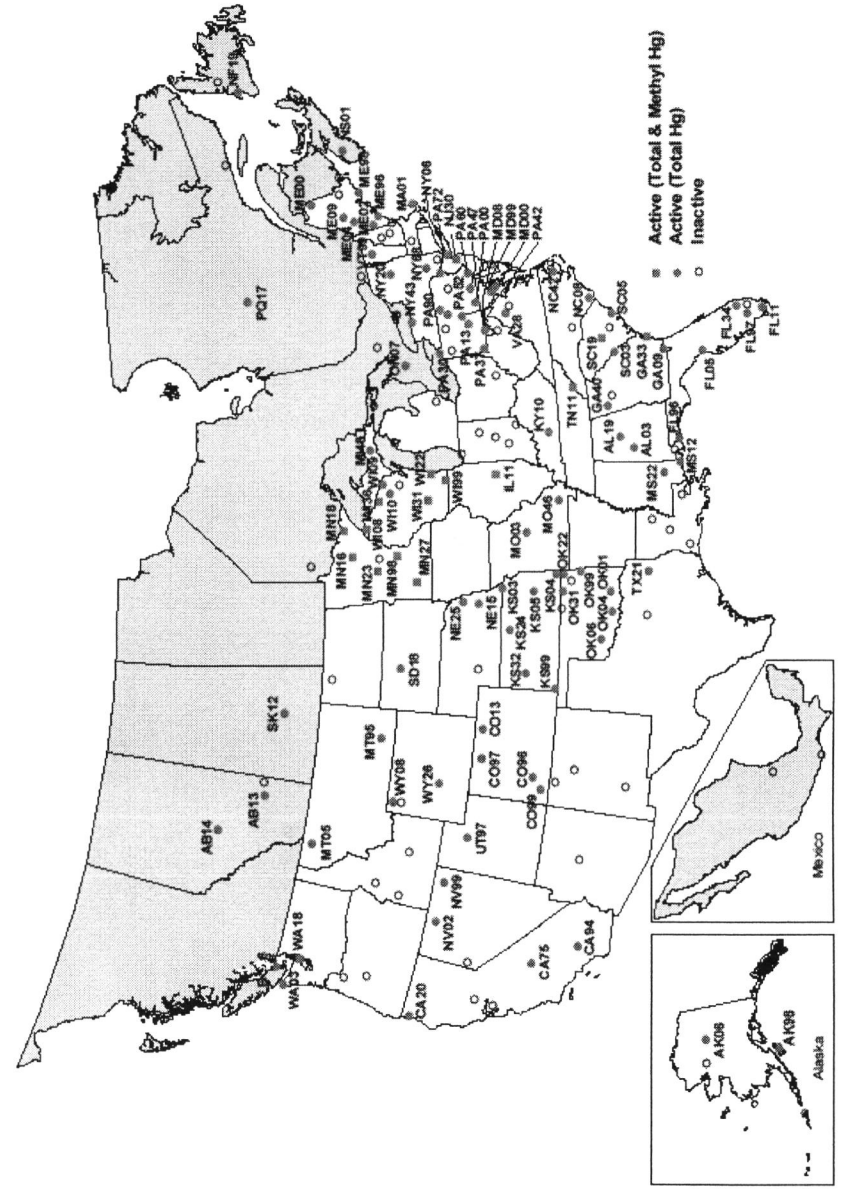
State/Province	Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>Maryland</b>					
	MD08	Piney Reservoir	MDN/AMNet/ NTN	State of MD/ Department of Natural Resources	08/10
	MD99	Beltsville	MDN/AMNet/ NTN	State of MD/ Department of Natural Resources	08/10
<b>Michigan</b>					
	MI96	Detroit		US Environmental Protection Agency - CAMD	10/07
<b>Minnesota</b>					
	MN18	Fernberg	NTN/MDN	US Environmental Protection Agency - CAMD	10/07
<b>Nebraska</b>					
	NE98	Santee		US Environmental Protection Agency - CAMD	04/11
<b>NewHampshire</b>					
	NH02	Hubbard Brook	NTN	US Environmental Protection Agency - CAMD	06/12
<b>New Jersey</b>					
	NJ98	Washington Crossing CASTNET		US Environmental Protection Agency - CAMD	03/11
<b>New Mexico</b>					
	NM98	Navajo Lake		US Environmental Protection Agency - CAMD	01/08
	NM99	Farmington		US Environmental Protection Agency - CAMD	01/08

State/Province	Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>New York</b>					
	NY16	Cary Institute		Cary Institute Of Ecosystem Studies	10/09
	NY20	Huntington Wildlife	MDN/AMNet/ NTN	US Environmental Protection Agency - CAMD	06/12
	NY67	Ithaca	AIRMoN	US Environmental Protection Agency - CAMD	10/07
	NY94	Nick's Lake		US Environmental Protection Agency - CAMD	11/12
	NY98	Whiteface Mountain	NTN	US Environmental Protection Agency - CAMD	11/12
<b>North Carolina</b>					
	NC06	Beaufort	NTN	US Environmental Protection Agency - CAMD	04/10
	NC25	Coweeta	NTN	US Environmental Protection Agency - CAMD	05/11
	NC26	Candor		US Environmental Protection Agency - CAMD	04/11
	NC30	Duke Forest		US Environmental Protection Agency - CAMD	06/08
<b>Ohio</b>					
	OH02	Athens Super Site	AMNet	US Environmental Protection Agency - CAMD	10/07
	OH27	Cincinnati		US Environmental Protection Agency - CAMD	10/07
	OH54	Deer Creek State Park	NTN	US Environmental Protection Agency - CAMD	03/11
<b>Oklahoma</b>					
	OK99	Stilwell	MDN/AMNet	US Environmental Protection Agency - CAMD	10/07
<b>Pennsylvania</b>					
	PA00	Arendtsville	NTN/MDN	US Environmental Protection Agency - CAMD	10/09
	PA29	Kane Experimental Forest	NTN/MDN	US Environmental Protection Agency - CAMD	03/11

State/Province	Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>South Carolina</b>					
	SC05	Cape Romain NWR	NTN/MDN	US Environmental Protection Agency - CAMD	10/07
<b>Tennessee</b>					
	TN01	Great Smoky Mountains NP- Look Rock		National Park Service - Air Resources Division	03/11
<b>Texas</b>					
	TX43	Cañonceta	NTN	US Environmental Protection Agency - CAMD	10/07
<b>Utah</b>					
	UT01	Logan	NTN	State of Utah	11/11
	UT97	Salt Lake City	MDN/AMNet	State of Utah	11/11
<b>Vermont</b>					
	VT99	Underhill	AMNet/MDN/ NTN	US Environmental Protection Agency - CAMD	11/12
<b>Virginia</b>					
	VA24	Prince Edward	NTN	US Environmental Protection Agency - CAMD	03/11
<b>Washington</b>					
	WA99	Mount Rainier NP - Tahoma Woods	NTN	National Park Service - Air Resources Division	03/11
<b>West Virginia</b>					
	WV18	Parsons	NTN	US Environmental Protection Agency - CAMD	06/11
<b>Wisconsin</b>					
	WI07	Horicon Marsh		US Environmental Protection Agency - CAMD	10/07
	WI35	Perkinstown	NTN	US Environmental Protection Agency - CAMD	03/11

State/Province	Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>Wyoming</b>					
	WY94	Grand Tetons National Park	NTN	National Park Service - Air Resources Division	09/11
	WY95	Brooklyn Lake		US Environmental Protection Agency - CAMD	06/12

# MDN Map and Site Listings



**National Atmospheric Deposition Program/Mercury Deposition Network Sites**

**July 31, 2013**

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<b>State/Province Site Code</b>	<b>Site Name</b>	<b>Collocation</b>	<b>Sponsoring Agency</b>	<b>Start Date</b>
<b>Alabama</b>				
AL03	Centreville	NTN	Atmospheric Research and Analysis, Inc	06/00
AL19	Birmingham	AMNet/MDN	Atmospheric Research and Analysis, Inc	12/10
<b>Alaska</b>				
AK00	Dutch Harbor		State of Alaska Department of Environmental Conservatio	09/09
AK06	Gates of the Arctic NP - Bettles	NTN	US Bureau of Land Management	11/08
AK98	Kodiak		State of Alaska Department of Environmental Conservatio	09/07
<b>California</b>				
CA20	Yurok Tribe-Requa		Electric Power Research Institute	08/06
CA75	Sequoia NP-Giant Forest	NTN	National Park Service - Air Resources Division	07/03
CA94	Converse Flats	NTN	USDA Forest Service	04/06
<b>Colorado</b>				
CO13	Fort Collins	AMoN	Colorado State University	06/12
CO96	Molas Pass	NTN	US Bureau of Land Management	06/09
CO97	Buffalo Pass - Summit Lake	NTN	USDA Forest Service	09/98
CO99	Mesa Verde NP-Chapin Mesa	NTN	National Park Service - Air Resources Division	12/01

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<b>State/Province Site Code</b>	<b>Site Name</b>	<b>Collocation</b>	<b>Sponsoring Agency</b>	<b>Start Date</b>
<b>Florida</b>				
FL05	Chassahowitzka NWR	NTN	US Fish & Wildlife Service - Chassahowitzka NWR	07/97
FL11	Everglades NP - Research Center	NTN/AMoN	South Florida Water Management District	03/96
FL34	Everglades Nutrient Removal Project		South Florida Water Management District	07/97
FL96	Pensacola	AMNet/NTN	Atmospheric Research and Analysis, Inc	12/10
FL97	Everglades - Western Broward County		South Florida Water Management District	11/06
<b>Georgia</b>				
GA09	Okefenokee NWR	NTN	US Fish & Wildlife Service - Air Quality Branch	07/97
GA33	Sapelo Island	NTN	Georgia Department of Natural Resources /Sapelo Island NERR	09/07
GA40	Yorkville	AMNet/AMoN	Atmospheric Research and Analysis, Inc	06/00
<b>Illinois</b>				
IL11	Bondville	AIRMoN/NTN/ AMoN	Illinois State Water Survey/NADP	01/99
<b>Kansas</b>				
KS03	Reserve	AMoN	Kansas Department of Health and Environment	01/08
KS04	West Mineral		Kansas Department of Health and Environment	10/08
KS05	Coffey County Lake		Kansas Department of Health and Environment	12/08
KS24	Glen Elder State Park		Kansas Department of Health and Environment	05/08
KS32	Lake Scott State Park	NTN	Kansas Department of Health and Environment	06/08
KS99	Cimarron National Grassland		Kansas Department of Health and Environment	12/08

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>Kentucky</b>				
KY10	Mammoth Cave NP-Houchin Meadow	NTN	National Park Service - Air Resources Division	08/02
<b>Maine</b>				
ME00	Caribou	NTN	University of Maine	05/07
ME02	Bridgton	NTN	Maine Department of Environmental Protection/EPA	06/97
ME04	Carrabassett Valley	NTN	Penobscot Indian Nation	02/09
ME09	Greenville Station	NTN	Maine Department of Environmental Protection/EPA	09/96
ME96	Casco Bay - Wolfe's Neck Farm	NTN	Maine Department of Environmental Protection/EPA	01/98
ME98	Acadia NP - McFarland Hill	NTN	Maine Dept of Environmental Protection/NPS-Acadia NP/	03/96
<b>Maryland</b>				
MD00	Smithsonian Environmental Res Ctr		MD DNR/Smithsonian Environmental Research Center	12/06
MD08	Piney Reservoir	NTN /AMNet/ AMoN	MD DNR/University of Maryland-Appalachian Lab	06/04
MD99	Beltsville	NTN /AMNet/ AMoN	Maryland Department of Natural Resources	06/04
<b>Massachusetts</b>				
MA01	North Atlantic Coastal Lab	NTN	NPS - Cape Cod National Seashore	07/03
<b>Michigan</b>				
MI48	Seney NWR - Headquarters	NTN	US Fish & Wildlife Service-Air Quality Branch	11/03

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>Minnesota</b>				
MN16	Marcel Experimental Forest	NTN	USDA Forest Service-North Central Research Station & Minnesota Pollution Control Agency	02/96
MN18	Fernberg	NTN/AMoN/ MLI	Minnesota Pollution Control Agency	03/96
MN23	Camp Ripley	NTN	Minnesota Pollution Control Agency	07/96
MN27	Lamberton	NTN	Minnesota Pollution Control Agency	07/96
MN98	Blaine		Minnesota Pollution Control Agency	02/08
<b>Mississippi</b>				
MS12	Grand Bay NERR	NTN /AMNet	NOAA - Air Resources Lab	03/10
MS22	Oak Grove		Atmospheric Research and Analysis, Inc	06/00
<b>Missouri</b>				
MO03	Ashland Wildlife Area	NTN	Missouri Department of Natural Resources /EPA	07/10
MO46	Mingo NWR		Missouri Department of Natural Resources /EPA	03/02
<b>Montana</b>				
MT05	Glacier NP - Fire Weather Station	NTN	National Park Service - Air Resources Division	10/03
MT95	Badger Peak		Northern Cheyenne Tribe	11/10
<b>Nebraska</b>				
NE15	Mead	NTN	Nebraska Department of Environmental Quality	06/07
NE25	Winnebago		Winnebago Tribe of Nebraska	11/09

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State/Province	Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>Nevada</b>					
	NV02	Lesperance Ranch		Nevada Dept of Conservation & Natural Resources/Frontier Global, Inc	01/03
	NV99	Gibb's Ranch		Nevada Dept of Conservation & Natural Resources/Frontier Global, Inc	02/03
<b>New Jersey</b>					
	NJ30	New Brunswick	AMNet	US Geological Survey	01/06
<b>New York</b>					
	NY06	Bronx	AMNet/NTN	New York Department of Environmental Conservation	01/08
	NY20	Huntington Wildlife	NTN/AMNet/ AMoN	Syracuse University /EPA	12/99
	NY43	Rochester	NTN	NYSERDA	01/08
	NY68	Biscuit Brook	NTN	US Geological Survey	03/04
<b>North Carolina</b>					
	NC08	Waccamaw State Park		North Carolina Dept of Environment & Natural Resources	02/96
	NC42	Pettigrew State Park		North Carolina Dept of Environment & Natural Resources	02/96

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State/Province	Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>Oklahoma</b>					
	OK01	McGee Creek		Oklahoma Department of Environmental Quality	10/06
	OK04	Lake Murray		Oklahoma Department of Environmental Quality	10/07
	OK06	Wichita Mountains NWR		Oklahoma Department of Environmental Quality	11/07
	OK22	Miami		Peoria Tribe of Indians of Oklahoma	03/12
	OK31	Copan		Oklahoma Department of Environmental Quality	10/06
	OK99	Stilwell	AMNet/AMoN	Cherokee Nation/EPA	04/03
<b>Pennsylvania</b>					
	PA00	Arendtsville	NTN/AMoN	PA Dept of Env Protection/Penn State University	11/00
	PA13	Allegheny Portage Railroad NHS	NTN	PA Dept of Env Protection/Penn State University	01/97
	PA21	Goddard State Park	NTN	PA Dept of Env Protection/Penn State University	03/10
	PA29	Kane Experimental Forest	NTN/AMoN	PA Dept of Env Protection/Penn State University	06/10
	PA30	Erie	NTN	PA Dept of Env Protection/Penn State University	06/00
	PA37	Waynesburg		Electrical Power Research Institute	05/99
	PA42	Leading Ridge	NTN	PA Dept of Env Protection/Penn State University	03/10
	PA47	Millersville	NTN	PA Dept of Env Protection/Penn State University	11/02
	PA52	Little Pine State Park	NTN	PA Dept of Env Protection/Penn State University	07/07
	PA60	Valley Forge	NTN	PA Dept of Env Protection/Penn State University	11/99
	PA72	Milford	NTN	PA Dept of Env Protection/Penn State University	09/00
	PA90	Hills Creek State Park	NTN	PA Dept of Env Protection/Penn State University	01/97

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State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>South Carolina</b>				
SC03	Savannah River	NTN	Savannah River Nuclear Company	01/01
SC05	Cape Romaine NWR	NTN/AMoN	US Fish & Wildlife Service - Air Quality Branch	03/04
SC19	Congaree Swamp		South Carolina Dept of Health & Environmental Control	03/96
<b>South Dakota</b>				
SD18	Eagle Butte		Cheyenne River Sioux Tribe/EPA	03/07
<b>Tennessee</b>				
TN11	Great Smoky Mountains NP-Elkmont	NTN	National Park Service - Air Resources Division	01/02
<b>Texas</b>				
TX21	Longview	NTN	Texas Commission on Environmental Quality	03/96
<b>Utah</b>				
UT97	Salt Lak. City	AMNet/AMoN	Utah Department of Environmental Quality	05/07
<b>Vermont</b>				
VT99	Underhill	AIRMoN/NTN/ AMNet	Univ of VT -Rubinstein School of Env & Nat Res/NEIWPC	07/04
<b>Virginia</b>				
VA28	Shenandoah NP-Big Meadows	NTN	National Park Service - Air Resources Division	10/02
<b>Washington</b>				
WA03	Makah National Fish Hatchery		Eurofins Frontier Global Sciences	03/07
WA18	Seattle - NOAA		Illinois State Water Survey & Frontier Global Sciences Inc	03/96

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State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>Wisconsin</b>				
WI08	Brule River		Wisconsin Department of Natural Resources	03/96
WI09	Poppo River	NTN	Wisconsin Department of Natural Resources	03/96
WI10	Potawatomi	NTN	Forest County Potawatomi Community/EPA	06/05
WI22	Milwaukee		Wisconsin Department of Natural Resources	10/02
WI31	Devils Lake		Wisconsin Department of Natural Resources	01/01
WI36	Trout Lake	NTN	Wisconsin Department of Natural Resources	03/96
WI99	Lake Geneva	NTN	Wisconsin Department of Natural Resources	01/97
<b>Wyoming</b>				
WY08	Yellowstone NP-Tower Falls	NTN	Wyoming Department of Environmental Quality	10/04
WY26	Roundtop Mountain		State of Wyoming - DEQ	12/11

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
<b>CANADA</b>				
<b>Alberta</b>				
AB13	Henry Kroeger		ATCO Power	09/04
AB14	Genesee		Jacques Whitford Stantec Axys Ltd.	07/06
<b>British Columbia</b>				
BC16	Saturna Island		Environment Canada	09/09
<b>Newfoundland</b>				
NF19	Stephenvill		Environmnet Canada	2/10
<b>Nova Scotia</b>				
NS01	Kejimkujik NP	AMNet	Environment Canada	07/96
<b>Ontario</b>				
ON07	Egbert		Environment Canada	03/00
<b>Quebec</b>				
PQ17	Chapais		Environment Canada	11/09

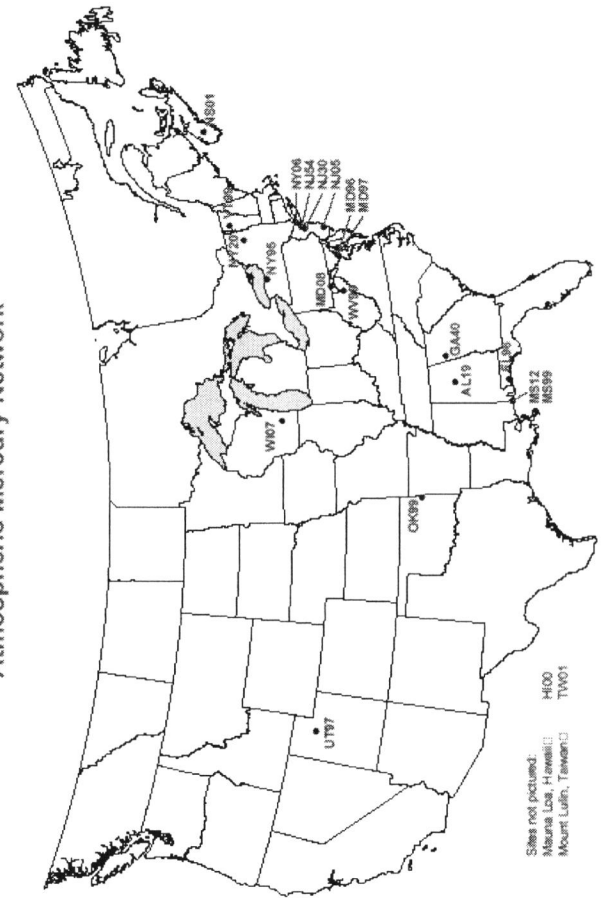
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# AMNet Map and Site Listings

## National Atmospheric Deposition Program Atmospheric Mercury Network



**National Atmospheric Deposition Program/Atmospheric Mercury Network Sites**

July 31, 2013

<b>State/Province</b>	<b>Site Code</b>	<b>Site Name</b>	<b>Collocation</b>	<b>Sponsoring Agency</b>	<b>Start Date</b>
<b>Alabama</b>					
	AL19	Birmingham	MDN/NTN	Atmospheric Research & Analysis, Inc.	12/10
<b>California</b>					
	CA48	Elkhorn Slough		US Environmental Protection Agency-CAMD	01/10
<b>Florida</b>					
	FL96	Pensacola	MDN/NTN	Atmospheric Research & Analysis, Inc.	12/10
<b>Georgia</b>					
	GA40	Yorkville	MDN/AMoN	Atmospheric Research & Analysis, Inc.	12/10
<b>Hawaii</b>					
	HI00	Mauna Loa		National Oceanic & Atmospheric Administration	01/12
<b>Maryland</b>					
	MD08	Piney Reservoir	MDN/NTN/AMoN	State of Maryland	01/08
	MD98	Beltsville II		NOAA/US Environmental Protection Agency-CAMD	01/07
	MD99	Beltsville	MDN/NTN/AMoN	NOAA/US Environmental Protection Agency-CAMD	11/06
<b>Mississippi</b>					
	MS12	Grand Bay NERR	MDN/NTN	National Oceanic & Atmospheric Administration	09/06
	MS99	Grand Bay NERR II		National Oceanic & Atmospheric Administration	10/07

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<b>State/Province</b>	<b>Site Code</b>	<b>Site Name</b>	<b>Collocation</b>	<b>Sponsoring Agency</b>	<b>Start Date</b>
<b>New Jersey</b>					
	NJ30	New Brunswick	MDN	State of New Jersey	07/02
	NJ54	Elizabeth Lab		State of New Jersey	01/04
<b>New York</b>					
	NY06	New York City	MDN	State of New York	08/08
	NY20	Huntington Wildlife Forest	MDN/NTN/AMoN	US Environmental Protection Agency-CAMD	11/07
	NY95	Rochester B		State of New York/NYSERDA	09/08
<b>Oklahoma</b>					
	OK99	Stilwell	MDN/AMoN	Cherokee Nation	10/08
<b>Utah</b>					
	UT97	Salt Lake City	MDN/AMoN	State of Utah	11/08
<b>Vermont</b>					
	VT99	Underhill	MDN/NTN	US Environmental Protection Agency-CAMD	01/08

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<b>State/Province</b>				
<b>Site Code</b>	<b>Site Name</b>	<b>Collocation</b>	<b>Sponsoring Agency</b>	<b>Start Date</b>
<b>Canada</b>				
NS01	Kejimikujik NP	MDN	Environment Canada	01/09
<b>Taiwan</b>				
TW01	Mt. Luril		Taiwan EPA	01/12

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The National Atmospheric Deposition Program (NADP) was established in 1977 under State Agricultural Experiment Station (SAES) leadership to address the problem of atmospheric deposition and its effects on agricultural crops, forests, rangelands, surface waters, and other natural and cultural resources. In 1978, sites in the NADP precipitation chemistry network first began collecting one-week, wet-only deposition samples for analysis at the Illinois State Water Survey's Central Analytical Laboratory (CAL), located at the University of Illinois, Urbana-Champaign. The network was established to provide data on amounts, temporal trends, and geographic distributions of the atmospheric deposition of acids, nutrients, and base cations by precipitation.

Initially, the NADP was organized as SAES North Central Regional Project NC-141, which all four SAES regions further endorsed in 1982 as Interregional Project IR-7. A decade later, IR-7 was reclassified as National Research Support Project No. 3 (NRSP-3), which it remains. NRSP projects are multistate activities that support research on topics of concern to more than one state or region of the country. Multistate projects involve the SAES in partnership with the USDA National Institute of Food and Agriculture and other universities, institutions, and agencies.

In October 1981, the federally supported National Acid Precipitation Assessment Program (NAPAP) was established to increase understanding of the causes and effects of acidic precipitation. This program sought to establish a long-term precipitation chemistry network of sampling sites distant from point source influences. Because of its experience in organizing and operating a national-scale network, the NADP agreed to coordinate operation of NAPAP's National Trends Network (NTN). To benefit from identical siting criteria and operating procedures and a shared analytical laboratory, NADP and NTN merged with the designation NADP/NTN. This merger brought substantial new federal agency participation into the program. Many NADP/NTN sites were supported by the USGS, NAPAP's lead federal agency for deposition monitoring.

In October 1992, the Atmospheric Integrated Research Monitoring Network (AIRMoN) joined the NADP. AIRMoN sites collect samples daily when precipitation occurs. In January 1996, the NADP established the Mercury Deposition Network (MDN), the third network in the organization. The MDN was formed to provide data on the wet deposition of mercury to surface waters, forested watersheds, and other receptors. In October 2009, the Atmospheric Mercury Network (AMNet) joined the NADP as the fourth network. AMNet measures the concentration of atmospheric mercury. In October 2010, the Ammonia Monitoring Network (AMoN) joined the NADP, measuring atmospheric ammonia concentrations using passive monitors.

SAES project NRSP-3 was renewed in 2009 and it continues to offer a unique opportunity for cooperation among scientists from land-grant and other universities, government agencies, and non-governmental organizations. It provides a framework for leveraging the resources of nearly 100 different sponsoring agencies to address contemporary and emerging issues of national importance.

*NADP Program Office  
Illinois State Water Survey  
2204 Griffith Drive  
Champaign, IL 61820-7495*

*NADP Home page: <http://nadp.isws.illinois.edu>  
Phone: 217/333-7871*