NADP Proceedings 2008-01

NADP 2008
Technical Committee Meeting

October 14 – 16, 2008
Madison, Wisconsin

Scientific Symposium Chair
Eric Prestbo
Tekran Instrument Corporation

PROCEEDINGS

Prepared by

Kathryn E. Douglas
NADP Program Office
Illinois State Water Survey
University of Illinois
Institute of Natural Resource and Sustainability
2204 Griffith Drive
Champaign, IL 61820

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Acknowledgements

The NADP would like to express their appreciation to the Wisconsin Department of Natural Resources and, especially, Bruce Roger for arranging the field trip to Crave's Dairy and the Pleasant Prairie Power Plant.

Special thanks goes to NADP and Illinois State Water Survey staff members Pam Bedient, Roger Claybrooke, Sara Olson, Nichole Samson and Lisa Volk for their support in assisting with the proceedings book, service awards, graphic support and meeting registration.

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Poster Session

NADP Scientific Symposium Agenda

NADP Technical Meeting and Scientific Symposium
Madison, Wisconsin
October 14 – 16, 2008

Tuesday, October 14, 2008		**Room Location**
Registration Desk Open All Day		University Foyer
8:00 a.m. - 9:00 a.m.	Joint Subcommittee Meeting	University Room
9:00 a.m. - 12:00 noon	Subcommittee Meetings	
	Network Operations	University Room
	Data Management & Analysis	Conference Room I
	Ecological Response and Outreach	Conference Room II
	Critical Loads (ad hoc)	Conference Room III
10:00 - 10:20	Break	
12:00 noon - 1:30 p.m.	Lunch - On your own	
1:30 - 3:30	Joint Subcommittee Meeting	University Room
3:00 - 3:45	Break	
3:45 - 5:00	Executive Committee Meeting	Conference Room IV

Wednesday, October 15, 2008		**Room Location**
Registration Desk Open All Day		University Foyer
8:00 a.m. - 9:00 a.m.	**Program Office Report, Awards and Announcements**	Wisconsin Ballroom

David Gay: NADP Coordinator
Tom Butler: Cornell University, NADP Chair
Eric Prestbo: Tekran Instrument Corporation, Scientific Symposium Chair

Keynote Addresses

9:00 – 9:30 **Thirty Years Down and a Century to Go! A Narrative History of the Origins and Early History of the National Atmospheric Deposition Program**
Ellis B. Cowling, University Distinguished Professor At-Large Emeritus North Carolina State University

9:30 – 10:00 **Invited: Wisconsin State Perspective on the Environment**
Matthew J. Frank, Wisconsin Department of Natural Resources Secretary

Wednesday, October 15, 2008		**Room Location**
Technical Session:	**MONITORING AND RESEARCH FOR AGRICULTURE IN THE NEXT DECADE** Session Chair: Greg Wetherbee U.S. Geological Survey	Wisconsin Ballroom
10:00 a.m. – 10:20 a.m.	**Keynote: Research and Monitoring Needs from an Agricultural Perspective** Raymond E. Knighton, USDA Cooperative State Research, Education and Extension Service	
10:20 – 10:40	**Concentration, Size Distributions, and Transport of Agricultural Aerosols** Naruki Hiranuma, Texas A & M University	
10:40 – 11:00	**Correspondence between Small- and Large-Scale Determinations of Ammonia Emissions from Dairy Barns** Mark Powell, USDA-ARS U.S. Dairy Forage Research	
11:00 – 11:20	**Measuring Exchange of Ammonia over Cropping Systems with the Modified Bowen Ratio Technique** Paul Doskey, Center for Environmental Science University of Chicago	
11:20 – 11:40	**Update on Methodologies and Findings of the National Air Emissions Measurement Study Open Source Component** Richard Grant, Purdue University	
11:40 – 12:00	**Using a Geographic Information System to Determine Wet Deposition Trends of Ammonium in the Central U.S.** Gregory Wetherbee, U.S. Geological Survey	
12:00 noon – 1:30 p.m.	Lunch – On your own	

Wednesday, October 15, 2008		**Room Location**
Technical Session:	**AMMONIA MEASUREMENTS** Session Chair: John Walker U.S. Environmental Protection Agency	Wisconsin Ballroom
1:30 p.m. - 1:50 p.m.	**Estimates of In-Canopy Ammonia Sources and Sinks Using Measured Profiles and Turbulence Closure Models** Jesse Bash, U.S. Environmental Protection Agency	
1:50 – 2:10	**Monitoring Ambient Atmospheric Chemistry along a Gradient of Ammonia Emission Density in Eastern North Carolina** John Walker, U.S. Environmental Protection Agency and Wayne Robarge North Carolina State University	
2:10 – 2:30	**Ammonia and Ammonium Measurements from the Southeastern U. S.** Rick Saylor, Atmospheric Research and Analysis, Inc.	
2:30 – 2:50	**Passive Ammonia Monitoring in the Central U.S.** Gary Lear, U.S. Environmental Protection Agency	
2:50 – 3:10	**Trent Regional Ammonia Monitoring using Passive Samplers (TRAMPS)** Antoni Zbieranowski, Trent University	
3:10 – 3:30	**Evaluation of Ammonia Measurements from CASTNet, IMPROVE, Passive and a New Sampling System** Derek Day, Colorado State University	
Technical Session:	**NADP – STANDING SENTINEL OVER AMERICA'S CROPS?** Session Chair: Van Bowersox Past NADP Coordinator	
3:30 – 3:50	**The Spread of Plant Diseases by Long-Range Atmospheric Transport and Deposition of Pathogen Propagules – A New Application for an Old Precipitation Sampling (NADP) Network** Van Bowersox, Past NADP Chair Sagar Krupa, University of Minnesota	
3:50 – 4:10	**The Application of the US Environmental Agency's Statistical Receptor Models to Determine the Sources of Microorganisms Attached to Airborne Particles** Robert Stevens, Florida Department of Environmental Protection	

Wednesday, October 15, 2008 — Room Location

Technical Session: **NADP – STANDING SENTINEL OVER AMERICA'S CROPS?** — Wisconsin Ballroom

Session Chair: Van Bowersox
Past NADP Coordinator

4:10 p.m.– 4:30 p.m. **Transport, Deposition and Detection of Bacterial Plant Pathogens: New Observations and Future Considerations**
Robert Seem, Cornell University

4:30 – 4:50 **Soybean Rust: Its History, Biology, Epidemiology and Importance to Crop Production**
James Kurle, University of Minnesota

4:50 – 5:10 **A Short Description of the NOAA HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) Model**
Rick Artz, NOAA Air Resources Lab

Poster Session and Reception — Room Location

NADP 30th Anniversary of Network Operations — Madison Ballroom
5:30 p.m.– 8:00 p.m.

Thursday, October 16, 2008 — Room Location

Registration Desk Open All Day — University Foyer

Technical Session: **CLIMATE CHANGE IMPACTS ON AIR QUALITY, DEPOSITION AND ECOSYSTEMS** — Wisconsin Ballroom

Session Chair: Rick Haeuber
U.S. Environmental Protection Agency

8:00 a.m. – 8:20 a.m. **Impacts of Global Climate and Emission Changes on U.S. Air Quality**
Xin-Zhong Liang, University of Illinois

8:20 – 8:40 **Future Climate Scenarios, Atmospheric Deposition and Precipitation Uncertainty**
Alice Gilliland, U.S. Environmental Protection Agency

8:40 – 9:00 **The Effects of Climate Change on Wet Deposition of Nitrogen, Sulfur, and Hydrogen across New York State during 1985 – 2007**
Douglas Burns, U.S. Geological Survey

9:00 – 9:20 **Critical Acid Load Limits in a Changing Climate: Implications and Solutions**
Steve McNulty, U.S Forest Service

Thursday, October 16, 2008		**Room Location**
Technical Session:	**CLIMATE CHANGE IMPACTS ON AIR QUALITY, DEPOSITION AND ECOSYSTEMS** Session Chair: Rick Haeuber U.S. Environmental Protection Agency	Wisconsin Ballroom
9:20 a.m. – 9:40 a.m.	**The Sensitivity of Heterogeneous Atmospheric Mercury Processes to Climate Change** Andy Rutter, University of Wisconsin	
9:40 – 10:00	**Chronic Enhancement of Mercury Methylation in a Boreal Wetland from Elevated Sulfate Deposition and Climate Change** Edward Swain, Minnesota Pollution Control Agency	
10:00 - 10:15	Break	
Technical Session:	**ECOSYSTEM EFFECTS OF ATMOSPHERIC DEPOSITION - SULFUR AND NITROGEN** Session Chair: Douglas Burns U.S. Geological Survey	
10:15 – 10:33	**Reductions in Atmospheric Nitrogen Deposition Linked to Increased Stream Silica on Five Appalachian Forest Basins** David DeWalle, Penn State University	
10:33 – 10:51	**Deposition and Cycling of Sulfur Control Mercury Accumulation in Isle Royale Fish** Paul Drevnick, Woods Hole Oceanographic Institute	
10:51 – 11:09	**Linking Data on Episodic Stream Acidification to Soil Chemistry in Assessments of Recovery from Acidic Deposition** Greg Lawrence, U.S. Geological Survey	
11:09 – 11:27	**Ecological Indicators of Effects of Changing Air Quality** Christine Negra, The Heinz Center	
11:27 – 11:45	**Air Quality Model Insights into Nitrogen Dry Deposition Missed by Current Networks** Robin Dennis, U.S. Environmental Protection Agency	
11:45 – 12:00	**Source Apportionment of Sulfur and Nitrogen Species at Rocky Mountain National Park using Modeled Conservative Tracer Releases and Tracers of Opportunity** William Malm, North Carolina State University	

Thursday, October 16, 2008		**Room Location**
12:00 noon – 1:30 p.m.	Lunch – On your own	
Technical Session:	**MERCURY MEASUREMENT, DEPOSITION AND EFFECTS** David Krabbenhoft, U.S. Geological Survey	Wisconsin Ballroom
1:30 p.m. – 1:50 p.m.	**High Mercury Wet Deposition at a Pristine Site in Puerto Rico** James Shanley, U.S. Geological Survey	
1:50 – 2:10	**Atmospheric Mercury Measurements in the Gulf of Mexico and Mid-Atlantic Regions** Winston Luke, NOAA Air Resources Lab	
2:10 – 2:30	**The Role of Regional Atmospheric Transport in Controlling Mercury Wet Deposition over the Northeastern United States** Peter Weiss, University of California, Santa Cruz	
2:30 – 2:50	**Ecological Indicators of Mercury in the Environment: Results from the Western Airborne Contaminants Assessment Project (WACAP) and the Disconnect between Deposition & Effects** Colleen Flanagan, National Park Service	
2:50 – 3:10	**Effect of Biomass Fires on Atmospheric Mercury Concentrations and Deposition in the United States** Krish Vijayaraghavan, Atmospheric & Environmental Research, Inc.	
3:10 – 3:30	**Observations and Interpretation of Aquatic Mercury Cycling from an Upper Midwest Lake Survey** David Krabbenhoft, U.S. Geological Survey	
Technical Session:	**EMERGING NOVEL MONITORING METHODS** Session Chair: Eric Prestbo Tekran Instrument Corporation	Wisconsin Ballroom
3:30 – 3:50 .	**Development of Surrogate Surfaces for Measurement of Mercury Dry Deposition** Seth Lyman, University of Nevada, Reno	
3:50 – 4:10	**Spatial Dry Deposition of Reactive Gaseous Mercury in West Central Alberta** Warren Kindzierski, University of Alberta	

Thursday, October 16, 2008 **Room Location**

Technical Session:	**EMERGING NOVEL MONITORING METHODS** Session Chair: Eric Prestbo Tekran Instrument Corporation	Wisconsin Ballroom
4:10 p.m. – 4:30 p.m.	**Pilot Study of Mercury in Litterfall at National Atmospheric Deposition Program Mercury Deposition Network Sites** Marty Risch, U.S. Geological Survey	
4:30 – 4:50	**Multi Component Vertical Gradient Measurements by WRD and SJAC Sampling as in GRAEGOR and GRAHAM** Rene Otjes, Energy Research Center of the Netherlands	
4:50 – 5:10	**A Field Instrument for Measuring Rain Conductivity in Real-time** Alfred Moyle, Penn State University	
5:10 – 5:30	**Perchlorate Deposition in Wet Precipitation across North America** Andrew Jackson, Texas Tech University	

Friday, October 17, 2008

Field Trip: Crave’s Dairy and Pleasant Prairie Power Plant

Itinerary

- Leave Concourse Hotel in Madison at approximately 8:00 a.m.
- Travel to Crave Dairy and arrive by 9:00 a.m.
- Picnic lunch
- Arrive at Pleasant Prairie Power Plant at 1:00 p.m.
- Leave Pleasant Prairie Power Plant around 3:00 p.m. for return trip to Madison

2008 NADP SITE OPERATOR AWARDS

National Trends Network Operator Awards

5 – Year Awards

SITE	OPERATOR NAME	SITE NAME	WET START	AGENCY
MD07	Rebecca Loncosky	Catoctin Mountain Park	May-03	National Park Service-ARD
MI51	Denise Dickson	Unionville	Jan-99	US Environmental Protection Agency-CAMD
MS19	Grace Norman	Newton	Nov-86	NOAA-Air Resources Lab
NY96	John Bredemeyer	Cedar Beach, Southold	Nov-03	US EPA/Suffolk Department of Health Service-Peconic Estuary Program
WA99	Rebecca Lofgren	Mount Rainier National Park – Tahoma Woods	Oct-99	National Park Service-ARD
WY00 &	John Korfmacher	Snowy Range	Apr-86	USDA Forest Service
WY95		Brooklyn Lake	Sep-92	USDA Forest Service

10 – Year Awards

SITE	OPERATOR NAME	SITE NAME	WET START	AGENCY
ID03	Michael Munts	Craters of the Moon NM	Aug-80	National Park Service-ARD
ME96 NTN & MDN	Don Prince	Casco Bay-Wolfe's Neck Farm	Jan-98	US EPA/Maine Department of Environmental Protection
MO03	Kevin Hosman	Ashland Wildlife Area	Oct-81	US Geological Survey
NM08	Linda Madron	Mayhill	Jan-84	US Geological Survey
WY97	Liz Oswald	South Pass City	Apr-85	USDA Forest Service-Bridger Teton NF

15 – Year Awards

SITE	OPERATOR NAME	SITE NAME	WET START	AGENCY
CO15	Ole Olsen	Sand Spring	Mar-79	Bureau of Land Management
PA15 NTN/AIRMoN	Robert Ziegler	Penn State	Jun-83	NOAA-Air Resources Lab
PA42	Kevin Horner	Leading Ridge	Apr-79	SAES-Penn State University

National Trends Network Operator Awards

SITE	OPERATOR NAME	SITE NAME	WET START	AGENCY
20 – Year Award				
TX16	Robert Moen	Sonora	Jun-84	US Geological Survey
25 – Year Awards				
IL18	David Lindgren	Shabbona	May-81	SAES-University of Illinois
IN20	Gary Zeissig	Roush Lake	Aug-83	US Geological Survey
MD13	Michael Newell	Wye	Mar-83	SAES-University of Maryland
30 – Year Award				
GA41	John Melin	Georgia Station	Oct-78	SAES-University of Georgia

History of the NADP

30 Years of Network Operations

Thirty Years Down and a Century to Go!
A Narrative History of the Origins and Early History of the National Atmospheric Deposition Program

Ellis B. Cowling
University Distinguished Professor At-Large Emeritus
North Carolina State University
Raleigh, North Carolina 27607

In 1947, Hans Egner, Professor of Horticulture at the Agricultural College near Uppsala, Sweden began the first regional program of research on the chemistry of precipitation and discovered that an accurate mass balance for growth and development of plants could not be calculated without considering the amounts of essential nutrients in precipitation. Egner's original network grew into an international program called the European Air Chemistry Network. Data from this Network provided important parts of the basis for Svante Odén's assertion in 1967 about an "insidious chemical warfare among the nation's of Europe" and Bert Bolin's publication "Sulfur in Air and Precipitation – Sweden's Case Study Contribution to the 1972 Stockholm Conference on the Human Environment."

Stimulated by these advances in scientific understanding about human-induced changes in the chemical climate of the Earth and impacts on crops, forests, and aquatic ecosystems, the US Forest Service organized the "First International Symposium on Acid Precipitation and the Forest Ecosystem." The major recommendation from this Symposium was "establishment of a permanent network of precipitation chemistry monitoring stations throughout the United States." On December 5, 1975, the idea of using the Regional Project system of State Agricultural Experiment Stations as the framework for a long-term, multi-agency network of precipitation chemistry monitoring sites was proposed and became known as the National Atmospheric Deposition Program.

Major achievements of NADP include:

1) Building and maintaining for 30 years, a uniquely successful partnership among many disparate federal, state, industrial, and university research communities.
2) Developing a high quality environmental database that is trusted by both scientific and policy leaders throughout North America and around the world.
3) Achieving a remarkable degree of personal and professional satisfaction through collaboration and cooperation among atmospheric, agricultural, forest, aquatic, and other natural resource scientists on a continental scale.
4) Maintaining a single Central Analytical Laboratory within the Illinois State Water Survey.
5) Maintaining cooperation with the Canadian CANSAP and CAPMoN networks.
6) Certification of network-wide QA/QC through site visits by EPA and the World Meteorological Organization.
7) Periodic peer reviews of NADP.
8) Special studies of atmospheric transport and deposition of pesticides and heavy metals and creation of NADP's Mercury Deposition Network (MDN) and Atmospheric Integrated Research Monitoring, Network (AIRMoN).
9) Using the Internet to disseminate NADP data and information.
10) Publishing isopleth maps showing spatial and temporal gradients in deposition of major nutrient cations and anions.
11) Learning to survive periodic budget crises and major changes in personnel.
12) Demonstrating that Title IV of the Clean Air Act Amendments of 1990 is working.

Tel: 919-515-7564, E-mail: ellis_cowling@ncsu.edu

History of Officers of the NADP

Year	Chair	Vice Chair	Secretary	Past Chair
1978-1979	Ellis Cowling		Sagar Krupa	
1979-1980	Ellis Cowling	John Skelly	James Galloway	
1980-1981	Ellis Cowling	Don Bogen	William McFee	
1981-1982	Ellis Cowling	William McFee	Stephen Norton	
1982-1983	Ellis Cowling	William McFee	Stephen Norton	
1983-1984	William McFee	David Shriner	Stephen Norton	Ellis Cowling
1984-1985	David Shriner	Dudley Raynal	John Robertson	William McFee
1985-1986	Dudley Raynal	John Robertson	Steven Lindberg	David Shriner
1986-1987	John Robertson	Wayne Banwart	Steven Lindberg	Dudley Raynal
1987-1988	Wayne Banwart	Steven Lindberg	Doug Sisterson	John Robertson
1988-1989	Steven Lindberg	Doug Sisterson	William McFee	Wayne Banwart
1989-1990	Doug Sisterson	William McFee	Sandy Verry	Steven Lindberg
1990-1991	William McFee	Sandy Verry	Mike Kelly	Doug Sisterson
1991-1992	Sandy Verry	Mike Kelly	Van Bowersox	William McFee
1992-1993	Mike Kelly	Van Bowersox	James Lynch	Sandy Verry
1993-1994	Van Bowersox	James Lynch	Richard Grant	Mike Kelly
1994-1995	James Lynch	Richard Grant	Stan Coloff	Van Bowersox
1995-1996	Richard Grant	Stan Coloff	Stephen Vermette	James Lynch
1996-1997	Stan Coloff	Stephen Vermette	Dennis Lamb	Richard Grant
1997-1998	Stephen Vermette	Dennis Lamb	James Lynch	Stan Coloff
1998-1999	Dennis Lamb	James Lynch	Richard Artz	Stephen Vermette
1999-2000	James Lynch	Richard Artz	Kathy Tonnessen	Dennis Lamb
2000-2001	Richard Artz	Kathy Tonnessen	Richard Grant	James Lynch
2001-2002	Kathy Tonnessen	Richard Grant	Gary Lear	Richard Artz
2002-2003	Richard Grant	Gary Lear	Cari Furiness	Kathy Tonnessen
2003-2004	Gary Lear	Cari Furiness	Kristi Morris	Richard Grant
2004-2005	Cari Furiness	Kristi Morris	Maggie Kerchner	Gary Lear
2005-2006	Kristi Morris	Maggie Kerchner	Tom Butler	Cari Furiness
2006-2007	Maggie Kerchner	Tom Butler	Eric Prestbo	Kristi Morris
2007-2008	Tom Butler	Eric Prestbo	Mark Nilles	Maggie Kerchner
2008-2009	Eric Prestbo	Mark Nilles		Tom Butler

Agricultural Advisors

	North Central Region	Northeastern Region	Southern Region	Western Region
2007-2008	Douglas Buhler Michigan State University	Edward Ashworth University of Maine	William Dugas Texas A&M University	Donald Snyder, Utah State University
2006-2007	Mary Ann Lila, University of Illinois	Mark Robson, Rutgers University	Steven Leath, North Carolina State University	Donald Snyder, Utah State University
2005-2006	Wayne Banwart, University of Illinois	Bruce Wiersma, University of Maine	Steven Leath, North Carolina State University	Donald Snyder, Utah State University
2004-2005	Wayne Banwart, University of Illinois	Bruce Wiersma, University of Maine	Gerald Arkin, University of Georgia	Donald Snyder, Utah State University
2003-2004	Wayne Banwart, University of Illinois	Bruce Wiersma, University of Maine	Gerald Arkin, University of Georgia	Donald Snyder, Utah State University
2002-2003	Wayne Banwart, University of Illinois	Bruce Wiersma, University of Maine	Gerald Arkin, University of Georgia	Donald Snyder, Utah State University
2001-2002	Wayne Banwart, University of Illinois	Bruce Wiersma, University of Maine	Gerald Arkin, University of Georgia	Donald Snyder, Utah State University
2000-2001	Wayne Banwart, University of Illinois	Bruce Wiersma, University of Maine	B. Allen Dunn, Clemson University	Lee Sommers, Colorado State University
1999-2000	Wayne Banwart, University of Illinois	Bruce Wiersma, University of Maine	William Brown, Louisiana State University	Lee Sommers, Colorado State University
1998-1999	Wayne Banwart, University of Illinois	Bruce Wiersma, University of Maine	William Brown, Louisiana State University	Lee Sommers, Colorado State University
1997-1998	Wayne Banwart, University of Illinois	Bruce Wiersma, University of Maine	William Brown, Louisiana State University	Lee Sommers, Colorado State University
1996-1997	George Ham, Kansas State University	Dagmar Cronn, University of Maine	William Brown, Louisiana State University	Lee Sommers, Colorado State University
1995-1996	Donald Field, University of Wisconsin	Dagmar Cronn, University of Maine	William Brown, Louisiana State University	Lee Sommers, Colorado State University
1994-1995	Roger Mitchell, University of Missouri	Dagmar Cronn, University of Maine	William Brown, Louisiana State University	Charles Laughlin, Colorado State University
1993-1994	Roger Mitchell, University of Missouri	Dagmar Cronn, University of Maine	Gerald Arkin, University of Georgia	Charles Laughlin, Colorado State University

Agricultural Advisors

	North Central Region	Northeastern Region	Southern Region	Western Region
1991-1992	H. Roald Lund, North Dakota State University	Dagmar Cronn, University of Maine	James Davidson, University of Florida	Landis Boyd, Colorado State University
1990-1991	H. Roald Lund, North Dakota State University	C. R. Frink, University of Connecticut	James Davidson, University of Florida	Landis Boyd, Colorado State University
1989-1990	Keith Huston, Ohio State University	C. R. Frink, University of Connecticut	James Davidson, University of Florida	
1988-1989	Keith Huston, Ohio State University	C. R. Frink, University of Connecticut	James Davidson, University of Florida	Robert Heil, Colorado State University
1987-1988	Keith Huston, Ohio State University	C. R. Frink, University of Connecticut	James Davidson, University of Florida	Robert Heil, Colorado State University
1986-1987	Keith Huston, Ohio State University	W. Lamar Harris, University of Maryland	James Davidson, University of Florida	Robert Heil, Colorado State University
1985-1986	Keith Huston, Ohio State University	W. Lamar Harris, University of Maryland	James Davidson, University of Florida	Robert Heil, Colorado State University
1984-1985	Keith Huston, Ohio State University	W. Lamar Harris, University of Maryland	F. A. Wood, University of Florida	Robert Heil, Colorado State University
1983-1984	Keith Huston, Ohio State University	W. Lamar Harris, University of Maryland	F. A. Wood, University of Florida	Lee A. Bulla, University of Idaho
1982-1983	Keith Huston, Ohio State University	W. Lamar Harris, University of Maryland	F. A. Wood, University of Florida	Lee A. Bulla, University of Idaho
1981-1982	Keith Huston, Ohio State University		Curtis Jackson, University of Georgia	
1980-1981	Keith Huston, Ohio State University		Curtis Jackson, University of Georgia	

Invited Speaker:

Matthew Frank, Wisconsin Department of Natural Resources, Secretary

Wisconsin State Perspective on the Environment

Matthew Frank, Wisconsin Department of Natural Resources, Secretary

About the Secretary of Natural Resources

Governor Jim Doyle appointed Matt Frank as Secretary of the Wisconsin Department of Natural Resources (DNR), effective September 1, 2007.

Matt Frank brings environmental enforcement experience and a lifelong love of the outdoors to the DNR. Secretary Frank comes to the DNR with extensive executive experience in state government, having served as Secretary of the Department of Corrections for more than four years and 22 years as an Assistant Attorney General for the Wisconsin Department of Justice. His tenure at DOJ included six years as Administrator of the Division of Legal Services during which time he oversaw the state's environmental protection defense and enforcement actions in state and federal courts.

As DNR Secretary, Matt Frank is committed to building upon Governor Doyle's environmental and conservation priorities, including reauthorizing the Stewardship program, expanding the state's commitment to clean and renewable energy, developing a statewide water conservation strategy, curbing the spread of invasive species, continuing efforts to combat fish and wildlife diseases, and streamlining administration of DNR regulatory programs. Secretary Frank believes that all Wisconsin citizens deserve to have safe water to drink, clean air to breathe, a healthy and sustainable environment, access to quality wildlife and habitat for hunting and fishing and a full range of outdoor recreation opportunities.

A Wisconsin native, Secretary Frank is an avid outdoorsman whose appreciation for the outdoors took root during his childhood in Cross Plains near the banks of Black Earth Creek. Secretary Frank is a 1978 graduate of Carleton College, and he received a law degree from the University of Wisconsin-Madison Law School in 1981.

Secretary Frank is married and has three sons, to whom he has passed his love of the outdoors through family activities including camping, fishing, hiking, canoeing, and kayaking.

Wisconsin State Perspective on the Environment

- Due to its numerous lakes and rich natural resources, Wisconsin has been a leader and strong supporter of acid deposition monitoring since the late 1970s and mercury (Hg) deposition monitoring since the early 1990s.
- began with a small network of deposition monitors but gradually expanded network to meet policy needs during past 3 decades.
- Currently supports seven (7) acid deposition trends monitoring sites. Several of sites operable since early 1980s.
- Wisconsin began monitoring mercury wet deposition on its own in the early 1990s with a small network - gradually network grew and was transitioned to the national mercury deposition network.
- In cooperation with the NADP, Wisconsin currently supports six (6) MDN sites throughout the state. These sites range from urban Milwaukee to rural areas in the lakes regions of the Northwoods.
- The WDNR believes it is good public policy to continue operating and supporting the mercury deposition network. There is inherent public value in measuring the effectiveness of the proposed mercury rule into the future.
- Data gathered at the acid and mercury deposition sites support policy development at the state and federal level and are used in many scientific and academic studies.
- First state in the nation to adopt an acid deposition control program in the mid 1980s. Program was later used as the model for federal acid deposition regulation.
- Acid deposition monitoring enabled the DNR to measure the tremendous success of these state and federal programs.
- pH levels in precipitation demonstrate continued improvement from 1994 to 2006 (*see maps below – size may be increased*)
- In addition to a very successful acid deposition control program, Wisconsin is in the process of adopting a strong, flexible multi-pollutant regulation for large coal-fired power plants in the state.
- The rule will reduce acid and mercury deposition to the environment.
- **90% reduction by 2015:** under proposed mercury rule, large coal-fired power plants must either meet a 90% mercury emission reduction or limit the concentration of mercury emissions by January 1, 2015.
- Multi-pollutant alternative requires the affected power plants to achieve nitrogen oxides (NOx) and sulfur dioxide (SO2) reductions beyond those currently required by federal and state regulations.
- Under the multi-pollutant approach, an additional six years is allowed to achieve the 90% mercury emission reduction standard.

TECHNICAL SESSION: MONITORING AND RESEARCH FOR AGRICULTURE IN THE NEXT DECADE

Session Chair: Greg Wetherbee, U.S. Geological Survey

Research and Monitoring Needs from an Agricultural Perspective

Raymond E. Knighton
USDA Cooperative State Research,
Education and Extension Service
Washington, DC

Agricultural production has benefited tremendously in the last 50 years from the application of nitrogen fertilizer to increase crop yields. Over this same time frame natural resource impairment has occurred from increases in reactive nitrogen pools in the environment. Research and education have been very instrumental in improving production and growing the agricultural economy. In some sectors this has led to geographic consolidation and intensification of agricultural production. National and global environmental interests now look to monitoring, research, and education to provide solutions to protect the environment and provide new economically viable directions in the agricultural economy. The National Atmospheric Deposition Program (NADP) has done an excellent job over the last 30 years in identifying spatial and temporal trends in atmospheric wet deposition and potential impacts to agriculture. Over this same time period, agriculture has recognized and better understood its role in contributing to nitrogen loading to these reactive nitrogen pools. Nitrogen loading to soil and water is much better understood than nitrogen loading to the atmosphere from agricultural sources. Over the last five years, emissions of nitrogenous gases from agricultural sources are much better understood. A real need exists to better understand the fate of dry deposition of nitrogen in managed and natural ecosystems, the bi-directional exchange of atmospheric ammonia with soil and plant canopies, and the gas-to-particle conversion of agricultural sources of ammonia. In addition to spatial and temporal trends in monitoring data, biological and chemical signatures may exist that will improve our understanding of sources and atmospheric fate which will lead to better physical and chemical atmospheric models. A continuing challenge for the NADP networks is for a systematic analysis and interpretation of existing monitoring data. One critical need in this regard is for potential source identification so that effective mitigation strategies can be identified. The future success of the NADP networks depends on timely, economic or environmentally relevant data products useful to research and education communities to develop value-added products for current and future problem solving.

*202-401-6417, rknighton@csrees.usda.gov

Concentration, Size Distributions, and Transport of Agricultural Aerosols

Naruki Hiranuma [1*], Sarah D. Brooks[1], Leah Cheek[1], Daniel C.O. Thornton[2],
Brent W. Auvermann[3], Rick Littleton[4]

Agricultural fugitive dust is a significant source of localized air pollution in the semi-arid southern Great Plains. In the Texas Panhandle, daily episodes of ground-level fugitive dust emissions from the cattle feedlots associated with increased cattle activity in the early evenings are routinely observed. Here we present measurements of the concentrations and size distributions of agricultural aerosols measured at the nominal downwind edge of the open-air cattle feedlot during summers of 2006, 2007 and 2008. A GRIMM sequential mobility particle sizer and GRIMM 1.108 aerosol spectrometer were used to measure aerosol size distributions in the range of 10 nm to 10 µm aerodynamic diameter. In addition to these continuous measurements at the downwind site, size distributions measurements collected further downwind (~5 km) will be used to observe and quantify aerosol dispersion and transport. In additional, coincident measurements of the aerosol hygroscopicity, chemical composition, and gas and particulate ammonia concentrations were collected at the feedlot. Relationships between these fundamental properties and the fate and transport of the aerosols will be discussed. The results of this study will provide important particulate emission data from a feedyard which is needed to improve our understanding of the role of agricultural particulates in local and regional air quality.

[1]*naruki10@tamu.edu
[1]*Dept. of Atmospheric Sciences, Texas A&M Univ., College Station, Texas*
[2]*Dept. of Oceanography, Texas A&M Univ., College Station, Texas*
[3]*Texas Agricultural Experiment Station, Amarillo, Texas*
[4]*Microscopy and Imaging Center, Texas A&M Univ., College Station, Texas*

Correspondence between Small- and Large-Scale Determinations of Ammonia Emissions from Dairy Barns

J.M. Powell[1*], G.A. Broderick[1], T.H. Misselbrook[2] and M.D. Casler[1]

Dairy barns are known to be major emitters of ammonia. However, quantifying ammonia emissions from dairy barns is difficult due to their large volume, open ventilation, and other factors. Correspondence between ammonia emissions derived from small-scale and large-scale operational studies could facilitate and reduce the cost of ammonia emission research. We measured the impact of dietary factors and bedding on ammonia emissions from small-scale laboratory vessels and from dairy cows housed in tie-stall barn chambers. Results from the barn chambers were validated through mass N balances and comparison of data on feed intake, manure N excretion and ammonia emission with published values of these parameters. In the diet studies, average daily ammonia-N emission (g/cow/day) during spring (18.8) was more than twice those in early-fall (8.4) and about three times greater than during winter (6.7). There were no differences in emissions from cows fed corn silage or alfalfa-silage. During spring, emissions were greater from cows fed high protein than from cows fed low protein diets. In the bedding study, ammonia-N emissions (g/heifer/day) from animals bedded with manure solids (20.0), newspaper (18.9) and straw (18.9) were similar and significantly greater than emissions from bedding with pine shavings (15.2); emissions during summer (20.4) and fall (21.0) were similar but twice those recorded during winter (10.1). In both the diet and bedding studies across all seasons, ammonia-N emissions accounted for 1 to 7% of consumed feed N and 2 to 10% of excreted N. As observed in the small-scale laboratory studies, bedding types that physically separate feces and urine (e.g., sand, pine shavings) have lower ammonia emissions than bedding that fail to do so. The correspondence between results (ammonia emission per unit barn floor area) of the laboratory and barn studies suggest that the small-scale, laboratory methods will provide a useful tool for screening treatments before testing on a larger operational scale. Results from these large-scale chamber studies provided accurate information on seasonal differences in diet and bedding impacts on ammonia emissions from tie-stall barns. Confidence in study results were derived from (1) the relatively high chamber N balances (the ability to account for most all feed and bedding N inputs in ammonia N and animal milk and manure N outputs); (2) the favorable comparisons between study results and published values of ammonia emissions; and (3) the close agreement between study estimates and published values of excreted N and urine N.

[1*] Email: mark.powell@ars.usda.gov, Phone: 608-890-0050
[1] USDA-ARS U.S. Dairy Forage Resh. Center, Madison, WI 53706 USA
[2] Institute of Grassland and Environmental Research, North Wyke, Okehampton,
Devon EX20 2SB, UK.

Measuring Exchange of Ammonia over Cropping Systems with the Modified Bowen Ratio Technique

Paul V. Doskey[1], David R. Cook[2], Michael E. Caughey[3]

Ammonia (NH_3), the only gas-phase alkaline substance in the atmosphere, reacts rapidly with sulfuric and nitric acids that are generated primarily by fossil fuel combustion to produce haze-forming fine aerosol. The principal sources of atmospheric NH_3 are animal waste, nitrogen fertilizers, decomposing plant material, biomass burning, and fossil fuel combustion. Emissions from agricultural crops are expected to originate from soil soon after fertilizer is applied and also from plants throughout the growing season. However, agricultural crops, particularly corn and soybeans, have received little attention as sources of NH_3. We developed a modified Bowen ratio technique to derive exchange rates of NH_3 with corn and soybean surfaces. Semi-continuous measurements of the gradient in NH_3 concentrations are made in concert with continuous measurements of the gradients in water vapor density and air temperature. The sampling and analytic systems for the modified Bowen ratio technique include the following components: an energy balance Bowen ratio station, a Teflon® sampling mast that draws ambient air from 2 heights above the surface into a temperature controlled enclosure, a wet effluent diffusion denuder for separating gas-phase NH_3 from particle-phase ammonium (NH_4^+), hybrid fluorometric flow analyzers for semi-continuous measurement of the gradient in NH_3 concentration, and an automated calibration system. Development of the gradient sampling and analytic techniques is described. Preliminary measurements over a soybean surface are also presented. The presentation concludes with a brief discussion of measurement and modeling needs for examining regional-scale fate and transport of NH_3.

[1] Center for Environmental Science, The University of Chicago, Chicago, IL 60637, 630-252-7662, pvdoskey@anl.gov
[2] Climate Research Section, Environmental Science Division, Argonne National Laboratory, Argonne, IL 60439, 630-252-5840, drcook@anl.gov
[3] Illinois State Water Survey, 2204 Griffith Dr., Champaign, IL 61820-7495, 217-333-1611, mcaughey@uiuc.edu

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Update on Methodologies and Findings of the National Air Emissions Measurement Study Open Source Component

R.H Grant*, M. Boehm, A. Lawrence, J. Wolf, and S Cortus
Purdue University, West Lafayette, IN.

The National Air Emissions Monitoring Study (NAEMS) is designed to provide quality-assured air emissions data from representative swine, dairy, egg layer, and broiler production facilities in the United States. This study is the result of an agreement between the livestock industry and the Environmental Protection Agency (EPA). The data collected will allow the U.S. EPA and livestock industry to reasonably determine which farms are subject to the regulatory provisions of the Clean Air Act and reporting requirements of CERCLA and EPCRA. NAEMS consists of two components: one focusing on gas and particulate emissions from barns and the other on gas emissions from open air waste sources including lagoons, basins and corrals. In the open source component, gaseous emissions of NH_3, H_2S, and various volatile organic compounds (VOCs) are being measured throughout the year at a number of farm operations with a range of characteristics to determine the variation in emissions with time of year, stability of the atmosphere, and facility operation. Instruments used in the open source component of NAEMS include sonic anemometers to characterize the wind, sensors to characterize the state of the atmosphere (temperature, relative humidity, solar radiation, barometric pressure, wetness), sensors to characterize the state of the source (temperature, pH, and oxidation redox potential for lagoons and manure pH, solids, and ammonium nitrogen for corrals and basins), and state-of-the-art instruments and systems for measuring the concentrations of the gases of interest along long paths near the source (primarily NH_3, H_2S, and some VOCs). Measurements began in the summer 2007 nd will continue through summer 2009. A total of 10 sites in 7 states are being monitored using this suite of instruments: Two sites measured continuously over one year each and eight sites sequentially measured for 10 to 20 days each season of the year.. Preliminary assessments of the technologies used and the types of information being collected will be discussed.

***rgrant@purdue.edu**, tel: 765-494-8048

Using a Geographic Information System to Determine Wet Deposition Trends of Ammonium in the Central U.S.

Natalie Latysh and Gregory Wetherbee*
U.S. Geological Survey, Branch of Quality Systems
Box 25046, MS 401, Denver Federal Center, Denver, CO

The U.S. Geological Survey evaluated trends in wet deposition of ammonium measured by the National Atmospheric Deposition Program (NADP) between 1994 – 2006 for the central U.S. region including: North Dakota, South Dakota, Minnesota, Wisconsin, Nebraska, Iowa, Illinois, Missouri, Kansas, Oklahoma, and Arkansas. Results from this study indicate that even though agriculture is the largest emissions source of ammonia in the central U.S., trends in agricultural emissions might have less influence on changes in nitrogen wet deposition than portrayed by NADP in recent years. No temporal trend is apparent in ammonium deposition in the central U.S. between 1994 – 2006, despite increasing wet-deposition ammonium concentrations depicted by NADP in annual concentration isopleth maps (http://nadp.sws.uiuc.edu/amaps2/). Using the ESRI ArcMap Spatial Analyst® geographic information system (GIS), annual ammonium deposition grids for the central U.S. were generated by multiplying the Parameter-elevation Regressions on Independent Slopes Model (PRISM) precipitation grids (http://www.prism.oregonstate.edu) by the NADP precipitation-weighted concentration grids (http://nadp.sws.uiuc.edu/isopleths/grids.asp). PRISM uses a more extensive and denser network of point measurements than the NADP, which may yield more detailed precipitation patterns for the central U.S. To evaluate changes in ammonium deposition, the annual ammonium deposition grid values were classified into four deposition ranges: <2.0, 2-3, 3-4, and >4.0 kilograms per hectare (kg/ha), and the percentages of grid cells within each of these ammonium deposition categories were plotted (figure 1). Regression analysis and the Seasonal Kendall Test of the annual PRISM data indicate a weak but decreasing trend in annual precipitation during 1994-2006. The decreasing precipitation offsets increases in ammonium concentration resulting in no net change in ammonium wet deposition. This study shows the potential utility of GIS in studying temporal wet deposition across the nation.

Study area

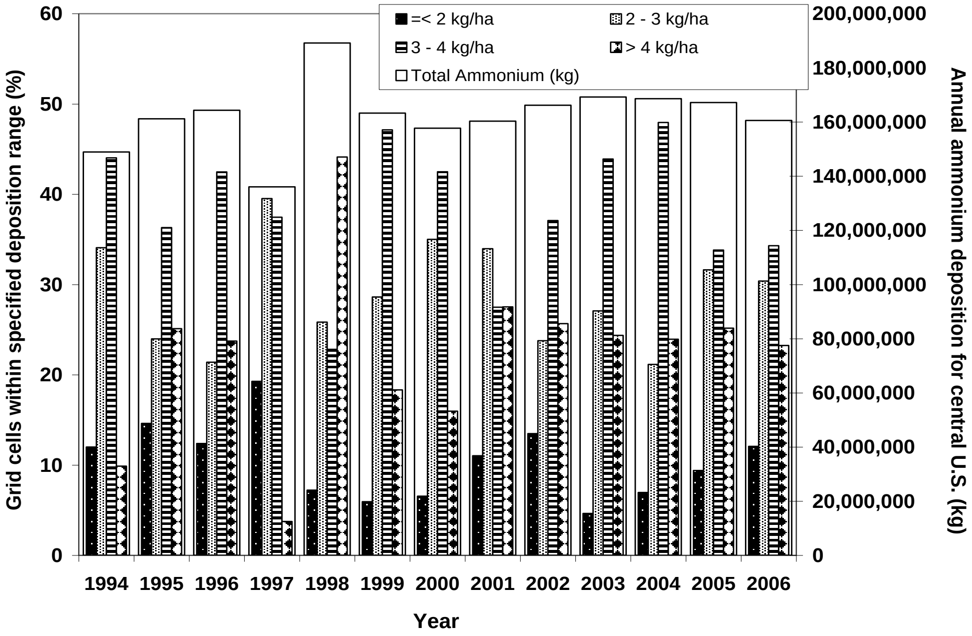


Figure 1. Percentage of grid cells within specific ammonium wet-deposition ranges and annual total ammonium wet-deposition in the central U.S. for 1994 – 2006.

TECHNICAL SESSION: AMMONIA MEASUREMENTS

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

Estimates of In-Canopy Ammonia Sources and Sinks Using Measured Profiles and Turbulence Closure Models

Jesse O. Bash* and John T. Walker
U.S. EPA National Exposure Research Laboratory
MD-E243-04, Research Triangle Park, NC 27711

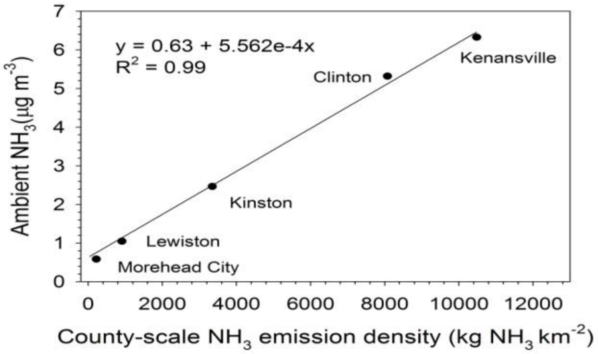
Estimates of in-canopy sources and sinks of ammonia in a fertilized corn, *Zea Mays,* field were inferred using measured in-canopy concentration profiles and analytical half order and K-ε turbulence closure models. Ammonia concentrations were measured at four heights in the canopy and one height above the canopy using manually collected denuders in addition to three collocated above canopy continuous Ammonia Measurement by ANnular Denuder with online Analysis (AMANDA) concentration. Vertical profiles of wind speed, heat, and momentum fluxes were made from inside the canopy to a height of 10 meters using 3-D sonic anemometers. Ancillary vertical profiles of temperature were measured using copper/constantan thermocouples for model evaluation. K-ε modeled ammonia and sensible heat fluxes agreed well with above canopy micrometeorological fluxes. The soil was found to be a consistent emission source, while the vegetation canopy was typically a net ammonia sink with the lower portion of the canopy being a constant sink. The upper portion of the canopy was dynamic, exhibiting periods of local deposition and evasion. The use of Eulerian based in-canopy models allowed for a physically descriptive partitioning of atmospheric-soil and atmospheric-vegetation exchange of measured scalars.

*Phone: (919) 541-0862, Fax: (919) 541-1379, bash.jesse@epa.gov

Monitoring Ambient Atmospheric Chemistry along a Gradient of Ammonia Emission Density in Eastern North Carolina

John T. Walker[1], Wayne P. Robarge[2*], Robert Austin[2]

Based on a several years of observations of ambient NH_3 concentrations in eastern NC, we have developed a tentative relationship between mean annual NH_3 concentration and county-scale NH_3 emission density (see figure). In an attempt to further validate the proposed relationship, we measured NH_3 concentrations in localized areas of high NH_3 emission densities as a function of distance from nearby strong point sources using ALPHA passive samplers (weekly samples; April 2007 to June 2008). Distance and orientation with respect to the nearest animal operation (swine or turkey) were chosen to provide a range of observations (total 24 sampling sites).



Consistent with our previous observations at a single swine operation, we observed a rapid drop in integrated weekly NH_3 concentrations beyond 1 km distance from the nearest source (typically < 10ug NH_3 m^{-3} during summer). This data was then combined with previous efforts via a model to generate a visual measure (Environment Systems Research Inc., ArcDesktop and ArcInfo Workstation ver. 9.2; Div. of Water Quality, NC Dept. Environ. Natural Resources registry of animal waste lagoons) of the spatial representation of weekly mean NH_3 concentrations as a function of distance from animal facilities (mainly swine). In general, our analysis supports the proposed relationship developed from previous single point observations of NH_3 concentrations in areas with high NH3 emission densities, although the exact relationship displayed may be somewhat fortuitous. However, the actual average NH_3 concentration experienced by a given location in an area with relatively high emission density is predominantly influenced by distance to the nearest facility. As such, areas with relatively high emission densities also represent areas where the probability of being within the local dispersion footprint of an emission source is greater than in areas with relatively low emission density, or where the predominant emission source is more uniform across the landscape (such as emissions from soil and vegetation).

[1] U.S. Environmental Protection Agency, NRMRL, Research Triangle Park, NC 27711
[2] North Carolina State University, Department of Soil Science, Raleigh, NC 27695-7619
[2*] wayne_robarge@ncsu.edu; 919-515-1454

Ammonia and Ammonium Measurements from the Southeastern U. S.

Rick D. Saylor[1], Karsten Baumann[2], Eric S. Edgerton[3], Benjamin E. Hartsell[4]

The Southeastern Aerosol Research and Characterization (SEARCH) study was designed and implemented in 1998-1999 in an effort to provide extensive long-term data on the sources and chemical characteristics of atmospheric particulate matter (PM) and gaseous precursors in the southeastern U. S. The SEARCH network is comprised of eight monitoring sites arranged into four urban (or suburban)/rural pairs located in four states in the southeast (Georgia, Alabama, Mississippi and Florida). Routine measurements at SEARCH sites include continuous trace gases (O_3, SO_2, CO, NO, NO_2, HNO_3 and NO_y), surface meteorology, daily 24-hr integrated filter-based fine and coarse PM mass and composition, as well as semi-continuous $PM_{2.5}$ mass and composition (including SO_4^{2-}, NO_3^-, NH_4^+, organic and elemental carbon, and soil-derived components). Since 2004, gaseous ammonia (NH_3) has been measured on a 24-hr integrated sampling schedule by citric acid impregnated annular denuders at all eight sites in the SEARCH network. Additionally, since mid-2007, continuous measurements of NH_3 with a 5-minute temporal resolution have been made at three SEARCH sites (one urban [Atlanta, Georgia] and two rural [Yorkville, Georgia; Oak Grove, Mississippi]). The paper will present analyses of 24-hr integrated denuder-based NH_3 measurements collected since 2004, as well as investigations of data from the recently initiated continuous NH_3 instrument. Trends of NH_3 in the southeast U.S. since 2004 will be examined and analyses of individual high NH_3 concentration episodes will be presented. The importance of local confined animal feeding operations (CAFOs) as sources of NH_3 will be demonstrated and analyses will be presented to investigate the possible processes that contribute to distinctive diurnal profiles that are observed at the urban/rural site pair in Georgia.

[1] Atmospheric Research & Analysis, Inc., 2422 Meadowglen Trail, Snellville, GA 30078, rsaylor@atmospheric-research.com, Ph: 770-736-4631
[2] Atmospheric Research & Analysis, Inc., 1000 Perimeter Park, Ste G, Morrisville, NC 27560, kbaumann@atmospheric-research.com
[3] Atmospheric Research & Analysis, Inc., 410 Midenhall Way, Cary, NC 27513, eedgerton@atmospheric-research.com
[4] Atmospheric Research & Analysis, Inc., 730 Avenue F, Ste 220, Plano, TX 75074, bhartsell@atmospheric-research.com

Passive Ammonia Monitoring in the Central U.S.

Lear, G.[1*], C. Sweet[2], M. Caughey[2], C. Lehmann[2], T. Dombek[2] and D. Gay[2]

Atmospheric scientists need ambient ammonia concentration measurements for use in air quality models and other studies. Unfortunately instrumental ammonia monitors are both expensive and difficult to operate for extended periods. To minimize costs and operate without electricity, for the past 2 years we have deployed Radiello® passive diffusion ammonia samplers at over 20 site network in the central U.S. At the Bondville, IL site (IL11) ammonia concentrations were measured concurrently using a standard pumped denuder method along with three alternative types of passive diffusion samplers Ogawa, Alpha and custom-built.

Typical network winter and spring two-week ammonia concentrations range between 0.5 and 10 ppbv. The highest averages are seen in SW Minnesota (8-10 ppb), with the highest network concentration reported in SE Kansas (15 ppb). The Texas panhandle site is consistently 4 to 6 ppb, and the lowest network concentrations were measured in New York (< ½ ppb). The Radiello system provides consistent results and good agreement with the denuder value for ammonia concentration. Disadvantages are its high cost and relatively high field blank values. Of the alternatives, the Alpha samplers appear to offer similar performance at lower overall cost of the Radiellos.

[1*] US Environmental Protection Agency, Clean Air Markets Division, 1200 Pennsylvania Avenue, Mail Code 6204J, Washington, D.C. 20460
[2] Illinois State Water Survey, University of Illinois, 2204 Griffith Dr, Champaign, IL 61820

Trent Regional Ammonia Monitoring using Passive Samplers (TRAMPS)

Antoni Zbieranowski * and Julian Aherne
Environmental and Resource Studies
Trent University, Peterborough, ON K9J 7B8

Atmospheric ammonia is a major pollutant and the most abundant alkaline component in the atmosphere. The primary emission source of ammonia is from livestock operations associated with agricultural activities. In high emission regions, ammonia can lead to the acidification and eutrophication of soils and surface waters in semi-natural ecosystems. Despite the importance of atmospheric ammonia very little monitoring of this gas is carried out in Ontario. Environment Canada’s Centre for Atmospheric Research Experiments in Egbert Ontario is the only location that continuously monitors ambient ammonia concentrations. The objective of the current study is to determine the spatial and temporal variation of ambient ammonia concentration in south central Ontario. Ten study sites were selected along a gradient of high to low agricultural intensity. Ammonia is being measured using a passive sampler (requires no power) known as a Willems badge (constructed, prepared and analysed at Trent University). Sampling is being carried out on a biweekly basis from August 2007 to August 2008. Samples are analysed using a colourimetric method for ammonia (wavelength of 655 nm). Results to date show a consistent increase in ammonia concentrations from late September through October and decrease from November to mid December across all sites with consistent low levels during the winter months to mid March where ammonia concentrations start to increase slightly and spike in mid to late April noted by site operators as a time when fertilizers and manure were heavily spread in the sampling areas of mid to high agricultural intensity. Spatially higher average ammonia levels (3.0–5.0 µg/m^3) are observed in regions of high agricultural intensity (0.1–1.0 µg/m^3 in low agricultural intensity areas). The normalised concentrations show synchronicity in levels at medium and high intensity agricultural regions and more variation in the low intensity agricultural regions indicating that although concentrations vary spatially the temporal trend in fluctuating ammonia concentrations follow a similar pattern across south central Ontario.

* E-mail: antonizbieranowski@trentu.ca
Telephone: (705) 748-1011 ext. 7959
ERS, Trent University, 1600 West Bank Drive, Peterborough Ontario, Canada K9J 7B8

Evaluation of Ammonia Measurements from CASTNet, IMPROVE, Passive and a New Sampling System

Derek Day[1*], Misha Schurman[2], Jeff Collett Jr.[2], Katie Beem[2], Brian Lee[3], William Malm[4]

Air pollution is known to have adverse effects on sensitive aquatic and high alpine ecosystems from the deposition of many different aerosol and gas phase species. Several different national networks have monitored air quality across the United States for a considerable period of time. For instance, dry deposition is estimated, from a model, using gas and particle concentrations and meteorological parameters measured by the Clean Air Status and Trends Network (CASTNet). Particulate matter is monitored within selected Parks and other Class 1 areas by the Interagency Monitoring of Protected Visual Environments (IMPROVE) network. While these networks have been successful in furthering our understanding of ambient aerosols and selected trace gases, they have proven to be insufficient both in the species that are measured and the time resolution of the measurements to fully characterize the ambient aerosol and adequately characterize short term deposition events.

Ammonia, NH_3, is ubiquitous and the most important basic gas in the atmosphere. Its reactions with acidic gases such as H_2SO_4 and HNO_3 are important sources of fine particles. The degree of neutralization of sulfate aerosol by ammonia gas determines the acidity of the sulfate aerosol, which is important to aerosol hygroscopicity, and thus particle growth and visibility, and to acid deposition, human health effects, and to the earth's radiation budget. The concentration of NH_3 in the atmosphere is also important for the gas/particle phase equilibria of some species such as ammonium nitrate, NH_4NO_3, which impacts visibility and can influence deposition. In some areas of the country, where livestock production and farming are intensive, ammonia can be the most prevalent form of nitrogen being deposited from the atmosphere. Despite the importance of the NH_3/NH_4^+ system to atmospheric chemistry there is no national network that has made routine measurements of ammonia gas and significant problems have been documented with the measurement of its particle phase counterpart ammonium ion.

The development of sampling protocols for network applicable monitoring of gas phase NH_3 and particle phase NH_4^+ are discussed. The modifications to the CASTNet and IMPROVE samplers required for this monitoring are also discussed. We report on the development of a new denuder based sampling system which may prove to be a better alternative to current sampling systems. We compare ammonia measurements from an intensive field study using the CASTNet, IMPROVE, URG, passive samplers and the new aerosol sampling system.

[1*] Colorado State University-CIRA, Fort Collins, CO Phone: 970-491-8354, Email: day@cira.colostate.edu
[2] CSU-Atmospheric Science Dept, Fort Collins, CO
[3] USEPA, Washington, DC
[4] Colorado State University-CIRA/National Park Service, Fort Collins, CO

TECHNICAL SESSION: NADP – STANDING SENTINEL OVER AMERICA'S CROPS?

Session Chair: Van Bowersox, Champaign, IL

The Spread of Plant Diseases by Long-Range Atmospheric Transport and Deposition of Pathogen Propagules – A New Application for an Old Precipitation Sampling (NADP) Network

Sagar Krupa[1] and Van Bowersox[2]

For more than four decades, scientists have been reporting long-range airborne transport of fungal spores, resulting in the spread of plant diseases across continents (Rayner and Hopkins, 1962) and even across oceans (Stover, 1962). A case in point is a sugarcane rust epidemic that erupted in the Dominican Republic in 1978, after more than 20 years of rust-free cane cultivation. Careful evaluation of potential causes for this outbreak led researchers to conclude that fungal spores originating from rust-infested sugarcane fields in Cameroon were the mostly likely source of inoculum (Purdy, Krupa, and Dean, 1985). Satellite imagery of Saharan dust transport, combined with air trajectory analysis, demonstrated that over a 9-day period, streamlines from Cameroon had followed a westward path across the Atlantic Ocean to the Caribbean island of Hispaniola, site of the Dominican Republic. A recent review article (Brown and Hovemiller, 2002) cites this as one example of the aerial dispersal and long-range transport of pathogens that resulted in a new plant disease being established thousands of kilometers from the nearest infection or source area.

The NADP network offers a spatial array of some 250 precipitation sampling stations that can be used to track pathogen deposition and the potential spread of airborne plant diseases to U.S. crop and forest ecosystems. For example, residues from NADP rain sample filters have tested positive for the DNA fingerprint of wheat stem (*Puccinia graminis*) and Asian soybean (*Phakopsora pachyrhizi*) rusts. The use of Polymerase Chain Reactions (PCR) and confirmation of the results by targeted rust-DNA sequencing have made the tests very sensitive and specific for these diseases. Application of a source-receptor model to several positive cases helped researchers identify probable *P. pachyrhizi* source areas (Krupa, et al, 2006). PCR test results for pathogens in NADP samples along with models to locate pathogen source areas can form the basis of a crop management decision support system. Combining disease risk predictions with data and information on air temperature, surface moisture, and crop growth conditions could help agricultural entrepreneurs make decisions in minimizing fungicide applications and improving cropping practices, thus resulting in environmental conservation and economic benefits. Such a system offers the avenue for an important new application of the NADP precipitation-sampling system.

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[1] University of Minnesota, St Paul, MN 55108 (krupa001@umn.edu)
[2] 1811 Clover Lane, Champaign, IL 61821 (soxxos@sbcglobal.net)

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The Application of the US Environmental Agency's Statistical Receptor Models to Determine the Sources of Microorganisms Attached to Airborne Particles

Robert K. Stevens Sr.[1*], Matthew Landis[2], Gary Norris[2]

Joseph M. Prospero et al, recently (2005, Ref.. 1) described the daily sampling and bio-analysis of aerosols carried on the trade winds from Africa to Barbados, West Indies that yielded significant concentrations of viable bacteria and fungi. Prospero et al used air parcel back trajectories to determine the origin of the particles collected, daily. In addition they used 2 sampling systems. One collected 24 hour samples on sterile microbiological filters (cellulose nitrate) and the other was a 47 mm diameter Whatman filter used to collect samples for sulfate and an array of other anions and cations. In addition samples were collected only when the winds were in the sector 335 degrees through North to 130 degrees. This research is interesting in that they revealed, Saharan dust from Africa not only contributed to increased particle mass loading in Barbados but also carried bacteria. This work by Prospero suggests that it may be possible to implement a similar study in North America to determine the sources and presence of viable fungi and or bacteria collected at conventional PM 10 and/ or PM 2.5 µm monitoring sites using EPA's receptor modeling methods and filter material compatible with bio-analysis. Our presentation will discuss two aspects of determining the presence and sources of biologically active fungi etc., in PM 2.5 and 2.5-10 µm particle samples.

That type of sampling and analysis methodology will yield both biologically viable samples but also provide samples that will serve as input to EPA's new receptor models. The application of the US EPA receptor models (Ref 2, Positive Matrix Factorization-3.0, UNMIX- 6.0) to determine source types contributing to the receptor site will be discussed. In addition the application of US EPA's Community Multi-Scale Air Quality Model(a Eulerian dispersion model to estimate impact of local, regional and global sources on selected receptor sites will be discussed. .Recommendations of an approach to collect viable samples to determine the presence of bacteria, fungi and other biologically active bodies will be presented.

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[1*] Florida Department of Environmental Protection, rstevens4@nc.rr.com
[2] US Environmental Protection, Research Triangle Park, NC

Transport, Deposition and Detection of Bacterial Plant Pathogens: New Observations and Future Considerations

Robert C. Seem
Department of Plant Pathology and Plant-Microbe Biology
New York State Agricultural Experiment Station
Cornell University, Geneva, NY 14456

Much of the focus of aerobiology and plant pathogen transport is focused on fungi. I will take a somewhat different approach by considering the transport, deposition and detection of bacterial plant pathogens with special attention to Asian citrus canker disease caused by the bacteria *Xanthomonas axonopodis* pv. *citri (Xac).* The surface ecology of bacteria represents a highly complex community. *Xac* functions normally in its local citrus grove community and typically spreads from a few to several hundred meters at a time. New evidence now shows that *Xac* can travel many kilometers under catastrophic weather conditions. The transport mechanisms may be different for bacteria considering their microbial ecology. Once deposited, bacterial community events start to drive the pathogen's development. Often, only when a resident population of bacteria reaches a certain density level will the colony behave as a pathogen (quorum sensing). Are bacteria transported as single cells or as small, clumped colonies? Different bacteria species can cooperate, thus allowing a pathogenic population to build faster with the aid of their non-pathogenic phylloplane neighbors. Are mixed populations of bacteria transported together? As bacterial density increases, colonies form biofilms. Do biofilms occur during transport if the bacteria are clumped? Detection methods should be able to discriminate these population differences - deposited bacterial population density as well as the population makeup. Emerging technologies could provide better techniques to measure these subtle characteristics.

Phone 315-787-2388, E-mail: rcs4@cornell.edu

Soybean Rust: Its History, Biology, Epidemiology and Importance to Crop Production

J. Kurle*, D. Malvick, S. Krupa, and C. Floyd
Department of Plant Pathology
495 Borlaug Hall
1991 Upper Buford Circle
University of Minnesota, St. Paul, MN 55108

Soybean Rust (SR) caused by the fungus *Phakopsora pachyrhizi* (*Pp*) is a destructive leaf disease of soybean that can cause severe yield losses. Discovered in Japan in 1902, SR spread to Africa by 1997, South America by 2001, and the U.S. by 2004.

Pp is an obligate parasite that relies on continuous production of aerially disseminated spores on a live host for survival and spread. *Pp* can survive on a variety of species including soybeans, dry and snap beans, peas, alfalfa and kudzu. In the United States *Pp* probably overwinters on annual and perennial alternative hosts in Florida, along the Gulf coast, and in southern Texas. Favorable environmental conditions, viable spores, and a susceptible host are necessary for SR to occur. Soybean infection is favored by temperatures from 21.8 to 24.3^{o} C. and six hours or more of leaf wetness. Soybean is susceptible whenever green leaf tissue is present.

In the U.S, because of synoptic atmospheric conditions that occur during the growing season, it is probable that aerial dispersal of spores from infected hosts in southern states such as Texas, Louisiana, and Oklahoma, or Mexico, to susceptible crops in the north will determine if SR can occur in the North Central states. Sentinel plots for detection of SR were established at 25 locations in MN during the 2006 and 2007 growing seasons. Samplers for collection of spores deposited by both wet and dry deposition were located in all plots. Leaf samples and particulate filters were collected weekly and leaf samples analyzed visually for SR symptoms. Particulate matter was recovered from the filters by sonication, DNA extracted, and *Pp* spores detected with a nested PCR assay. Results indicating that *Pp* spores were present were confirmed by DNA sequence analysis.

Spores of *Pp* were detected in MN on four filter samples collected between July 31 and August 29, 2006 and seven filter samples collected between June 22 and August 23, 2007, periods with precipitation. However**,** no symptoms of SR were observed in MN in either in 2006 or 2007. The absence of SR symptoms may be a consequence of unfavorable environmental conditions, deposition of non-viable spores, or failure to detect SR symptoms at low disease levels, since the disease has been reported from near the vicinity in Iowa.

* Corresponding author: Phone: 612-625-8200, Fax: 612-625-9728, kurle001@umn.edu
Dean Malvick dmalvick@umn.edu
Sagar Krupa krupa001@umn.edu
Crystal Floyd floyd005@umn.edu

A Short Description of the NOAA HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) Model

Richard S. Artz*, Roland Draxler, Glenn Rolph, Ariel Stein, Barbara Stunder
NOAA Air Resources Laboratory
1315 East West Highway, R/ARL
Silver Spring, MD 20910

The HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) model is a complete system for computing simple air parcel trajectories to complex dispersion and deposition simulations. As a result of a joint effort between NOAA and Australia's Bureau of Meteorology, the model has recently been upgraded. New features include improved advection algorithms, updated stability and dispersion equations, a new graphical user interface, and the option to include modules for chemical transformations. Without the additional dispersion modules, Hysplit computes the advection of a single pollutant particle, or simply its trajectory.

The model can be run interactively on the Web through the READY system on the Air Resources Laboratory Web site (www.arl.noaa.gov/ready) or the code executable and meteorological data can be downloaded to a Windows PC. The Web version has been configured with some limitations to avoid computational saturation of our Web server. The registered PC version is complete with no computational restrictions, except that users must obtain their own meteorological data files. The meteorological input fields used by Hysplit are required to be in "ARL packed" format. All gridded meteorological data available on our site are already in this form and may be FTP'd to a PC without conversion. The unregistered version is identical to the registered version except that it will not work with forecast meteorology data files.

A short description of model features and recent updates, as well as a few example products will be presented.

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* Corresponding author: 301-713-0972, Richard.Artz@noaa.gov

TECHNICAL SESSION: CLIMATE CHANGE IMPACTS ON AIR QUALITY, DEPOSITION AND ECOSYSTEMS

Session Chair: Rick Haeuber, U.S. Environmental Protection Agency

Impacts of Global Climate and Emission Changes on U.S. Air Quality

Xin-Zhong Liang[1*], Donald J. Wuebbles[1], Ho-Chun Huang[2],
Jinhong Zhu[1], Zhining Tao[1], Feng Liu[1], and Jintai Lin[3]

A state-of-the-art integrated modeling system has been developed and applied to quantify the individual and combined impacts of global climate and emission changes on U.S. air quality at regional to local scales, from the present to 2050 and 2100. Simulations from two global general circulation models (GCMs) under the IPCC SRES A1Fi, B1, A2, B2 emissions scenarios are used to drive the regional modeling system that produce downscaling of the U.S. present climate, future change and their impacts on air quality as well as the uncertainty of the results. It is shown that the dynamic downscaling can significantly reduce biases of the driving global models in simulating the present climate/air quality patterns and that this improvement has important consequences for future projections of regional climate/air quality changes. For both the present and future climate simulations, the regional modeling system results are sensitive to the planetary forcings imposed by outputs from different global models as well as to its own physical process representations, especially different cumulus parameterizations, with strong regional dependence. Due to these sensitivities, there are large uncertainties involved in application of model projections of future climate/air quality changes for decision making at regional to local scales. Given significant uncertainties in estimating/projecting surface emissions and important contributions from long-range pollutant transport, decision making on future U.S. air quality regulation is challenging.

[1]University of Illinois at Urbana-Champaign, Champaign, IL 61820
[2]Science Applications International Corporation, Camp Springs, MD 20746
[3]Harvard University, Cambridge, MA 02138

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[*] *Corresponding author address:* Dr. Xin-Zhong Liang, University of Illinois at Urbana-Champaign, 2204 Griffith Dr., Champaign, IL 61820-7495. E-mail: xliang@uiuc.edu.

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Future Climate Scenarios, Atmospheric Deposition, and Precipitation Uncertainty

Alice Gilliland*, Kristen Foley, and Chris Nolte
U.S. EPA Office of Research and Development
USEPA Mailroom E243-01
109 T.W. Alexander Drive
Research Triangle Park, NC 27711

Recent studies have developed "downscaled" regional climate simulations based on the Intergovernmental Panel on Climate Change (IPCC) greenhouse gas (GHGs) scenarios, global climate models (GCMs), and regional meteorological models. These regional climate scenarios have been used for assessment of climate impacts on a range of endpoints, including potential impacts on air quality with an emphasis on ozone. Here, we will present some examples of future (ca. 2050) changes in atmospheric deposition from a recent sensitivity study of climate impacts on air quality, but then focus more on evaluation of the precipitation predictions and potential impacts that precipitation uncertainties may have on atmospheric deposition of nutrients. This will include a comparison of the current regional climate results to observations and comparison of the future precipitation changes to IPCC's most recent GCM simulations over North America. Based on precipitation uncertainties under current climate conditions and the range of potential future precipitation scenarios, a range of future precipitation scenarios are needed when considering future climate impacts on atmospheric deposition and ecosystem effects. While not yet available, ensemble precipitation predictions such as the North American Regional Climate Change Assessment Program (http://www.narccap.ucar.edu) could prove to be most useful in considering how future climate may impact atmospheric deposition of nutrients on a regional scale.

* Chief, Model Evaluation and Applications Branch
Atmospheric Modeling Division
National Exposure Research Laboratory
(919) 541-0347, gilliland.alice@epa.gov

The Effects of Climate Change on Wet Deposition of Nitrogen, Sulfur, and Hydrogen across New York State during 1985 – 2007

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

Many wet deposition sites operated by the National Trends Network (NTN) of the National Atmospheric Deposition Program have data records that extend for 20 to 30 years, a sufficient length to explore the role of climate change in deposition patterns. In this study, the effects of climate change on trends in concentrations and loads of sulfate (SO_4^{2-}), inorganic nitrogen (N), and hydrogen (H^+) were determined for seven NTN sites in New York State during 1985 – 2007. During this period, precipitation amount increased by a mean of >10 mm yr^{-1} at these sites, consistent with global increases in precipitation that have been attributed to climate warming and decreases in atmospheric aerosols. Concentrations of SO_4^{2-}, nitrate (NO_3^-), and H^+ have decreased significantly at all of these sites by about 35 to 55%, consistent with decreases in Title IV emissions over this period. Loads of SO_4^{2-} and H^+ have also decreased at nearly all sites, though by about 10% less than concentrations due to increases in precipitation over the period of record. In contrast, inorganic N loads have shown a statistically significant increase at only one of the seven NTN sites, and the average decrease for all sites was about half that of the decrease in NO_3^- concentrations. These muted trends in inorganic N loads are attributed to: (1) lower decreases in NO_3^- concentrations than those of SO_4^{2-}, (2) increased precipitation, and (3) no change in ammonium concentrations. A recent study has suggested that global precipitation amount increased by about 7% per ^{o}C of warming during 1987 to 2006; the expected extent of future increases is an area of active debate in the climatology community, and is likely to be affected by several factors in addition to greenhouse gas-driven warming. The results of this study indicate that future climate change should be considered in models of the expected effects of emissions reductions on wet deposition of S and N oxide pollutants.

Critical Acid Load Limits in a Changing Climate: Implications and Solutions

Steven G. McNulty*
USDA Forest Service
Southern Global Change Program
920 Main Campus Dr., Suite 300, Raleigh, NC 27606.

The federal agencies of the United States (US) are currently developing guidelines for critical nitrogen load limits for US forest ecosystems. These guidelines will be used to develop regulations designed to maintain pollutant inputs below the level shown to damage specified ecosystems. By traditional definition, an ecosystem is considered to be at risk when nitrogen loads exceed a critical level. The excess over the critical load is termed the exceedance, and a larger exceedance is often considered to pose a greater risk of damage to an ecosystem. This definition of critical loads applies to acute or chronic individual stress impacts, but does not work well when an ecosystem is subjected to multiple environmental stresses. For example, the mountains of western North Carolina received some of the highest rates of nitrogen deposition in the eastern US, but these nitrogen deposition levels are still considered to be below the critical load rate. The area experienced a moderate three year drought from 1999-2002. In 2001, white pine and spruce trees began to die in large numbers in the area. The initial evidence confirmed that the affected trees were killed by the southern pine beetle (SPB). This insect species is not normally successful at colonizing these tree species because heavy oleoresin production exudes the boring beetles from impacted trees. Subsequent investigations revealed that the relative ratio of above ground to below ground biomass was high compared to ratios of same species from lower nitrogen deposition areas. I believe that elevated nitrogen deposition reduced the root biomass, reduced the tree water uptake potential, reduced oleoresin production, and caused the trees to become more to susceptible to insect colonization during the drought period. If multiple stress (i.e., drought, and insects) impacts are included, then the forests in this area were in exceedance of their critical nitrogen threshold. Recent advances in ecosystem modeling of multiple stress impacts on forest ecosystems allow for more complex analysis of multiple stress scenarios. This paper explores how multiple environmental stress impacts can be assessed using computer models to determine variable critical load limits. The implications for improved forest management and pollutant regulation will also be presented.

*steve_mcnulty@ncsu.edu, phone: 919 515 9489

The Sensitivity of Heterogeneous Atmospheric Mercury Processes to Climate Change

Andrew P. Rutter[1], James J, Schauer[1,2], Martin M. Shafer[1,2], Robert J. Griffin[3],
Tracey Holloway[1], Michael R. Olson[1], Michael Robinson[1], Peter Vanderveer[4], Joel Creswell[1],
Pat Gorski [2], Al Clary[2], Justin L. Mallek[1], Andrew M. Parman[1]

The sensitivity of heterogeneous atmospheric mercury physicochemical processes to variance in environmental conditions is only partially understood, but is central to understanding the atmospheric transport and fate of natural and anthropogenic emissions of mercury under future climate scenarios. The importance of this sensitivity lies in the fact that although gaseous elemental mercury consists of greater than 99% of atmospheric mercury away from the influences of urban areas and point sources, reactive mercury (the remaining fraction) is the predominant species that deposits from the atmosphere. Therefore only slight variations in the mass conversion of GEM to RM can have significant impacts on mercury removal from the atmosphere. In order to successfully predict modern and future atmospheric mercury source receptor relationships, the dependence of these physicochemical processes on environmental conditions must be parameterized for use in models.

Under support from the US EPA STAR Program, researchers at UW-Madison and the University of New Hampshire are addressing these needs with a project that is divided into four modules: 1) climate sensitivity measurements of gaseous elemental mercury and reactive dry deposition to a variety of environmental surfaces; 2) measurements of the dependence of aqueous mercury speciation in surrogate and synthetic fog and cloud water on environmental conditions; 3) smog chamber studies of modifications in GEM oxidation by heterogeneous VOC/O_3/OH/NO_x photochemical reaction systems; and, 4) a comparison between a year of rural and urban hourly measurements of atmospheric GEM and RM concentrations, and corresponding results from CMAQ-Hg updated with the findings from project modules 1-3 and recent peer-reviewed publications. An overview of all four modules will be presented with particular attention given to preliminary results from the dry deposition module (1).

GEM dry deposition sensitivity to climate variance was evaluated by exposing a variety of environmental surfaces and plants to isotopically enriched GEM in a controlled environment room at the UW-Madison Biotron Facility. Uptake of isotopically enriched GEM from deciduous and conifer trees, grass turf, 3 types of soil, sand, concrete, asphalt, adsorbent coated quartz fiber filter deposition coupons, and a water surface sampler were quantified over several days of exposure that were conducted over a range of irradiances, temperatures and relative humidities. After exposure the mercury was recovered from the samples using thermal and acidic treatments, and then analyzed for the content of the isotopically enriched GEM by high resolution ICPMS. We will explore the performance of these new experimental methods, and present initial findings.

[1] Environmental Chemistry and Technology Program, 660 N. Park St, Madison, WI 53705.
[2] Wisconsin State Laboratory of Hygiene, 2601 Agriculture Drive, Madison, WI 53718.
[3] College of Engineering and Physical Sciences, University of New Hampshire, Durham, NH 03824
[4] Biotron, University of Wisconsin – Madison, 2115 Observatory Drive, Madison, WI 53706

Chronic Enhancement of Mercury Methylation in a Boreal Wetland from Elevated Sulfate Deposition and Climate Change

Jill Coleman Wasik[1], Edward Swain[2], Daniel Engstrom[3*], Bruce Monson[2],
Brian Branfireun[4], Randy Kolka[5], Steve Balogh[6], Jeff Jeremiason[7]

We present here the results of a long-term, ecosystem-scale experiment in which sulfate deposition to a boreal wetland was increased in order to examine the synergistic effects of atmospheric sulfate and mercury (Hg) on production and export of the bioaccumulative neurotoxin, methylmercury (MeHg). A whole-wetland irrigation system for amending sulfate deposition through simulated rainfall was established in the fall of 2001 at the USFS Marcell Experimental Forest (MEF) in northern Minnesota. The 2-ha wetland was divided into control and experimental halves, and the experimental half was treated with a sulfate solution meant to increase annual sulfate loading by four times the current rate of atmospheric deposition. We focus here on the study-years 2005 - 2007 and address in particular possible chronic effects and recovery of wetlands previously impacted by elevated sulfate deposition.

Similar to previous years, peat porewater MeHg concentrations and %MeHg in the experimental treatment spiked three days after the spring (May) sulfate application, while control levels remained constant. The increase in MeHg coincided with declining sulfate concentrations, indicating Hg methylation by sulfate-reducing bacteria (SRB) as the likely process. A similar spike was not observed following the summer (July) applications, because dry conditions prevented sulfate from reaching the water-table. The methylation response to fall (October) additions in 2005 and 2007 was complicated by a prolonged summer drought and late-season water-table rise which regenerated sulfate from within the peat, stimulating SRB activity and Hg methylation just prior to the addition date. This response was evident in both the experimental and control sections, but was much more pronounced in the former. Drought-induced sulfate regeneration was also evident in the higher sulfate and MeHg concentrations prior to the spring addition in 2006 and 2007, as compared to 2005.

Beginning with the 2006 field season a recovery treatment, in which sulfate addition was suspended to a portion of the experimental section of the wetland, was incorporated into the project design to simulate the effects of reduced sulfate deposition. Sulfate and MeHg concentrations and %MeHg declined in the recovery treatment over the spring period, while the experimental sites continued to respond to sulfate loading following the spring additions. However, the recovery section remained elevated in sulfate and Hg relative to the control, indicating a persistent influence of the added sulfate. Chronic effects of sulfate addition are also evident in the divergence in MeHg concentrations (and %MeHg) between experimental and control treatments over the six years of the study. Results of this long-term experiment imply that boreal wetlands affected for decades by high sulfate deposition will continue to experience lingering, elevated mercury methylation, especially when the effects of climate remobilize previously sequestered sulfate.

[1] Water Resources Science, University of Minnesota
[2] Minnesota Pollution Control Agency
[3] St. Croix Watershed Research Station, Science Museum of MN

[4] Department of Geography, University of Toronto at Mississauga
[5] Northern Research Station, US Forest Service
[6] Metropolitan Council Environmental Services
[7] Department of Chemistry, Gustavus Adolphus College

TECHNICAL SESSION: ECOSYSTEM EFFECTS OF ATMOSPHERIC DEPOSITION – SULFUR AND NITROGEN

Session Chair: Doug Burns, U.S. Geological Survey

Reductions in Atmospheric Nitrogen Deposition Linked to Increased Stream Silica on Five Appalachian Forest Basins

David R. DeWalle[1] and Anthony R. Buda

Reductions in atmospheric nitrogen (N) deposition appear to be linked to increases in stream silica (Si) on five unglaciated Appalachian forest basins in Pennsylvania. Possible causes for this linkage being investigated are: (1) reduced N deposition is causing reduced productivity and thus reducing assimilation of Si by diatoms and terrestrial vegetation and/or (2) reduced N deposition is leading to increased respiration by soil heterotrophs, which is increasing silicate weathering. NADP and CASTNet data for the region clearly show downward trends in N deposition over the past two decades. Concomitantly, stream nitrate levels have been declining and Si levels have been increasing on the five basins being studied as part of the EPA Long-Term Monitoring program. Molar Si/N ratios computed for the five streams are >>1 indicating that N is limiting to diatom production (critical ratio ≈ 1), thus reduced N deposition could have caused reduced assimilation of Si by diatoms. Declining dissolved organic carbon found in these streams may also be a manifestation of declining ecosystem productivity caused by reduced N deposition. However, trends in stream Si/N are positive, indicating that reduced diatom productivity and assimilation, which would release Si in direct proportion to N declines, probably was not the sole cause of increasing Si. Furthermore, increasing trends in stream dissolved inorganic carbon and sodium also indicate that increased weathering of sodium-aluminosilicate minerals has taken place. Long-term stream monitoring on these five basins suggests that a shift in ecosystem Si cycling, and perhaps C cycling, has occurred due to reduced N deposition. Continued monitoring of atmospheric deposition and stream chemistry along with critical experimentation are needed to fully understand these previously unreported impacts of reduced N deposition.

[1] Professor Emeritus of Forest Hydrology, School of Forest Resources, Penn State University, Univ. Park, PA 16802 drdewalle@psu.edu

[2] Hydrologist - Post Doctoral Scientist, USDA/ARS, University Park, PA 16802

Deposition and Cycling of Sulfur Control Mercury Accumulation in Isle Royale Fish

Paul E. Drevnick[1]*, Donald E. Canfield[2], Patrick R. Gorski[3], Avery L.C. Shinneman[4], Daniel R. Engstrom[5], Derek C.G. Muir[6], Gerald R. Smith[7], Paul J. Garrison[8], Lisa B. Cleckner[3], James P. Hurley[3,8], Robert B. Noble[9], Ryan R. Otter[1], James T. Oris[1]

Mercury contamination of fish is a global problem. Consumption of contaminated fish is the primary route of methylmercury exposure in humans and is detrimental to health. Newly mandated reductions in anthropogenic mercury emissions aim to reduce atmospheric mercury deposition and thus mercury concentrations in fish. However, factors other than mercury deposition are important for mercury bioaccumulation in fish. In the lakes of Isle Royale, USA, reduced rates of sulfate deposition since the Clean Air Act of 1970 have caused mercury concentrations in fish to decline to levels that are safe for human consumption, even without a discernable decrease in mercury deposition. Therefore, reductions in anthropogenic sulfur emissions may provide a synergistic solution to the mercury problem in sulfate-limited freshwaters.

* Presenting and corresponding author: Department of Marine Chemistry & Geochemistry, Woods Hole Oceanographic Institution, Watson 117, MS#51, Woods Hole, MA 02543, USA; phone: (508)289-3551; fax: (508)457-2075; e-mail: pdrevnick@whoi.edu

[1] Department of Zoology, Miami University, Oxford, Ohio 45056, USA,

[2] Nordic Center for Earth Evolution, Institute of Biology, University of Southern Denmark, Campusvej 55, 5230 Odense M, Denmark,

[3] Environmental Chemistry and Technology Program, University of Wisconsin, 680 North Park Street, Madison, Wisconsin 53706, USA,

[4] Department of Geology and Geophysics, University of Minnesota, 310 Pillsbury Drive SE, Minneapolis, Minnesota 55455, USA,

[5] St. Croix Watershed Research Station, Science Museum of Minnesota, 16910 152nd Street North, Marine on St. Croix, Minnesota 55047, USA,

[6] Water Science and Technology Directorate, Environment Canada, 867 Lakeshore Road, Burlington, Ontario L7R 4A6, Canada,

[7] Museum of Zoology, University of Michigan, 1109 Geddes Avenue, Ann Arbor, Michigan 48109, USA,

[8] Bureau of Integrated Science Services, Wisconsin Department of Natural Resources, 2801 Progress Road, Madison, Wisconsin 53716, USA,

[9] Department of Mathematics and Statistics, Miami University, Oxford, Ohio 45056, USA

Linking Data on Episodic Stream Acidification to Soil Chemistry in Assessments of Recovery from Acidic Deposition

Lawrence, G.B.[1*], Roy, K.M.[2], Baldigo, B.P.[1], Passy, S.I.[3], Simonin, H.A.[4],
Shortle, W.C.[5],Smith, K. T.[5], David, M.B.[6]

Increasing evidence demonstrates that episodic acidification can be as harmful to aquatic ecosystems as chronic acidification. In recent studies in the Adirondack region of New York, elimination of an entire age class of brook trout was documented during spring snowmelt, and stream diatom communities during non-acidifed summer base flows showed similar levels of impact to those sampled during snowmelt episodes. Episodic acidification of streams has also been shown to be much more widespread than chronic acidification. In an 85-km^2 watershed in the Catskill region of New York, the percentage of acidified stream reaches increased from 16% to 82% from base flow to high flow, and in the western Adirondack region, the percentage of acidified streams at base flow ranged from 19% to 35% and increased to 66% at high flow.

Stream sampling also serves as a useful indicator of acidified soils due to the strong linkage between soil chemistry and stream chemistry during high flows. This linkage can be demonstrated with the base cation surplus (BCS), a recently developed measure of water chemistry that is directly related to the mobilization of toxic inorganic Al. Significant relationships ($p < 0.05$) were observed between the BCS and the base saturation of the Oa horizon ($R^2 = 0.68$), and the upper B horizon ($R^2 = 0.39$) in 11 Adirondack watersheds. These data also indicated that mobilization of inorganic Al occurred at base saturation values less than about 12% in the upper B horizon, and less than about 40% in the Oa horizon of these watersheds.

As the role of soils in episodic acidification becomes better defined, growing evidence also indicates that acidic deposition has reduced the ability of soils to buffer inputs of acidity. However, data on soil change remains limited with respect to magnitude and rate of change, as well as regional extent. In an effort to improve the characterization of soil change in the Northeastern U.S. and Eastern Canada, a cooperative has been formed to promote the development of improved methods and the organization of collaborative projects. Included in this work is the resampling of soils in 2003-2004 that were first sampled in 1992-1993. Preliminary data analysis indicates that statistically significant changes were observed in some soil measurements. These results provide support for the use of soil monitoring in detecting soil changes on decadal time step.

[1*] U.S. Geological Survey, 425 Jordan Road, Troy, NY, 12180; USA; glawrenc@usgs.gov
[2] New York State Department of Environmental Conservation, Box 296, Ray Brook, NY, 12977, USA
[3] University of Texas at Arlington, Department of Biology, Box 19498, Arlington, Texas 76019, USA
[4] New York State Department of Environmental Conservation, 8314 Fish Hatchery Road, Rome, NY, 13440, USA (retired)
[5] USDA Forest Service, Northeastern Research Station, P.O. Box 640, Durham, NH, USA
[6] University of Illinois, NRES, W-503 Turner Hall, 1102 South Goodwin Ave., Urbana, IL, 61801

Ecological Indicators of Effects of Changing Air Quality

Christine Negra and Robin O'Malley
The Heinz Center, 900 Seventeenth Street, NW, Suite 700
Washington, DC 20006

Measurement of atmospheric composition, pollutant deposition and ecological condition are essential for monitoring the influence of changing air quality on terrestrial and aquatic ecosystems. Focusing on nitrogen, sulfur, mercury and ozone, a suite of indicators has been developed to track air pollution induced ecological impairment and to document improvements resulting from air pollution reductions. Twenty-nine experts from public and private institutions reviewed 30 broad categories of ecological endpoints in 11 major ecosystem types and produced a refined list of 28 potential indicator metrics, sorted by level of scientific development. These potential metrics encompass four major types of ecological effects: (1) acidification in terrestrial and freshwater ecosystems; (2) nitrogen enrichment in terrestrial, freshwater and coastal systems; (3) mercury methylation and bioaccumulation in aquatic systems; and (4) ozone-induced plant damage.

To develop useful indicators, a number of challenges must be addressed. Across time and space, terrestrial and aquatic systems vary considerably in their exposure and response to air pollutants. Exposure may vary seasonally or interannually and may be characterized by acute episodes or chronically elevated concentrations. Ecological alteration may reflect contemporary or historical deposition. Indicator metrics, and the spatial and temporal scale of reporting, should be designed to enable tracking of slow and fast responses across affected ecosystems. In addition to air pollution, ecological systems are affected to varying degrees by a wide range of stressors (e.g., climate change, land use change, fire and other disturbances, extractive uses). To document ecological changes that result primarily from air pollutant exposure or air quality management strategies, indicators should optimally be designed to parse out confounding factors. Finally, ecological response may be initially chemical and secondarily biological, yet parameters of greatest management and public interest tend to be biological. To the greatest degree possible, indicators should reflect scientific understanding of linkages across air pollutant exposure/ deposition, primary ecological responses and secondary effects on organisms, species and biological communities.

This presentation will report on recommended indicators for tracking the ecological effects of atmospheric deposition of nitrogen, sulfur and mercury and elevated ambient ozone. Findings will be presented for: (1) specific indicator metrics; (2) stratified reporting strategies to account for heterogeneity in ecological response; (3) optimal temporal and geographic scales of indicator reporting; and (4) available and needed data sources.

*202-737-6307, negra@heinzctr.org

Air Quality Model Insights into Nitrogen Dry Deposition Missed by Current Networks

Robin L. Dennis
U.S. EPA
NERL Atmospheric Modeling Division
MD: E243-04
Research Triangle Park, NC 27711

An emerging critical use of network data is the assessment of total deposition and changes in total deposition relative to target levels or critical loads and the tracking of air management effectiveness. Important reductions in both sulfur and nitrogen deposition are expected between now and 2020. An assessment of total, wet plus dry, deposition is required to assess current levels and expected trends. Key end points are acidity (involving S and N) and nutrient enrichment (involving N). The issue regarding uncertainty is dry deposition. For sulfur (S) we are fine because we measure all species important to the sulfur budget. For reactive nitrogen (Nr = oxidized N + reduced N) we are not o.k. for dry deposition estimates because we are not measuring all of the species important to the nitrogen budget. In particular, the oxidized-N portion that is missing is associated with NO, NO_2, PAN, and N_2O_5 and the reduced-N portion that is missing is associated with NH_3. The Community Multiscale Air Quality model, CMAQ, is used as a tool to gain insights into the budget gaps: where they are and how big they are. Simulations for a 12-km grid for the eastern United States are used for the analysis. For oxidized N, CASTNet measures only HNO_3 and aNO_3^-. The oxidized-N budget fraction captured by dry deposition of these two species is 60-80% in rural areas (missing 20-40%) and 30-70% in urban areas (missing 30-70%). For reduced N, CASTNet measures only aNH_4^+. The reduced-N budget fraction captured by dry deposition of this specie is 2-20% in high emission areas (missing 80-98%) and 50-80% in low emission areas (missing 20-50%). The spatial patterns of these gaps are presented for the eastern U.S. CMAQ is also used to address the question of whether total deposition can be “faked” by using a simple multiplier of wet deposition. The answer is tricky for the east and likely “no” for the west. CMAQ answers are expected to change for reduced N when ammonia bi-directional exchange is fully incorporated in the model.

Tel: 919-541-2870, Email: dennis.robin@epa.gov

Source Apportionment of Sulfur and Nitrogen Species at Rocky Mountain National Park using Modeled Conservative Tracer Releases and Tracers of Opportunity

William C. Malm[1], Bret A. Schichtel[1], Michael G. Barna[1], Kristi A. Gebhart[1],
Jeffrey L. Collett, Jr.[2], and Sonia M. Kreidenweis[2]

Changes in ecosystem function are occurring because of emissions of nitrogen and sulfate species along the Front Range of the Colorado Rocky Mountains, as well as sources farther east and west. The nitrogen compounds include both oxidized and reduced nitrogen. The Rocky Mountain Atmospheric Nitrogen and Sulfur study (RoMANS) was initiated to better understand the origins of sulfur and nitrogen species as well as the complex chemistry occurring during transport from source to receptor. Specifically, the goals of the study are to characterize the atmospheric concentrations of sulfur and nitrogen species in gaseous, particulate, and aqueous phases (precipitation and clouds) along the east and west sides of the Continental Divide; identify the relative contributions to atmospheric sulfur and nitrogen species in Rocky Mountain National Park (RMNP) from within and outside of the state of Colorado; identify the relative contributions to atmospheric sulfur and nitrogen species in RMNP from emission sources along the Colorado Front Range versus other areas within Colorado; and identify the relative contributions to atmospheric sulfur and nitrogen species from mobile sources, agricultural activities, and large and small point sources within the state of Colorado. As part of the study, a monitoring program was initiated for two 1-month time periods, one during the spring, the other during late summer/fall. Monitoring data of ammonium/ammonia, nitrogen oxide/nitrates, and sulfur dioxide/sulfates are combined with tracers of opportunity and modeled releases of conservative tracers from source regions around the United States to apportion these species to their respective sources, using a variety of receptor modeling tools.

[1] National Park Service, Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, Colorado, 80523-1375
[2] Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, 80523-1371

TECHNICAL SESSION: MERCURY MEASUREMENT, DEPOSITION AND EFFECTS

Session Chair: David Krabbenhoft, U.S. Geological Survey

High Mercury Wet Deposition at a Pristine Site in Puerto Rico

James B. Shanley[1], Mark A. Engle[2], David P. Krabbenhoft[3], Robert Brunette[4]
Martha Scholl[2], Mark L. Olson[3], Joseph W. Troester[5]

Measurements of atmospheric wet depostion of mercury are few in tropical latitudes. We report here on two years of wet Hg deposition at a tropical wet forest at 18.3º N latitude in the Luquillo Mountains, northeastern Puerto Rico, USA. Despite receiving unpolluted air masses off the Atlantic Ocean from northeasterly trade winds, the site averaged 27.9 $\mu g\ m^{-2} yr^{-1}$ wet Hg deposition, or about 30% more than Florida and the Gulf Coast, the highest deposition areas of the USA. These high Hg deposition rates are driven in part by high rainfall, which averaged 2855 $mm\ yr^{-1}$. The volume-weighted mean Hg concentration was 9.8 $ng\ L^{-1}$, somewhat lower than the southeastern USA, but high concentrations occurred even in high-rainfall weeks; there was no significant relation between Hg concentration and weekly rainfall depth. During a two month period, we measured atmospheric concentration and speciation of Hg at sea level and on a mountain ridge (750 m) above the deposition station (476 m). Particulate Hg and reactive gaseous mercury (RGM) concentrations were low, consistently < 12 $pg\ m^{-3}$. Given this apparent lack of RGM at ground level to support the high wet Hg deposition, we suggest that RGM is being scavenged by precipitation and/or cloud water either after formation in the mixing layer, or by high cloud tops scavenging RGM from above the mixing layer. Photooxidation of Hg^0 from the global pool is likely more intense in the tropics and helps to maintain a pool of RGM. The high wet Hg deposition found at this tropical site unimpacted by point sources makes a case for monitoring other tropical locations.

[1] United States Geological Survey, Montpelier, VT
[2] United States Geological Survey, Reston, VA
[3] United States Geological Survey, Middleton, WI
[4] Frontier Geosciences, Seattle, WA
[5] Project for Management of Water Resources, Baboua, Central African Republic

Atmospheric Mercury Measurements in the Gulf of Mexico and Mid-Atlantic Regions

Winston Luke[1*], Mark Cohen[1], Paul Kelley[1], Steve Brooks[2], Jake Walker[3]

The presence of mercury in the environment, its wide distribution and cycling in coastal and aquatic ecosystems, and risks to human health constitute a major environmental resource management issue. The majority of mercury emitted to the environment is injected into the atmosphere through the combustion of fossil fuels, incineration of mercury-containing waste, and metallurgical processes (e.g., smelting). Wet and dry atmospheric deposition delivers mercury to sensitive aquatic ecosystems, where it can be converted to more toxic and bio-available forms such as methylmercury. Human exposure to methylmercury, which adversely affects the nervous system, results from consumption of contaminated fish and other organisms in the aquatic food web.

Despite mercury's importance, however, many of the complex processes controlling its movement through the environment are poorly understood, and there is debate over the efficacy of emission controls in reducing mercury concentrations in estuarine and marine fish. In 2006 the National Atmospheric Deposition Program (NADP) introduced the Atmospheric Mercury Initiative to address many of these uncertainties. The initiative seeks to establish a network of sites to "…measure event-based mercury wet deposition, air concentrations of mercury in its gaseous and particulate forms, and meteorological and land-cover variables needed for estimating dry deposition fluxes [NADP, 2006]."

We present recent results from two such sites in the emerging network: a rural site at the Grand Bay National Estuarine Research Reserve (NERR) in Moss Point, MS, and a suburban site on the campus of the Beltsville Agricultural Research Center (BARC) in Beltsville, MD. The measured atmospheric mercury concentrations at the sites (elemental Hg(0), reactive gaseous mercury, and fine particulate mercury) will be summarized and compared with earlier results from 2007. Data will also be interpreted using ancillary measurements of primary (CO, NO/NO_Y, SO_2) and secondary (O_3) trace gases at each site; prevailing meteorology; and back trajectory analyses. Data collected in short-duration episodes of high mercury concentrations will be presented and discussed. Finally, results of studies designed to determine the role of sea salt aerosols in the marine environment will also be presented.

[1] NOAA/Air Resources Laboratory (R/ARL), SSMC3, Rm. 3316, 1315 East West Hwy., Silver Spring, MD 20910; *(301) 713-0295, Winston.Luke@noaa.gov
[2] Canaan Valley Institute, P.O. Box 673, Davis, WV 26260; (304) 463-4739
[3] Grand Bay National Estuarine Research Reserve, 6005 Bayou Heron Rd., Moss Point, MS 39562; (228) 475-7047

The Role of Regional Atmospheric Transport in Controlling Mercury Wet Deposition over the Northeastern United States

Peter Weiss-Penzias[1], Eric Prestbo[2], Curtis Pollman[3]

We present an investigation of the regional influence of large coal-combustion and other industrial mercury sources on mercury concentrations in wet deposition in the northeastern United States. Mercury concentrations in weekly integrated precipitation samples were obtained from three Mercury Deposition Network (MDN) sites that are progressively down-wind of numerous coal-fired power plants (CFPPs) in the Ohio River Valley region: Millford, Pennsylvania (PA72), Huntington, New York (NY20), and Bridgton, Maine (ME02). Seasonal and week-to-week variability in mercury concentrations at each site were investigated using ensembles of atmospheric back trajectories from each precipitation event during 2004-2005 and by calculating the residence time of each trajectory in an emissions area encompassing a ~500 km x ~500 km region with the most CFPPs. At all three sites, trajectory residence times were at a maximum in the month of June, which generally matches the season cycle in mercury concentrations. However, only PA72 produced consistently significant linear correlations between weekly mercury concentration and trajectory residence time ($r = 0.52$, $n = 85$ weekly samples, $P < 0.0001$), suggesting that the spatial extent of direct mercury pollution transport is < 700 km. The trajectory residence time/mercury concentration relationship was strongest at PA72 during March-May ($r = 0.77$, $n = 31$, $P < 0.0001$), and weakest in September-November ($r = -0.06$, $n = 26$). Volume-weighted mercury concentrations at PA72 are elevated compared to NY20 and ME02 by 10-25% in the summer, fall, and winter, and by 60% during the spring. Due to the strong linear relationship with trajectory residence time, this excess is attributed to direct pollution transport from the CFPP region. Additionally, we find that the 2001-2006 annual downward trend in volume-weighted mercury concentration at PA72 for the spring and summer months (the time of year with the most transport from the CFPP region) is statistically significant (-1 ng/L/year, $P < 0.05$), whereas the annual trend in the fall and winter months is not statistically significant. This suggests that further emissions reductions at CFPPs during the spring and summer would have a proportionally larger effect of lowering mercury in wet deposition at PA72 than emissions reductions at other times of the year.

[1] Department of Environmental Toxicology, University of California, Santa Cruz, CA 95064, pweiss@ucsc.edu, 831-429-1474
[2] Tekran Instrument Corporation, Toronto, ON, eprestbo@tekran.com, 416-449-3084
[3] Aqua Lux Lucis, Inc., 8411 NW 55th Place, Gainesville FL, cpollman@aqualuxlucis.org, 352.222.4039

Ecological Indicators of Mercury in the Environment: Results from the Western Airborne Contaminants Assessment Project (WACAP) and the Disconnect between Deposition & Effects

Colleen Flanagan[1*], Dixon Landers[2], Luke Ackerman[3], Adam Schwindt[4], Staci Simonich[5],
Carl Schreck[5], Michael Kent[5], Don Campbell[6];

Accumulation of mercury in aquatic food webs and its toxic effects on aquatic biota are of growing concern both for the health of the fish and the piscivores that prey upon them. This is of particular significance for high latitude and high altitude national parks because it is known that mountainous and Arctic areas are sinks for some contaminants. Therefore, the National Park Service initiated the Western Airborne Contaminants Assessment Project (WACAP) in 2002 to evaluate the risk to park ecosystems from airborne contaminants. Concentration of airborne contaminants (e.g., mercury, pesticides) in air, snow, water, sediment, lichen, conifer needles, and fish was determined in 8 core parks; more limited assessment focusing on vegetation was conducted in 12 secondary parks. Concentrations of contaminants measured in fish were also compared to human and/or wildlife contaminant health thresholds. Atmospheric deposition and flux of contaminants was measured via snowpack samples and lake sediment cores.

Mercury concentrations in fish exceeded human health thresholds in 20 of 169 fish sampled at 6 of 14 lakes in 5 of 8 parks (Noatak, Gates of the Arctic, Olympic, Mount Rainier, and Sequoia) between 2003 and 2005. Concentrations of mercury also exceeded risk thresholds for health impacts to piscivorous birds and mammals. Deposition fluxes of mercury in snow ranged from 336 ng/m^2/yr at Denali to 3600 ng/m^2/yr at Olympic, while sediment profiles at Olympic, Mount Rainier, Rocky Mountain, Glacier, and Sequoia National Parks show stabilization at fairly high percent enrichment values. Concentrations of mercury in fish were not always directly related to levels in atmospheric deposition and flux, however. For instance, mercury bioaccumulation in the arctic aquatic foodwebs was higher (ca. 175 ng/g ww Hg) although sediment data indicated that mercury deposition was relatively low (ca. 3 μg/m^2/yr) in those Arctic parks. This finding is likely due to in-lake biological processes that vary among lakes, and supports the usefulness of fish as a key indicator of mercury in the environment and subsequent impacts to food webs.

The mercury-methylating environment (microbes that convert deposited mercury into the bioavailable methylmercury) and food web structure control bioaccumulation and biomagnification of mercury, effectively disconnecting the link between mercury concentrations measured in snow and sediment from mercury concentrations in fish. While measuring mercury deposition may provide useful information for emissions regulation and source attribution, WACAP results suggest that fish sampling provides further evidence of actual effects upon the environment.

[1*] 303-969-2011, E: colleen_flanagan@nps.gov

[1] National Park Service, Air Resources Division, Lakewood, Colorado; [2] US Environmental Protection Agency, Western Ecology Division, Corvallis, Oregon; [3] FDA Center for Food Safety & Applied Nutrition, College Park, Maryland; [4] Denver Museum of Nature and Science, Denver, Colorado; [5] Oregon State University, Corvallis, Oregon; [6] US Geological Survey, Denver, Colorado

Effect of Biomass Fires on Atmospheric Mercury Concentrations and Deposition in the United States

Krish Vijayaraghavan[1*], Prakash Karamchandani[1], Shu-Yun Chen[1], Rochelle Balmori[1],
Leonard Levin[2], Christine Wiedinmyer[3], Hans Friedli[3]

Summer-time wildfires frequently occur in several regions of North America. Human-initiated burning of ground cover is also commonly employed for land clearing and land-use change. Measurements have found that such biomass burning, both lightning-induced and prescribed, can release significant levels of mercury into the air. These emissions comprise almost exclusively gaseous elemental mercury (Hg^0) and particulate mercury (Hg_p), and little reactive gaseous mercury (RGM). This paper investigates the effect of mercury emissions from biomass fires on atmospheric mercury concentrations and deposition in the United States during 2002 using an advanced air quality model. The model used, AMSTERDAM (Advanced Modeling System for the Transport, Emissions, Reactions and Deposition of Atmospheric Matter) is a state-of-the-science multi-pollutant model that is based on USEPA's Community Multiscale Air Quality (CMAQ) model and offers sophisticated treatments of ozone, particulate matter and mercury processes. Model performance is evaluated using mercury wet deposition data from the Mercury Deposition Network (MDN) and other measurements. The impact of fire Hg emissions on air concentrations and wet and dry deposition of Hg^0, RGM and Hg_p in the continental United States is studied.

[1] Atmospheric & Environmental Research, Inc. (AER), 2682 Bishop Drive, Suite 120,
San Ramon, CA 94583
[1*] Phone: 925-244-7127, Email: krish@aer.com
[2] EPRI, 3420 Hillview Avenue, Palo Alto, CA 94304
[3] National Center for Atmospheric Research, 1850 Table Mesa Drive, Boulder, Colorado 80305

Observations and Interpretation of Aquatic Mercury Cycling from an Upper Midwest Lake Survey

David Krabbenhoft

Abstract not available at the time of printing

TECHNICAL SESSION: EMERGING NOVEL MONITORING METHODS

Session Chair: Eric Prestbo, Tekran Instrument Corporation

Development of Surrogate Surfaces for Measurement of Mercury Dry Deposition

Seth Lyman[1*], Mae Gustin[1], Eric Prestbo[2], Phil Kilner[2]

Dry deposition of atmospheric mercury is thought to be an important pathway for input of mercury to aquatic and terrestrial environments. However, methods to measure mercury dry deposition flux are not well established. For the past three years, we have focused on development and characterization of a surrogate surface method for estimation of dry deposition of reactive gaseous mercury (RGM). The resulting method consists of a surface that is deployed facing down while mounted in an aerodynamic holder. The samplers are easy to deploy and inexpensive when compared with automated instrumentation. Minimum deployment time depends on RGM concentrations and may be as low at 12 hours. A polysulfone cation-exchange membrane is used as the surrogate surface. Accumulation of mercury on the surface is well correlated with air RGM concentrations ($r = 0.93$, $p < 0.001$) and with modeled RGM deposition ($r = 0.97$, $p < 0.001$), though deposition to surrogate surfaces is about three times greater than modeled RGM deposition to a desert ecosystem. The deposition velocity of RGM to the surrogate surface is 1.5 ± 0.4 cm s-1 (mean ± standard deviation), similar to modeled deposition velocity in the absence of surface resistance (1.2 ± 0.3 cm s-1). Performance of the surfaces has been evaluated extensively in a number of locations, including Nevada, Florida, Georgia, and Michigan. Additionally, performance of the surfaces has been examined under controlled conditions in a laboratory chamber. Environmental parameters that have been manipulated in the chamber to test surface response include temperature, humidity, ozone concentration, RGM concentration, and gaseous elemental mercury concentration.

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[1] University of Nevada, Reno, Department of Natural Resources and Environmental Science, MS 370, Reno, Nevada, 89557, *775-784-4966 (phone), 775-784-4789 (fax), slyman@cabnr.unr.edu

[2] Tekran Instruments, 330 Nantucket Blvd, Toronto, Ontario MIP2P4, Canada

Spatial Dry Deposition of Reactive Gaseous Mercury in West Central Alberta

Warren Kindzierski[1*], Bob Brunette[2,] Gerard Van der Jagt[2], Ryan Nelson[2],
Phil Kilner[3], Eric Prestbo[3]

Four coal-fired power plants are situated about 60 km from Edmonton in west central Alberta. Collectively, these plants have the capacity to generate a total of 4,277 megawatts to Alberta's electrical grid. A passive sampling approach developed by Frontier GeoSciences Inc. is being used to obtain weekly or bi-weekly measurements of reactive gaseous mercury (RGM) in an effort to understand the role of local mercury emissions and atmospheric deposition within the regional area. Cation-exchange membranes are deployed as surrogate surfaces for measurement of RGM deposition at six locations using the same schedule as the NADP Mercury Deposition Network. One of the locations is a Mercury Deposition Network site.

The sampling locations were selected based upon regional modeling of atmospheric mercury deposition in response to proposed expansions at two of the plants. Two sampling locations are within 5 to 10 km of the plants representing inferred high deposition loading. Another two locations are within 25 to 35 km of the plants representing inferred intermediate deposition loading. Finally, two sampling locations are within 20 to 35 km of the plants representing inferred low deposition loading.

The cation-exchange membranes are deployed on Frontier Geosciences Inc. specially-designed polyurethane aerodynamic sampling heads in a face down position. Mercury adsorbed to the membranes is extracted by Frontier GeoSciences Inc. using 100 mL of 10% 2N bromine monochloride and analyzed using US EPA Method 1631. Field sampling techniques and measured dry deposition rates for a nine-month period (April through December 2007) will be presented and discussed.

[1] University of Alberta, School of Public Health, Edmonton, Alberta;
Phone: 780-492-0382; Email: warrenk@ualberta.ca
[2] Frontier Geosciences Inc., Seattle, Washington; Phone: 604-987-3037;
Email: BobB@frontiergeosciences.com
[3] Tekran Corporation, Toronto, Ontario; Phone: 206-755-0750; Email: eprestbo@tekran.com

Pilot Study of Mercury in Litterfall at National Atmospheric Deposition Program Mercury Deposition Network Sites

Martin R. Risch
U.S. Geological Survery
5957 Lakeside Boulevard
Indianapolis, Indiana 46278
(317) 290-3333 x 163
mrrisch@usgs.gov

Atmospheric mercury can be transported to aquatic or terrestrial ecosystems through wet and dry deposition. Mercury wet deposition has been monitored for more than 10 years at National Atmospheric Deposition Program Mercury Deposition Network (MDN) sites in North Anerica. Mercury dry deposition generally is not measured directly and a national monitoring program to estimate dry deposition is in development. Data on mercury wet and dry deposition are needed to evaluate regional- and continental-scale deposition models and to assess changes in deposition resulting from reductions in mercury emissions required by regulation.

Forests can enhance mercury dry deposition by scavenging mercury from the air. Rates of mercury dry deposition to forests are known to be several times the rates of mercury wet deposition to open areas at the same location. Information about mercury in litterfall is a measure of mercury dry deposition to forests. Litterfall is forest canopy material, mostly leaves and needles, that drop from the trees to the forest floor. Mercury in litterfall consists primarily of mercury attached to the surface of leaves and needles and mercury incorporated into the foliage tissue. Because previous studies of mercury in litterfall have been for small watersheds, litterfall data from MDN sites could provide a larger scale for comparing wet and dry deposition to forest landscapes in North America.

In fall 2007, the U.S. Geological Survey (USGS) began investigating mercury in litterfall at MDN sites through a pilot study in which litterfall samples were collected at 12 MDN sites in 6 states. The purpose of the pilot study was to test methods that could be implemented at a greater number of MDN sites in the future. In the pilot study, the USGS provided sampling kits and instructions to MDN site operators who placed sampling boxes at randomly selected points in a forest study plot near each of the 12 MDN sites. Litterfall was allowed to accumulate in the sampling boxes for one month; two sets of samples were collected at each site. The litterfall samples were shipped to the USGS where they were frozen, dried, weighed, ground, homogenized, and analyzed for total mercury and methylmercury. Mercury dry deposition in litterfall was computed as the product of sample concentration and sample dry weight per sampling-box area.

This presentation provides results from the pilot study, compares litterfall mercury dry deposition with mercury wet deposition, and examines factors contributing to differences in litterfall dry deposition among the MDN sites in the pilot study.

Multi Component Vertical Gradient Measurements by WRD and SJAC Sampling as in GRAEGOR and GRAHAM

Otjes[1*], R.P., Jongejan[1], P.A.C., Blom[1], M.J., ten Brink[1], H.M., Erisman[1], J.W.,
Thomas[2], R.M., Wichink Kruit[3], R.J.

Wet Rotating Denuders (WRD) and Steam Jet Aerosol Collectors (SJAC) have been used for over a decade now in on-line measurement of water-soluble gases and aerosols. By applying multiple sampling units it became possible to perform vertical gradient measurements. This method is used in the GRAHAM, an analyzer for ammonia. The GRAHAM consists of three WRD's combined with a gas diffusion conductivity cell. In laboratory studies the relative standard deviation for the three channels was 0.34% when exposed to an ammonia calibration gas of 8 microgram/m^3. The detection limit is 0.02 microgram/m^3.

A recent development is the GRAEGOR. Apart from ammonia this monitor measures nitric acid, hydrochloric acid, sulfur dioxide and the aerosol-components sulfate, nitrate, chloride, and ammonium. The GRAEGOR uses two sampling units. Each WRD is followed by a SJAC for collection and analysis of the aerosols. There is an option to also analyze the cations with cation-chromatography. The average relative standard deviation is 2% for the components mentioned, at a typical concentration of 1 ug m^{-3}. The detection limits were similar to that of the GRAHAM, viz., 0.01-0.03 ug m^{-3}.

The instruments have been successfully deployed for gas flux measurements. For aerosols, which usually have a 10 times lower deposition velocity, gradients were harder to resolve. Gradients by GRAEGOR have been detected at a fertilized field fetch showing both heterogeneous particle gas-phase reactions as well as particle deposition. GRAHAM detected gradients above a non-fertilized grassland. A flux precision of better than 1 ng/m^2/s was established.

* Air Quality and Climate Change, ECN (Energy Research Centre of the Netherlands)
PO Box 1, 1755 ZG Petten, Netherlands, Tel: +31224564264, Email: otjes@ecn.nl
[1] Energy Research Centre of the Netherlands (ECN),
[2] Centre for Ecology and Hydrology Scotland (CEH),
[3] Dutch National Institute for Public Health and Environment (RIVM)

A Field Instrument for Measuring Rain Conductivity in Real-time

Alfred M. Moyle* and Dennis Lamb
Meteorology Department, 503 Walker Building
The Pennsylvania State University
University Park, PA 16802

NADP data have repeatedly demonstrated that summertime rains in the northeastern United States are characteristically acidic due to high concentrations of sulfate, a chemical signature that can be traced back to the release of sulfur dioxide during the burning of coal in the region. Attempts to model source-receptor relationships and the spatial patterns of acidic deposition depend on the kind of precipitation chemistry data that AIRMoN and NTN provide for validation (ground truth). However, the acquisition of complete chemical data is expensive, especially when ever-higher spatial and temporal resolution is needed to test model results or reveal mechanistic information about cloud processes. The strong statistical links that exist between the concentration of sulfate, pH, and the electrical conductivity of rainwater have allowed us to develop a relatively inexpensive, single-parameter monitor of precipitation quality that meets the scientific needs.

Experience gained during the summer seasons of 2006 and 2007 demonstrated that electrical conductivity is relatively easy to measure in a field setting. The variations in conductivity can be monitored continuously throughout individual storms, indirectly yielding high temporal resolution of rain pH and sulfate concentration. Unique chemical signatures from convective and stratiform rain events were evident from data gathered by sampling on the roof of the Walker Building on the Penn State campus, some 10 km from the nearest NADP site (PA15).

The conductivity monitor has now been collocated with the AIRMoN, NTN, and CAPMoN samplers at the PA15 site, thus allowing unambiguous comparisons to be made between the diverse data sets. The new, continuous measurements of conductivity will supplement the current measurement strategies based on daily and weekly sampling, thereby providing new insights into the chemical evolution of acidic storms and furthering the technology for eventually monitoring rain acidity remotely in real-time across a mesonetwork of stations.

*Corresponding author - Telephone: 814-863-4526; Email: amm14@psu.edu

Perchlorate Deposition in Wet Precipitation across North America

W. Andrew Jackson* and Srinath Rajagopolan
Department of Civil and Environmental Engineering, Texas Tech University,
Lubbock, Texas 79409-1023, USA.

Perchlorate (ClO_4^-) contamination continues to be an important environmental issue due to its potential health impacts, the number of areas with affected groundwater, and the possibility of new legislation. Perchlorate is primarily used as an oxidant in solid rocket propellants and to a lesser extent on a mass basis in flares, fireworks, and some explosives. Natural perchlorate has been known to exist for over a century but until recently was thought to only occur in the Atacama Desert. Natural perchlorate is believed to be of atmospheric origin, yet no systematic study has been conducted to evaluate perchlorate deposition rate and possible seasonal or spatial variations. Perchlorate wet deposition was evaluated weekly at 16 NADP sites across the continental US as well as Puerto Rico and Alaska for a three year period (October 2004-October 2007). In addition, 8 additional sites were evaluated in the third year of the study. Perchlorate (ClO_4^-) analysis used sequential ion chromatography-mass spectroscopy-mass spectroscopy (IC-MS/MS) with a lower quantitation limit of 5 ng/L. Perchlorate concentrations varied from <5 ng/L to a high of 102 ng/L with a mean of 14.1 ± 13.5 ng/L for the 1578 total samples. Perchlorate annual deposition by site ranged from a low of 12.5 (TX) to 157 mg/ha-year (NE) and averaged 65 ± 30 mg/ha-year for all sites. Perchlorate concentrations and deposition were generally highest in May-August declining to lows in December-February. Perchlorate concentration is significantly ($p < 0.001$) related to all other monitored ions (Ca^{+2}, Na^+, K^+, NH_4^+, NO_3^-, $Cl,^-$, SO_4^{-2}, and pH) except Mg^{+2}, although the regression coefficients are generally quite low (< 0.3), except for Ca^{+2}, NH_4^+, and NO_3^- ($r = 0.40$, 0.41, and 0.38 respectively). Average annual perchlorate deposition was correlated ($r > 0.5$; $p < 0.001$) with Ca^{+2}, K^+, NH_4^+, NO_3^-, Cl^-, and SO_4^{-2} . Deposition of ClO_4^- by precipitation in the continental United States (excluding AK, HI, and Puerto Rico) while diffuse, represents a potential annual net mass flux of 51,000 kg, a value comparable to the estimated annual environmental releases from other known ClO_4^- sources.

* Phone: 806-742-2801 (230); email:Andrew.jackson@ttu.edu

POSTER SESSION

IN ALPHABETICAL ORDER BY FIRST AUTHOR

Calcium and Nitrate Limitation

Tom W. Baribault*, Richard Kobe and David Rothstein
Michigan State University
126 Natural Resources
East Lansing, MI 48824

Aboveground net primary production (ANPP) in temperate forests could be regulated by multiple soil resources, but many studies have focused on solely nitrogen limitation. We evaluated a broad suite of resources in three major categories—nitrogen (nitrate, ammonium, N-mineralization), cations (calcium, magnesium, manganese, potassium, phosphorous, acidity), and water availability—as predictors of ANPP across a natural fertility-productivity gradient in the post-glacial landscape of northwestern Lower Michigan. Within the context of effects of atmospheric deposition on soil nutrients, our goals were to: 1) evaluate the strongest predictors of productivity within and among resource categories; and 2) test for soil resource effects on wood versus leaf production.

We measured annual ANPP, including wood and leaf increments, and soil resource availability at 13 sites across the fertility gradient. We fit models of four functional forms to each combination of resource and $\mathrm{ANPP}_{\mathrm{wood}}$, $\mathrm{ANPP}_{\mathrm{leaf}}$, and $\mathrm{ANPP}_{\mathrm{total}}$. We used Akaike's Information Criterion to assess relative empirical support of different resources and functional forms as predictors of ANPP. Including all sites, $\mathrm{ANPP}_{\mathrm{total}}$ and $\mathrm{ANPP}_{\mathrm{wood}}$ were best predicted by sigmoid functions of exchangeable Ca, whereas $\mathrm{ANPP}_{\mathrm{leaf}}$ was best predicted by a Michaelis-Menten function of soil nitrate.

$\mathrm{ANPP}_{\mathrm{total}}$ and $\mathrm{ANPP}_{\mathrm{wood}}$ reached an asymptote at relatively low Ca levels. Across the nine least fertile sites, Ca again was the best predictor of $\mathrm{ANPP}_{\mathrm{total}}$ and $\mathrm{ANPP}_{\mathrm{wood}}$, though as a linear function. However, $\mathrm{ANPP}_{\mathrm{total}}$ and $\mathrm{ANPP}_{\mathrm{wood}}$ were positively, but not significantly, correlated to nitrate at sites with elevated Ca, suggesting sequential nutrient limitation by first Ca and then nitrate. Under low fertility conditions, $\mathrm{ANPP}_{\mathrm{leaf}}$ constitutes the majority of ANPP total, but $\mathrm{ANPP}_{\mathrm{wood}}$ becomes the major component as soil fertility increases. To assess the potential for direct Ca limitation, we calculated an approximate annual calcium budget for each site. Current exchangeable Ca could supply ~3 to 10 years of Ca demand, suggesting the potential for direct calcium limitation at the lower fertility sites if weathering and mineralization rates are low.

Atmospheric deposition of Ca is insufficient to meet tree physiological demands, but would exert some influence on productivity at low-fertility sites. Both acidic deposition and nitrogen deposition can contribute to leaching of Ca; if Ca is limiting, then productivity may be reduced over time even at high-productivity sites. The strength of these correlative findings suggests limitation by Ca and nitrate, and we are assessing these results with experimental nutrient amendments.

*(517) 355-7599, baribaul@msu.edu

Aboveground Production across A Soil Resource Gradient: Potential Application of a Regional Air Quality Model to Simulate Dry Deposition of Total Nitrogen at National Parks

Michael G. Barna[1*] and Marco A. Rodriguez[2]

Weekly estimates of dry deposited nitric acid (HNO_3), particulate ammonium (NH_4+) and particulate nitrate (NO_3-) are provided by the Clean Air Status and Trends Network (CASTNet). There are, of course, many more nitrogen-containing species in the atmosphere that may play a role in dry deposition. These include "total reactive nitrogen" (NO_y) which, in addition to nitric acid and particulate nitrate measured by CASTNet, is composed of nitrogen oxides (NO_x), organic nitrogen (including peroxy acetyl nitrate, or PAN), nitrous acid (HONO), dinitrogen pentoxide (N_2O_5) and nitrate radical (NO_3). Reduced forms of nitrogen, such as ammonia (NH_3) and ammonia derivatives (e.g., amines), are other examples of potentially important nitrogen species. To quantify the impact of this "missing nitrogen" to dry deposition, the CAMx regional air quality model was used. Nitrogen species that 1) exist in appreciable concentrations in the atmosphere and 2) are characterized by rapid deposition velocities are anticipated to play a significant role in the total dry deposition budget.

Rocky Mountain National Park (RMNP), located approximately 100 km northwest of Denver in Colorado's Front Range, is the subject of extensive atmospheric deposition research. Initial CAMx estimates of annual dry deposition at RMNP indicate that, during 2002, the estimated total nitrogen was 2.2 kg/ha/yr vs. 1.0 kg/ha/yr, as reported by CASTNet. This difference is largely attributed to the contribution of ammonia, and to a lesser extent nitrate radical and organic nitrates. This presentation will present more information regarding dry deposition at RMNP, as well as estimated values for other national parks.

[1]*Mike Barna, 970-490-8692, barna@cira.colostate.edu, *Air Resources Division, National Park Service, Fort Collins, CO 80524, USA*
[2]*CIRA, Colorado State University, Fort Collins, CO 80524, USA*

Continued Field Comparison Of MDN Mercury Wet Deposition Collectors: MDN Aerochem and MDN NCONN-ADS

Robert Brunette[1], Gerard Van der Jagt[1], Erick Miller[2], Robert Tordon[3], David Gay[4], Doug Disney[1], Ryan Nelson[1], Jason Karlstrom[1], Adela Blaga[1], Jeanne Faverman[1], Felicia Merritt[1]

On October 24, 2006 the NADP voted and approved the use of a second MDN wet deposition collector (MDN NCONN-ADS) in an effort to modernize and eventually replace the aging original MDN collector design (MDN Aerochem). The MDN Aerochem (MDN ACM) is still deployed at a majority of the MDN sites and continues to support the MDN well. The new MDN NCONN-ADS has replaced several aging MDN ACM collectors and essentially has been deployed at all new MDN sites started since January 2007. The MDN NCONN-ADS collector utilizes an optical sensor versus the MDN ACM 11 grid sensor and has several features that greatly improve the operational efficiency of wet deposition mercury collection.

Although the MDN NCONN-ADS collector, prior to approval, was well tested and compared to the MDN Aerochem, it was encouraged to continue co-located collector measurements in order to monitor any potential differences in capture efficiency and chemistry for mercury. Three sites have continued these co-located MDN collector measurements: (1) Seattle, Washington State (MDN WA18) operated by Frontier Geosciences Inc (collector comparison ~ 3 years) (2) Kejimkujik National Park, Nova Scotia, Canada operated by Environment Canada (collector comparison ~ 1 year) and (3) Underhill, Vermont (MDN VT99) operated by Ecosystems Research Group, Ltd (collector comparison ~ 3 years). Capture efficiency, total mercury in precipitation and total mercury wet deposition at all three of these geographically diverse sites are presented.

[1] Frontier Geosciences Inc
[2] Ecosystems Research Group, Ltd.
[3] Environmental Canada, Nova Scotia
[4] Illinois State Water Survey

Establishing an Ambient Mercury Baseline in New York State

Kevin Civerolo[1]*, Dirk Felton, Tom Gentile, Steve DeSantis, Matthew Hirsch, and Oliver Rattigan

The New York State Department of Environmental Conservation (NYSDEC) received a grant from EPA to establish continuous monitoring of ambient concentrations and weekly wet deposition of mercury in New York, consistent with the proposed NADP Atmospheric Mercury Initiative. These baseline data will be used to help monitor the progress of planned mercury reduction strategies targeting the municipal waste incineration and coal-fired electricity generation sectors. Fully speciated Tekran analyzers and MDN-type bucket collectors have been deployed at two urban locations, Rochester and New York City. The wet deposition samplers have been in operation since January 2008, while the Tekrans were installed during the summer of 2008. Precision measurements demonstrate that for Hg(0) the Tekran analyzers agree to within 5%. The initial wet deposition data from these two urban locations will be compared with similar MDN data from more rural sites (Biscuit Brook, Huntington Wildlife, and West Point) in the state.

[1] New York State Department of Environmental Conservation,Division of Air Resources,
625 Broadway, Albany, NY 12233
*E-mail: kxcivero@gw.dec.state.ny.us; Phone: 1-518-402-8383; Fax: 1-518-402-9035

2006-2007 Measurements of Atmospheric Mercury Species at a Coastal Site in Atlantic Canada

John Dalziel*, Robert Tordon, Stephen Beauchamp
Air Quality Science Division
Meteorological Service of Canada
Environment Canada
45 Alderney Drive
Dartmouth, N.S. B2Y 2N6

Environment Canada has been continuously measuring the levels of three gaseous Hg species – gaseous elemental mercury (GEM), reactive gaseous mercury (RGM), particulate (P-Hg) fine fraction (<2.5 µm) - at an urban coastal site since January 2006. This poster illustrates and discusses data collected at our site in Halifax, Nova Scotia (Canada) from January 2006 to June 2007. This 18 month data set show GEM (5 minute sampling) having a median of ≈ 1.7 ng m^{-3} and a range of 0.72 to 46.5 ng m^{-3} ; RGM (3 hour sample) a median of ≈ 2.5 pg m^{-3} with a range from the detection limit (dl) to 140 pg m^{-3} and P-Hg (3 hour sample) a median of 1.73 pg m^{-3} and a range from dl to 31 pg m^{-3}. The median levels of RGM and P-Hg are only a small percentage of the Total Gaseous Mercury (TGM), 0.14% for RGM and 0.10% for P-Hg.

Temporal trends of elevated GEM were noted in the spring and early summer and more uniform levels observed during winter months. P-Hg events were more predominant in winter and early spring periods. For RGM, elevated levels occurred during the spring and early summer. A diurnal trend in RGM shows elevated levels beginning near mid day and continuing through the evening and night time period. The lowest levels of RGM are generally measured in the early morning to about noon. A diurnal trend for P-Hg was not evident.

RGM did show significant associations with air temperature, solar radiation and relative humidity. An observed trend of decreased levels of RGM during precipitation events coincided with the negative relationship observed with relative humidity. The significance of wind direction contributing to RGM levels was also observed and attributed to an effect from local sources. An analysis of air quality parameters versus Hg species shows ozone having its most significant association with RGM and an inverse association with GEM. Also noted, were $PM_{2.5}$ and NO_2 have varying degrees of association with all three Hg species.

* Phone: 902-426-6791, Email: john.dalziel@ec.gc.ca

Total Dissolved Nitrogen in Precipitation: Measurable or Not?

Tracy Dombek, Lee Green and Christopher Lehmann
Central Analytical Laboratory
National Atmospheric Deposition Program
Illinois State Water Survey
Champaign, IL 61820

Concentrations of ammonium and nitrate, the dissolved inorganic components of nitrogen, are routinely determined in wet deposition samples collected for the National Atmospheric Deposition Program (NADP), however, the dissolved organic components are not routinely evaluated. A previous study conducted by the Central Analytical Laboratory (CAL) developed and evaluated an automated in-line persulfate digestion method via Flow Injection Analysis (FIA) for the determination of total dissolved organic components of nitrogen utilizing samples from the NADP AIRMoN sites. The total dissolved fraction of nitrogen was obtained by subtracting the nitrate (measured by IC) as N and ammonium (measured by FIA ammonium method) as N from the result obtained by FIA TN method.

The previous study reported minimal differences for filtered vs. unfiltered samples: an average of < 5% organic nitrogen at Bondville, IL (IL11) over a 1 year period and as high as 11.2 % organic nitrogen in samples from the Canaan Valley Institute, WV (WV99) for a 6-week period in July-August of 2005.

The purpose of this poster is to further the approach of the previous study and to identify total dissolved organic nitrogen in monthly composites of wet deposition samples collected for NADP. Excess unfiltered NADP wet samples for 3 sites IL11, WV99, and Penn State, PA (PA15) were saved and preserved by refrigeration. Precipitation-volume-weighted monthly composites were created and analyzed for total dissolved nitrogen. All analyses were conducted on the same day for all analytes. Filtered vs. unfiltered samples were also measured to verify that the differences are minimal, to confirm the findings of the previous CAL study.

A secondary purpose of this study was to reveal if ammonium and nitrogen gained or lost in NADP samples is being converted between organic and inorganic species. Samples with measurable differences between the original and subsequent reanalysis were reanalyzed for total dissolved nitrogen, nitrate and ammonium to determine if the ammonium and nitrate lost were measurable as total dissolved nitrogen.

Expanding Our Knowledge of Wet and Total Deposition through Resin Technology: Possibilities for Extending the NADP Network

Ewing, H. A.[1], Voeller, G. E.[1], Lehmann, C.[2], Dombek, T.[2], and Weathers, K. C.[3]

The NADP and CASTNET are critical national networks for monitoring trends in deposition and its spatial variation across the country. However, the density of both networks is insufficient to fully characterize wet, dry, and total deposition across landscapes, especially in areas with complex patterns of topography or land cover. We describe here what is known about the utility of resin technology and the steps needed to make resins a viable part of an extended national monitoring network. Our laboratory experiments loading anion, cation, and mixed resins have shown that resins can effectively capture—and then be extracted to measure—atmospheric loads of the anions NO_3^-, Cl^-, SO_4^{2-}, and Br^-. Cation recovery in the laboratory has been less effective, particularly for the divalent cations Ca^{2+} and Mg^{2+} and in experiments with small loadings. Field studies have used resins in dense networks both in the open and under canopies to provide time-integrated measures of both wet and total deposition of several ionic species, demonstrating the potential of resins to extend monitoring of deposition spatially. We propose a design for further laboratory- and field-based testing of resin technology necessary for implementation in a national network such as NADP. Such work would include tests of resin efficiency, the suitability of different extractant solutions, resin stability during storage (pre- and post-deployment), resin response to freezing and drying, and comparisons of resin collections to aqueous field loads. With further testing, resin technology could effectively extend the wet-deposition—and eventually also the total-deposition—networks through their time-integrated measure of atmospheric ion deposition to complex terrain. We also highlight the ways in which multiple kinds of institutions—including undergraduate institutions, established analytical labs, and the NADP lab at the Illinois State Water Survey—can play a role in the development of this technology.

[1] Program in Environmental Studies, Bates College, Lewiston, ME
[2] Illinois Sate Water Survey, Champaign, IL
[3] Cary Institute of Ecosystem Studies, Millbrook, NY

Final Validation of Arsenic, Selenium and a Full Suite of Metals in Rainwater Using ICP-DRC-MS

Monica Garcia-Strickland, Amy L. Dahl, and Robert Brunette
Frontier Geosciences Inc, 414 Pontius Ave. N., Seattle WA 98109, (206) 622-6960

The National Atmospheric Deposition Program (NADP) – Mercury Deposition Network (MDN) has been operating since 1994 and is well established with over 110 sites collecting wet deposition for total mercury with a subset of sites measuring methyl mercury. With mercury as a well established part of the NADP, the MDN Hg Analytical Lab (HAL) began an initiative to accurately measure a series of priority trace metals including but not limited to Ag, As, Be, Cd, Cr, Cu, Pb, Ni, Se, Zn.

Since 1998, the HAL has conducted trace metals wet deposition studies at a total of 20 MDN sites. At present, the HAL has made many advances to support this initiative for the NADP MDN: (1) Modified collector for trace metals collection (2) Designed and field tested trace metals sample train (3) Developed routine trace metals sample train cleaning protocols (4) Developed standard operating procedures for trace metals field sampling. The final step of this initiative involves the development of an ultra low-level detection limit technique for quantifying a full suite of metals in rainwater.

Due to ionic interferences in the measurement of low-level concentrations of selenium and arsenic via standard ICP-MS, these samples have been analyzed via hydride generation atomic fluorescence spectrometry (HG-AFS). In order to measure the full suite of metals in rainwater, the HAL has had to split each rainwater sample into 3 sub-samples (1) As by HG-AFS (2) Se by HG-AFS and (3) Cd, Cu, Cr, Ni, Pb, Zn, and Be are measured by standard ICP-MS. This labor intensive approach has made it cost prohibitive to measure the full suite of metals in rainwater as well as cumbersome for data management.

The HAL has overcome these inefficiencies through the design and validation of an ICP-MS based technique using Dynamic Reaction Cell (DRC) technology. DRC removes certain polyatomic interferences for a variety of metals; specifically As, Se and Ni for these samples. The HAL has successfully optimized operating parameters such that only one preparation and analytical run is required for all metals of interest. Analyzing all metals in one run has allowed for decreased operating costs, simplified data processing requirements and a reduction in the amount of sample required, an important benefit for volume-limited wet deposition samples.

Full validation of this method for analysis of trace metals in wet deposition will be demonstrated by

1. DRC optimization for As, Se and Ni
2. MDL/PQL studies for As, Se and Ni by ICP-DRC-MS and all metals of interest by standard ICP-MS
3. Comparison of twenty wet deposition samples analyzed for As and Se by ICP-MS, ICP-DRC-MS and HG-AFS.

Determination of Passive Ammonia Concentrations by the Method of Flow Injection Analysis at a Network of Air Monitoring Sites

Nina Gartman
Central Analytical Laboratory
National Atmospheric Deposition Program
Illinois State Water Survey
Champaign, IL 61820

The determination of ambient ammonia concentrations at a network of air monitoring sites is carried out by Flow Injection Analysis. Field samples for this study are collected from 21 sites in the USA and Canada using Radiello passive diffusion gas samplers, which cores, made of microporous polyethylene coated with phosphoric acid, adsorb ammonia as ammonium ions. After 14 days of exposure at field sites samplers with related field blanks are shipped to Central Analytical Laboratory (CAL).

CAL analysts perform the extraction of ammonium from the samplers with high purity deionised water and then determine the concentration of ammonium in extracts. Ammonium ion is quantified by flow injection analysis as indophenol - the adsorbance of its blue color, which is directly proportional to the ammonium concentration, is measured at 630 nm. The method detection limit is 0.005 mg NH_4/L.

Quality Control includes several levels of checks to assure accurate data readings. The deviations from standard procedure of determination NH_4 on FIA include storing samples at 4^0C, stirring samples before the analysis and using a modified buffer.

Expanding our Knowledge of Wet and Total Deposition through Resin Technology: Laboratory-Scale Development at the NADP's Central Analytical Laboratory

L. Green[1], T. Dombek[1], S. Smith[1], C. Lehmann[1],
H. Ewing[2], G. Voeller[2], and K. Weathers[3]

Field and laboratory studies reported in the literature have demonstrated the use of ion exchange resins in monitoring networks to provide time-integrated measures of both wet and total deposition of several ionic species. Such methods may provide a cost-effective way to expand the capacity of NADP monitoring stations to better characterize wet, dry, and total deposition in areas with complex patterns of topography or land cover. In collaboration with the Bates College and the Cary Institute of Ecosystem Studies, the NADP Central Analytical Laboratory (CAL) has embarked on further laboratory-scale testing of resin technology for future network deployment by the NADP.

Researchers have evaluated bulk deposition of sodium, potassium, calcium and magnesium using 1M HCl as the ion extractant, and deposition of sulfate, nitrate and chloride using 1M KI as the extractant. Mixed bed resins have also been evaluated for ammonium and nitrate measurements using 2M KCl as the extractant, and other cations and anions using KI as the extractant.

The CAL is developing analytical methodologies and bench-scale protocols to demonstrate its capability to reproduce the results reported in the literature, and further develop research efforts by Bates College and the Cary Institute. The CAL is currently measuring known samples to verify Method Detection Limits (MDLs), and other data quality parameters. Various commercially-available ion exchange resins and extractant solutions will be evaluated for their ion capture and extraction efficiency. A bench-scale setup will be used to load ion exchange resins with NADP/National Trends Network samples to directly compare previously measured precipitation samples with recoveries from resins.

[1] Central Analytical Laboratory, Illinois State Water Survey, Champaign, IL
[2] Program in Environmental Studies, Bates College, Lewiston, ME
[3] Cary Institute of Ecosystem Studies, Millbrook, NY

Concentration, Size Distributions, and Transport of Agricultural Aerosols

Naruki Hiranuma [*1], Sarah D. Brooks[1], Leah Cheek[1], Daniel C.O. Thornton[2],
Brent W. Auvermann[3], Rick Littleton[4]

Agricultural fugitive dust is a significant source of localized air pollution in the semi-arid southern Great Plains. In the Texas Panhandle, daily episodes of ground-level fugitive dust emissions from the cattle feedlots associated with increased cattle activity in the early evenings are routinely observed. Here we present measurements of the concentrations and size distributions of agricultural aerosols measured at the nominal downwind edge of the open-air cattle feedlot during summers of 2006, 2007 and 2008. A GRIMM sequential mobility particle sizer and GRIMM 1.108 aerosol spectrometer were used to measure aerosol size distributions in the range of 10 nm to 10 µm aerodynamic diameter. In addition to these continuous measurements at the downwind site, size distributions measurements collected further downwind (~5 km) will be used to observe and quantify aerosol dispersion and transport. In additional, coincident measurements of the aerosol hygroscopicity, chemical composition, and gas and particulate ammonia concentrations were collected at the feedlot. Relationships between these fundamental properties and the fate and transport of the aerosols will be discussed. The results of this study will provide important particulate emission data from a feedyard which is needed to improve our understanding of the role of agricultural particulates in local and regional air quality.

* naruki10@tamu.edu
[1] *Dept. of Atmospheric Sciences, Texas A&M Univ., College Station, Texas*
[2] *Dept. of Oceanography, Texas A&M Univ., College Station, Texas*
[3] *Texas Agricultural Experiment Station, Amarillo, Texas*
[4] *Microscopy and Imaging Center, Texas A&M Univ., College Station, Texas*

Intercomparison of Techniques to Measure NH_3 Concentrations and Fluxes above a Fertilized Corn Field

Jones MR[1], Walker JT[1], Luke W[2], Meyers T[2], Bash JO[3], Myles L[2], Nemitz E[4], Robarge W[5]

A number of measurement techniques and methods were deployed to measure NH_3 concentrations and fluxes. The experiment was conducted from April to August 2007 in a fertilized corn field near Lillington, North Carolina, where a consortium of government agencies and universities contributed six unique NH_3 measurement techniques. An upgraded AMANDA system (Ammonia Measurement by ANnular Denuder sampling with on line Analyser), which measured NH_3 concentrations via an improved conductivity cell, was configured in a 3-height gradient mode above the vegetation for determination of canopy-scale air-surface exchange. Two Nitrolux-200 (Pranalytica, Inc.) photoacoustic spectrometers were run in a 2–height NH_3 flux gradient mode with automated switching between sampling heights. A 2-height manual denuder (URG) gradient system was run during two 2-week intensives to provide 3-hour integrated NH_3 concentrations and fluxes. A second manual denuder (URG) system provided 12-hour integrated NH_3 concentrations at a single measurement height for the duration of the experiment. Toward the end of the growing season, manual denuders (URG) were periodically deployed in a 5-height vertical profile to provide in- and above-canopy NH_3 concentrations. Finally, weekly passive (ALPHA) NH_3 samples were also collected for the duration of the experiment.

These techniques provided a broad range of the available methods for measuring NH_3 concentrations and fluxes. The experiment demonstrated the benefits and weaknesses of the different methods and provided much needed NH_3 flux and concentration data for fertilized cropping systems in the US.

* Corresponding author: 919-260-9097, matjceh@yahoo.com
[1] US EPA, National Risk Management Research Laboratory
[2] NOAA, Air Resources Laboratory
[3] US EPA, National Exposure Research Laboratory
[4] Center for Ecology and Hydrology, Edinburgh
[5] North Carolina State University, Department of Soil Science

National Air Emissions Monitoring Study: Swine Feeding Operations in North Carolina

Jihoon Kang* and Wayne P. Robarge
North Carolina State University,
Department of Soil Science,
Raleigh, NC 27695-7619

There are increasing concerns about the environmental and health effects of air emissions from animal feeding operations (AFOs) with the increasing size, geographic concentration, and suburbanization of these operations. The National Air Emission Monitoring Study (NAEMS) was established in 2006 by a voluntary Air Compliance Agreement between the EPA and the pork, dairy, egg and broiler industries to highlight the air quality issues associated with AFOs with respect to compliance with EPA regulations. The objectives of the NAEMS include 1) accurately assess emissions from livestock operations and compile a database for estimation of emission rates and 2) promote a national consensus for emissions-estimation methods/procedures from livestock operations. Currently the NAEMS monitors a total of 38 different barns across eight states of U.S., representing one of four main animal industries, namely, swine, dairy, layers, and broilers. Each of barns continuously monitors particulate matter (PM_{10}, $PM_{2.5}$, or TSP), volatile organic carbon (VOC), ammonia (NH_3), hydrogen sulfide (H_2S), and carbon dioxide (CO_2) according to the EPA-approved standard operating procedures. Department of Soil Science at NC State University monitors air emissions from a sow farm (breeding, gestation, and farrowing) and a finisher farm (three finishing barns) in Duplin County, NC. Introduction to the NAEMS, NC swine site description, instrument setup, and preliminary results will be discussed.

*Corresponding author: Jihoon Kang, jkang@ncsu.edu, 919-513-3841

Modeling Gaseous Emissions from Agricultural Liquid Swine Waste

Sang Ryong Lee[1], Wayne P. Robarge[1*], and John T. Walker[2]

Confined animal feeding operations (CAFOs) are now recognized as relatively large emitters of various pollutants or pollutant-precursors including ammonia (NH_3), hydrogen sulfide (H_2S), methane (CH_4), volatile organic carbons (VOCs) and fine particulate matter (PM_{10} and $PM_{2.5}$). The points of origin of these emissions vary within CAFOs depending on the animal population present. For swine production, most CAFOs within the United States have relatively large surface areas of liquid waste (lagoons and pits within the housing units), which can make substantial contributions to emissions. This study was initiated to increase our understanding of emissions of NH_3, H_2S and VOCs from liquid swine waste, and to evaluate the potential application of the US EPA waste water treatment model (WATER9) to successfully predict emissions. Emissions of gases across the air-liquid interface are in general a function of a number of variables [pH, liquid temperature, total dissolved concentration, presence of other solutes and dissolved organics, and turbulence (wind speed)]. In North Carolina, animal feeding operations for swine are required to have their waste lagoons analyzed four times a year. This information is available from the Agronomic Division Soil Testing Laboratory, NC Department of Agriculture and Consumer Services in Raleigh, NC, and constitutes a suitable database from which to model emissions from swine lagoons. Presented in this poster is the current status of our attempts to build the necessary databases [lagoon analyses (pH, total ammoniacal nitrogen concentration), meteorological data (air temperature, wind speeds), mass transfer coefficients for the gases of interest, estimates of lagoon sizes and location using geographical information systems (GIS)] to use with WATER9 to project emissions of NH_3, H_2S and VOCs from the more than 2000 active swine lagoons in eastern NC. Supplementing this modeling effort will be actual observations of emissions from two swine facilities in eastern NC, which are part of the National Air Emissions Monitoring Study (NAEMS). Our model projections will be compared to actual emissions as reported by the NAEMS project, as well as projections based on empirical models of emissions that are in the literature, and published measured emissions from lagoons using various measurement techniques (e.g. dynamic flow-thru chambers, floating wind-tunnels, or micrometeorological gradient techniques). Boundary conditions for the model projections will include emission estimates based on simple mass-balances from swine facilities and total emission estimates based on emission factors. This project is designed to support our continuing efforts to understand the fate and transport of pollutants emitted from CAFOs, and develop tools to predict reductions in emissions with the adoption of alternative technologies for handling waste that are shown to be economically viable.

[1]North Carolina State University, Department of Soil Science, Raleigh, NC 27695-7619
[2]U.S. Environmental Protection Agency, NRMRL, Research Triangle Park, NC 27711

Using Critical Loads to Look at Improvements in Acidic Surface Water Conditions since the 1990 Amendments to the Clear Air Act: Case Study Adirondack, NY

Lynch, J., Kolian, M.J., and Haeuber, R.
US EPA, 1200 Pennsylvania Ave. N.W.
Washington, DC 20460, USA

Acid deposition has affected hundreds of lakes and thousands of miles of headwater streams in the Adirondack region of New York State. The diversity of life in these acidic waters has been greatly reduced. The poor buffering capacity of the thin, acidic soils in the Adirondack Mountains makes the lakes and ponds particularly susceptible to acidification. Since the mid-1990's, lakes in the Adirondack region are finally showing signs of recovery. The good news is that emissions of sulfur dioxide and nitrogen oxides have been reduced and as a result acidic deposition of sulfate and nitrate has decreased in surface waters approximately 26 and 13%, respectively. This has led to improvement in the acid neutralizing capacity (ANC) of these water bodies. Although improvement in water quality is a good sign, it does not tell us if a particular lake or a group of lakes have recovered from decades of acidic deposition. However, the critical loads approach does allow for evaluation of whether a water body has reached recovery for acidic deposition. Critical loads and exceedances for lake surface water and acidity were calculated for 187 lakes in the Adirondack region. The Steady-State Water Chemistry (SSWC) model was used to calculate the critical load, relying on water chemistry data from the TIME/LTM network. An ANC threshold of 50 ueq/L was selected for this case study. Exceedances were calculated from deposition for the period before implementation of the Acid Rain program (ARP) (1989-1991) and for the period of 2004-2006 to judge improvements as a result of the ARP. On average, the critical load for lakes in the Adirondack region is 164 meq/m2/yr, while it is 48 meq/m2/yr for the most sensitive lakes (i.e. ANC less than 100 ueq/L). For the period from 2004 to 2006, 65% of the lakes within the TIME/LTM network continued to receive levels of acid deposition that exceeded the lake's critical load down from 72% of lakes before implementation of the Acid Rain Program. Despite improvement in water quality that has occurred over the past decades in the Adirondack region, additional reduction in acidic deposition is needed in order for greater recovery of these sensitive aquatic systems.

Evaluating Spatial Variability in Nitrate Deposition Sources to Watersheds in the Rocky Mountains using δ^{18}O and δ^{15}N in Nitrate

Leora Nanus[1*], Mark W. Williams[2], Donald H. Campbell[1], Emily M. Elliott[3], Carol Kendall[4]

Nitrate deposition can adversely affect sensitive aquatic habitats of high-altitude watersheds. Results of analyses of nitrogen isotopes in water samples from 37 lakes and 7 precipitation sites were used to evaluate regional patterns in sources of nitrate deposition across five National Parks. The analyses indicate that nitrate (NO_3) concentrations in lakes sampled during baseflow in 2004, ranged from the detection limit (~1 μeq/L) to 38 μeq/L, δ^{18}O (NO_3) values ranged from -5.7 to +21.3 permil, and δ^{15}N (NO_3) values ranged from -6.6 to +4.6 permil. δ^{18}O (NO_3) in precipitation ranged from +71 to +78 permil. The ranges in values of δ^{15}N (NO_3) in precipitation and lakes overlap; however, δ^{15}N (NO_3) in precipitation is more depleted than δ^{15}N (NO_3) in lake water, with values ranging from -5.5 to -2.0 permil. The values of δ^{15}N (NO_3) are significantly related ($p < 0.05$) to estimates of inorganic N, sulfate, and acidity in wet deposition, suggesting that the spatial variability of δ^{15}N (NO_3) over the Rocky Mountains may be related to source areas of these solutes. Regional patterns show that NO_3 concentrations and δ^{15}N (NO_3) values generally are more enriched in lakes and precipitation from the Southern Rockies and at higher elevations, compared to values at lower elevations and in the Northern Rockies. The correspondence of high NO_3 concentrations and enriched δ^{15}N (NO_3) values in precipitation with high NO_3 and enriched δ^{15}N (NO_3) values in lake waters, suggests that deposition of inorganic N in wetfall may affect the amount of NO_3 in lakes through a combination of direct and indirect processes such as enhanced nitrification.

*Corresponding author. U.S. Geological Survey, WRD-CWSC, Federal Center, PO Box 25046, MS 415, Lakewood, Colorado 80225.
303/236-4882 ext. 250 (ph), 303/236-4912 (fax), lnanus@usgs.gov
[1] U.S. Geological Survey, WRD-CWSC, Federal Center, Denver, Colorado.
[2] University of Colorado at Boulder and Institute of Arctic and Alpine Research, Boulder, Colorado
[3] University of Pittsburgh, Department of Geology and Planetary Science, Pittsburgh, Pennsylvania.
[4] U.S. Geological Survey, WRD-National Research Program, Menlo Park, California

Atmospheric Mercury Instrument Intercomparison

Mark Olson[1], David Krabbenhoft[1], Philip Kilner[2]

The USGS and USEPA conducted an assessment of instrument performance to determine the concentration of mercury fractions in the atmosphere. Four atmospheric speciation systems were compared which continuously measure gaseous elemental mercury (GEM), gaseous oxidized mercury (GOM), and fine-fraction particulate-bound mercury ($PBM_{2.5}$) respectively. The study was conducted at a warehouse facility the USGS uses for instrument set up and testing. Instrument intakes were connected to a common high flow, unheated manifold and inlet concentrations were varied to create dynamic conditions simulating variability observed in the field. Accuracy of the GOM thermal desorption, line transfer and quantification was evaluated both in the warehouse and the field using pre-spiked denuders with a known loading of $HgCl_2$.

Results from the dynamic testing showed elemental and particulate mercury percent relative standard deviation was less than 10%, although gaseous oxidized mercury was higher, around 18%. Denuder spiking results were better (11% RSD) suggesting a portion of the variability for gaseous oxidized mercury may be due to variations in the intake gas. The specific challenges of intercomparisons of low level mercury speciation measurements will be presented.

[1] US Geological Survey, 8505 Research Way, Middleton, WI 53562
[2] Frontier Geosciences (currently with Tekran Research and Development)

The Hidden Costs of Maintaining Old Equipment

Jeff Pribble, Matt Layden*, Tim Leon and Mark Rhodes
Illinois State Water Survey, Institute of Natural Resource and Sustainability,
University of Illinois, 2204 Griffith Drive, Champaign, IL 61820

The true cost of maintaining equipment in a monitoring network can be difficult to quantify. Many costs are hidden. The Aerochem collector and Belfort raingage have served the NADP network well throughout its 30-year history, but have become increasingly expensive to maintain due to their age. Costs associated with equipment repairs were estimated using information from the NADP's Supplies and Parts (SAP) database, shipping records, and by estimating the labor required to repair and ship components. These costs can be quantified at the CAL and the NED. Other costs are more difficult to quantify as they are realized at the individual sites. These costs include: operator labor to troubleshoot and diagnose a problem, travel to and from the site, and shipping from the site. Results from this study are presented in this poster with recommendations for ways to save the NADP and individual sites money.

*Corresponding author: 800-952-7353

Contaminated? or NOT Contaminated?

Jane Rothert and Phyllis Ballard
Illinois Water Survey, Champaign, IL
217-333-7942 rothert@illinois.edu

Is the sample contaminated or is it not? That is the question. This poster looks at artificial samples with known contaminants added and addresses two different issues: Is the CAL seeing all of the contaminants that come into the lab and are they correctly identifying them and how do these contaminants actually affect the sample concentration? Samples of deionized water were sent to the laboratory disguised as real samples. Known contaminants had been placed in some of them (others were left clean) to determine whether the contamination screening process in the laboratory was accurate and uniform across all analysts. At the preliminary report review, the samples were renumbered as QA samples and their chemistry and the lab contamination reviewed. The dirtiest sample was one containing an insect with Cl concentration = 2.544 ppm and Ca concentration = 1.506 ppm. The other analyte concentrations were equally high.

Organic Nitrogen (ON) in Wet Deposition in Rocky Mountain National Park

Florian M. Schwandner[1*], Katherine B. Beem[1], Suresh Raja[1], Yury Desyaterik[1],
Sonia Kreidenweis[1], William Malm[2], Jeffrey L. Collett, Jr. [1]

Measurements of inorganic and organic nitrogen deposition inside and near Rocky Mountain National Park during the Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) Study of spring and summer 2006 demonstrated that 11-53% of the total wet nitrogen deposition is as Organic Nitrogen (ON). Atmospheric organic nitrogen can include contributions from biological sources, oxidation products of combustion emissions, and reduced forms of nitrogen such as organic analogs of ammonia. For example, primary organic amines can react with organic acids to form secondary amides which themselves can partition into or adsorb onto particles and be transported significant distances before being deposited.

Our work on ON in wet deposition samples includes a systematic comparison between two methods: conventional UV-photo-oxidation with ON determined by difference of pre- and post-digestion inorganic nitrogen content from ion chromatography, and Total Nitrogen (TN) analyses using a Shimadzu TOC/TN analyzer. The individual handling, reagents, and laboratory procedures are being evaluated to assess the robustness of our method. In addition to systematic evaluation of the methods, we conduct time series measurements of blanks, natural samples, and standards, from laboratory, field, and controlled refrigerated storage, in order to understand storage and exposure differences in terms of sample and analyte stability.

To elucidate possible sources and processes responsible for the formation of organonitrogen compounds, work is also under way to speciate the organic nitrogen contents of both current and archive samples from the RoMANS study using various liquid and gas chromatographic methods, as well as quadrupole and Time-of-Flight mass spectrometry.

* Corresponding author, ph. (970) 491-8641
[1] Colorado State University, Department of Atmospheric Sciences, Fort Collins, CO 80523-1371
[2] CIRA/NPS, Colorado State University, Fort Collins, CO 80523-1371

E-mail:
Schwandner: fschwand@atmos.colostate.edu
Beem: kbeem@atmos.colostate.edu
Raja: sraja@clarkson.edu
Desyaterik: desyaterik@atmos.colostate.edu
Kreidenweis: sonia@atmos.colostate.edu
Malm: malm@cira.colostate.edu
Collett: collett@atmos.colostate.edu

Ammonia Monitoring in the Upper Green River Basin, Wyoming

Florian M. Schwandner[1]*, H. James Sewell[2], Jeffrey L. Collett[1], John V. Molenar[3],
Cassie Archuleta[3], Mark Tigges[3], Lincoln Sherman[3], Suresh Raja[1]

A 15-month ammonia air monitoring study was conducted at Boulder, Wyoming, in the Upper Green River Basin - a region experiencing rapid natural gas development with potential consequences of air quality and visibility impacts in the adjacent Class I Bridger Wilderness. The objective of this study is to characterize the local airborne nitrogen budget, specifically concentrations of ammonia and related gases and particles over one year. Samples were collected twice per week beginning December 15, 2006 and Ending May 31, 2008, using coated annular denuders and stacked filters in a URG sampler, analyzed at Colorado State University's Atmospheric Science Department.

NH_3 concentrations are variable throughout the year and below 1 ppbv for most of the monitoring period, peaking in August 2007 at 1.55 ppbv, with a yearly mean value of 0.24 ppbv. Concentrations are below or near detectable limits from December through February in 2007 and 2008. Elevated NH_3 concentrations coincide with warmer summer months. A shift in ammonium nitrate equilibrium toward the gas phase might be responsible for some of this increase, although an increase in total reduced nitrogen (ammonium + ammonia) during the summer suggests that changes in emissions and or transport patterns are likely also important contributors.

*Corresponding author, ph. (970) 491-8641
[1] Colorado State University, Department of Atmospheric Sciences, Fort Collins, CO 80523-1371
[2] Shell Exploration & Production Company, 4582 S. Ulster Street Parkway, Suite 500, Denver, CO 80237
[3] Air Resource Specialists, Inc., 1901 Sharp Point Drive Suite E, Fort Collins, CO 80525

E-mail:
Schwandner: fschwand@atmos.colostate.edu
Sewell: Jim.Sewell@shell.com
Collett: collett@atmos.colostate.edu
Molenar: JMolenar@air-resource.com
Archuleta: Carchuleta@air-resource.com
Tigges: MTigges@air-resource.com
Sherman: LSherman@air-resource.com
Raja: sraja@clarkson.edu

Quantifying Direct Contributions of Atmospheric Nitrate to Streams during Snowmelt

Stephen D. Sebestyen[1]*, James B. Shanley[2], Elizabeth W. Boyer[3], and Carol Kendall[4]

At an upland forest in northeastern Vermont, USA where atmospheric nitrogen deposition is chronically elevated, we quantified sources of water and nitrate to elucidate the effects of atmospheric wet deposition of nitrate on stream nitrate concentrations during snowmelt events. Using high-frequency stream water samples, isotopic tracers, and end-member mixing analysis, we determined that the high concentration of stream water nitrate during snowmelt was a mix of nitrate from the melting snowpack and nitrate that was flushed to the stream from nitrified sources in the landscape. The presence of isotopically distinct atmospheric nitrate in streams indicated that atmospheric sources may quickly move to streams and short-circuit biogeochemical processes that typically retain nitrogen in the landscape. Overall, the direct input of nitrate from atmospheric sources (7 to 10% of the stream nitrate outflow from the catchment) was small. However, our study highlights how a combined isotopic and hydrological approach can be used to detect and quantify the direct effects of atmospheric nitrogen pollution on forest streams.

[1] USDA Forest Service, 1831 HWY 169 E, Grand Rapids, MN, 55744,
* Ph: 218-326-7108 Email: ssebestyen@fs.fed.us
[2] United States Geological Survey, Montpelier, VT
[3] University of California, Berkeley, CA
[4] United States Geological Survey, Menlo Park, CA

Update: NADP Atmospheric Mercury Initiative

Tim Sharac[1], Eric Prestbo[2], David Gay[3], David Schmeltz[1], Mark Olson[4]

We report on the progress made over the last 15 months to establish a North American atmospheric mercury speciation network to support dry deposition estimates, emission regulation impacts, model evaluation, and long-term trends. The scientific and coordination milestones include:

- Atmospheric mercury expert workshop to harmonize methodologies used into a standard operating procedure
- Computer programming to develop a draft daily instrument QA and data reduction program
- Coordinating and contributing to a larger national effort to establish a multi-media mercury monitoring program
- Collaborating with operators of 8 established monitoring sites to generate speciated mercury data with data quality, data completeness and data submittal requirements
- Providing instrument technical support to collaborating site operators
- Completing a series of intercomparison challenges for the instruments to help establish operational QA criteria (see poster by Olson et al.,)
- Addition of an expert atmospheric mercury instrument technician as site liaison (50%)
- Development of a draft operating budget

In the future, work under this initiative will focus on continued development of a quality assurance program. This will include enhancing the data QA and reduction program, testing and improving the standard operating procedure and providing an approved, sustainable mechanism to post NADP atmospheric mercury speciation monitoring data on the website. We will also continue to reach out to a broad cross-section of agencies and institutions to coordinate mercury monitoring activities, building on current efforts and encouraging new collaborative partnerships.

[1] USEPA Clean Air Markets Division
[2] Tekran Instruments
[3] University of Illinois – NADP Program Office
[4] USGS, Middleton, WI

Osmium in Precipitation is from Refining of Platinum Ores

Mukul Sharma[1], Cynthia Chen[1], and Peter N. Sedwick[2]

Osmium (Os) is a platinum group element. Its concentration in the earth's crust is about 30 picogram/g. Atmospheric sources of Os include cosmic dust, volcanic and continental mineral aerosols. Refining of platinum ores, automobile catalytic converter exhaust, burning of trees, coal and petroleum could also provide Os to the atmosphere. Osmium isotopic composition of these sources is highly variable. Radiogenic ^{187}Os is produced from the β-decay of ^{187}Re, which has a half-life of 42 billion years. The Os isotopic compositions (ratio of ^{187}Os with respect to stable ^{188}Os) of potential atmospheric sources of Os vary from 0.13 to >13, reflecting their Re/Os ratio and the time elapsed after their formation. On average, the ^{187}Os/^{188}Os ratios of cosmic dust is ~0.13 (with^{187}Re/^{188}Os = 0.36)--about ten times lower than that of continental mineral dust (=1.26 with ^{187}Re/^{188}Os = 48). The isotopic composition of Os associated with platinum bearing sulfide ores from the Merensky Reef, South Africa that produces about 70% of world's Pt, is mainly between 0.15 and 0.20. Processing of base-metal (mainly Cu, Ni, Zn, and Pb) sulfide ores could also introduce Os into atmosphere. The ^{187}Os/^{188}Os ratios of sulfide deposits are variable. In some cases they are similar to the platinum ores (e.g., Noril'sk, Russia; Yilgarn craton, Australia) and in others they are highly radiogenic due to involvement of continental crust in their formation (e.g., Sudbury, Canada). Finally, the ^{187}Os/^{188}Os for bitumen range from 3.3 to 13.7 and ^{187}Os/^{188}Os values for hydrocarbons are from 1.2 to 4.2 all of which are highly radiogenic. Because of the large isotopic contrast between these sources, Os isotopes provide an easy means to assess the extent of anthropogenic contribution.

The Os isotopic composition in rain and snow samples collected in Hanover, New Hampshire is ~0.2, which is similar to ores supplying the platinum group elements used in automobile catalytic converters. The Os isotopic composition of precipitation from the high Sierra Nevada, California, southern India and Antarctica are similarly low. We argue that human activities have contaminated the global troposphere with highly-reactive OsO_4, which is produced as a result of the refining of ores enriched in platinum group elements; automobile emissions are a secondary but minor source.

[1]Radiogenic Isotope Geochemistry Laboratory, Department of Earth Sciences, Dartmouth College, 6105 Sherman Fairchild Hall, Hanover, NH 03755, USA
[2]Bermuda Institute of Ocean Sciences, St George's, GE01, Bermuda

Developing a State-Wide Mercury Monitoring and Assessment Network

John Sherwell
Power Plant Research Program
Department of Natural Resources
Annapolis, MD 21401
410-260-8667 ph
jsherwell@dnr.state.md.us

In response to concern over elevated levels of methylmercury in fish tissue from catches in the state's fresh water rivers and streams, a monitoring and assessment program has been developed to understand the sources, transport, transformation, deposition, biogeochemistry and assimilation of mercury.

The poster will describe the components of the overall program:

- Characterization of the major atmospheric emissions sources
- Studies of atmospheric processes – modeling and measurement
- On-going ambient air and deposition studies
- Research on the biogeochemistry of mercury in a landscape setting
- Fish tissue monitoring, and
- Socioeconomic implications of consumption advisories

The study results will be briefly summarized with links to reports and principal investigators.

CASTNET Field Blank Filters

Marcus O. Stewart[1], Garry L. Price[1], Christopher M. Rogers[1], Thomas F. Lavery[2]

CASTNET utilizes an open-face, three-stage filter pack to measure sulfur and nitrogen species. Filter pack handling procedures are designed to minimize handling and, consequently, reduce any opportunities for contamination and misdirection. Sample integrity is maintained by ensuring that materials in contact with filters do not affect measured analytes. Field blanks are used to assess the sample integrity during the packing, shipping, receiving, and unpacking phases of the operation.

Field blanks are prepared quarterly for each CASTNET site. The filter packs used for the field blanks contain a nonstandard connection that cannot be installed in the sampling system in the field. The filter pack with the field blank is prepared and loaded according to standard CASTNET procedures. The field blanks are clearly identified and labeled to prohibit their removal from the resealable plastic bag used for shipping. When the field blank filter is returned from a site, it is unpacked, extracted, and analyzed following procedures for exposed filters. The field blank program and results for 2007 are summarized in the poster.

[1] MACTEC Engineering & Consulting, Inc., 404 SW 140th Terrace, Newberry, FL 32669-3000
[2] Kleinfelder, 30 Porter Road, Littleton, MA 01460

A Comparison of Wet-Deposition of Nitrogen from New NTN Site TX43 “Canonceta” with nearby Historical Trends Using Three Spatial Interpolation Techniques

Jeetendra K. Upadhyay*, Brent W. Auvermann**, Jack Bush, Kenneth D. Casey
Texas AgriLife Research & Extension Center, Texas A&M University
6500 Amarillo Blvd. West, Amarillo, TX 79106 Tel. (806) 677-5600

Wet deposition occurs when a particle or gas molecule is collected from the air and carried to the earth’s surface by precipitation. The major reactive species of nitrogen (N) in the atmosphere are nitrogen oxides, nitrate (NO_3^-) and ammonia (NH_3). These components are highly reactive nitrogen species pool and are relatively soluble in water. They may be subjected to wet deposition through precipitation as nitrate (NO_3^-) and ammonium (NH_4^+). The primary, national network of wet deposition monitors is the National Atmospheric Deposition Program/National Trends Network (NADP/NTN). The agency’s monitoring sites provide weekly estimates of the wet deposition of nine inorganic chemicals: calcium, magnesium, potassium, sodium, ammonia, nitrate, chloride, sulfate and phosphate.

In July 2007, the NTN added monitoring site TX43 “Canonceta” in the southern High Plains of Texas, a region known for its intensive production agriculture. We are interested in knowing how the first year of wet-deposition data at TX43 aligns with the spatial trends in the historical data from the surrounding NTN sites. We present here three different interpolation schemes, inverse distance weighted (IDW), spline, and kriging, to obtain the wet-deposition maps of the pollutants in the region. IDW results showed that total inorganic nitrogen wet deposition at TX43 was found to be between 2.68 and 3.14 kg/ha. Wet deposition of NO_3^- and NH_4^+ at the same site were in the range 3.75-4.55 and 2.31-2.73 kg/ha, respectively. According to spline technique, wet deposition of inorganic nitrogen at TX43 was in the range 2.53-3.35 kg/ha, and for NO_3^-, wet deposition was on upper range of 2.11-3.68 kg/ha. Ammonium (NH_4^+) wet deposition at TX43 was between 2.22 and 2.83 kg/ha. Ordinary kriging interpolation technique with an anisotropy (directionality) option estimated wet deposition of inorganic nitrogen at TX43 in the range 2.53-3.35 kg/ha, and for NO_3^-, wet deposition was on upper range of 2.11-3.68 kg/ha. Ammonium (NH_4^+) wet deposition at TX43 was between 2.22 and 2.83 kg/ha. Results show that all three methods are suitable candidates for prediction at the desired site. Kriging can be the best suited interpolation method in the case of data showing anisotropy. According to NADP (2006), the wet deposition of inorganic nitrogen from nitrate and ammonium in 2006 in the region (TX43) was in the range of 2.0-3.0 kg/ha. NO_3^- and NH_4^+ wet deposition for 2006 was in the range 4.0-6.0 kg/ha and 2.5-3.0 kg/ha, respectively. These values compared well across all three interpolation schemes. Our first year of wet-deposition data of TIN at TX43 shows 1.7 kg/ha, however we are still into the calendar year.

* Email: jkupadhyay@ag.tamu.edu, **BAuverma@ag.tamu.edu

Hach Environmental's OTT Pluvio Precipitation Gage Is Approved for Use at NADP Sites

Christel Valentine*

The NADP commissioned testing of modern precipitation gages beginning in 1998. The only precipitation gage that fully participated in all three phases of the formal test program, and continued field-testing conducted through 2007, the OTT Pluvio from Hach Environmental is approved for use at NADP sites.

Hach Environmental now offers the complete solution, the OTT NADP Pluvio with Remote Monitoring Module (RMM). The RMM is and advanced ruggedized communication module designed to meet NADP requirements and logging needs.

The OTT Pluvio is already in use in critical precipitation networks throughout the world by organizations including: NWS / ASOS, German Weather Service, Hydro Quebec, Swedish Meteorological and Hydrological Institute, Danish Institute of Agriculture and Royal Netherlands Meteorological Institute. NADP sites now have the opportunity to take advantage of its unmatched performance, functionality and reliability.

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*For more information, contact: Hach Environmental
Tel:800-949-3766 ext 1 Email: sales@hachenvironmental.com

Air-Surface Exchange of Ammonia in a Fertilized Corn Field from Pre-Planting through Canopy Senescence

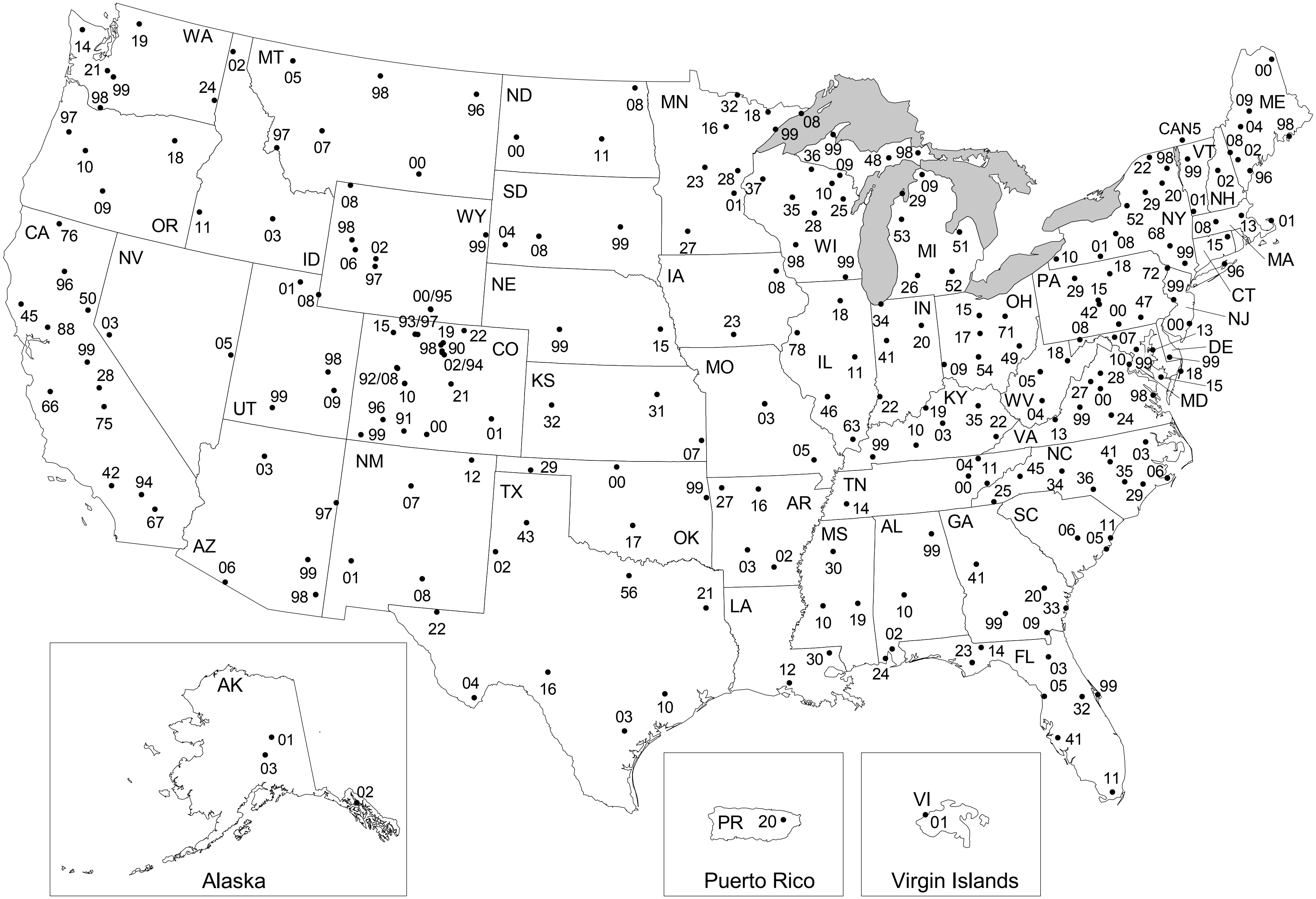
J.T. Walker[1*], M. Jones[1], L. Myles[2], W. Luke[2], T. Meyers[2], J. Bash[3], D. Schwede[3],
E. Nemitz[4], W. Robarge[5]

During the spring and summer of 2007, an experiment was conducted near Lillington, NC to examine NH_3 air-surface exchange processes in a fertilized corn field. Multiple air concentration and flux measurement techniques were used to quantify NH_3 emission and deposition from pre-planting through canopy senescence. The objectives of the experiment were to: compare methods for measurement of NH_3 air concentrations and fluxes; quantify NH_3 emissions immediately following fertilization; quantify the cumulative flux of NH_3 over the course of an entire growing season; and examine the relative importance of soil vs. foliage exchange pathways with respect to net canopy-scale fluxes. A general overview of the experiment is presented along with results illustrating temporal patterns in concentrations, fluxes, and soil/plant chemistry. Relationships between NH_3 flux and soil/plant chemistry and moisture status are described. Measurements of NH_4^+ and H^+ in the soil solution, leaf sub-stomatal cavities, and leaf surface water are used in combination with resistance modeling to examine the relationships between net canopy-scale fluxes and soil, stomatal, and cuticular exchange pathways.

*Corresponding Author: 919-541-2288, walker.johnt@epa.gov
[1]US EPA, National Risk Management Research Laboratory
[2]NOAA, Air Resources Laboratory
[3]US EPA, National Exposure Research Laboratory
[4]Center for Ecology and Hydrology, Edinburgh
[5]North Carolina State University, Department of Soil Science

NTN MAP AND SITE LISTINGS

National Atmospheric Deposition Program
National Trends Network



National Atmospheric Deposition Program/National Trends Network Sites
July 31, 2008

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Alabama				
AL02	Delta Elementary	MDN	Mobile Bay Nat'l Estuary Prog & Dauphin Island Sea Lab	06/01
AL10	Black Belt Research & Extension Center		US Geological Survey	08/83
AL24	Bay Road	MDN	Mobile Bay Nat'l Estuary Prog & Dauphin Island Sea Lab	05/01
AL99	Sand Mountain Research & Extension Center		Tennessee Valley Authority	10/84
Alaska				
AK01	Poker Creek		USDA Forest Service	12/92
AK02	Juneau		USDA Forest Service/University of Alaska Southeast	06/04
AK03	Denali NP - Mount McKinley		National Park Service - Air Resources Division	06/80
Arizona				
*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		US Environmental Protection Agency-CAMD	02/99
AZ99	Oliver Knoll		US Geological Survey	08/81
Arkansas				
AR02	Warren 2WSW		US Geological Survey	05/82
AR03	Caddo Valley		US Geological Survey	12/83
AR16	Buffalo NR - Buffalo Point		National Park Service - Air Resources Division	07/82
AR27	Fayetteville		US Geological Survey	04/80
California				
CA28	Kings River Experimental Watershed		USDA Forest Service/Pacific Southwest Research Station	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		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	Big Bear Municipal Water District	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
Colorado				
CO00	Alamosa		US Geological Survey	04/80
CO01	Las Animas Fish Hatchery		US Geological Survey	10/83
CO02	Niwot Saddle		NSF-Institute of Artic & Alpine Research/University of CO	06/84
CO08	Four Mile Park		US Environmental Protection Agency-CAMD	12/87
CO10	Gothic		US Environmental Protection Agency-CAMD	02/99
CO15	Sand Spring		Bureau of Land Management	03/79
CO18	Ripple Creek Pass		Air Sciences, Inc	05/03
CO19	Rocky Mountain NP - Beaver Meadows		National Park Service - Air Resources Division	05/80
CO21	Manitou		USDA Forest Service	10/78
CO22	Pawnee		NSF-Shortgrass Steppe LTER/Colorado State University	05/79
CO90	Niwot Ridge-Southeast		NSF-Institute of Artic & Alpine Research/University of CO	01/06

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
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		USDA Forest Service	07/86
CO97	Buffalo Pass - Summit Lake	MDN	USDA Forest Service	02/84
CO98	Rocky Mountain NP - Loch Vale		USGS/Colorado State University	08/83
CO99	Mesa Verde NP - Chapin Mesa	MDN	US Geological Survey	04/81
Connecticut				
CT15	Abington		US Environmental Protection Agency-CAMD	01/99
Delaware				
DE99	Trap Pond State Park		US Environmental Protection Agency-CAMD	05/03
Florida				
FL03	Bradford Forest		St John’s River Water Management District	10/78
FL05	Chassahowitzka NWR	MDN	US Fish & Wildlife Service - Air Quality Branch	08/96
FL11	Everglades NP - Research Center	MDN	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
FL99	Kennedy Space Center		NASA/Dynamac Corporation	08/83
Georgia				
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, NOAA-NERR, & GA Dept of Natural Resources	11/02
GA41	Georgia Station		SAES-University of Georgia	10/78
GA99	Chula		US Geological Survey	02/94
Idaho				
ID02	Priest River Experimental Forest		USDA Forest Service	12/02
ID03	Craters of the Moon NM	MDN	National Park Service - Air Resources Division	08/80
ID11	Reynolds Creek		US Geological Survey	11/83
Illinois				
IL11	Bondville	AIRMoN/MDN	US Environmental Protection Agency-CAMD	02/79
IL18	Shabbona		SAES-University of Illinois	05/81
IL46	Alhambra		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
Indiana				
IN20	Roush Lake	MDN	US Geological Survey	08/83
IN22	Southwest-Purdue Agricultural Center		US Geological Survey	09/84
IN34	Indiana Dunes NL	MDN	National Park Service - Air Resources Division	07/80
IN41	Agronomy Center for Research and Extension		SAES-Purdue University	07/82
Iowa				
IA08	Big Springs Fish Hatchery		US Geological Survey	08/84
IA23	McNay Memorial Research Center		US Geological Survey	09/84

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Kansas				
KS07	Farlington Fish Hatchery		US Geological Survey	03/84
KS31	Konza Prairie		SAES-Kansas State University	08/82
KS32	Lake Scott State Park	MDN	US Geological Survey	03/84
Kentucky				
KY03	Mackville		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		NOAA-Air Resources Lab	09/83
KY35	Clark State Fish Hatchery		US Geological Survey	08/83
KY99	Mulberry Flats		TVA/Murray State University	12/94
Louisiana				
LA12	Iberia Research Station		US Geological Survey	11/82
LA30	Southeast Research Station		US Geological Survey	01/83
Maine				
ME00	Caribou	MDN	NOAA-Air Resources Lab	04/80
ME02	Bridgton	MDN	EPA/Maine Dept of Environmental Protection	09/80
ME04	Carrabassett Valley		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
Maryland				
MD07	Catoctin Mountain Park		National Park Service - Air Resources Division	05/03
MD08	Piney Reservoir	MDN	MD DNR/University of Maryland-Appalachian Lab	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	Maryland Department of Natural Resources	06/04
Massachusetts				
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
MA13	East		Northeast States for Coordinated Air Use Management	02/82
Michigan				
MI09	Douglas Lake		SAES-Michigan State University	07/79
MI26	Kellogg Biological Station		SAES-Michigan State University	06/79
MI29	Peshawbestown	MDN	US Environmental Protection Agency-CAMD	01/02
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		National Park Service - Air Resources Division	02/83

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Minnesota				
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	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
Mississippi				
MS10	Clinton		US Geological Survey	07/84
MS19	Newton		NOAA-Air Resources Lab	11/86
MS30	Coffeeville		Tennessee Valley Authority	07/84
Missouri				
MO03	Ashland Wildlife Area		US Geological Survey	10/81
MO05	University Forest		US Geological Survey	10/81
Montana				
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
Nebraska				
NE15	Mead	MDN	SAES-University of Nebraska	07/78
NE99	North Platte Agricultural Experiment Station		US Geological Survey	09/85
Nevada				
NV03	Smith Valley		US Geological Survey	08/85
NV05	Great Basin NP - Lehman Caves		National Park Service - Air Resources Division	01/85
New Hampshire				
NH02	Hubbard Brook		USDA Forest Service	07/78
New Jersey				
NJ00	Edwin B Forsythe NWR		US Fish & Wildlife Service - Air Quality Branch	10/98
NJ99	Washington Crossing		US Environmental Protection Agency	08/81
New Mexico				
NM01	Gila Cliff Dwellings NM		New Mexico Environment Department - AQB	07/85
NM07	Bandelier NM		DOE-Los Alamos National Lab/National Park Service	06/82
NM08	Mayhill		US Geological Survey	01/84
NM12	Capulin Volcano NM		New Mexico Environment Department - AQB	11/84

State/Province Site Code		Site Name	Collocation	Sponsoring Agency	Start Date
New York					
	NY01	Alfred		US Geological Survey	08/04
	NY08	Aurora Research Farm		USDA/Cornell University	04/79
	NY10	Chautauqua		US Geological Survey	06/80
	NY20	Huntington Wildlife	MDN	EPA/SUNY-College of Environmental Science & Forestry	10/78
	NY22	Akwesasne Mohawk - Fort Covington		US Environmental Protection Agency - CAMD	08/99
	NY29	Moss Lake		US Geological Survey	07/03
	NY52	Bennett Bridge		EPA/State University of New York-Oswego	06/80
	NY68	Biscuit Brook	MDN	US Geological Survey	10/83
	NY96	Cedar Beach, Southold		EPA/Suffolk Dept of Health Service-Peconic Estuary Prog	11/03
	NY98	Whiteface Mountain		US Geological Survey	07/84
	NY99	West Point	MDN	US Geological Survey	09/83
North Carolina					
	NC03	Lewiston		North Carolina State University	10/78
	NC06	Beaufort		US Environmental Protection Agency-CAMD	01/99
	NC25	Coweeta		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		North Carolina State University	11/85
North Dakota					
	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
Ohio					
	OH09	Oxford		US Geological Survey	08/84
	OH15	Lykens		US Environmental Protection Agency-CAMD	01/99
	OH17	Delaware		USDA Forest Service	10/78
	OH49	Caldwell		US Geological Survey	09/78
	OH54	Deer Creek State Park		US Environmental Protection Agency-CAMD	01/99
	OH71	Wooster		US Geological Survey	09/78
Oklahoma					
	OK00	Salt Plains NWR		US Geological Survey	12/83
	OK17	Great Plains Apiaries		NOAA-Air Resources Lab	03/83
	OK29	Goodwell Research Station		US Geological Survey	01/85
	OK99	Stilwell	MDN	US Environmental Protection Agency/Cherokee Nation	05/07
Oregon					
	OR09	Silver Lake Ranger Station		US Geological Survey	08/83
	OR10	H J Andrews Experimental Forest	MDN	USDA Forest Service	05/80
	OR18	Starkey Experimental Forest		US Geological Survey	03/84
	OR97	Hyslop Farm		US Environmental Protection Agency-CAMD	04/83

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Pennsylvania				
PA00	Arendtsville	MDN	US Environmental Protection Agency-CAMD	01/99
PA15	Penn State	AIRMoN	NOAA-Air Resources Lab	06/83
PA18	Young Woman's Creek		US Geological Survey	04/99
PA29	Kane Experimental Forest		USDA Forest Service	07/78
PA42	Leading Ridge		SAES-Pennsylvania State University	04/79
PA47	Millersville	MDN	Pennsylvania Depart of Environmental Protection/PSU	11/02
PA72	Milford	MDN	USDA Forest Service	12/83
Puerto Rico				
PR20	El Verde		USDA Forest Service	02/85
South Carolina				
SC05	Cape Romain NWR	MDN	US Fish & Wildlife Service - Air Quality Branch	11/00
SC06	Santee NWR		US Geological Survey	07/84
SC11	North Inlet-Winyah Bay NERR		Baruch Institute for Marine Coastal Science/NOAA	01/02
South Dakota				
SD04	Wind Cave National Park-Elk Mountain		National Park Service - Air Resources Division	11/02
SD08	Cottonwood		NOAA-Air Resources Lab	10/83
SD99	Huron Well Field		US Geological Survey	11/83
Tennessee				
TN00	Walker Branch Watershed	AIRMoN	DOE/Oak Ridge National Lab/Lockheed-Martin	03/80
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
Texas				
TX02	Muleshoe NWR		US Geological Survey	06/85
TX03	Beeville		NOAA-Air Resources Lab	02/84
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	Cañónceta		Texas A&M University-Texas Agrilife Research	07/07
TX56	LBJ National Grasslands		US Geological Survey	09/83
Utah				
UT01	Logan		US Geological Survey	12/83
UT08	Murphy Ridge		BP Amoco	03/86
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
Vermont				
VT01	Bennington		US Geological Survey	04/81
*VT99	Underhill	AIRMoN/MDN	US Geological Survey	06/84
Virgin Islands				
VI01	Virgin Islands NP - Lind Point		National Park Service - Air Resources Division	04/98

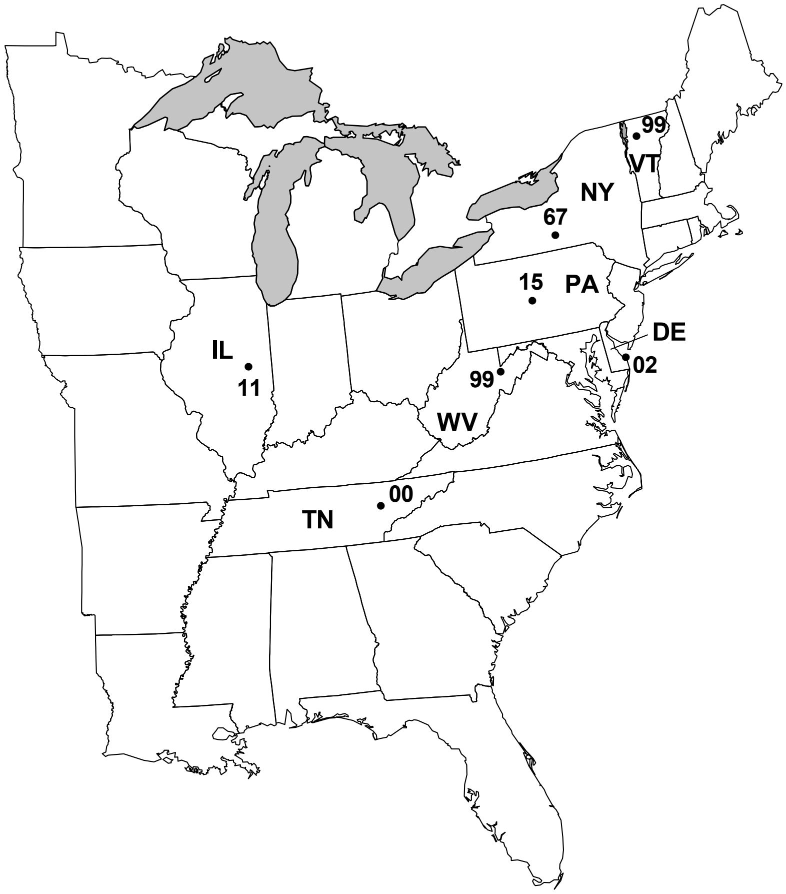
State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Virginia				
VA00	Charlottesville		US Geological Survey	10/84
VA10	Mason Neck Wildlife Refuge		Virginia Department of Environmental Quality	08/03
VA13	Horton's Station		Tennessee Valley Authority	07/78
VA24	Prince Edward		US Environmental Protection Agency-CAMD	01/99
VA27	James Madison University Farm		US Environmental Protection Agency-CAMD	07/02
VA28	Shenandoah NP - Big Meadows	MDN	National Park Service - Air Resources Division	05/81
VA98	Harcum	MDN	Virginia Department of Environmental Quality	08/04
VA99	Natural Bridge Station		Virginia Department of Environmental Quality	07/02
Washington				
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		National Park Service - Air Resources Division	10/99
West Virginia				
WV04	Babcock State Park		US Geological Survey	09/83
WV05	Cedar Creek State Park		US Environmental Protection Agency-CAMD	01/99
WV18	Parsons		USDA Forest Service	07/78
Wisconsin				
WI09	Popple River	MDN	Wisconsin Department of Natural Resources	12/86
WI10	Potawatomi	MDN	EPA/Forest County Potawatomi Community	06/05
WI25	Suring		Wisconsin Department of Natural Resources	01/85
WI28	Lake Dubay		Wisconsin Department of Natural Resources	06/82
WI35	Perkinstown		US Environmental Protection Agency-CAMD	01/99
WI36	Trout Lake	MDN	Wisconsin Department of Natural Resources	01/80
WI37	Spooner		Wisconsin Department of Natural Resources	06/80
*WI98	Wildcat Mountain		Wisconsin Department of Natural Resources	08/89
WI99	Lake Geneva	MDN	Wisconsin Department of Natural Resources	06/84
Wyoming				
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
WY95	Brooklyn Lake		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
Canada				
CAN5	Frelighsburg		US Geological Survey	10/01

*At these sites the U.S. Geological Survey (VT99 & WI98) and National Park Service - Air Resources Division (AZ03) sponsor a second collector for measuring network precision.

AIRMoN MAP AND SITE LISTING

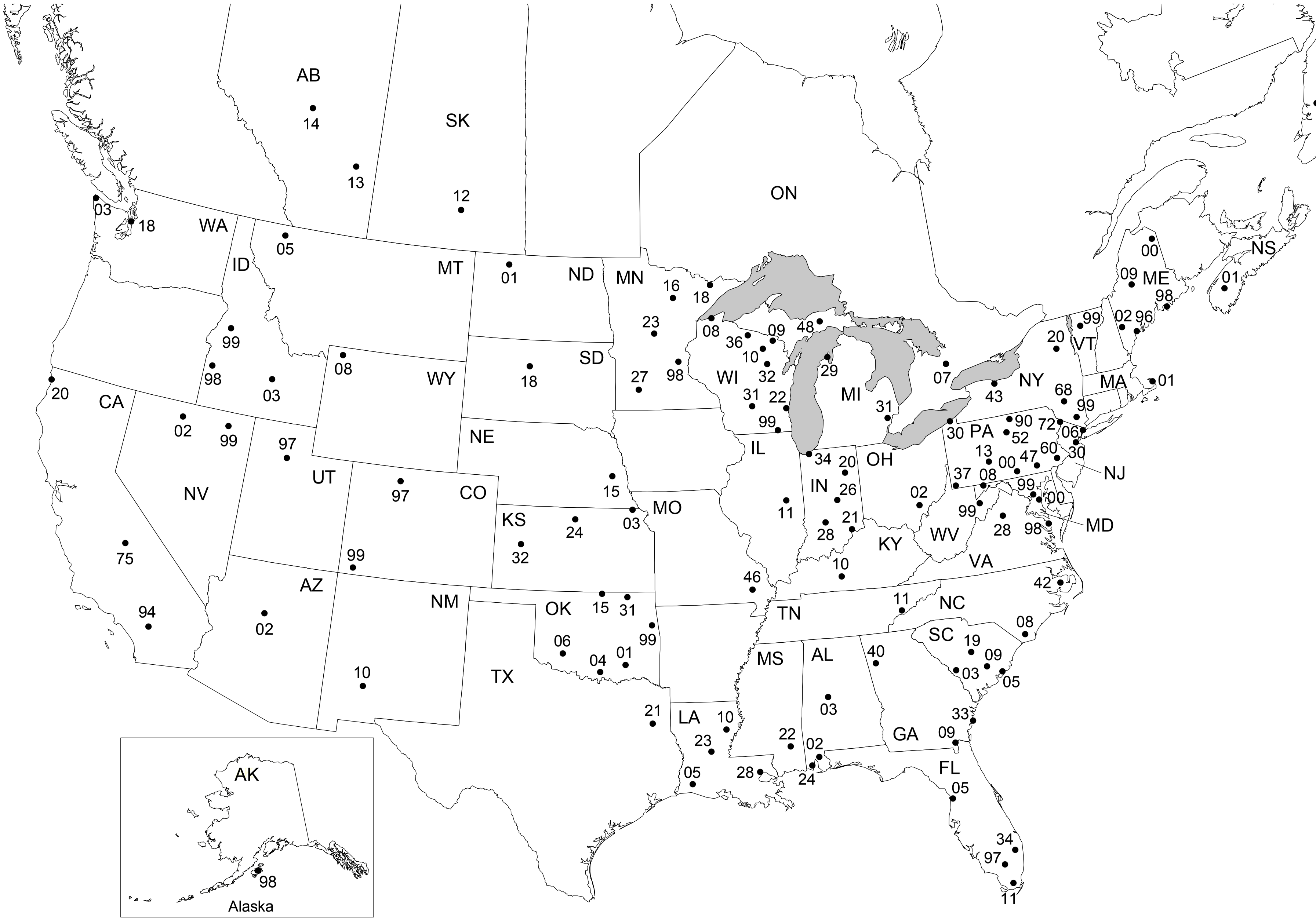
NADP/Atmospheric Integrated Research Monitoring Network Sites
July 31, 200~~8~~

State Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Delaware				
DE02	Lewes		NOAA-Air Resources Laboratory	09/92
Illinois				
IL11	Bondville	MDN & NTN	NOAA-Air Resources Laboratory	10/92
New York				
NY67	Cornell University		NOAA-Air Resources Laboratory	09/92
Pennsylvania				
PA15	Penn State	NTN	NOAA-Air Resources Laboratory	10/92
Tennessee				
TN00	Oak Ridge National Lab	NTN	NOAA-Air Resources Laboratory	09/92
Vermont				
VT99	Underhill	MDN & NTN	NOAA-Air Resources Laboratory	01/93
West Virginia				
WV99	Canaan Valley Institute		NOAA-Air Resources Laboratory	06/00



MDN MAP AND SITE LISTINGS

National Atmospheric Deposition Program
Mercury Deposition Network



National Atmospheric Deposition Program/Mercury Deposition Network Sites
July 31, 2008

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Alabama				
AL02	Delta Elementary	NTN	Mobile Bay National Estuary Prog & Dauphin Island Sea Lab	06/01
AL03	Centreville		Southern Company/Atmospheric Research and Analysis, Inc	06/00
AL24	Bay Road	NTN	Mobile Bay National Estuary Prog & Dauphin Island Sea Lab	05/01
Alaska				
AK98	Kodiak		State of Alaska Department of Environmental Conservation	09/07
Arizona				
AZ02	Sycamore Canyon		Arizona Department of Environmental Quality/EPA	02/06
California				
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	Big Bear Municipal Water District	04/06
Colorado				
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
Florida				
FL05	Chassahowitzka NWR	NTN	US Fish & Wildlife Service - Air Quality Branch	07/97
FL11	Everglades NP - Research Center	NTN	South Florida Water Management District	*03/96
FL34	Everglades Nutrient Removal Project		South Florida Water Management District	07/97
FL97	Everglades - Western Broward County		South Florida Water Management District	11/06
Georgia				
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	07/07
GA40	Yorkville		Southern Company/Atmospheric Research and Analysis, Inc	06/00
Idaho				
ID03	Craters of the Moon NM	NTN	Idaho Department of Environmental Quality	10/06
ID98	Deer Flats		Idaho Department of Environmental Quality	03/08
ID99	McCall		Idaho Department of Environmental Quality	11/07
Illinois				
IL11	Bondville	AIRMoN/NTN	Illinois State Water Survey/NADP	*01/99
Indiana				
IN20	Roush Lake	NTN	Indiana Department of Environmental Management/USGS	10/00
IN21	Clifty Falls State Park		Indiana Department of Environmental Management/USGS	01/01
IN26	Fort Harrison State Park		Indiana Department of Environmental Management/USGS	04/03
IN28	Bloomington		Indiana Department of Environmental Management/USGS	12/00
IN34	Indiana Dunes NL	NTN	Indiana Department of Environmental Management/USGS	10/00
Kansas				
KS03	Reserve		Kansas Department of Health and Environment	01/08
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

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Kentucky				
KY10	Mammoth Cave NP-Houchin Meadow	NTN	National Park Service - Air Resources Division	08/02
Louisiana				
LA05	Lake Charles		Louisiana Department of Environmental Quality	10/98
LA10	Chase		Louisiana Department of Environmental Quality	10/98
LA23	Alexandria		Louisiana Department of Environmental Quality	02/01
LA28	Hammond		Louisiana Department of Environmental Quality	10/98
Maine				
ME00	Caribou	NTN	University of Maine	05/07
ME02	Bridgton	NTN	Maine Department of Environmental Protection/EPA	06/97
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/EPA	*03/96
Maryland				
MD00	Smithsonian Environmental Res Ctr		MD DNR/Smithsonian Environmental Research Center	12/06
MD08	Piney Reservoir	NTN	MD DNR/University of Maryland-Appalachian Lab	06/04
MD99	Beltsville	NTN	Maryland Department of Natural Resources	06/04
Massachusetts				
MA01	North Atlantic Coastal Lab	NTN	NPS - Cape Cod National Seashore	07/03
Michigan				
MI29	Peshawbestown	NTN	Grand Traverse Band of Ottawa & Chippewa /EPA	05/07
MI31	Sterling Heights		US Geological Survey	09/05
MI48	Seney NWR - Headquarters	NTN	US Fish & Wildlife Service-Air Quality Branch	11/03
Minnesota				
MN16	Marcell Experimental Forest	NTN	USDA Forest Service-North Central Research Station & MNPCA	*02/96
MN18	Fernberg	NTN	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
Mississippi				
MS22	Oak Grove		Southern Company/Atmospheric Research and Analysis, Inc	06/00
Missouri				
MO46	Mingo NWR		Missouri Department of Natural Resources /EPA	03/02
Montana				
MT05	Glacier NP - Fire Weather Station	NTN	National Park Service - Air Resources Division	10/03
Nebraska				
NE15	Mead	NTN	Nebraska Department of Environmental Quality	06/07
Nevada				
NV02	Lesperance Ranch		Nevada Dept of Conservation & Natural Resources/Frontier Geosciences, In	01/03
NV99	Gibb’s Ranch		Nevada Dept of Conservation & Natural Resources/Frontier Geosciences, In	02/03
New Jersey				
NJ30	New Brunswick		US Geological Survey	01/06
New Mexico				
NM10	Caballo		Bureau of Reclamation/New Mexico State University	05/97

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
New York				
NY06	Bronx		New York Department of Environmental Conservation	01/08
NY20	Huntington Wildlife	NTN	Syracuse University /EPA	12/99
NY43	Rochester		New York Department of Environmental Conservation	01/08
NY68	Biscuit Brook	NTN	US Geological Survey	03/04
NY99	West Point	NTN	US Dept of Education/John Jay College-City University of New York	10/06
North Carolina				
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
North Dakota				
ND01	Lostwood NWR		U S Environmental Protection Agency	11/03
Ohio				
OH02	Athens Super Site		Ohio University/EPA	12/04
Oklahoma				
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
OK15	Newkirk		Cherokee Nation/EPA	03/05
OK31	Copan		Oklahoma Department of Environmental Quality	10/06
OK99	Stilwell	NTN	Cherokee Nation/EPA	04/03
Pennsylvania				
PA00	Arendtsville	NTN	PA Dept of Environmental Protection/Penn State University	11/00
PA13	Allegheny Portage Railroad NHS		PA Dept of Environmental Protection/Penn State University	01/97
PA30	Erie		PA Dept of Environmental Protection/Penn State University	06/00
PA37	Holbrook		Electric Power Research Institute	05/99
PA47	Millersville	NTN	PA Dept of Environmental Protection/Penn State University	11/02
PA52	Little Pine State Park		PA Dept of Environmental Protection/Penn State University	07/07
PA60	Valley Forge		PA Dept of Environmental Protection/Penn State University	11/99
PA72	Milford	NTN	PA Dept of Environmental Protection/Penn State University	09/00
PA90	Hills Creek State Park		PA Dept of Environmental Protection/Penn State University	01/97
South Carolina				
SC03	Savannah River		Savannah River Nuclear Solutions	01/01
SC05	Cape Romaine NWR	NTN	US Fish & Wildlife Service - Air Quality Branch	03/04
SC09	Alibi Hunt Club		US Geological Survey	11/05
SC19	Congaree Swamp		South Carolina Dept of Health & Environmental Control	*03/96
South Dakota				
SD18	Eagle Butte		Cheyenne River Sioux Tribe/EPA	03/07
Tennessee				
TN11	Great Smoky Mountains NP-Elkmont	NTN	National Park Service - Air Resources Division	01/02
Texas				
TX21	Longview	NTN	Texas Commission on Environmental Quality	*03/96
Utah				
UT97	Salt Lake City		Utah Departent of Environmental Quality	05/07

State/Province Site Code	Site Name	Collocation	Sponsoring Agency	Start Date
Vermont				
VT99	Underhill	AIRMoN/NTN	NOAA/Univ of VT-Rubinstein School of Envirn & Natural Resources	07/04
Virginia				
VA28	Shenandoah NP-Big Meadows	NTN	National Park Service - Air Resources Division	10/02
VA98	Harcum	NTN	Virginia Department of Environmental Quality	12/04
Washington				
WA03	Makah National Fish Hatchery		Washington State Department of Ecology	03/07
WA18	Seattle - NOAA		Illinois State Water Survey & Frontier Geosciences Inc	03/96
West Virginia				
WV99	Canaan Valley Institute	AIRMoN	NOAA - Air Resources Lab	06/07
Wisconsin				
**WI08	Brule River		Wisconsin Department of Natural Resources	*03/96
WI09	Popple 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
WI32	Middle Village		Menominee Indian Tribe/EPA	01/02
WI36	Trout Lake	NTN	Wisconsin Department of Natural Resources	*03/96
WI99	Lake Geneva	NTN	Wisconsin Department of Natural Resources	01/97
Wyoming				
WY08	Yellowstone NP-Tower Falls	NTN	Wyoming Department of Environmental Quality	10/04
CANADA				
Alberta				
AB13	Henry Kroeger		ATCO Power	09/04
AB14	Genesee		Jacques Whitford Axys Ltd.	07/06
Newfoundland				
NF09	Cormak		Environment Canada	05/00
Nova Scotia				
NS01	Kejimkujik NP		Environment Canada	07/96
Ontario				
ON07	Egbert		Environment Canada	03/00
Saskatchewan				
SK12	Bratt’s Lake BSRN		Environment Canada	05/01

*These dates mark the official start of NADP/MDN operations. Data for a transition network operating in 1995 and early 1996 are available from the NADP web site at http://nadp.sws.uiuc.edu/mdn/mdn_trandata_rpt.html.

**At this site the NADP Program Office sponsors a second collector for the purpose of measuring network precision.

PROCEEDINGS NOTES

Proceeding Notes

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