



**9th International Conference on Acid Deposition
Successes Achieved and the Challenges Ahead**

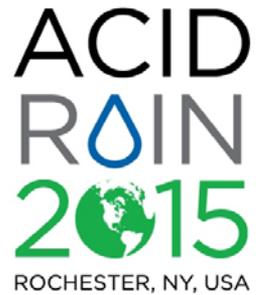
**October 19-23, 2015
Rochester, NY**



Conference Schedule

Monday, Oct. 19, 2015	
Continental Breakfast	7:30 – 8:00 am
NADP Joint Session	8:00 – 10:00 am
NADP Subcommittee Sessions	10:00 – 12:00 pm
Lunch Provided	12:00 – 1:00 pm
NADP Joint Subcommittee Session	1:00 – 2:30 pm
NADP Executive Session	2:30 – 4:30 pm
Welcome Reception/Student Poster Session	5:00 – 8:30 pm
Tuesday, Oct. 20, 2015	
Continental Breakfast	7:30 – 8:00 am
Welcome & Introduction	8:00 – 8:30 am
Keynote Speaker #1	8:30 – 9:30 am
Break	9:30 – 10:00 am
Keynote Speaker #2	10:00 – 11:00 am
Keynote Speaker #3	11:00 – 12:00 pm
Lunch (On your own)	12:00 – 1:30 pm
Breakout Session #1 (A,B,C)	1:30 – 3:15 pm
Break	3:15 – 3:45 pm
Poster Session #2	3:45 – 5:30 pm
Wednesday, Oct. 21, 2015	
Continental Breakfast	7:30 – 8:00 am
Keynote Speaker #4	8:00 – 9:00 am
Keynote Speaker #5	9:00 – 10:00 am
Break	10:00 – 10:20 am
Breakout Session #2 (A,B,C)	10:20 – 12:05 pm
Lunch (On your own)	12:05 – 1:35 pm
Breakout Session #3 (A,B,C)	1:35 – 3:20 pm
Break	3:20 – 3:40 pm
Breakout Session #4 (A,B,C)	3:40 – 5:25 pm
Evening at the George Eastman House	6:00 – 10:00 pm
Thursday, Oct. 22, 2015	
Continental Breakfast	7:30 – 8:00 am
Keynote Speaker #6	8:00 – 9:00 am
Keynote Speaker #7	9:00 – 10:00 am
Break	10:00 – 10:20 am
Breakout Session #5 (A,B,C)	10:20 – 12:05 pm
Lunch (On your own)	12:05 – 1:35 pm
Breakout Session #6 (A,B,C)	1:35 – 3:20 pm
Break	3:20 – 3:40 pm
Poster Session #3	3:40 – 5:25 pm
Friday, Oct. 23, 2015	
Continental Breakfast	7:30 – 8:00 am
Breakout Session #7 (A,B,C)	8:00 – 9:45 am
Closing Ceremonies	9:45 – 10:00 am
Optional Field Trip – Niagara Falls	12:00 – 8:00 pm

PROCEEDINGS



**9th International Conference on Acid Deposition
“Successes Achieved and the Challenges Ahead”**

**October 19-23, 2015
Rochester, New York, USA**

**Scientific Symposium Co-Chairs
Dr. Douglas Burns
Dr. David Gay**

October 2015

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Welcome Letter

On behalf of those who helped to plan and have supported this event, we would like to welcome you to the 9th International Conference on Acid Deposition. Much planning has gone into making this conference a reality, and we hope that you find Acid Rain 2015 to be a useful and productive meeting.

We chose to hold this conference here in beautiful New York State, which has been and continues to be a focal point for concern about acidic deposition and is the location where much research has been carried out to better understand this problem.

Over the next four days, research will be presented that represents the most recently available data and current understanding of emissions, deposition, and related environmental effects across the globe. Scientists from around the world are present, and we hope that you will experience a productive atmosphere for the exchange of information and ideas. The conference will feature 7 keynote addresses and about 300 oral and poster presentations that represent the most recent research on acidic deposition.

We also hope that you have chosen to attend one or more of our trips to area attractions, including the Friday field trip to Niagara Falls, which is truly a natural wonder of the world. The City of Rochester, a beautiful venue for this meeting, has been a wonderful partner in this event, so please take some time to see the surrounding city and experience its rich history. We cordially invite you out to the George Eastman House on Wednesday night, for an evening of food, entertainment, and conversation among conference participants.

So with this brief introduction, we again extend our welcome to Acid Rain 2015, and hope that you have a stimulating stay in Rochester.

Sincerely,



David A. Gay
Co-Organizers of Acid Rain 2015

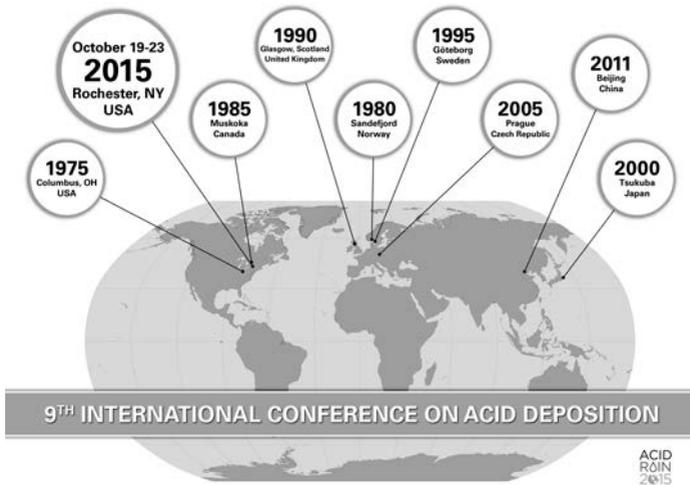


Douglas A. Burns

History of the ICAD Meeting

Acid rain became a widely recognized environmental problem in the 1970s as data and research showed acidification of surface waters and deleterious effects on fish and other biota in sensitive regions of Europe and North America. The 1st International Conference on Acid Deposition, held in 1975 in Columbus, Ohio, provided a forum for scientists and policy makers to discuss the extent of environmental degradation caused by acid deposition and to inform future clean air policies. This conference has been held subsequently every five years across locations in Europe, Canada, and Asia (see below).

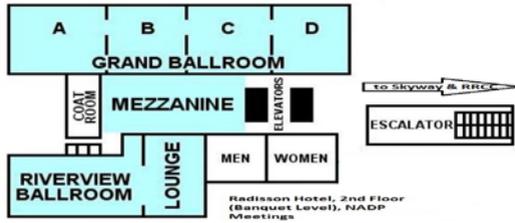
Now, the 9th **International Conference on Acid Deposition** is returning to the US for the first time since 1975 with the theme of “**Successes Achieved and the Challenges Ahead.**” Tremendous progress has been made in Europe and North America over the past three decades at reducing the emissions that form acid rain, while in Asia emissions may just be starting to decline.



General Information

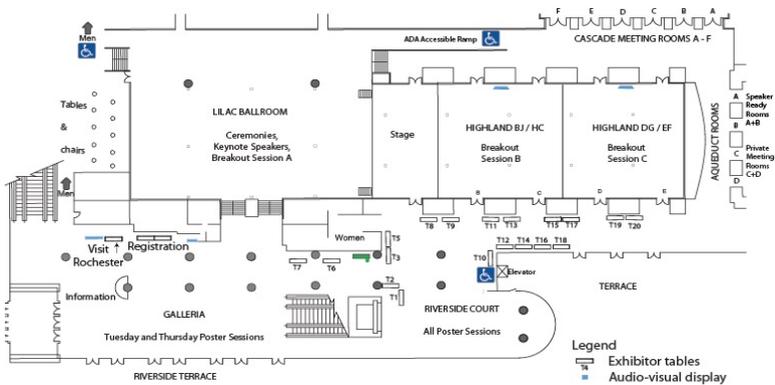
Meeting Venues

Monday's National Atmospheric Deposition Program Business Meeting will be held on the Banquet Level of the Radisson Hotel (attached to the RRCC).



Acid Rain 2015 is being held at the Rochester Riverside Convention Center. Conveniently located in the heart of Rochester, New York, the Rochester Riverside Convention Center enjoys a scenic setting on the Genesee River plus enclosed walkway connections to Hyatt and Radisson Hotels (conference hotels) and parking garages.

Rochester Riverside Convention Center
 123 East Main Street
 Rochester, NY 14604-1619 USA
 Phone: +1-800-856-1678
 Email: info@rrcc.com
 Website: www.rrcc.com



George Eastman House

Designed by J. Foster Warner and built between 1902 and 1905, the George Eastman House is a National Historic Landmark. The estate originally included a stable, garage, barn, five greenhouses, and many vegetable and flower gardens on eight and one-half acres. The 35,000-square-foot Colonial Revival house contains 37 rooms, 13 baths, and nine fireplaces, and cost \$300,000 to build.

After his death in 1932, Eastman left his house to the University of Rochester. In 1947, the house was chartered as a photographic museum by the State of New York. In 1989, a new building was completed on the property to display and house the Museum's growing collections of photographs, photographic equipment, books, and motion pictures.

Join us for an evening at the historic George Eastman House on Wednesday, October 21, 2015 from 6:00 to 10:00 pm.

- Heavy Appetizers
- Tours
- Entertainment
- Cash Bar

George Eastman House
900 East Avenue
Rochester, NY 14607
Phone: +1-585-271-3361
eastmanhouse.org

Shuttle Service (5:30-11:00 pm)

Shuttle service from the hotels to and from our reception at the George Eastman House (GEH) will begin at 5:30 pm and continue until 11:00 pm. Shuttle buses will loop between hotels and the GEH all evening. Buses will loop to Radisson/Hyatt – Eastman House at 15 to 20 minute intervals with the last bus departing from the Eastman House at 11:00 pm.

Poster Sessions

All three poster sessions will be held on the main floor of the Conference Center. The information below has the times of the poster event, when your poster should be put up, and when it should be taken down. We encourage all to leave their posters up for the entire presentation time.

Poster Setup

Poster setup will start 2 hours before each session, and all posters need to be ready to be displayed at the start of the individual session. Posters should remain up until the removal time before the next poster session.

Poster Session Presentations, Setup, and Removal Times

Poster Session #1 (Student PS) Monday, Oct. 19, 5-8:30 pm

Setup: Monday, 1-3:30 pm, Removal: Tuesday, 12-1 pm

Poster Session #2 Tuesday, Oct. 20, 3:45-5:30 pm

Setup: Tuesday 1-3:30 pm, Removal: Thursday, 12-1 pm

Poster Session #3 Thursday, Oct. 22, 3:40-5:25 pm

Setup: Thursday, 1-3:30 pm, Removal: Friday, 10:30 am -12 pm

Upon check-in to the Conference, each presenter should locate their assigned poster board(s) during the setup times given above. The boards are arranged in numerical order. Pushpins for the poster sessions will be provided. The online scientific program should be referenced for updates at <http://acidrain2015.org/program>.

Poster Removal

Posters must be removed at the assigned times. All remaining posters will be removed and moved to the registration desk for pick up. Posters remaining after this time will be recycled.

Poster Help

Staff will be available to provide assistance in locating a poster, ordering additional equipment, providing supplies, and answering general questions. If you need additional supplies, please feel free to bring them with you.

Expectations for the Poster Session

You are expected to have a representative at your poster for questions and presentation during the assigned poster session times. After the poster session, please leave your poster up for others to see it after the session is over. Presenters are encouraged to leave their contact information on their boards to accommodate further discussions and correspondence pertaining to their research.

Planning Committees for the 9th International Conference on Acid Deposition

Scientific Advisory Committee

- Dr. Hajime Akimoto - Asia Center for Air Pollution Research, Niigata, Japan
- Dr. Kevin Bishop – Swedish Univ. Of Agricultural Sciences, Uppsala, Sweden
- Dr. Charles Driscoll – Syracuse University, Syracuse, NY, USA
- Dr. Lei Duan – Tsinghua University, Beijing, China
- Dr. Keith Eshleman – Appalachian Laboratory, Frostburg, MD, USA
- Ms. Katherine Fallon Lambert – Harvard Forest and Science Policy Exchange, Petersham, MA, USA
- Dr. Christine Goodale – Cornell University, Ithaca, NY, USA
- Dr. Jakub Hruska – Czech Geological Survey, Prague, Czech Republic
- Dr. Thorjörn Larssen – Norwegian Institute for Water Research, Oslo, Norway
- Dr. Gregory Lawrence – United States Geological Survey, Troy, NY, USA
- Dr. Alisa Mast – United States Geological Survey, Denver, CO, USA
- Dr. Filip Moldan – Swedish Environmental Research Inst., Stockholm, Sweden
- Dr. Donald Monteith – Center for Ecology & Hydrology, Lancaster, England, UK
- Dr. Nobu Ohte – University of Tokyo, Tokyo, Japan
- Dr. James Sickman – University of California, Riverside, CA, USA
- Dr. Timothy Sullivan – E&S Environmental Chemistry, Corvallis, OR, USA
- Dr. Pamela Templer – Boston University, Boston, MA, USA
- Mr. Robert Vet – Environment Canada, Toronto, ON, Canada
- Dr. Kathleen Weathers – Cary Inst. of Ecosystem St., Millbrook, NY, USA

Organizing Committee

- Mr. Richard Artz – U.S. National Oceanic and Atmospheric Administration, USA
- Ms. Tamara Blett – United States National Park Service, Denver, Colorado, USA
- Dr. Emily Elliott – University of Pittsburgh, Pittsburgh, Pennsylvania, USA
- Mr. Dirk Felton – New York State Dept. of Env. Cons., Albany, New York USA
- Dr. Richard Haeuber – U.S. Environ. Protection Agency, Washington, DC, USA
- Mr. Gregory Lampman – NY State Energy Research & Dev. Authority, Albany, NY, USA
- Dr. Christopher Lehmann – NADP, University of Illinois, Champaign, IL, USA
- Prof. Neng-Huei (George) Lin, National Central University, Taiwan
- Mr. Mark Nilles – United States Geological Survey, Denver, Colorado, USA
- Mr. Ralph Perron – United States Department of Agriculture–Forest Service
- Ms. Lisa Volk – NADP, University of Illinois, Champaign, IL, USA
- Mr. Greg Wetherbee – United States Geological Survey, Denver, Colorado, USA
- Dr. Leiming Zhang – Environment Canada, Toronto, Canada

Sponsors

The 9th International Conference on Acid Deposition was brought to you, in part, by these supporting groups.

Gold Level (\$20,000 or more)

- New York State Energy Research and Development Authority (NYSERDA)
- Environment Canada

Silver Level (\$12,500-\$19,999)

- Illinois State Water Survey (ISWS)
- New York State Department of Environmental Conservation (NYSDEC)

Bronze Level (\$6,000-\$12,499)

- World Meteorological Organization/Global Atmosphere Watch (WMO/GAW)

Basic Level (\$4,000-\$5,999)

- Amec Foster Wheeler (AMEC)
- Central Analytical Laboratory (CAL) at the University of Illinois at Urbana-Champaign

Other

- Adirondack Council

NADP Cooperators

- National Atmospheric Deposition Program (NADP)
- United States Environmental Protection Agency (US EPA)
- United States Geological Survey (USGS)
- National Oceanic and Atmospheric Administration (NOAA)
- National Park Services (NPS)
- United States Department of Agriculture - Forest Service (USDAFS)
- USDA Forest Service - Watershed, Fish, Wildlife, Air & Rare Plants

Exhibitors

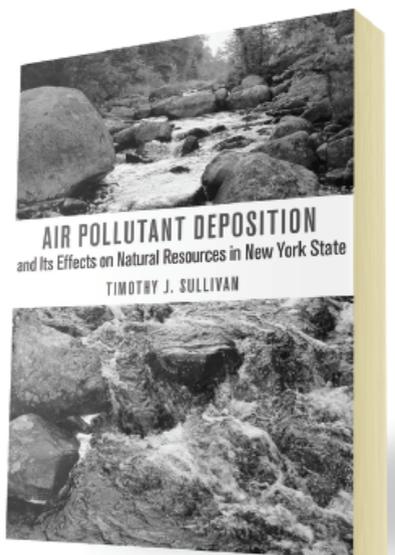
- NCON Systems
- Eurofins – Frontier Global Sciences

CORNELL UNIVERSITY PRESS

Comstock Publishing Associates

“An essential resource for those interested in science that supports policy about sulfur, nitrogen and mercury pollution in New York and beyond.”

—*Ivan Fernandez,*
University of Maine



AIR POLLUTANT DEPOSITION AND ITS EFFECTS ON NATURAL RESOURCES IN NEW YORK STATE

TIMOTHY J. SULLIVAN

\$34.95 paper

In *Air Pollutant Deposition and Its Effects on Natural Resources in New York State*, Timothy J. Sullivan provides a comprehensive synthesis of past, current, and potential future conditions regarding atmospheric sulfur, nitrogen oxides, ammonium, and mercury deposition; surface water chemistry; soil chemistry; forests; and aquatic biota in New York.

This book will inform scientists, resource managers, and policy analysts regarding the state of scientific knowledge on these complex topics and will provide much needed information to help set emissions reduction goals, evaluate incremental improvements, conduct cost/benefit analyses, and prioritize research needs.



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NEW YORK
STATE OF
OPPORTUNITY.

NYSERDA

9th International Conference on Acid Deposition Agenda

Conference Schedule

Monday, October 19, 2015

Room Location

Open All Day	Registration Desk	Radisson Hotel
8:00 a.m.–10:00 a.m.	Joint Subcommittee Meeting	Riverview Ballroom
10:00 a.m.–12:00 p.m.	Subcommittee Meetings Network Operations Ecological Response and Outreach	Riverview Ballroom Grand Ballroom C
12:00 p.m.-1:00 p.m.	Lunch provided	Grand Ballroom A
1:00 p.m. – 2:30 p.m.	Joint Subcommittee Meeting	Riverview Ballroom
2:30 p.m. – 4:30 p.m.	Executive Committee Meeting	Lounge
5:00 p.m. – 8:30 p.m.	Conference Welcome Reception and Student Poster Session	Riverside Convention Center

Tuesday, October 20, 2015		Room Location
Open All Day	Registration/Office	Riverside Convention Center
8:00 a.m. – 8:30 a.m.	Welcome Doug Burns: Co-Organizer of Acid Rain 2015 U.S. Geological Survey David Gay: Co-Organizer of Acid Rain 2015 NADP Coordinator	Lilac Ballroom
8:30 a.m. – 9:30 a.m.	Keynote Address #1 Acid Rain in the US: Science, Policy, Environmental Monitoring, and Ecosystem Recovery Charles Driscoll, Syracuse University	
9:30 a.m. – 10:00 a.m.	Break	
10:00 a.m. – 11:00 a.m.	Keynote Address #2 Acid Rain in Europe: Past, Present, and Future Peringe Grennfelt, IVL, Gothenburg, Sweden	
11:00 a.m. – 12:00 p.m.	Keynote Address #3 Acid Rain in Asia: Emissions, Deposition, and Environmental Effects Lei Duan, Tsinghua University, Beijing, China	
12:00 p.m. – 1:30 p.m.	Lunch on your own	
Breakout Session 1: (Block A)	Emissions of Air Pollutants Session Chair: Dirk Felton, NYSDEC	Lilac Ballroom
1:30 p.m. – 1:50 p.m.	Long-term trends in air emissions reductions and corresponding policy in New York State, the United States and Canada Ona Papageogiou, NYSDEC	
1:50 p.m. – 2:10 p.m.	Elemental characterization and source identification of atmospheric particulate matter (PM_{2.5}) across major cities of Pakistan Jabir H. Syed, State Key Laboratory of Organic Geochemistry, Guangzhou Institute of Geochemistry Chinese Academy of Sciences	

Tuesday, October 20, 2015

Room Location

Lilac Ballroom

- 2:10 p.m. – 2:30 p.m. **Diurnal And nocturnal trends of acid rain in a mid-sized Andean city: Understanding volcanic and anthropogenic source**
Carlos Mario González, Universidad Nacional de Colombia Sede Manizales
- 2:30 p.m. – 2:50 p.m. **Spatio-temporal variability in isotopic signatures of atmospheric NOx emissions from vehicles**
David J. Miller, Brown University
- 2:50 p.m. – 3:10 p.m. **INVITED - Characterization of United States Atmospheric Emissions: Current, Past and Future Conditions**
Richard Scheffe, U.S. Environmental Protection Agency
- 3:10 p.m. – 3:15 p.m. **Session Wrap-up**
- Breakout Session 1:
(Block B)** **Status and Trends of Surface Water Chemistry - I** **Highland BJ/HC**
Session Chair: Donald Monteith, NERC Centre for Ecology & Hydrology
Session Co-Chair: Kevin Civerolo, NYSDEC
- 1:30 p.m. – 1:50 p.m. **INVITED - Status and trends in surface water acidification: Where in the world are we?**
John L. Stoddard, U.S. Environmental Protection Agency
- 1:50 p.m. – 2:10 p.m. **High quality long-term monitoring: Swedish experiences with assessments of surface water acidification and recovery**
Jens Fölster, Swedish University of Agricultural Science
- 2:10 p.m. – 2:30 p.m. **Long-term sulphur and nitrogen input-output budgets in European forested catchments (1990-2012)**
Jussi Vuorenmaa, Finnish Environment Institute
- 2:30 p.m. – 2:50p.m. **Recovery of stream water from acidification due to declining S deposition in a Japanese cedar forest near the Sea of Japan**
Hiroyuki Sase, Asia Center for Air Pollution Research
- 2:50 p.m. – 3:10 p.m. **Is surface water acidification a serious regional issue in China?**
Ting Zhang, Tsinghua University
- 3:10 p.m. – 3:15 p.m. **Session Wrap-up**

Tuesday, October 20, 2015

Room Location

Highland DG/EF

Breakout Session 1: (Block C)	Critical Loads: A Bridge between Science and Policy Session Chair: Tamara Blett, National Park Service	
1:30 p.m. – 1:50 p.m.	When is a Critical Load for N Deposition Critical? Kevin Hicks, Stockholm Environment Institute (SEI), University of York	
1:50 p.m. – 2:10 p.m.	What is left for researchers in acid rain research: A review of state-of-the-art assessment effects-based research and modelling Harald Ulrik Sverdrup, University of Iceland	
2:10 p.m. – 2:30 p.m.	How much is too much? Regulating industrial emissions in northwest British Columbia, Canada Patrick Williston, British Columbia Ministry of Environment	
2:30 p.m. – 2:50 p.m.	Critical loads exceedance and relative risk maps based on the simulated S and N depositions over the past 25 years in Japan Naoyuki Yamashita, Asia Center for Air Pollution Research	
2:50 p.m. – 3:10 p.m.	Lichen critical loads for atmospheric nitrogen and sulfur deposition in forests of the United States Linda Geiser, USDA Forest Service	
3:10 p.m. – 3:15 p.m.	Session Wrap-up	
3:15 p.m. – 3:45 p.m.	Break	Galleria
3:45 p.m. – 5:30 p.m.	Poster Session #2	Galleria and Riverside Court

Wednesday, October 21, 2015

Room Location

Open All Day Registration/Office

**Riverside Convention
Center**

Wednesday, October 21, 2015

Room Location

Lilac Ballroom

8:00 a.m. – 9:00 a.m. **Keynote Address #4**
**Acid Rain: A Global Comparison of Deposition and Ecosystem
Response**
Robert Vet, Environment Canada, Toronto, Ontario and Thorjorn
Larssen, NIVA, Oslo, Norway

9:00 a.m. – 10:00 a.m. **Keynote Address #5**
Emissions, Deposition, and Environmental Cycling of
Atmospheric Nitrogen: An Isotope Perspective
Emily Elliott, Univ. of Pittsburgh

10:00 a.m. – 10:20 a.m. **Break**

Breakout Session 2: **Deposition of Air Pollutants - I** **Lilac Ballroom**
(Block A)
Session Chair: Jason Lynch, US EPA
Session Co-Chair: George Lin, National Central Univ, Taiwan

10:20 a.m. – 10:40 a.m. **INVITED - Observed and modelled trends in atmospheric**
concentrations and wet deposition of sulphur and nitrogen in
EMEP, 1990-2012
Wenche Aas, NILU, Norwegian Institute for Air Research

10:40 a.m. – 11:00 a.m. **Atmospheric abundance of reactive nitrogen species over Indo**
Gangetic plains (India)
Saumya Singh, Jawaharlal Nehru University at New Delhi

11:00 a.m. – 11:20 a.m. **Long-term trends in atmospheric deposition across France:**
Drivers, forecasts and impacts
Aude Pascaud, Mines Douai

11:20 a.m. – 11:40 a.m. **Spatial and temporal patterns in air and rainfall pollutant**
concentrations measured over the UK during the last 30 years
Ron Smith, Centre for Ecology and Hydrology

11:40 a.m. – 12:00 p.m. **Spatial and temporal variation of the acid rain in the Mexico City**
Metropolitan Zone
Humberto Bravo A, Universidad Nacional Autónoma de México

Wednesday, October 21, 2015

Room Location

Lilac Ballroom

12:00 p.m. – 12:05 p.m. **Session Wrap-up**

Breakout Session 2: Status and Trends of Surface Water Chemistry - II Highland BJ/HC
(Block B)

Session Chair: Donald Monteith, NERC Centre for Ecology & Hydrology

Session Co-Chair: Kevin Civerolo, NYSDEC

10:20 a.m. – 10:40 a.m. **35 years of upland water quality monitoring in the UK: Foreseen events, unforeseen events, non-events and extreme events**
Chris Evans, Centre for Ecology and Hydrology

10:40 a.m. – 11:00 a.m. **Long-term monitoring in Kejimikujik National Park Nova Scotia reveals increasing aluminum concentrations in rivers**
Shannon Sterling, Dalhousie University

11:00 a.m. – 11:20 a.m. **Patterns of nutrient dynamics in Adirondack lakes recovering from acid deposition**
Jacqueline Gerson, Syracuse University

11:20 a.m. – 11:40 a.m. **Delayed and variable recovery from acid deposition in Shenandoah National Park streams: A story of geologic history, long-term monitoring, and management of air and water resources**
Ami Riscassi, University of Virginia

11:40 a.m. – 12:00 p.m. **Acid deposition and acidification of waters in South Africa**
Kari Austnes, Norwegian Institute for Water Research (NIVA)

12:00 p.m. – 12:05 p.m. **Session Wrap-up**

Breakout Session 2: Liming to Promote Ecosystem Recovery Highland DG/EF
(Block C)

Session Chair: Gregory Lampman, NYSERDA

10:20 a.m. – 10:40 a.m. **Response of Stream Chemistry and Young-of-Year Brook Trout to Lime Applications in Acidified Tributaries to Honnedaga Lake**
Daniel Josephson, Dept. of Natural Resources, Cornell University

10:40 a.m. – 11:00 a.m. **Long-term effects of liming on fish in Swedish streams and lakes**
Kerstin Holmgren, Swedish University of Agricultural Sciences

Wednesday, October 21, 2015

Room Location

Highland DG/EF

- 11:00 a.m. – 11:20 a.m. **Use of the acid-base budget approach to monitor the acidification of soils and to evaluate the effect and the necessity of forest liming**
Martin Greve, Research Institute for Forest Ecology and Forestry
(Rhineland-Palatinate)
- 11:20 a.m. – 11:40 a.m. **Acid Rain Recovery via Alkali Road Runoff Channels**
Kenneth Anderson II, PA Fish & Boat Commission
- 11:40 a.m. – 12:00 p.m. **Long-term effects of forest liming on growth and vigor of northern hardwoods and associated changes in soil and foliage chemistry**
Robert Long, USDA Forest Service
- 12:00 p.m. – 12:05 p.m. **Session Wrap-up**
- 12:05 p.m. – 1:35 p.m. **Lunch on your own**
- Breakout Session 3:
(Block A)** **Deposition of Air Pollutants II** **Lilac Ballroom**
Session Chair: Jason Lynch, US EPA
Session Co-Chair: George Lin, National Central Univ, Taiwan
- 1:35 p.m. – 1:55 p.m. **Recent analysis of EANET data for trends and variability factor of wet deposition in East Asia**
Hiroaki Minoura, Asia Center for Air Pollution Research
- 1:55 p.m. – 2:15 p.m. **Atmospheric Reactive Nitrogen in Rocky Mountain National Park**
Katherine B. Benedict, Department of Atmospheric Science, Colorado State University
- 2:15 p.m. – 2:35 p.m. **The Increasing Importance of Deposition of Reduced Nitrogen in the United States**
Jeff Collett, Colorado State University
- 2:35 p.m. – 2:55 p.m. **Assessment of precipitation chemistry at regionally representative sites in the interior of South Africa**
Pieter Gideon van Zyl, North-West University at Potchefstroom, South Africa
- 2:55 p.m. – 3:15 p.m. **Overview of Taiwan Acid Deposition Network and the Response of Long-term Precipitation Chemistry to Air Pollution Control Policies**
Neng-Huei (George) Lin, National Central University

Wednesday, October 21, 2015

Room Location

Lilac Ballroom

3:15 p.m. – 3:20 p.m.

Session Wrap-up

**Breakout Session 3:
(Block B)**

**Atmospheric Nitrogen Deposition I:
Biological Effects**

Highland BJ/HC

Session Chair: Nobu Ohte, Kyoto University

Session Co-Chair: Emily Elliott, Univ of Pittsburgh

1:35 p.m. – 1:55 p.m.

**Foliar chemical evidence of effects of excess nitrogen on the
biogeochemistry of a temperate hardwood forest**

Frank S. Gilliam, Marshall University

1:55 p.m. – 2:15 p.m.

**Nitrogen saturation, soil acidification, and ecological effects in a
subtropical pine forest on acid soil in Southwest China**

Lei Duan, Tsinghua University

2:15 p.m. – 2:35 p.m.

**Incorporating mechanisms of atmospheric nitrogen into the
Canopy: Soil continuum of a suburban forest in Japan**

Nobuhito Ohte, Kyoto University

2:35 p.m. – 2:55 p.m.

**Effects of atmospheric deposition on nitrogen retention and
carbon sequestration in temperate forest ecosystems**

Pamela H. Templer, Boston University

2:55 p.m. – 3:15 p.m.

**Declining nitrate-N yields in the Upper Potomac River basin
(USA): what is really driving progress under the Chesapeake Bay
restoration?**

Keith N. Eshleman, University of Maryland Center for Environmental
Science, Appalachian Laboratory

3:15 p.m. – 3:20 p.m.

Session Wrap-up

**Breakout Session 3:
(Block C)**

Status and Trends of Soil Chemistry

Highland DG/EF

Session Chair: Mary Beth Adams, USDA Forest Service

Session Co-Chair: Paul Hazlett, Natural Resources Canada – Canadian
Forest Service

1:35 p.m. – 1:55 p.m.

**INVITED - Declining Acidic Deposition Begins Reversal of Forest:
Soil Acidification in the Northeastern U.S. and Eastern Canada**

Gregory Lawrence, U.S. Geological Survey

Wednesday, October 21, 2015

Room Location

Highland DG/EF

- 1:55 p.m. – 2:15 p.m. **Acidification trends in soils and surface waters in boreal areas: Accumulation of organic matter and variations in ionic strength important but overlooked drivers**
Stefan Löfgren, Department of Aquatic Sciences and Assessment, SLU
- 2:15 p.m. – 2:35 p.m. **The effects of 25 years of soil acidification in a forested ecosystem: An update from The Fernow Whole Watershed Acidification Study**
Mary Beth Adams, USDA Forest Service
- 2:35 p.m. – 2:55 p.m. **Acidity and nutrient constraints on the soil organic matter balance**
Filip Oulehle, Czech Geological Survey and Global Change Research Centre
- 2:55 p.m. – 3:15 p.m. **Health Consequences of Acid Rain in South West Sweden**
Ingegerd Rosborg, Division of Land and Water Resources Engineering School of Architecture and the Built Environment, KTH Royal Institute of Technology
- 3:15 p.m. – 3:20 p.m. **Session Wrap-up**
- 3:20 p.m. – 3:40 p.m. **Break**
- Breakout Session 4: (Block A)** **Atmospheric Modeling of Air Pollutants** **Lilac Ballroom**
Session Chair: Donna Schwede, US EPA
Session Co-Chair: Leiming Zhang, Environment Canada
- 3:40 p.m. – 4:00 p.m. **INVITED - Modeling Atmospheric Composition Matters: To Air Quality, Weather, Climate and More**
Gregory R. Carmichael, University of Iowa
- 4:00 p.m. – 4:20 p.m. **Sensitivities of simulated PM_{2.5} health effects and source contributions to aerosol models**
Yu Morino, National Institute for Environmental Studies
- 4:20 p.m. – 4:40 p.m. **Long-term variation of the ratio of nitrate to non-seasalt sulfate in precipitation over East Asia during 2000-2011**
Syuichi Itahashi, Environmental Science Research Laboratory, Central Research Institute of Electric Power Industry

Wednesday, October 21, 2015

Room Location

Lilac Ballroom

- 4:40 p.m. – 5:00 p.m. **Estimates of Acid Deposition in Alberta and Saskatchewan Using A Chemical Transport Model**
Paul Andrew Makar, Air Quality Research Division, Environment Canada
- 5:00 p.m. – 5:20 p.m. **Deposition of acidifying species in the Waterberg of South Africa in response to expanding coal-fired power generation**
Stuart Piketh, Unit for Environmental Science and Management, North-West University
- 5:20 p.m. – 5:25p.m. **Session Wrap-up**
- Breakout Session 4:
(Block B)** **Biogeochemical Models Applied to Acidification and Recovery** **Highland BJ/HC**
Session Chair: Filip Moldan, IVL Swedish Environmental Research Institute
Session Co-Chair: Tim Sullivan, E&S Environmental
- 3:40 p.m. – 4:00 p.m. **INVITED - Biogeochemical Models Applied to Acidification and Recovery: Where We've Been, How We've Done, and Where We're Going**
Jack Cosby, Centre for Ecology and Hydrology
- 4:00 p.m. – 4:20 p.m. **Assessing anthropogenic impact on boreal lakes with historical fish species distribution data and hydrogeochemical modeling**
Salar Valinia, Swedish University of Agricultural Sciences
- 4:20 p.m. – 4:40 p.m. **Recovery of acid-impaired streams in Great Smoky Mountains National Park from acid deposition**
Habibollah Fakhraei, Syracuse University
- 4:40 p.m. – 5:00 p.m. **Modeling the impact of climate change on the acid-base status of a forested, upland watershed in Shenandoah National Park, Virginia**
Todd M. Scanlon, University of Virginia
- 5:00 p.m. – 5:20 p.m. **Exploiting a long-term dataset to make even longer-term model predictions of the acidification status of soils and waters: Possibilities and limits**
Richard Skeffington, University of Reading, UK
- 5:20 p.m. – 5:25p.m. **Session Wrap-up**

Wednesday, October 21, 2015

Room Location

Highland DG/EF

Breakout Session 4: (Block C)	Linkages of Acid Rain to Climate Change and the Carbon Cycle Session Chair: Christine Goodale, Cornell University Session Co-Chair: Chris Evans, Centre for Ecology and Hydrology
3:40 p.m. – 4:00 p.m.	INVITED - Temperature, Precipitation and Nitrogen Effects on the Terrestrial Carbon Cycle Tara Greaver, National Center for Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency
4:00 p.m. – 4:20 p.m.	Attributing spatial and temporal changes in soil C and pH in the UK to acid deposition and other environmental drivers Amy Thomas, Centre for Ecology and Hydrology
4:20 p.m. – 4:40 p.m.	Widespread forest recovery across the central Appalachian Mountains (U.S.) following reductions in pollutant emissions Richard Thomas, West Virginia University
4:40 p.m. – 5:00 p.m.	Assessing the rates of recovery from acidification under climate change in the Northeastern USA S. Belyazid, Centre for Environment and Climate Research, Lund University
5:00 p.m. – 5:20 p.m.	Achieving the Swedish environmental quality objective “Natural acidification only” in a world of changing climate, forestry practices and air pollution Filip Moldan IVL, Swedish Environmental Research Institute
5:20 p.m. - 5:25 p.m.	Session Wrap-up
5:25 p.m. – 6:00 p.m.	Break
6:00 p.m. – 10:00 p.m.	Evening at the George Eastman House

Thursday, October 22, 2015

Open All Day Registration/Office

Room Location

**Riverside Convention
Center**

Thursday, October 22, 2015

Room Location

Lilac Ballroom

8:00 a.m. – 9:00 a.m. **Keynote Address #6**
Acid Rain and Climate Change
Heleen de Wit, NIVA, Oslo, Norway

9:00 a.m. – 10:00 a.m. **Keynote Address #7**
Acid Rain in a Changing Energy and Regulatory Environment
Dallas Burtraw, Resources for the Future, Washington, DC

10:00 a.m. – 10:20 a.m. **Break**

Breakout Session 5: **Linkages of Sulfur and Nitrogen with Lilac Ballroom**
(Block A) **other Air Pollutants**
Session Chair: Christopher Lehmann, NADP/CAL
Session Co-Chair: Andy Johnson, Maine DEP

10:20 a.m. – 10:40 a.m. **INVITED - The Forest's Perception of Multi-Air Pollutant**
Stressors in the 21st Century
I.J. Fernandez, University of Maine, School of Forest Resources,
Climate Change Institute, and School of Food and Agriculture

10:40 a.m. – 11:00 a.m. **Dry and wet deposition of air pollutants in North China**
Yuepeng Pan, Institute of Atmospheric Physics, Chinese Academy
of Sciences

11:00 a.m. – 11:20 a.m. **The sensitivity of summer time surface ozone concentrations to**
dry deposition in the United States
Sarah Kavassalis, University of Toronto

11:20 a.m. – 11:40 a.m. **Analysis of Meteorological conditions on a persistent haze**
process in Yangtze River Delta
Rui Han, NMIC

11:40 a.m. – 12:00 p.m. **Measurements of atmospheric hydroperoxides over a rural site**
in Japan using a helicopter
Koichi Watanabe, Toyama Prefectural University

12:00 p.m. – 12:05 p.m. **Session Wrap-up**

Thursday, October 22, 2015

Room Location

Highland BJ/HC

- Breakout Session 5: (Block B)** **Atmospheric Nitrogen Deposition II: Biological Effects**
Session Chair: Pamela Templer, Boston University
Session Co-Chair: James Sickman, University of California
- 10:20 a.m. – 10:40 a.m. **INVITED - Terrestrial ecosystem responses to N deposition: The effect of site and climate on critical loads of nitrogen for forests in the northeastern U.S.**
Linda H. Pardo, USDA Forest Service, Northern Research Station
- 10:40 a.m. – 11:00 a.m. **Continental Scale Analysis of Tree Growth, Mortality, and Recruitment Responses to Nitrogen Deposition Reveal Regional and Species-specific variability that May Enhance and Concentrate Mitigation Efforts**
Kevin Horn, Virginia Tech
- 11:00 a.m. – 11:20 a.m. **INVITED - A biodiversity indicator for the assessment of nitrogen deposition**
Wieger Wamelink, Alterra, Wageningen UR
- 11:20 a.m. – 11:40 a.m. **Modelling soil and vegetation response to atmospheric nitrogen deposition and climate change in French forests.**
S. Rizzetto, Toulouse University
- 11:40 a.m. – 12:00 p.m. **The nitrogen fingerprint in European forest vegetation**
Thomas Dirnböck, Environment Agency Austria
- 12:00 p.m. – 12:05 p.m. **Session Wrap-up**
- Breakout Session 5: (Block C)** **Role of Forestry and Land Management Highland DG/EF**
Session Chair: Kevin Bishop, Uppsala University and SLU
- 10:20 a.m. – 10:40 a.m. **Critical biomass harvesting: Applying a new concept for Swedish forest soils**
Cecilia Akselsson, Department of Physical Geography and Ecosystem Science, Lund University
- 10:40 a.m. – 11:00 a.m. **Acidic Deposition and Timber Harvesting Will Continue to Reduce Essential Nutrients Needed for Healthy Watersheds**
Bill Jackson, USDA Forest Service

Thursday, October 22, 2015

Room Location

Highland DG/EF

- 11:00 a.m. – 11:20 a.m. **INVITED - Comparison of current and long-term Ca weathering rates in the White Mountains of New Hampshire**
Ruth D. Yanai, SUNY College of Environmental Science of Forestry
- 11:20 a.m. – 11:40 a.m. **Changes in catchment biogeochemistry under future scenarios of acid deposition and forestry practices in Central Europe**
Jakub Hruška, Global Change Research Center, Academy of Sciences of the Czech Republic
- 11:40 a.m. – 12:00 p.m. **Acidity and base cations in forest soils as affected by deposition reduction and whole-tree harvesting: Application of the HD-MINTEQ model**
Jon Petter Gustafsson, Department of Soil and Environment, Swedish University of Agricultural Sciences
- 12:00 p.m. – 12:05 p.m. **Session Wrap-up**
- 12:05 p.m. – 1:35 p.m. **Lunch on your own**
- Breakout Session 6: (Block A)** **Linkages of Acid Rain with the Mercury Cycle** **Lilac Ballroom**
Session Chair: Dave Schmeltz, US EPA
- 1:35 p.m. – 1:55 p.m. **INVITED - Current and Past Sulfate Inputs Control Methylmercury in a Boreal Peatland**
Jill Coleman Wasik, University of Wisconsin River Falls
- 1:55 p.m. – 2:15 p.m. **Stream mercury at five Czech catchments across an Hg and S deposition gradient**
James B. Shanley, U.S. Geological Survey
- 2:15 p.m. – 2:35 p.m. **Anthropogenic Mercury Accumulation in Forested Watersheds of Pennsylvania**
Elizabeth Boyer, Penn State University
- 2:35 p.m. 2:55 p.m. **Controlling Factors of Long-Term Trends in Mercury Wet Deposition and Precipitation Concentrations at Huntington Wildlife Forest**
Zhuyun Ye, State University of New York College of Environmental Science and Forestry

Thursday, October 22, 2015

Room Location

Lilac Ballroom

- 2:55 p.m. – 3:15 p.m. **Wet Deposition Monitoring Networks of Mercury and Acid Rain in Taiwan**
Guey-Rong Sheu, National Central University
- 3:15 p.m. – 3:20 p.m. **Session Wrap-up**
- Breakout Session 6:
(Block B)** **Cycling of Base Cations in Ecosystems** **Highland BJ/HC**
Session Chair: Scott Bailey, University of New Hampshire
Session Co-Chair: Stephen Norton, University of Maine
- 1:35 p.m. – 1:55 p.m. **Dynamics of calcium and magnesium in forest ecosystems assessed by a multi-isotopic tracing experiment**
Gregory van der Heijden, INRA-BEF Champenoux France
- 1:55 p.m. – 2:15 p.m. **Ecosystem Alkalization from Oil Sands Emissions**
Shaun Watmough, Trent University
- 2:15 p.m. – 2:35 p.m. **Do soil weathering rates in south-central Ontario protect forests from acidification under current deposition?**
Grant Stott, Trent University
- 2:35 p.m. – 2:55 p.m. **Influence of windblown dust on snowpack chemistry and snowmelt timing in mountains of the western U.S.**
David W. Clow, U.S. Geological Survey
- 2:55 p.m. – 3:15 p.m. **The importance of water residence time distributions for the flux of weathering products**
Martin Erlandsson, Uppsala University
- 3:15 p.m. – 3:20 p.m. **Session Wrap-up**
- Breakout Session 6:
(Block C)** **Clean Air Policies, Economics, and Society** **Highland DG/EF**
Session Chair: Rocci Aguirre, The Adirondack Council
Session Co-Chair: John Sheehan, The Adirondack Council
Session Co-Chair: Mandy Warner, Environmental Defense Fund
- 1:35 p.m. – 1:55p.m. **The Rocky Mountain Park Initiative: A Unique Approach to Reducing Nitrogen Deposition**
Lisa Devore, Colorado Department of Public Health and Environment

Thursday, October 22, 2015

Room Location

Highland DG/EF

1:55 p.m. – 2:15 p.m.	Social and economic impacts of the acidification and potential recovery of Adirondack ecosystems Jesse Caputo, SUNY College of Environ. Science & Forestry
2:15 p.m. – 2:35 p.m.	Evidence-based impacts of SO2 policies 1990-2012: A Swedish case study Stefan Åström, IVL Swedish Environmental Research Institute Ltd and Chalmers University of Technology
2:35 p.m. - 2:55 p.m.	The effects of China's control policies on historical and future trends on atmospheric pollutant emissions Yu Zhao, Nanjing University
2:55 p.m. – 3:15 p.m.	Measuring the Value of Acid and Mercury Pollution in New York State through Property Values (In progress) Chuan Tang, Clarkson University
3:15 p.m. – 3:20 p.m.	Session Wrap-up
3:20 p.m. – 3:40 p.m.	Break
3:40 p.m. – 5:25 p.m.	Poster Session #2

Galleria

Galleria and Riverside Court

Friday, October 23, 2015		Room Location
Open AM	Registration/Office	Riverside Convention Center
Breakout Session 7: (Block A)	Advances in Quantifying Total Atmospheric Deposition Session Chair: Kristi Morris, National Park Service Session Co-Chair: Gary Lear, US EPA	Lilac Ballroom
8:00 a.m. – 8:20 a.m.	A Hybrid Approach for Estimating Total Deposition in the United States Gary Lear, USEPA	
8:20 a.m. – 8:40 a.m.	Trends over 30 years in the mass budgets of sulphur, oxidized and reduced nitrogen and ozone over the UK and their implication for residence times, linearities and understanding the wet and dry deposition processes Prof David Fowler, Centre for Ecology and Hydrology	
8:40 a.m. – 9:00 a.m.	Quantification of atmospheric nitrogen deposition across China based on a nationwide monitoring network Xuejun Liu, China Agricultural University	
9:00 a.m. – 9:20 a.m.	EADN Advances in Measurements of Atmospheric Ozone, Nitrogen, Sulphur Compounds in Dry Deposition across Equatorial African Great Lakes Vincent O. Madadi, University of Nairobi	
9:20 a.m. – 9:40 a.m.	Comparison of Various Approaches for Estimating Total Nitrogen Deposition to Forests and other Ecosystems Mark E Fenn, USDA Forest Service, PSW Research Station	
9:40 a.m. – 9:45 a.m.	Session Wrap-up	
Breakout Session 7: (Block B)	Controls on DOC in Surface Waters Cycle Session Chair: Jakub Hruska, Czech Geological Survey Session Co-Chair: Salar Valinia, NIVA / SLU	Highland BJ/HC
8:00 a.m. – 8:20 a.m.	INVITED - Trends in DOC in northern surface waters in North America and Europe Heleen A. de Wit, Norwegian Institute for Water Research	

Friday, October 23, 2015

Room Location

Highland BJ/HC

8:20 a.m. – 8:40 a.m. **Millennial-scale changes in lake-water carbon cycling in northern European boreal lakes: Teasing apart the competing roles of climate, land use and acidification**
Richard Bindler, Umeå University, Sweden

8:40 a.m. – 9:00 a.m. **Stoichiometric and Isotopic Evidence for Drivers of Inverse DOC-Nitrate Loss Patterns in Forested Catchments**
Christine L. Goodale, Cornell University

9:00 a.m. – 9:20 a.m. **Dissolved organic carbon changes since the pre-industrial period redefine the extent of Swedish surface water acidification and help resolve a classic controversy**
Kevin Bishop, Uppsala University and SLU

9:20 a.m. – 9:40 a.m. **DOC concentrations of New England (USA) lakes: Is there a response to changing atmospheric deposition?**
William H. McDowell, University of New Hampshire

9:40 a.m. – 9:45 a.m. **Session Wrap-up**

Breakout Session 7: Status and Trends of Aquatic Highland DG/EF
(Block C) Biological Communities
Session Chair: Kerstin Holmgren, Swedish University of Agricultural Sciences
Session Co-Chair: Barry Baldigo, U.S. Geological Survey

8:00 a.m. – 8:20 a.m. **Hindered, stubborn or confused? Explaining the patchiness of biological responses to the declining acidity of surface waters**
Don Monteith, NERC Centre for Ecology & Hydrology

8:20 a.m. – 8:40 a.m. **Status and trends in stream ecosystems in limed, acidic or neutral waters (benthic diatoms, benthic fauna, fish)**
Cecilia Andrén, Stockholm University

8:40 a.m. – 9:00 a.m. **Response of fish assemblages to changing acid-base chemistry in Adirondack long-term monitoring lakes, New York, USA**
Barry Baldigo, US Geological Survey

9:00 a.m. – 9:20 a.m. **Recovery of young brown trout (*Salmo trutta*) in acidified streams: What are critical values for acid-neutralizing capacity?**
Trygve Hesthagen, Norwegian Institute for Nature Research

Friday, October 23, 2015

Room Location

Highland DG/EF

9:20 a.m. – 9:40 a.m. **Long-term observation of biological and chemical recovery in the Ore Mountains` stream Grosse Pyra (Saxony, GERMANY)**
Martina Keitel, Saxon State Company for Environment and Agriculture

9:40 a.m. – 9:45 a.m. **Session Wrap-up**

Friday, October 23, 2015

Room Location

Lilac Ballroom

9:45 a.m. – 10:00 a.m. **Closing Ceremony**

12:00 p.m. – 8:00 p.m. **Optional Niagara Falls Tour**



KEYNOTE SPEAKER #1

DR. CHARLES DRISCOLL, SYRACUSE UNIVERSITY

INTRODUCED BY DR. DOUGLAS BURNS

Charles T. Driscoll is a Distinguished Professor at Syracuse University. He received his PhD from Cornell University. His research addresses the effects of disturbance on forest, freshwater, and marine ecosystems, including air pollution (acid and mercury deposition), industrial and municipal waste, land-use, and climate change. Driscoll has testified at US Congressional and state legislative committee hearings, and served on many local, national, and international committees. He is a member of the US National Academy of Engineering.

KEYNOTE SPEAKER #2

**DR. PERINGE GRENNFELT, IVL,
GOTHENBURG, SWEDEN**

INTRODUCED BY DR. FILIP MOLDAN

Peringe Grennfelt has been involved in transboundary air pollution issues since the early alarms on acid rain around 1970. He participated in the development of the European monitoring network that later became EMEP. He participated in the Lake Gårdsjön Project and was deeply involved in the development of the Critical Loads concept in the late 1980s. He was also responsible for the organization of the 1995 Acid Rain Conference in Gothenburg. He has also been involved in the development of the multi-pollutant multi-effect concept, which was the basis for the Gothenburg Protocol under CLRTAP. Since the 1980s he has worked under EMEP and from 2011 he has chaired the Working Group on Effects. He has also been coordinating several research programs on air pollution and acid rain, e.g., the ASTA research program.

KEYNOTE SPEAKER #3

**DR. LEI DUAN, TSINGHUA UNIVERSITY,
BEIJING, CHINA**

INTRODUCED BY DR. THORJORN LARSEN

Dr. Lei Duan, professor at the School of Environment, Tsinghua University, is an environmental scientist with current interests and lengthy experience in monitoring and modeling the effects of environmental changes, such as those that result from atmospheric deposition on soil, surface water, and terrestrial ecosystems. He oversees several monitoring sites and does many regional surveys on acidification, nitrogen cycling, and mercury transport in various ecosystems in China. In addition, he has broad experience in supporting policy-making on effects-based air pollution control. He is author/co-author of about 100 peer-reviewed publications.

KEYNOTE SPEAKER #4

MR. ROBERT VET, ENVIRONMENT CANADA, TORONTO, ONTARIO AND DR. THORJORN LARSEN, NIVA, OSLO, NORWAY

**ROBERT VET INTRODUCED BY MR. RICHARD ARTZ
THORJORN LARSEN INTRODUCED BY DR. KEVIN BISHOP**

Robert Vet is a senior scientist with Environment Canada whose research activities include atmospheric deposition, regional air quality, transboundary transport, measurement-model fusion, and scientific data management. He leads a group responsible for the analysis of atmospheric deposition and air quality data collected by the Canadian Air and Precipitation Monitoring Network and the management of atmospheric research data. Mr. Vet is a long-term member of the World Meteorological Organization's (WMO) Scientific Advisory Group for Total Atmospheric Deposition and has contributed to multiple international projects. He was lead author and editor of a recently published WMO global assessment of precipitation chemistry and deposition.

Thorjørn Larssen is Research Director at the Norwegian Institute for Water Research (NIVA). He is also Adjunct Professor in environmental chemistry at the University of Oslo. He received his PhD in environmental chemistry in 1999, with a thesis on acid rain in China. He has since worked on a range of environmental issues, including water pollution and management, mercury and organic micropollutants. He has worked in many countries, including as a Visiting Professor in China at Tsinghua University and at the Chinese Academy of Sciences. Thorjorn has broad research interests, as represented by a broad portfolio of projects, and about 80 papers in the international peer-reviewed literature that cover topics in environmental chemistry, biogeochemistry, environmental monitoring, and environmental health.

KEYNOTE SPEAKER #5

DR. EMILY ELLIOTT, UNIV. OF PITTSBURGH

INTRODUCED BY DR. ELIZABETH BOYER

Dr. Emily M. Elliott is an Associate Professor in the Department of Geology and Planetary Science and an Adjunct Associate Professor in the Department of Civil and Environmental Engineering at the University of Pittsburgh. Her research program examines the tight coupling between human activities and reactive nitrogen distribution in atmospheric, terrestrial, and aquatic ecosystems at multiple spatial scales using stable isotope geochemistry. She directs operations of the Regional Stable Isotope Laboratory for Earth and Environmental Science Research. Prior to joining the University of Pittsburgh in 2007, she was a Postdoctoral Researcher with the U.S. Geological Survey, Water Resources Division. She earned her M.S. and Ph.D. in the Department of Geography and Environmental Engineering at Johns Hopkins University in Baltimore, MD.

KEYNOTE SPEAKER #6

DR. HELEEN DE WIT, NIVA, OSLO, NORWAY

INTRODUCED BY DR. DON MONTEITH

Heleen de Wit is a senior research scientist at the Norwegian Institute for Water Research in Oslo, Norway. She is a catchment biogeochemist who is interested in the effects of atmospheric deposition and climate on element cycling. Her research career began in Wageningen, the Netherlands, where she studied the interactions of aluminum and dissolved organic matter in acidified forest soils. Since then, she has studied topics such as fine roots and mycorrhiza, needle chemistry, carbon sequestration in soils and biomass, patterns of change in forest ecotones and climate feedbacks, forest harvest effects on streamwater, long-term trends in lake and streamwater chemistry, and mercury accumulation in aquatic filter-feeders. A common theme in her research is the role of solid and dissolved organic matter in ecosystem function. She was born in the Netherlands, and has resided in Norway for over 20 years.

KEYNOTE SPEAKER #7

DR. DALLAS BURTRAW, RESOURCES FOR THE FUTURE, WASHINGTON, DC

INTRODUCED BY DR. RICHARD HAEUBER

Dallas Burtraw serves as the Darius Gaskins Senior Fellow at Resources for the Future in Washington, DC. His work focuses on creating efficient and politically rational control of air pollution from the electricity sector, and he has written extensively on electricity industry regulation and environmental outcomes. Recently, he has written on the application of the Clean Air Act to reduce greenhouse gases and is conducting modeling on behalf of several states as they consider options for compliance with the Clean Power Plan. He has estimated the opportunities for efficiency improvements in the electric power sector and the distribution of cost of various approaches to emissions pricing. His research also assesses the benefits of regulation. He has studied approaches to regulation of nitrogen and sulfur dioxide in the US, and has conducted integrated assessment modeling of emissions from the power sector including health and ecosystem effects and valuation. He has studied the role for policy interactions including regional efforts within a national system and provided technical guidance in the design of regional cap-and-trade programs in the US. He has also examined the cost-effectiveness of emissions trading in the EU. Burtraw holds a Ph.D. in economics and a master's degree in public policy from the University of Michigan.

**BREAKOUT SESSION 1 (BLOCK A):
EMISSIONS OF AIR POLLUTANTS**

Session Chair: Dirk Felton, NYSDEC

[O1A-1] Long-term trends in air emissions reductions and corresponding policy in New York State, the United States and Canada

Presenter: Ona Papageorgiou, New York State Dept. of Environmental Conservation, Air Resource Div., 625 Broadway, 2nd Floor, Albany, NY 12233

Author(s): O. Papageorgiou and M. Barnes, New York State Department of Environmental Conservation, Division of Air Resources, Albany, NY

The New York State Department of Environmental Conservation (NYSDEC) has a decades-long history of protecting human health and the environment through air emissions regulations. Emissions data from point, area and mobile sources have been continuously collected and estimated to capture the emissions profiles and establish best policy practices. Regulatory and policy decisions are based on emissions and monitored data revealing where the greatest benefit may occur. The progress in air emissions reductions is evident when data trends in emissions profiles are compared with the NYSDEC monitoring network. Here we present policy actions and the corresponding long-term trends in sulfur dioxide (SO₂), nitrogen oxides (NO_x) as well as other air pollutants related to acid rain. Emissions monitoring programs in conjunction with long-term air emission trends highlight the success of clean air regulations targeting NO_x and SO₂ in New York, the United States and Canada.

[O1A-2] Elemental characterization and source identification of atmospheric particulate matter (PM_{2.5}) across major cities of Pakistan

Presenter: Jabir H. Syed

State Key Laboratory of Organic Geochemistry, Guangzhou Institute of Geochemistry Chinese Academy of Sciences Guangzhou 510640, China
Email: jabirshah100@yahoo.com

Author(s): Jabir H. Syed, Ishwar C. Yadav, Jun Li, Gan Zhang

State Key Laboratory of Organic Geochemistry, Guangzhou Institute of Geochemistry Chinese Academy of Sciences Guangzhou 510640, China

We conducted a first time detail survey to establish baseline levels and behavior of airborne pollutants in the urban centers across the country. Concentration and source apportionment of PM_{2.5} monitored at eight (8) major cities (Karachi, Lahore, Quetta, Peshawar, Rawalpindi, Multan, Faisalabad and Gilgit) across Pakistan have been reported in this study. PM_{2.5} aerosol samples were collected during July-Aug, 2014 on three consecutive days and nights for 12 hr duration on quartz fiber filters using a high volume sampler. A total of 48 samples were collected (6 from each city) and mass of PM_{2.5} was analyzed for organic and elemental carbon (OC/EC), water soluble ions (WSO) and heavy metals (HM) contents. Overall mean concentrations of PM_{2.5} for a day & night (24 hrs) were measured highest in Quetta (717 $\mu\text{g m}^{-3}$) and lowest in Gilgit (13.9 $\mu\text{g m}^{-3}$) while PM_{2.5} mass concentrations for day hours were recorded double than night hours. Daily mean concentrations of OC were measured maximum (20.2 $\mu\text{g m}^{-3}$) from Quetta city while black carbon average levels were found highest (4.27 $\mu\text{g m}^{-3}$) in the filter samples from industrial city i.e., Faisalabad. Among water soluble ions, SO₄²⁻, NO₃⁻ and NH₄⁺ were the most abundant ionic species, which are among the highest levels reported in the literatures in the world. Principle component analysis (PCA) revealed the emissions from local sources, e.g., fossil fuel consumption by motorized transport and power plants, farming, burning of agricultural residues, industrial and construction activities and regional secondary aerosol sources likely from coal and/or biomass burning contributed the major proportion of pollutants across the country.

[O1A-3] DIURNAL AND NOCTURNAL TRENDS OF ACID RAIN IN A MID-SIZED ANDEAN CITY. UNDERSTANDING VOLCANIC AND ANTHROPOGENIC SOURCES

Presenter: Carlos Mario González, Universidad Nacional de Colombia Sede Manizales, cmgonzalezd@unal.edu.co

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Contribution of anthropogenic and volcanic SO₂ emissions in the formation of acid rain in the Andean city of Manizales, Colombia, were analyzed in terms of diurnal and nocturnal profiles of acid rain. Manizales is a densely populated city located on the western slopes of the central range of the Andes (urban population 367000; urban area 54km²; 2150 m.a.s.l). Two local sources of pollutants are important in Manizales: Emissions from fuels in a city with high vehicular ownership (254 vehicles per 1000 inhabitants), and industrial activity due to thermal processing of wastes, metal recycling and food processing. Local climate in the city is characterized by low wind speed (below 4 m/s) and high annual rainfall (1870 mm/yr). In a regional context, there is the influence from an active volcano (Nevado del Ruiz); a natural source of sulfur species and ash located 28 km away from urban zone. Prevailing winds follow diurnal air flow regimes –upslope during the day, downslope during the night. The nocturnal pattern of air movement is important for possible transport of sulfur gas emissions from Nevado del Ruiz volcano.

Previous studies showed the presence of acid rain in Manizales (mean VWM-pH levels around 4.9 units). However, the lack of information regarding dynamics of anthropogenic and volcanic emissions (fluxes and dispersion patterns), makes difficult the comprehension and characterization of acid rain phenomenon. In order to understand sources and dynamics of acid rain formation, rain samples were taken during one year for different day/night periods. Acidity, sulfate and nitrate concentration profiles were analyzed and compared with meteorological information in terms of precipitation and wind patterns. Results revealed two different patterns of acidity and ion concentrations, with higher levels during daytime periods. High sulfates content in rain with respect to nitrates suggested higher influence of sulfur gases in acid rain formation.

[O1A-4] Spatio-temporal variability in isotopic signatures of atmospheric NO_x emissions from vehicles

Presenter: David J. Miller, Brown University, david_j_miller@brown.edu

Author(s): David J. Miller, Brown University, Paul Wojtal, Brown University, Mary O'Connor, Brown University, Meredith G. Hastings, Brown University

Atmospheric nitrogen oxides (NO_x = NO + NO₂) play key roles in atmospheric chemistry and radiative forcing. Their oxidation products, nitric acid or nitrate, have significant contributions to acid deposition, with implications for ecosystem health. On-road vehicle NO_x sources currently dominate U.S. anthropogenic emission budgets, yet vehicle NO_x emissions have uncertain contributions to regional nitrogen deposition patterns. NO_x isotopic signatures offer a potentially valuable observational tool to trace vehicle source impacts on regional acid deposition. We characterize the spatio-temporal variability of vehicle NO_x emission isotopic signatures using a field and laboratory-verified technique for actively capturing NO_x in solution to quantify the nitrogen isotopic composition ($\delta^{15}\text{N-NO}_x$) to within $\pm 1.5\text{‰}$ (1σ) precision. We present novel on-road mobile and stationary urban $\delta^{15}\text{N-NO}_x$ measurements at minutes to hourly resolution to evaluate regional source gradients on U.S. Northeast and Midwest highways during summer and fall seasons, as well as on-road and urban background diurnal variations in Providence, RI. We observe on-road $\delta^{15}\text{N-NO}_x$ signatures are negative and span a narrow range (-6‰ to -10‰), even for differing traffic conditions in the U.S. Northeast. Diesel truck route on-road $\delta^{15}\text{N-NO}_x$ measurements have more negative values than those on gasoline vehicle dominated routes. Roadside $\delta^{15}\text{N-NO}_x$ measurements conducted at sub-hourly resolution range from -3‰ to -8‰ and are impacted by dilution with urban background NO_x. We use these observations to estimate the range of representative $\delta^{15}\text{N-NO}_x$ source signatures for U.S. vehicle fleet-integrated roadway emission plumes. Our novel approach suggests that previously reported isotopic signatures for vehicle NO_x are not necessarily representative. These results have important implications for evaluating isotopic signature ranges for distinguishing vehicle NO_x sources and tracking their contributions to regional acid deposition.

[O1A-5] Characterization of United States Atmospheric Emissions: Current, Past and Future Conditions

Presenter: Richard Scheffe, U.S. Environmental Protection Agency

Author(s): R.Scheffe, V. Rao, J. Drukenbrod, M. Strum and M. Houyoux
U.S. Environmental Protection Agency

Over two decades of progress in reducing emissions from the two major anthropogenic contributors of inorganic gases, power generation and transportation, has lead` to dramatic changes in the relative contributions and importance across major source sectors. Consequence of this progress, anticipated to continue for at least another decade, are resulting in challenges associated with properly accounting for emissions of largely uncontrolled sources, such as wildfires, biogenics and agricultural operations, which now dominate atmospheric loading relative to anthropogenic sources. Looking ahead, expected, yet unknown, modifications in United States energy policy driven by technological changes and possible consideration of climate change will dramatically impact future profiles of emissions three or more decades from now. In the near term, major inorganic gases will continue to decline significantly pending implementation of EPA's rules addressing Mercury and Air Toxics (MATs) and cross-state pollutant transport.

**BREAKOUT SESSION 1 (BLOCK B):
STATUS AND TRENDS OF SURFACE WATER
CHEMISTRY - I**

*Session Chair: Donald Monteith, NERC Centre
for Ecology & Hydrology*

Session Co-Chair: Kevin Civerolo, NYSDEC

[O1B-1] Status and trends in surface water acidification: Where in the world are we?

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Trends in the key variables influencing surface water acidification in North America, Europe and Asia present a contrast in current status. Emissions declines (beginning ca. 1970), and resulting decreases in deposition, have produced wildly successful changes in sulfate concentrations in lakes and streams across North America and Europe; declines of more than 75% are not uncommon. More recently, nitrogen deposition has also strongly declined and is perhaps responsible for widely observed decreases in surface water nitrate. Sustained chemical recovery (decreases in acid neutralizing capacity, gran alkalinity and pH; increases in DOC) has now been observed throughout both continents. As combined deposition at individual sites nears or falls below projected critical loads, much of the scientific effort currently underway is aimed at refining the critical load calculations, examining assumptions, and contrasting chemical vs. biological recovery.

In contrast, sulfur emissions (and presumably S deposition) have declined for a much shorter time period in China. Data from sensitive surface water sites in southeastern China suggest that sulfate will respond rapidly to declining S deposition, but long time series of surface water chemistry are only now being developed. Nitrogen and calcium deposition also play important roles in acidification in China, but it is not possible to describe trends in any of the key variables of surface water acidification and recovery. Instead, much of the work focusses on quantifying loads, characterizing soil and surface water sensitivity, and elucidating how sulfur, nitrogen and calcium are processed in sub-tropical soils, so that critical loads models can be adapted or developed for application in China.

[O1B-2] High quality long-term monitoring: Swedish experiences with assessments of surface water acidification and recovery

Presenter: Jens Fölster, Swedish University of Agricultural Sciences,
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Author(s): Jens Fölster, Martyn N. Futter, Richard K. Johnson and Anders Wilander, Swedish University of Agricultural Sciences,

Surface water acidification and recovery are long term processes related to changing deposition but confounded by climatic variation and land management including forestry. Credible trend assessment needs long term, high quality time series with consistent collection, analysis and management protocols so as to separate changes due to acidification from other sources of variation. The Swedish example of 50 years of freshwater monitoring shows how such data can be obtained and can serve as an example for surface water monitoring programs in other countries and regions.

The program started with strong cooperation between scientists and society to address pressing concerns related to surface water eutrophication. When acidification came up as environmental issue in the 1970s, it was apparent that the original focus on monitoring large lakes and river mouths had to be widened to include smaller lakes and streams.

Today the program holds hundreds of time series of water chemistry with up to 50 years of continuous data. Sampling, analysis and data storage have been performed by the same unit personnel throughout the years. International scientific review helped to ensure program rigor and relevance. Participation in international networks within e.g. UN-ECE LRTAP convention, has led to quality improvements by laboratory inter-calibrations as well as cooperative publications in high ranked journals. Open access to all data for both scientists and authorities has further contributed to improving data quality and to comprehensive use of the data. Time series have been used to demonstrate recovery from acidification and are an important resource for model calibration as well as assessments of the effectiveness of emission control and liming programs.

Reference:

Fölster, J., R.K. Johnson, M.N. Futter, A. Wilander (2014). "The Swedish monitoring of surface waters: 50 Years of adaptive monitoring." *Ambio* 43: 3-18.

[O1B-3] Long-term sulphur and nitrogen input-output budgets in European forested catchments (1990-2012)

Presenter: Jussi Vuorenmaa, Finnish Environment Institute,
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Empirical scientific evidence based on environmental monitoring is essential for evaluating the ecosystem benefits of costly emission reduction policies, and a long-term integrated environmental monitoring approach including physical, chemical and biological variables is needed. The multidisciplinary International Cooperative Programme on Integrated Monitoring (UNECE CLTRAP ICP IM) studies the ecosystems effects of air pollution and climate change in undisturbed forested catchments. We calculated site-specific annual input-output budgets for sulphate and total inorganic nitrogen (TIN = NO₃-N + NH₄-N) and analysed temporal trends for input (deposition) and output (runoff water) fluxes and for net retention/release of sulphate and TIN at 17 European ICP IM sites in 1990–2012. Large differences in input and output fluxes of sulphate and TIN were observed between the different sites, with the highest values at sites in southeastern Scandinavia, central and eastern Europe and lowest values at more remote sites in northern regions. Total sulphate and TIN deposition have significantly decreased at 90% and 65% of the sites, respectively. Sulphate output fluxes also clearly decreased, being significant at 60% of the sites. TIN fluxes in runoff showed mixed response with both decreasing and increasing trends, but fluxes were decreasing rather than increasing. Input-output budgets for sulphate showed a net retention in the early 1990s, but since the late 1990s most of the catchments shifted from retention towards net release. This indicates that forest soils are now releasing stored airborne sulphur that had accumulated in the past. TIN showed a mixed response with increasing or decreasing retention, but generally TIN is still strongly retained in the catchments. These results confirm the effects of emission reduction measures, but clear responses were not observed at all sites. These processes are also sensitive to changes in climatic variables, and further monitoring of mass balance budgets is thus needed.

[O1B-4] Recovery of stream water from acidification due to declining S deposition in a Japanese cedar forest near the Sea of Japan

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Japan has historically suffered from a large atmospheric deposition of sulfur and nitrogen (S and N), derived from domestic emission sources in the 1960s–1970s, and transboundary air pollution from the Asian continent since the 1980s. The deposition of non-sea salt (nss) SO_4^{2-} and other major ions is known to increase significantly in winter due to seasonal west winds on the Sea of Japan coast, which suggests a long-range transportation of air pollutants. We have been measuring deposition by rainfall outside the forest canopies (RF) and throughfall and stemflow (TF+SF), and stream water (SW) chemistry in a Japanese cedar plantation near the Sea of Japan, Central Japan, since 2002. Over the last decade, the mean annual deposition of SO_4^{2-} and N by TF+SF was 28 kg S ha⁻¹ year⁻¹ and 16 kg N ha⁻¹ year⁻¹, respectively. The SO_4^{2-} deposition by TF+SF significantly declined during the observation period (2002–2013). Moreover, nss- SO_4^{2-} deposition by TF+SF peaked in 2006 and started to decline thereafter. The latest S emission inventories in China showed a similar trend; therefore, the observed deposition likely reflects on the general emission trend. Accordingly, SO_4^{2-} concentrations in SW declined with an increasing alkalinity. In fact, the weighted mean SO_4^{2-} concentrations in SW were significantly correlated with annual SO_4^{2-} deposition. The SW in the study forest may be recovering from acidification due to a decline in SO_4^{2-} deposition. An isotopic analysis of S suggested that the S deposited from the atmosphere was once retained in the forest and then gradually flowed into SW. This retention-release cycle likely changes with the atmospheric input of S. In contrast, no clear trend was observed for N deposition. However, since NO_3^- concentration in SW has been increasing continuously, N saturation may progress gradually with maturation of the trees in the study forest.

[O1B-5] Is surface water acidification a serious regional issue in China?

Presenter: Ting Zhang, Tsinghua University, zt99964@126.com

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Following Europe and North America, East Asia, mainly China, became the global hotspots of acid deposition, with very high deposition of both sulfur (S) and nitrogen (N) occurring in large areas in the southwest and southeast. Although surface water acidification used to be a serious regional environmental issue, as a result of acid deposition, in Northern Europe and North America, the issue has not been widely detected in China. A regional survey of about 100 small streams in forested catchments in southwest and east west China in recent years indicated that most of the sampled streams were basic (with pH no less than 7.0), even with acid soil (mainly Haplic Acrisol) in the catchments. The sulfate concentrations of these streams were quite low (most lower than 0.5 mg/L), especially in southeast China. In contrast, the nitrate concentrations were commonly higher than 1.0 mg/L. These results showed greater contribution of nitrogen deposition than sulfur deposition to surface water acidification. However, both sulfate and nitrate concentrations were usually much lower than those expected on the basis of rainfall chemistry, which implied the occurrence of large sinks of sulfate and nitrate in soil. Adsorption in the acid soil and denitrification may be one important sink of sulfate and nitrate respectively. Therefore, surface water acidification is not a serious regional issue in China.

**BREAKOUT SESSION 1 (BLOCK C):
CRITICAL LOADS: A BRIDGE BETWEEN
SCIENCE AND POLICY**

*Session Chair: Tamara Blett, National Park
Service*

[O1C-1] When is a Critical Load for N Deposition Critical?

Presenter: Kevin Hicks, Stockholm Environment Institute (SEI), University of York, UK, kevin.hicks@york.ac.uk

Author(s): Mike Ashmore, SEI, University of York, UK, Carly Stevens, Lancaster University, UK and Roland Bobbink, B-WARE BV the Netherlands, Laurence Jones, CEH Bangor, UK

The critical load approach was originally designed as a broad guideline to thresholds for adverse effects of air pollution on terrestrial ecosystems at regional (European) scale under the UNECE Convention on Long Range Transboundary Air Pollution (LRTAP). In an effort to protect Natura 2000 sites for the conservation of natural habitats and of wild fauna and flora in Europe under the Habitats Directive of the European Commission critical loads have been employed at more local scales to assess permitting applications for industrial installations. In terms of risks to a site from further pollution burden, and adopting a fair and reasonable approach to protection and permitting, these decisions need to be made along with the understanding that a significant proportion of all protected sites may already be predicted to exceed their critical loads for nutrient nitrogen (N) and/or acidity (and in some cases critical levels) as a result of existing levels of air pollution. This raises a key question: if there is already an identified risk of harmful effects from air pollution (i.e. predicted critical level or load), what (if any) additional air pollution arising from a new installation is acceptable? This paper presents the results of a study that assessed the availability of reliable dose-response data in the Europe which could be used to assess the implications of exceedance of the critical load for nutrient N in terms of species numbers. The study used empirical critical loads and levels for N which are based on observed botanical responses in field studies and experiments. In some cases there is evidence for a threshold above the minimum critical load for grasslands when considering point sources of ammonia. The limitations and implications of this result are discussed, for example, some adverse effects can occur before any species are lost.

[O1C-2] What is left to for researchers in acid rain research: A review of state-of-the-art assessment effects-based research and modelling

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40 years after the 1975 Columbus, Ohio acid rain conference, and 39 years after the 1976 Stockholm conference on acid rain, and 23 years after the 1988 Skokloster Workshop on critical loads, with a number of sulphur, nitrogen, ozone, particles and heavy metal protocols in place in Europe under the ECE/LRTAP convention, Europe can see significant improvements in environmental conditions in a number of areas where damage was earlier seen to lakes, rivers, forests and open land vegetation, as well as significant effects on human health. Effects-based field research cooperated with integrated modelling and with countermeasure optimization with integrated assessment modelling for Europe. However, still a number of issues remain, and remain to be solved. The acid rain policies can now be seen to suffer from a post-success syndrome, where it becomes difficult to complete the process because the political policies are being mistaken for actions being done. The problems of acidification and air pollution related nitrogen pollution have been drastically reduced in the most affected areas of Europe and North America, but the job is still only half done for nitrogen and airborne particles and three quarters done for acidification. At the same time, air pollution with acidification and nitrogen excess is being seen in other parts of the world with strongly developing economies. The author addresses some of the remaining issues, and how the modelling and the field experiments should continue to support transferring the success of critical loads approach to those other areas. The effects-oriented assessment models have shown extraordinary good success in supporting policy development, but these will risk failure unless the work is continued to completion.

[O1C-3] How much is too much? Regulating industrial emissions in northwest British Columbia, Canada

Presenter: Patrick Williston, British Columbia Ministry of Environment, patrick.williston@gob.bc.ca

Author(s): Patrick Williston, British Columbia Ministry of Environment; Julian Aherne and Shaun Watmough, Environmental and Resource Studies, Trent University; Dave Marmorek, Carol Murray, Alexander Hall, and Patricia de la Cueva Bueno, ESSA Technologies Ltd.; Anna Henolson, Trinity Consultants Inc.; and John Laurence, Consulting Plant Pathologist

Northwest British Columbia, Canada, a sparsely populated and largely natural region, is targeted for rapid industrial growth owing to development of a smelter and multiple proposed liquefied natural gas (LNG) export facilities. Consequently, the air quality in this region may experience considerable increases in contaminant loadings within the next decade. This is in contrast to many regions of the world where emissions management is leading toward decreased loadings. The Kitimat and Prince Rupert airsheds, for example, include permitted and potential industrial emissions ranging from approximately 42–98 t/d of sulphur dioxide (SO₂) and nitrogen oxides (NO_x). To ensure ecosystem integrity, an effects-based approach was used to assess and regulate industrial air emissions of SO₂ and NO_x. The central question was to better understand how much (SO₂ and NO_x) is too much in advance of potential impacts. Critical levels and loads of acidity and nutrient nitrogen were determined to identify vegetation, water bodies and forest soils at risk of exceedance under newly proposed industrial emissions, and the approach has been incorporated into the development of regulatory triggers for emissions reductions in support of permitting. While beneficial for estimating emissions levels that are protective of the environment, the critical loads approach has exposed policy and data gaps that are challenging to address. A comparison between the neighboring Kitimat and Prince Rupert airsheds demonstrated important differences including biophysical and climatic characteristics, current and predicted emissions chemical profiles, patterns of deposition, and receptor sensitivities. Despite challenges, critical levels and loads have been used to develop guidance tools for environmental assessment in British Columbia.

[O1C-4] Critical loads exceedance and relative risk maps based on the simulated S and N depositions over the past 25 years in Japan

Presenter: Naoyuki Yamashita, Asia center for air pollution research, nyamashita@acap.asia

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S and N emissions in East Asia have increased since 1980s. Also in Japan, S and N depositions increased from the 1980s to the 2000s due to the increase in emission in China, whereas local S emissions have substantially declined since the 1980s. This may significantly affect the spatial pattern of the depositions in Japan during past several decades; the high depositions area was extended from pacific side to the Sea of Japan side. Nevertheless, a spatial assessment of acidification risk for the ecosystems has not been updated in Japan. In particular, critical load map of acid deposition has not been published at national scale since the late 1990s. Our objectives were 1) to propose new relative risk map (acid-sensitivity map) for acidification, which was weighted by the cumulative acid deposition simulated for the past 25 years, and by the sensitivity of the soil and bedrock to acid deposition, 2) to update critical loads map of sulfur and nitrogen (acidity and N leaching) based on the new scientific knowledge since 2000s, and 3) to calculate the exceedance of both critical loads by simulated S and N depositions in the 1980s and the 2000s. In the new risk map of the acidification, high-risk areas commonly occupy large areas of central Japan and western Japan along the Sea of Japan. In the risk map using a weighted overlay for cumulative acid deposition and only bedrock sensitivity, the high-risk areas corresponded to 73% of all rivers for which a decline trend in the pH was observed from 2001 to 2009. Exceedance of the critical loads for S and N and changes in the area with the exceedance from the 1980s to the 2000s are discussed with the risk map and the symptoms of acidification or N leaching reported in field observation.

[O1C-5] Lichen critical loads for atmospheric nitrogen and sulfur deposition in forests of the United States

Presenter: Linda Geiser, USDA Forest Service, lgeiser@fs.fed.us

Author(s): Linda Geiser, USDA-Forest Service, Watersheds, Fish, Wildlife, Air & Rare Plants, Washington D.C.; Heather Root, Weber State University, Ogden, Utah; and Sarah Jovan, USDA-Forest Service, Pacific Northwest Research Station, Portland, OR

Critical loads identify air pollutant loadings below which no adverse effects are known to occur to particular ecosystem components. Understanding critical loads for multiple taxa provides a scientific basis for air-resource related decision-making. We derive empirical nitrogen and sulfur critical loads for epiphytic macrolichens, a sensitive component of forested ecosystems. We used the Forest Service Forest Inventory and Analysis lichen community protocol data and Community Multi-scale Air Quality modeled sulfur deposition from 9,000 sites in the continental US and Alaska. We plotted deposition vs. detection frequency of individual species and rated species sensitivity as the deposition at peak detection frequency. To calculate site scores, we averaged the abundance-weighted sensitivity ratings of the species present. Community level surface response curves to sulfur deposition for the eastern and western US were modeled using Hyperniche and 9-12 pollution, climatic, forest structure, and location variables. Pollution favored smaller, more compact eutrophic species at the expense of larger, leafy and pendant green algal and cyanolichens with higher ecological value. This effect was enhanced by warmer, drier climates. Detection probabilities of approximately 25% of species decreased above 0.80 kg N/ha/y and 0.7 kg S/ha/y in the west and 4.2 and 2.5 in the east. Community level shifts favoring tolerant over sensitive species were observed above 1.5 kg N and 0.7 kg S in the west, and 4.2 kg N and 2.5 kg S in the east. However due to the paucity of clean sites in the East, we recommend a single critical load for the US for sulfur equivalent to the western values. Because species within forest ecosystems are interdependent, exceedances of lichen critical loads are expected to adversely affect many tree-dwelling invertebrates, small mammals, birds and ungulates that use them as habitat, nesting materials, and forage.

**BREAKOUT SESSION 2 (BLOCK A):
DEPOSITION OF AIR POLLUTANTS - I**

Session Chair: Jason Lynch, US EPA

*Session Co-Chair: George Lin, National Central
University, Taiwan*

[O2A-1] Observed and modelled trends in atmospheric concentrations and wet deposition of sulphur and nitrogen in EMEP, 1990-2012

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European-scale harmonized monitoring of atmospheric composition was initiated in the early 1970s, and the activity has generated a comprehensive dataset, which allows the evaluation of regional and spatial trends of air pollution during a period of more than 40 years. Here, we present an overview of the observed and modelled trends in wet deposition and air concentrations of sulphur and nitrogen species in Europe from 1990-2012 from the European Monitoring and Evaluation Programme (EMEP). About 20 sites have measurements of air components for the complete period, while 40 sites have long-term observations of precipitation chemistry.

Observed and modelled average concentrations in air and wet deposition of sulphur show a substantial decrease. More than 90% (Mann Kendall, $p < 0.05$) of the sites show significant decreases for all species. There is a larger decrease in SO_2 than in SO_4^{2-} . The mean annual reduction of SO_2 is about 4% (Sen slope relative to 1990) in both model and observed concentration, while for sulphate in aerosol and precipitation around 3% decrease per year. The modelled trend of sulphate is slightly larger than the trend in the observation.

For observed and modelled oxidized and reduced nitrogen species there is also a decreasing trend, though less substantial than for sulphur. Significant decreases are observed at about 50% of the sites depending on component, higher percentage of significance of modelled sites. The mean annual reductions in wet deposition of total nitrogen ($\text{NO}_3^- + \text{NH}_4^+$) is about 1% decrease per year for the observed deposition, somewhat higher for the model results. The trend is slightly larger in oxidised nitrogen than for reduced nitrogen.

[O2A-2] Atmospheric abundance of reactive nitrogen species over Indo Gangetic plains (India)

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In India around 70 % of population lives in villages taking care of agriculture to meet the demand of food supply. In order to get higher yield of agriculture and food product, increased practice of fertilizer application has added extra load of nutrients especially the reactive nitrogen (Nr) species viz NH_3 and NO_x . Growing energy demand has resulted in increased emission of NO_x from coal combustion in thermal power plant and the petroleum combustion in transport sector. In addition, biomass burning in traditional cooking and heating is also a significant source of NO_x in Indian region.

Significance of the study lies in the fact that increasing Nr emissions have adverse impact on human health, plant, soil and water bodies directly and to see the effect, knowledge of emission and deposition for Nr at different sites should be there.

Considering the implications of these two species (NH_3 and NO_x) in changing N cycle, the present study was carried out in Indo Gangetic plains (IGP) at two sites of different characteristic (urban and rural) to study the emissions and atmospheric levels in relation to their sources and role of meteorological parameters. Study presents seasonal and diurnal variations of gaseous reactive nitrogen species at urban & rural sites to observe the contribution of different sources of atmospheric Nr. Atmospheric abundance of two major gaseous inorganic (Nr) species i.e NH_3 and NO_2 has been measured for one year, on monthly basis. Average concentrations of NH_3 at urban and rural site have been recorded as 40.4 ± 16.8 and $51.57 \pm 22.8 \mu\text{g}/\text{m}^3$ respectively. The average concentrations of NO_2 have been recorded as 24.4 ± 13.5 and $18.8 \pm 12.6 \mu\text{g}/\text{m}^3$ at urban & rural site respectively. Dynamics of Nr at both sites will be discussed in details at the conference.

Key words: Reactive nitrogen, ammonia, nitrogen dioxide, agriculture, urban air

[O2A-3] Long-term trends in atmospheric deposition across France: Drivers, forecasts and impacts

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Atmospheric deposition is a potential fate of a wide range of atmospheric pollutants and of its impact on ecosystems. The analysis of the long term behavior of atmospheric deposition is relevant to study source-receptor relationships. This work aim at identifying the drivers and the environmental impacts of the atmospheric deposition changes over the last two decades in France. Different advanced statistical approaches were applied on the databases of three French background monitoring networks: MERA/EMEP, CATAENAT/ICPForests and BAPMoN/GAW including 37 sites. Northern sites had higher concentrations of anthropogenic derived compounds (nssSO_4^{2-} , NO_3^- , NH_4^+ and H^+) from source areas mainly located in Northern and Central Europe. A significant downward trend was observed for nssSO_4^{2-} concentrations according to the decrease in SO_2 emissions, while no clear change appeared for NO_3^- concentrations. However, the current decrease of base cations deposition limits the soil buffering capacity. As a consequence, the acidification process remains an issue especially for some sensitive areas such as the Landes forest or the southern of the Massif Central. A predictive model was built using historical data with precursor emissions and rainfall as explicative variables. Based on 4 climatic scenarios and the EU emission reduction objectives, the predictions indicate a probable 50% decrease in nssSO_4^{2-} deposition over the period 2020-2040 relative to the period 1990-2008, but no change in NO_3^- and a slight increase in NH_4^+ depositions. Finally, our results showed that the density of measurement sites over the French territory was strong enough to create maps of deposition fluxes, which is a reliable tool to assess chemical transport models. The comparison with the EMEP/MS-CW model points out some discrepancy areas, especially in Mediterranean region for NO_3^- atmospheric deposition and in the western part of France for NH_4^+ atmospheric deposition.

[O2A-4] Spatial and temporal patterns in air and rainfall pollutant concentrations measured over the UK during the last 30 years

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The UK through Defra has supported a number of rural air quality networks measuring gas, rainfall and aerosol concentrations across the country (e.g. UKEAP: AGANet, NAMN, Precip-Net, Rural NO₂). The site numbers vary between networks with usually around 20-30 sites to cover a land area of almost 250000 km², and the longest runs of data are for rainfall ion concentrations at some sites in Precip-Net which were set up in 1986. These observational data are used to generate spatial maps of concentrations that then feed into estimates of pollutant deposition to the land surface, forming one element of the emission/deposition budget for the country.

Fowler et al (2005) showed that clustering sites exhibiting similar patterns of change provided regional scale trends for rainfall ion concentrations that showed statistically significant trends between regions and helped in the interpretation when individual site trends were generally harder to interpret. Multivariate spatio-temporal model-based estimation and other recent statistical developments following the work of Cressie and Wikle (2011) allow much improved estimation of non-linear trends over time, better modelling of the spatial processes that produce the concentration maps, and a significant improvement in the estimation of the uncertainties. As air and precipitation chemistry trend data increasingly show non-linearities in the emission-exposure-deposition relationships, improved statistical methods will become more important to define the spatial patterns.

[O2A-5] Spatial and temporal variation of the acid rain in the Mexico City Metropolitan Zone

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In Mexico City Metropolitan Zone (MCMZ) in the mid-1980s, particles and sulfur dioxide were presented as main atmospheric pollutants; when seeking to reduce their emissions, the consumed fuel oil was replaced in Power Plants by natural gas; undoubtedly this action reduced the levels of these pollutants. In relation to acid rain, this phenomenon actually exists in the MCMZ, despite the fact that the sulphur dioxide levels in the atmosphere, currently does not present a problem, since their levels do not exceed the air quality standards.

The University of Mexico since the middle of the year 2002 is collaborating with the Federal District Government studying the atmospheric deposition in 16 sampling stations distributed in the MCMZ.

This paper presents the spatial and temporal variation of rain chemical composition since 2003 until 2014. The identified parameters were: pH, conductivity and ion concentration (Na^+ , NH_4^+ , K^+ , Mg_2^+ , Ca_2^+ , SO_4^{2-} , NO_3^- and Cl^-) by HPLC.

The pH decreases from North to South along the MCMZ, being the Southwest area where the lower annual volume weighted mean pH values were determined, obtaining a value of 3.8 in 2007. It was observed that sulfate concentration was majority with regarding other ions (35-60%) and its correlation with nitrate and hydronium ions increased in the Southwest area.

Sulfate and nitrate presented their major deposition in the West area. Therefore it is necessary to establish strategies for the reduction of acid rain precursor's emissions in the up wind sources that are outside the MCMZ and where strict measures for its reduction have not been implemented.

**BREAKOUT SESSION 2 (BLOCK B):
STATUS AND TRENDS OF SURFACE WATER
CHEMISTRY - II**

*Session Chair: Donald Monteith, NERC Centre
for Ecology & Hydrology*

Session Co-Chair: Kevin Civerolo, NYSDEC

[O2B-1] 35 years of upland water quality monitoring in the UK: Foreseen events, unforeseen events, non-events and extreme events

Presenter: Chris Evans, Centre for Ecology and Hydrology, cev@ceh.ac.uk

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Iain Malcolm, Freshwater Fisheries Laboratory, Marine Scotland.

When long-term catchment studies were established in the UK during the 1980s, there was a broad understanding of the role of atmospheric sulphur and to a lesser extent nitrogen as acidifying pollutants, and of the key soil mechanisms leading to acidity and aluminium leaching into surface waters. Since that time, S emissions in the UK have decreased by over 90%, leading to dramatic chemical recovery in many upland water bodies. It is now clear that this decrease in acid deposition has had profound consequences for the biogeochemical functioning of upland ecosystems, often over-riding the effects of other anticipated drivers of change such as land-management and climate. Some of these changes were not foreseen, most notably the general increase in dissolved organic carbon across large parts of Europe and North America, whereas some changes that were foreseen remain elusive, notably nitrogen saturation. Based on a range of data from the UK Upland Waters Monitoring Network, long-term paired catchment studies, and field experimental manipulations, we consider these foreseen and unforeseen changes, and the new mechanistic insights that have been gained from long-term monitoring as a consequence of the observations. In addition, we consider the role and impact of extreme events, in relation to both climate (extreme rainfall, drought and sea-salt deposition events), human activity (forest clearance), and the interaction between the two (wildfire). We argue that many of the observed responses to climatic extremes and land-use are both consistent with, and provide insights into, the biogeochemical functioning of catchments in response to changes in acid deposition. This suggests in turn that our ability to accurately predict the future impacts of drivers such as climate change and shifting land-use on upland ecosystems will benefit substantially from the understanding built up through decades of 'acid rain' research and the associated long term datasets that continue to develop. Policy and land-management decisions made in ignorance of these processes, or in the absence of supporting long-term monitoring data, risk aiming for outcomes that are not achievable, or of triggering unintended consequences for the status and functioning of terrestrial and aquatic ecosystems.

[O2B-2] Long-term monitoring in Kejimikujik National Park Nova Scotia reveals increasing aluminum concentrations in rivers

Presenter: Shannon Sterling, Dalhousie University, shannon.sterling@dal.ca

Author(s): Shannon Sterling, Dalhousie University
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Tom Clair, Dalhousie University
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Elevated aluminum levels in rivers is known to be toxic for aquatic species, in particular *Salmo salar*; however it was only recently aluminum has been identified as a potential threat to *Salmo salar* populations in South Western Nova Scotia, Canada (SWNS) (Dennis and Clair 2012). Previously, it was thought SWNS rivers contained enough DOC to render the aluminum in rivers inactive. A key remaining question is whether aluminum levels are declining following atmospheric pollution reductions. Here we make a first assessment of long term (1980-2011) aluminum concentration trends in three watersheds located in SWNS, as measured by weekly grab samples. Our results show that total aluminum levels have significantly increased from 1980-2011 in all three sites. Data also indicate that calcium levels have yet to recover even with declining concentrations of riverine sulfate. This new knowledge that aluminum is at toxic levels and is worsening will have implications for policy on acidification mitigation in SWNS; this is an urgent issue as the local salmon population numbers currently are declining to near extirpation levels.

[O2B-3] Patterns of nutrient dynamics in Adirondack lakes recovering from acid deposition

Presenter: Jacqueline Gerson, Syracuse University

Author(s): Charles T Driscoll, Syracuse University and Karen M Roy, New York State Department of Environmental Conservation

With decreases in acid deposition, nitrogen: phosphorus (N:P) ratios in lakes are anticipated to decline, decreasing P limitation of phytoplankton and potentially altering food web dynamics. This effect could be particularly pronounced in the Adirondack Mountains of New York, a historic hotspot for effects of acid deposition. In this study, we evaluate spatial patterns of nutrient dynamics in Adirondack lakes and use these to infer potential future temporal patterns. We calculated Mann-Kendall Tau correlations among total phosphorus (TP), chlorophyll a, dissolved organic carbon (DOC), acid neutralizing capacity (ANC), and nitrate (NO_3^-) concentrations in Adirondack lakes to evaluate the hypothesis that decreases in atmospheric N and S deposition will increase dissolved organic matter (DOM) inputs and subsequently decrease P limitation in freshwater ecosystems historically impacted by acidification. We also compared these changes among lake-watershed characteristics (e.g., seepage, chain drainage, non-chain drainage, thin glacial till, medium glacial till). We found that correlations were highly dependent upon the different groundwater flowpaths of seepage versus drainage lakes. Differentiations among till depths were also important in determining correlations due to water interaction with surficial geology. Additionally, we found low NO_3^- : TP values in seepage lakes compared to chain drainage lakes and headwater drainage lakes, implying a high likelihood of future shifts in limitation patterns for seepage lakes. With increasing DOC and decreasing NO_3^- coinciding with decreases in acid deposition, there is reason to expect changes in nutrient dynamics in Adirondack lakes. Seepage lakes may become N-limited, while drainage lakes may become less P-limited, both resulting in increased productivity. Long-term measurements of TP and chlorophyll a from the Adirondacks are needed to inform how future decreases in atmospheric N deposition influence trophic status of lake systems throughout the region.

[O2B-4] Delayed and variable recovery from acid deposition in Shenandoah National Park streams: A story of geologic history, long-term monitoring, and management of air and water resources

Presenter: Ami Riscassi, University of Virginia, alr8m@virginia.edu

Author(s): Ami Riscassi and Todd Scanlon, University of Virginia, and Jalyn Cummings, National Park Service, Shenandoah National Park

The Shenandoah Watershed Study (SWAS), a cooperative agreement between the University of Virginia and Shenandoah National Park (SHEN), was established in 1979 to provide increased understanding of hydrologic and biogeochemical changes that occur in response to acidic deposition and other ecosystem stressors. Decades of monitoring during a period of steadily decreasing acid deposition demonstrated that while acidity significantly declined in most U.S. waters, the southern Appalachian Mountain streams were a notable exception. Located south of the last glaciation, the soils in this region are older and more weathered, and therefore able to retain more sulfate, which slowly reaches the stream, offsetting any reductions in acid deposition. Additional analysis of long-term (1987-2011) streamwater chemistry trends within SHEN and surrounding watersheds revealed variability in responses are tied to bedrock composition. Declines in acid neutralizing capacity associated with base-poor bedrock indicate the susceptibility to episodic acidification remains a serious concern for the ecological health of these systems. These findings have been, and are currently, used by resource managers charged with protecting both air and water resources of the Park.

SWAS data coupled with SHEN's extensive record of atmospheric deposition, from one of most comprehensive air quality monitoring and research programs within the National Park System, show a complete picture of the non-linear and site-specific relationship between atmospheric deposition and aquatic chemistry. By sharing both Park air quality and SWAS water quality data with regulators through the air quality permitting process, National Park Service staff are able to provide the necessary information to argue against new air pollution sources in order to protect park resources from further deterioration. Together, the two park-based programs provide a rare wealth of data to state as well as federal regulators to help implement reductions of industrial sources of pollution and revise national air quality standards.

[O2B-5] Acid deposition and acidification of waters in South Africa

Presenter: Kari Austnes, Norwegian Institute for Water Research (NIVA), kari.austnes@niva.no

Author(s): Kari Austnes, Norwegian Institute for Water Research, Chris J. Curtis and Londiwe Khuzwayo, University of the Witwatersrand, and Stuart J. Piketh, North-West University

South Africa has the largest industrialised economy in Africa, with coal as the major energy source, giving substantial emissions of sulphur (S) and nitrogen (N). Data on wet and dry deposition of S and N are sparse, but indicate that deposition rates are comparable to those shown to cause acidification of European soils and waters. The limited data on effects of acid deposition on surface waters indicate that acid sensitive waters are fairly widespread. The objective of the AcidWater project is to provide the first systematic study of freshwater acidification in South Africa. Deposition, stream chemistry and invertebrate status are monitored in different regions of South Africa, covering gradients in deposition and sensitivity. Critical loads and exceedances will be estimated, and dynamic modelling (MAGIC) applied. Monitoring data collected so far indicate that pH is highest (~6.5) in the highly industrialised Highveld region and lower (~5.5) in the assumed more sensitive Waterberg region in the north-east, close to major coal-fired power plants. The pH was lowest (~4) in the less industrialised South-western Cape region, but this can partly be related to natural acidity (DOC concentration ~20 mg/l, compared to 2-3.5 in the other regions). Acid Neutralising Capacity (ANC) data are at present (June 2015) only available from the Waterberg region. Out of 29 sampled streams, 16 had ANC less than 50 $\mu\text{eq/l}$, of which three had ANC less than 20 $\mu\text{eq/l}$, indicating both acidified streams and streams at risk of acidification. Preliminary critical loads estimated for Waterberg streams are frequently low (~75% <25 $\text{meq/m}^2/\text{yr}$, depending on input parameters), which given present knowledge of deposition indicate that they are exceeded or nearly exceeded in many of the streams. The critical loads calculations also indicated that there is a need to adapt the methodology used to calculate critical loads to South African conditions.

**BREAKOUT SESSION 2 (BLOCK C):
LIMING TO PROMOTE ECOSYSTEM RECOVERY**

Session Chair: Gregory Lampman, NYSERDA

[O2C-1] Response of Stream Chemistry and Young-of-Year Brook Trout to Lime Applications in Acidified Tributaries to Honnedaga Lake

Presenter: Daniel Josephson, Dept. of Natural Resources, Cornell Univ., Ithaca, NY 14853

Author(s): Daniel Josephson¹, Clifford Kraft¹, Jason Siemion², Barry Baldigo², and Scott George², ¹ Department of Natural Resources, Cornell University, Ithaca, NY 14853, ² United States Geological Survey, New York Water Science Center, Troy, NY 12180

Despite decades of atmospheric acid deposition, a heritage brook trout population has survived in Honnedaga Lake in the Adirondack region of New York. Open-lake trap net catches declined throughout the 1970s, when brook trout were considered extirpated from the lake but survived in some circum-neutral tributaries. Amendments to the Clean Air Act in 1990 mandated reductions in sulfate and nitrogen oxide emissions. By 2000, brook trout had re-colonized the lake coincident with reductions in surface-water sulfate, nitrate, and inorganic aluminum. Brook trout are currently absent or at low densities in 78% of tributaries that are either episodically or chronically acidified with associated toxic inorganic aluminum levels ($>2 \mu\text{mol/L}$). The acidified nature of most tributaries was hypothesized to limit the distribution and abundance of young-of-year trout and the size of the adult brook trout population in the lake.

We are investigating the potential to accelerate the recovery of brook trout abundance through lime applications to tributaries. Water chemistry and young-of-year brook trout response to lime application was assessed in two episodically acidified tributaries. Early results show comparable increases in pH and decreases in inorganic aluminum in both tributaries; while young-of-year brook trout density increased 3-to-10 fold in one tributary but was not different in the other tributary. The differential response by young-of-year brook trout appears to be related to the amount of groundwater inputs and spawning activity specific to each tributary.

[O2C-2] Long-term effects of liming on fish in Swedish streams and lakes

Presenter: Kerstin Holmgren, Swedish University of Agricultural Sciences, Department of Aquatic Resources, Institute of Freshwater Research, Drottningholm, kerstin.holmgren@slu.se

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Thousands of Swedish lakes and rivers have been limed since 1977, at experimental scale until 1981, and then increasing to a large-scale national management action. The annual amount of limestone spread peaked at more than 200,000 tons during 1998-2002. As an adjustment to decreasing acidification, the amount of lime decreased and recently stabilized at about 120,000 tons per year. Standard sampling of fish assemblages in lakes and streams was an important part of monitoring the effects of liming. More than 1300 limed lakes were sampled with multi-mesh gillnets (EN 14757), and electrofishing (EN 14011) was done at 1029 sites in 669 rivers where liming occurred in the upstream catchment. Data from large-scale fish monitoring were quality assured and stored in nationally managed and publically accessible data bases, i.e. the National Register of Survey test-fishing (NORS) and the Swedish Electrofishing Register (SERS). We show the importance of long-term liming of acidified streams and rivers, for slowly achieving positive effects on fish populations and assemblages on a national scale. The proportion of limed stream sites with no fish decreased with time, and after more than 16 years this proportion was not significantly different between limed sites and non-limed reference sites with minimum pH > 5.4. Increasing trends were observed for species richness and for proportion of sites with presence of young-of-the-year fish, and it took between 13-16 years and more than 20 years, to approach values observed at reference sites. Abundance of brown trout (*Salmo trutta*), perch (*Perca fluviatilis*) and roach (*Rutilus rutilus*) increased at sites sampled both before and after liming. A similar national evaluation of long-term effects of liming on fish of acidified lakes is needed, and we will indicate how preconditions for evaluation differ between rivers and lakes.

[O2C-3] Use of the acid-base budget approach to monitor the acidification of soils and to evaluate the effect and the necessity of forest liming

Presenter: Martin Greve, Research Institute for Forest Ecology and Forestry (Rhineland-Palatinate), martin.greve@wald-rlp.de

Author(s): Joachim Block, Research Institute for Forest Ecology and Forestry and Willy Werner, Trier University

Acid atmospheric deposition is decreasing since the 1980s, mainly due to reduced sulfur dioxide emissions. But the input of acidic nitrogen compounds remains still at a high level. In Rhineland-Palatinate (Germany), where a high percentage of the forest area is located on poor soils with low buffer capacity, extensive liming actions were performed in order to compensate the negative consequences of the acid deposition. In 1988, three study areas with control plots and different liming treatments from 3 to 15 t dolomitic limestone ha⁻¹ were established to investigate the effectivity of liming regarding acid compensation and its impact on forest ecosystems.

Long term input-output nutrient and acid-base budgets were calculated based on the 24 years of measurements of deposition and seepage water. A detailed sampling of the forest stand allowed the calculation of the incorporated nutrients into the biomass and the acid load due to biomass increment. Base cation release due to mineral weathering was estimated by the model PROFILE.

The results show that over the whole observation period, the acid load exceeds the buffer capacity by base cations of the investigated forest ecosystems. Accordingly, higher release of aluminum and destabilization of clay minerals could be observed. Nitrate and sulfate output increased after liming treatment in different intensities for the three study plots, leading to higher acid load of the ecosystem compared to the untreated control plot. But the higher acid load was compensated by the carbonates of the dolomitic limestone resulting in a lower aluminum release.

The declining sulfate output by seepage water and the planned reduction of nitrogen emissions should lead to a long-term decrease in acid load and nutrient loss. The results show that until then liming is still required for forest stands on base poor soils to prevent further acidification and the destruction of clay minerals.

[O2C-4] Acid Rain Recovery via Alkali Road Runoff Channels

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Acidification of Brook Trout (*Salvelinus fontinalis*) streams represents a threat to fish production and recruitment in much of Pennsylvania. Pennsylvania's Mosquito Creek watershed, was once a premier wild Brook Trout fishery, but is now impacted by acid precipitation. Low solute concentrations, alkalinity <20 mg/L, confirm the watershed and its ecosystem are vulnerable to current and future acid deposition. Poor water quality is ubiquitous across the watershed during high flows, with Acid Neutralizing Capacity (ANC) values that are often negative and pH seldom exceeding 5.5 standard units (SU). Elevated total dissolved aluminum (AITD) levels observed during runoff events in the monitoring portion of this project have shown acid precipitation impairments. The Mosquito Creek Sportsmen's Association (MCSA) and its partners undertook remediation efforts within several sub-watersheds of basin. The project goal was to improve water quality and enhance the Brook Trout fishery. Pre-treatment monitoring and project design was followed by the placement of limestone materials along dirt and gravel roads or otherwise retrofitted into existing stormwater management systems. Sixty-one treatment systems were constructed and ten miles of road surface received limestone sand amendments. Following construction water quality and fisheries response monitoring efforts were advanced to evaluate treatment effectiveness. Treatment-induced improvement in pH, ANC, AITD, Calcium, conductivity, alkalinity and hot acidity were observed at all monitoring stations. Mean pH below treatments increased to 6.36 SU, from the control mean pH of 4.98 SU. Mean ANC increased from -3.82 to 192 meq/L. Fishery monitoring confirmed a positive response to treatments. A robust Brook Trout biomass was increase from 8.94 kg/ha to 38.74 kg/ha was observed. This project has successfully demonstrated that road based stormwater treatments may provide chemical and biological improvements in watersheds that are impaired by acid deposition.

[O2C-5] Long-term effects of forest liming on growth and vigor of northern hardwoods and associated changes in soil and foliage chemistry

Presenter: Robert Long, USDA Forest Service, rlong@fs.fed.us

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Sugar maple (*Acer saccharum* Marsh.) is a keystone species in the northern hardwood forest, and declines episodes have negatively affected the growth and health of sugar maple in portions of its range over the past 50+ years. A widespread decline event in the mid-1980s resulted in extensive sugar maple dieback and mortality across the unglaciated Allegheny Plateau in northern Pennsylvania. Long-term acidic deposition inputs were hypothesized to contribute to changes in sugar maple health. In 1985, a liming study was initiated to evaluate responses to a one-time application of 22.4 Mg ha⁻¹ of dolomitic limestone in four northern hardwood stands in Potter County, PA.

Sugar maple basal area increment (BAINC) increased significantly ($P \leq 0.05$) in limed plots from 1995 through 2008, crown vigor improved for limed trees from 1990 to 1999, and flower and seed crops were larger in limed plots than in unlimed plots. American beech (*Fagus grandifolia* Ehrh.) were unaffected by lime throughout the study. Black cherry (*Prunus serotina* Ehrh.), had reduced BAINC in limed plots compared with trees in unlimed plots and cumulative black cherry mortality was higher in limed plots (21.2%) compared with unlimed plots (6.1%).

By 2001, only 3 kg ha⁻¹ of lime remained undissolved while increases in exchangeable Ca and Mg, and pH continued through 2006 and as deep as 35-45 cm in the mineral soil. Sugar maple foliage from limed plots showed similar increases in Ca and Mg and decreases in Mn concentrations in 1995 and 2006. In a related retrospective soil study, we measured significant losses of Ca and Mg on a pool basis over 30 years (1967-1997) and increases in Al and pH through the soil profile. These results highlight long-term deposition impacts and the persistence of a single lime treatment that improved sugar maple growth and health.

**BREAKOUT SESSION 3 (BLOCK A):
DEPOSITION OF AIR POLLUTANTS - II**

Session Chair: Jason Lynch, US EPA

*Session Co-Chair: George Lin, National Central
University, Taiwan*

[O3A-1] Recent analysis of EANET data for trends and variability factor of wet deposition in East Asia

Presenter: Hiroaki Minoura, Asia Center for Air Pollution Research, Niigata, Japan, minoura@acap.asia

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Rapid economic developments of Eastern Asian countries have significantly change the status of air pollution in recent years. An increase in the emission quantity due to industrial development, a change in the quality of fuel for the purpose of improving the air pollution, substances in the atmosphere is changing complex. Recognizing the adverse effects of acid deposition and its transboundary nature, efforts have been made by countries in the East Asia and established the Acid Deposition Monitoring Network in East Asia (EANET) in 2000. The latest wet deposition data of 2013 for 53 monitoring sites of 12 counties in East Asia was analyzed in comparison with the past 5 years, and obtained the trends and variability factor. The pH of precipitation shows improvement trends to average 0.08 increase (0.6 ~ -0.8) was observed. This trend is significant in urban sites and rural sites, 27 sites showed increase and 4 sites showed decrease. On the other hand, mixed variation was seen in Remote site (increase in 10, decrease in 10). Temporal and spatial variation of sulfate, nitrate, and ammonium ions in precipitation and their relation with dry deposition concentrations and trace gases in addition to weather data will be discussed.

[O3A-2] Atmospheric Reactive Nitrogen in Rocky Mountain National Park

Presenter: Katherine B. Benedict, Department of Atmospheric Science, Colorado State University, kbenedic@engr.colostate.edu

Author(s): Yi Li, Department of Atmospheric Science, Colorado State University; Greg R. Wentworth, Department of Chemistry, University of Toronto; Yixing Shao, Department of Atmospheric Science, Colorado State University; Evelyn Bangs, Department of Atmospheric Science, Colorado State University; Bret Schichtel National Park Service/Cooperative Institute for Research in the Atmosphere; Jennifer G. Murphy, Department of Chemistry, University of Toronto; Jeffrey L. Collett, Jr., Department of Atmospheric Science, Colorado State University

The geography and meteorology of Colorado provide a unique but complex case to examine sources of nitrogen that influence Rocky Mountain National Park (RMNP). The Front Range of Colorado consists of an urban corridor with high population density and a variety of urban emission sources. Just to the east of the Front Range, land use changes to highly agricultural with many ranches, farms, and confined-animal feeding operations and lower population density. Understanding the degree to which these different sources are influencing RMNP is a challenge that motivated a 2014 measurement campaign in which gas, particle, and precipitation measurements of reduced and oxidized nitrogen compounds (ammonia, nitric acid, ammonium, and nitrate) as well as volatile organic compounds were collected as a means of identifying source tracers. Analysis of this dataset is supplemented by previous measurements made in RMNP in 2006, 2009, and 2010 to further our understanding of the sources of nitrogen deposition. Previous results indicate the importance of deposition of reduced nitrogen, especially ammonia, in RMNP. To further explore the impacts of ammonia, additional measurements from the eastern plains to the Front Range of Colorado provide insight into the spatial variability of ammonia concentrations and the potential for plumes of high concentrations of ammonia to reach RMNP. The bi-directional nature of ammonia atmosphere-surface exchange is also of great interest and we will consider how ambient contributions of ammonia within RMNP are influenced both by transport from outside park boundaries and by local ammonia emission/re-emission.

[O3A-3] The Increasing Importance of Deposition of Reduced Nitrogen in the United States

Presenter: Jeff Collett, Colorado State University, collett@atmos.colostate.edu

Author(s): Jeff Collett, Colorado State University, Yi Li, Colorado State University, Bret Schichtel, National Park Service, John Walker U.S. Environmental Protection Agency, Donna Schwede, U.S. Environmental Protection Agency, Doris Chen, U.S. Environmental Protection Agency, Chris Lehmann, Illinois State Water Survey, Melissa Puchalski, U.S. Environmental Protection Agency, and David Gay, Illinois State Water Survey

Rapid development of agricultural activities and fossil fuel combustion in the United States led to a great increase of reactive nitrogen (Nr) emissions in the second half of the twentieth century. These emissions have been linked to excess nitrogen (N) deposition in natural ecosystems through dry and wet deposition pathways. U.S. efforts to reduce NO_x emissions since the 1970s have substantially reduced nitrate deposition, as evidenced by decreasing trends in long-term wet deposition data. These decreases in nitrate deposition along with increases in deposition of wet ammonium deposition have altered the balance between oxidized and reduced nitrogen deposition. Across most of the U.S., wet deposition has evolved from a nitrate dominated situation in the 1980s to an ammonium dominated situation in recent years. Because ammonia has not been a regulated air pollutant in the U.S., its historical measurement has not been common. Recent measurement efforts, however, provide a more comprehensive look at ammonia concentrations across several regions of the U.S. These data, along with more routine measurements of gas phase nitric acid and fine particle ammonium and nitrate, permit new insight into the balance of oxidized and reduced nitrogen in the total (wet + dry) U.S. inorganic reactive nitrogen deposition budget. Utilizing two years of N-containing gas and fine particle observations from 37 monitoring sites across the U.S. and assuming an ammonia dry deposition velocity equal to 70% of the modeled nitric acid deposition velocity, we estimate that reduced nitrogen contributes, on average, approximately 65 percent of the total inorganic N deposition budget. Dry ammonia deposition plays an especially key role in N deposition compared with other N deposition pathways, contributing from 19% to 65% in different regions. The sensitivity of these values to a bidirectional treatment of ammonia surface-atmosphere exchange will be discussed, but the broad picture remains unchanged. With reduced N species now dominating the wet and dry reactive N deposition budgets in much of the country, the U.S. will need to consider ways to reduce ammonia emissions if it is to continue progress toward reducing N deposition to sustainable levels defined by ecosystem critical loads.

[O3A-4] Assessment of precipitation chemistry at regionally representative sites in the interior of South Africa

Presenter: Pieter Gideon van Zyl, North-West University at Potchefstroom, South Africa, pieter.vanzyl@nwu.ac.za

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South Africa is the economical hub of southern Africa and is regarded as an important source region of atmospheric pollutants. An intense nitrogen dioxide (NO₂) hotspot is clearly visible from space over the South African Mpumalanga Highveld, while South Africa is also regarded as the 9th largest atmospheric sulphur (S) emitting country. Notwithstanding the importance of South Africa and the need for long-term monitoring programs, very limited data has been published on the chemical composition of precipitation for this region. In this presentation, the chemical composition and wet deposition determined for rain samples collected from 2009 – 2014 at four South African IDAF (IGAC DEBITS Africa) sites are presented and discussed, as well as compared to previous precipitation chemistry reported at these sites. These sites are considered to be regionally representative of the north-eastern interior (that also include the NO₂ hotspot) where the major anthropogenic emission sources in South Africa are situated. The annual volume weighted mean indicated that the concentration of anthropogenically associated species were much higher at two sites in close proximity of anthropogenic activities, while the concentrations of maritime and terrigenous species were higher at the two sites not directly impacted by major anthropogenic sources. Back trajectory analysis, however, did indicate that these two remote sites are impacted by air masses passing over the source region through anticyclonic recirculation. In general, an increase in wet deposition of S and nitrogen (N) were observed at all the sites compared to previous results reported. In addition, an increase in H⁺ concentration is observed at all the sites with the related pH distributions indicating more rain events with lower pH values. This could be ascribed to a significant increase in anthropogenic activities and population growth in this part of South Africa with an associated increase in energy demand.

[O3A-5] Overview of Taiwan Acid Deposition Network and the Response of Long-term Precipitation Chemistry to Air Pollution Control Policies

Presenter: Neng-Huei (George) Lin, Department of Atmospheric Sciences, National Central University, Taiwan, nhlin@cc.ncu.edu.tw

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Since 1970's, the pH of rainwater has been widely measured in 25 meteorological stations in Taiwan. Till 1990's, a national acid deposition network (14 sites at present stage) was established for detailed precipitation chemistry. This study overviews the general precipitation chemistry and wet deposition of major ions based on above network in Taiwan. Meanwhile, the long-term trend of major ion chemistry and their wet deposition were correlated with SO₂ and NO_x emission inventories and also assessed in response to air pollution control policies. Overall, principal ions in rainwater were Cl⁻, Na⁺, and SO₄²⁻, followed by NH₄⁺ and NO₃⁻. For northern Taiwan, rain events containing higher amounts of SO₄²⁻ were found to be associated with northeast monsoon and frontal systems, which are capable of transporting atmospheric pollutants to the sites via long-range transport. In contrast, particularly for the south, relatively high NO₃⁻ was observed during the episodes of locally-formed convective storms, indicating the influences of local industrial activities. It is clearly seen that the SO₄²⁻ in rainwater collected in Taipei, the capital city of Taiwan, was tremendously decreased by 60% in 25 years. However, NO₃⁻ was increased by about 30%. Furthermore, on average, northern Taiwan had the highest loading of sulfate (> 100 kg ha⁻¹ yr⁻¹) and nitrate (> 50 kg ha⁻¹ yr⁻¹) over the island in early 1990's, compared with less than 50 kg ha⁻¹ yr⁻¹ for both ions in recent years. The average deposition ratio of SO₄²⁻/NO₃⁻ over the entire network was about 2.1 for the years before 2000 and was significantly decreased to be below 1.5, indicating the effectiveness of sulfur emission control, while, the NO_x emission was elevated primarily owing to mobile sources. The contribution of emissions from local sources and through long-range transport to the sulfate and nitrate wet deposition on Taiwan was also analyzed.

**BREAKOUT SESSION 3 (BLOCK B):
ATMOSPHERIC NITROGEN DEPOSITION I:
BIOGEOCHEMISTRY**

Session Chair: Nobu Ohte, Kyoto University
*Session Co-Chair: Emily Elliott, University of
Pittsburgh*

[O3B-1] Foliar chemical evidence of effects of excess nitrogen on the biogeochemistry of a temperate hardwood forest

Presenter: Frank S. Gilliam, Marshall University, gilliam@marshall.edu

Author(s): Frank S. Gilliam, Marshall University and Jake H. Billmyer, Marshall University

Excess nitrogen (N) in terrestrial ecosystems arises from anthropogenically-increased atmospheric N deposition, a phenomenon common in eastern US forests. In spite of the Clean Air Act, which has effectively decreased N emissions, atmospheric concentrations of reactive N remain high. Excess N in forest ecosystems has been shown to alter biogeochemical cycling of essential plant nutrients, primarily in the form of enhanced production and leaching of nitrate, which potentially facilitates leaching losses of base cations. The purpose of our study was to investigate this phenomenon using a multifaceted approach to examine foliar nutrients of individual herbaceous layer species in one N-treated watershed (WS3—receiving aerial applications of 35 N kg/ha/yr as ammonium sulfate, from 1989 to the present) and two untreated reference watersheds (WS4 and WS7) at the Fernow Experimental Forest, WV. In 1993, we analyzed foliar tissue of *Viola rotundifolia*, a dominant herb layer species and prominent on all seven plots in each watershed. In 2013 and 2014, we used *Rubus allegheniensis*, which had become the predominant species on WS3 and had increased in cover on both reference watersheds. Foliar N and potassium (K) was higher and foliar calcium (Ca) was lower on WS3 than on the reference watersheds for both species. Magnesium (Mg) was lower on WS3 for *Viola*, but was not different among watersheds for *Rubus*. Notably, foliar manganese (Mn) of *Rubus* averaged >4 times that of *Viola*, and was significantly higher on WS3 than on the reference watersheds. A Mn-based mechanism is proposed for the N-mediated increase in *Rubus* on N-treated WS3. Results generally support the hypothesis that excess N contributes to leaching of Ca and, to a lesser degree, Mg, but not of K. Data suggest that excess N deposition can both cause profound shifts in herb community composition and alter biogeochemical cycling of forest ecosystems.

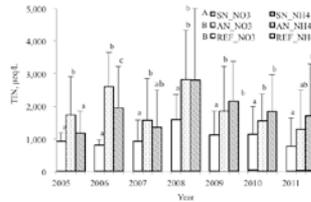
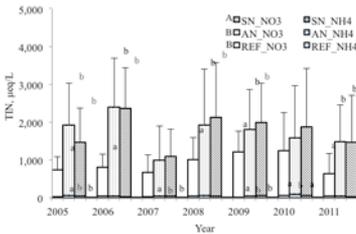
[O3B-2] Nitrogen saturation, soil acidification and ecological effects in a subtropical pine forest on acid soil in Southwest China

Presenter: Lei Duan, Tsinghua University, lduan@tsinghua.edu.cn

Author(s): Lei Duan, Wenjing Liu, Ting Zhang

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Elevated anthropogenic nitrogen (N) deposition has caused widespread nitrate (NO_3^-) leaching, an indication of N saturation, in temperate and boreal forests across the northern hemisphere. So far, the occurrence of N saturation in subtropical forests and its effects on the chemistry of the typically highly weathered soils, forest growth and biodiversity have received little attention. Here, we investigated N saturation and the effects of chronically high N inputs on soil and vegetation in a typical, subtropical Masson pine (*Pinus Massoniana*) forest at Tieshanping, southwest China. Seven years of N flux data obtained in ambient conditions and in response to field manipulation, including a doubling of N input either as ammonium nitrate (NH_4NO_3) or as sodium nitrate (NaNO_3) solution, resulted in a unique set of N balance data. Our data showed extreme N saturation with near-quantitative leaching of NO_3^- , by far the dominant form of dissolved inorganic N in soil water (Figure 1). Even after seven years, NH_4^+ , added as NH_4NO_3 , was nearly fully converted to NO_3^- ; thus giving rise to a major acid input into the soil. Despite the large acid input, the decrease in soil pH was insignificant, due to pH buffering caused by Al^{3+} mobilization and enhanced SO_4^{2-} adsorption. In response to the NH_4NO_3 -induced increase in soil acidification and N availability, ground vegetation showed significant reduction of abundance and diversity, while Masson pine growth further declined. By contrast, addition of NaNO_3 did not cause soil acidification. The comparison of NH_4NO_3 treatment and NaNO_3 treatment indicated that pine growth decline was mainly attributed to acidification-induced nutrient imbalance, while the loss in abundance of major ground species was the combining effect of N saturation and acidification. Therefore, N emission control is of primary importance to curb further acidification and eutrophication of forest soils in much of subtropical south China.



(a) (b)

Figure 1. Annual average TIN of soil water in top layer (a) and bottom layer (b) under each treatment from 2005 to 2011.

[O3B-3] Incorporating mechanisms of atmospheric nitrogen into the canopy: Soil continuum of a suburban forest in Japan

Presenter: Nobuhito Ohte, Kyoto University, nobu@bre.soc.i.kyoto-u.ac.jp

Author(s): Nobuhito Ohte, Kyoto University; Jun Shi, University of Tokyo; Naoko Tokuchi, Kyoto University; Tomoki Oda, University of Tokyo

Heavy nitrogen (N) deposition often generates high nitrate (NO_3^-) accumulations in soils of forested ecosystems. In order to clarify the mechanisms of its dynamics in relation to the N transformations, we monitored NO_3^- isotope values in deposition processes along the canopy–soil continuum of a suburban forest of Tokyo, Japan with heavy inorganic N reposition ($> 40 \text{ kg N ha}^{-1} \text{ year}^{-1}$). We used stable isotopes of N and oxygen (O) to trace the source and transformation dynamics of NO_3^- in two types of forest stands: a plantation of *Cryptomeria japonica* (conifer; CJ) and a natural secondary forest of *Quercus acutissima* (broadleaf, deciduous tree; QA). We measured NO_3^- and ammonium (NH_4^+) concentrations, as well as $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ values of NO_3^- , in rainfall, throughfall, stem flow, litter layer water, and soil waters. Gross mineralization and nitrification rates were also measured by the pool dilution method using ^{15}N tracers.

Seasonal variations were found in the $\delta^{15}\text{N}$ \square values of throughfall and stem flow NO_3^- at both CJ and QA sites, and in the $\delta^{18}\text{O}$ values of throughfall and stem flow NO_3^- at the QA site. The range in the $\delta^{18}\text{O}$ values of rain and throughfall NO_3^- was high (65–70‰) but decreased rapidly to 2–5‰ in soil waters. At the QA site, $\delta^{18}\text{O}$ values of stem flow NO_3^- decreased to 40‰ during several rain events, especially in the growing season. Atmospheric NO_3^- deposition was effectively replaced by microbially produced NO_3^- mainly in the organic (litter) horizon and surface part of the mineral soils under excess N deposition in this suburban forest. Gross rate observation evidenced that very high microbial activity, including both immobilization and nitrification in organic-rich horizons near the surface, contributed to incorporating atmospheric NO_3^- effectively into the internal microbial N cycle. Comparing to the cases in the low N deposition sites, the nitrification activity in was significantly larger, while the difference in mineralization among them was not always large. Additionally, we found evidences of microbial nitrification in the canopy (tree surface) of the QA stand in summer.

[O3B-4] Effects of atmospheric deposition on nitrogen retention and carbon sequestration in temperate forest ecosystems

Presenter: Pamela H. Templer, Boston University, ptempler@bu.edu

Author(s): Gary Lovett, Cary Institute of Ecosystem Studies
Kathleen C. Weathers, Cary Institute of Ecosystem Studies
Mary Arthur, University of Kentucky
Alexandra Rodriguez, Museo Nacional de Ciencias Naturales-CSIC
Lynn Christenson, Vassar College
Christine L. Goodale, Cornell University

Human activities have led to increased emissions of reactive nitrogen (N) to the atmosphere, which have increased atmospheric N deposition onto terrestrial ecosystems. While N emissions have declined in the northeastern U.S., deposition rates remain significantly elevated over pre-industrial levels. Past studies show that many forests in the U.S. retain a large proportion of atmospheric N deposition over short timescales, but the amount of N retained varies with forest type and level of N inputs, and the long-term fate of N remains uncertain. Even if forests retain a large amount of deposited N, any nitrate leached can lead to N saturation. The Catskill Mountains in New York receive among the highest inputs of N deposition in the northeastern United States. We conducted a long-term ^{15}N field tracer experiment to determine how N moves through soil, microbial and plant pools under different tree species and fertilization regimes. We examined single-species plots of American beech (*Fagus grandifolia*), eastern hemlock (*Tsuga canadensis*), red oak (*Quercus rubra*) and sugar maple (*Acer saccharum* Marsh.) one and eleven years after tracer addition. Using paired plots we compared the effects of ambient levels of atmospheric N inputs to additions of $50 \text{ kg N ha}^{-1} \text{ yr}^{-1}$. Within the first 300 days ^{15}N recovery was 22% lower in the fertilized plots compared to the ambient plots, and red oak stands had the largest drop in ^{15}N recovery with fertilization. Most N is retained within soil, with vegetation accounting for a minority of the N retention. These results indicate that forest N retention varies with forest type and changes depending on N inputs. Because vegetation represents a smaller N sink compared to soils, we also conclude that growth enhancement and stimulation of carbon sequestration in aboveground biomass from atmospheric N deposition is likely to be modest with atmospheric N deposition.

[O3B-5] Declining nitrate-N yields in the Upper Potomac River basin (USA): What is really driving progress under the Chesapeake Bay restoration?

Presenter: Keith N. Eshleman, University of Maryland Center for Environmental Science, Appalachian Laboratory, eshleman@al.umces.edu

Author(s): Keith N. Eshleman and Robert D. Sabo, University of Maryland Center for Environmental Science, Appalachian Laboratory

Reducing nutrient pollution of surface and coastal waters in the U.S. and elsewhere remains a major environmental and engineering challenge for the 21st century. In the case of the Chesapeake Bay restoration, we still lack scientific proof that watershed management actions can effectively reduce nonpoint-source nutrient loads from the land to this estuary. While the current management paradigm is that implementation of best management practices (BMP's) is responsible for turning the tide against nutrient pollution, we have taken a different approach based on analysis of long-term (1986-present) nitrate-N trends in streams and major tributaries of the Upper Potomac River Basin (UPRB) to determine whether trends can be explained by drivers that have been largely overlooked. We found that (1) dramatic reductions in annual discharge-weighted nitrate-N concentrations and yields (YN) across the UPRB, including in some tributaries dominated by non-forested land, can be largely attributed to reductions in atmospheric N deposition (DN) as opposed to on-the-ground management actions such as implementation of BMP's; (2) the observed water quality changes comport with a modified kinetic N saturation model (MKNSM) in which $dYN/dDN = 1 - a$ varies as an exponential function of DN (where a is a dimensionless, variable watershed N retention factor); (3) the MKNSM can separate the nitrate-N yield that is responsive to atmospheric deposition from an unresponsive (or "legacy") yield; and (4) N saturation from atmospheric N deposition appears to be an inherently reversible process. We conclude that NO_x emission controls have produced dramatic improvements in water quality in the UPRB, despite the fact that the 1990 Clean Air Act Amendments (and subsequent U.S. NO_x control programs) never anticipated the region-wide water quality benefits demonstrated in the present study. These results reflect one of a very few water quality "success stories" in the Chesapeake Bay restoration and have important ramifications for the 2017 "mid-point assessment" that is part of the latest Chesapeake Bay Watershed Agreement.

**BREAKOUT SESSION 3 (BLOCK C):
STATUS AND TRENDS OF SOIL CHEMISTRY**

*Session Chair: Mary Beth Adams, USDA Forest
Service*

*Session Co-Chair: Paul Hazlett, Natural
Resources Canada – Canadian
Forest Service*

[O3C-1] Declining Acidic Deposition Begins Reversal of Forest-Soil Acidification in the Northeastern U.S. and Eastern Canada

Presenter: Gregory Lawrence, U.S. Geological Survey, glawrenc@usgs.gov

Author(s): G. Lawrence, U.S. Geological Survey
P. Hazlett, Natural Resources Canada–Canadian Forest Service;
I. Fernandez, University of Maine;
R. Ouimet, Direction de la recherche forestiere, ministere des Foret, de la Faune et des Parcs du Que´bec;
S. Bailey, USDA Forest Service;
W. Shortle, USDA Forest Service;
K. Smith, USDA Forest Service;
M. Antidormi, U.S. Geological Survey

A consistent decreasing trend in acidic deposition levels over the past several decades has led to partial chemical recovery of surface waters. However, depletion of soil Ca from acidic deposition has slowed surface water recovery and led to the impairment of both aquatic and terrestrial ecosystems. Nevertheless, documentation of acidic deposition effects on soils has been limited, and little is known regarding the response of soils to ongoing declines in acidic deposition. To address this problem, resampling of soils in eastern Canada and the northeastern U.S. was done at 27 sites exposed to reductions in wet sulfate deposition of 5.7% to 76%, over intervals of 8 to 24 years. Decreases of exchangeable Al in the O horizon, and increases in pH in the O and B horizons were seen at a majority of sites. Among all sites, reductions in sulfate deposition were positively correlated with base saturation ($P < 0.01$), and negatively correlated with exchangeable Al ($P < 0.05$) in the O horizon. However, base saturation in the B horizon decreased at one-third of the sites, with no increases. It's not clear whether this change is part of the recovery response, but it's not consistent with the conceptual model of recovery that assumes replenishment of bases from weathering as cation leaching fluxes are reduced by decreases in deposition. Nevertheless, this study is the first to link declines in acidic deposition to soil changes that represent a reversal of acidic deposition effects on soils.

**[O3C-2] Acidification trends in soils and surface waters in boreal areas:
Accumulation of organic matter and variations in ionic strength important
but overlooked drivers**

Presenter: Stefan Löfgren, Department of Aquatic Sciences and Assessment, SLU, Uppsala, Sweden, Stefan.Lofgren@slu.se

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2. Jon Petter Gustafsson, Department of Soil and Environment, SLU, P.O. Box 7014, SE-750 07 Uppsala, Sweden, jon-petter.gustafsson@slu.se
3. Ulf Skyllberg, Department of Forest Ecology and Management, SLU, SE-901 83 Umeå, Sweden, ulf.skyllberg@slu.se

Much of the theory of soil and water acidification was outlined during the 1970:ies and the 1980:ies. Here we build on concepts developed at that time, but also include some new processes. The role of organic matter build-up in soils and its interaction with Al-compounds for the pH buffering in soils and runoff are highlighted. We quantify differences in the effects of biomass production and mineral acid acidification beyond the commonly adapted concepts of changes in pH (intensity) and acid neutralizing capacity (ANC). The mobility and retention of conjugate bases to proton donors, the role of aluminum and its complexes with organic matter and changes in soil solution ionic strength are assessed. Special emphasis is put on soil - solution chemistry along the water flow paths from recharge to discharge areas. The evaluation is done by model simulations (HD-MINTEQ, based on Visual MINTEQ) based on existing data for a set of scenarios. A common view is that increased anthropogenic sulfur deposition caused acidification due to the increased input of H⁺. However, our results indicate that the enhanced ionic strength, caused by high concentrations of SO₄²⁻ ions in deposition balanced by different cations, may have been at least as important as the elevated H⁺ deposition for the acidification of soil solution and surface waters. The reason is that large pools of historically accumulated soil organic matter (“potential acidity”) rapidly react on ionic strength changes. Hence, neither the acidification nor the recovery process related to SO₄²⁻ deposition can be handled without taking into account the accumulated “potential acidity” and ionic strength effects on the soil – solution chemistry in different soil layers. Additionally, chronic or episodic sea salt deposition may have a profound effect on the soil – solution chemistry, with large impact on the surface water acidity.

[O3C-3] The effects of 25 years of soil acidification in a forested ecosystem: An update from The Fernow Whole Watershed Acidification Study

Presenter: Mary Beth Adams, USDA Forest Service, mbadams@fs.fed.us

Author(s): William T. Peterjohn, West Virginia University, bpj@wvu.edu;
Frank S. Gilliam, Marshall University, Gilliam@marshall.edu

A paired watershed study was begun in 1989 at the Fernow Experimental Forest in West Virginia, USA, to investigate the effects of long-term elevated acidic deposition and soil acidification on whole-watershed ecosystem dynamics. Ammonium sulfate fertilizer ($35.5 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ and $40.5 \text{ kg S ha}^{-1} \text{ yr}^{-1}$) has been added to a forested watershed (WS3) that supported a 20-year-old stand of eastern deciduous hardwoods since 1989. Additions of N and S represent approximately twice the ambient amounts of nitrogen and sulfur received as throughfall from 1981-1983 in an adjacent mature forested watershed (WS4), that serves as a reference watershed for this study. Another adjacent watershed (WS7) serves as a second reference watershed for comparing forested stands of similar age. When surface soils (0-10cm) in WS3 are compared with those in WS7, we find several signs of acidification including lower pH, lower extractable Ca, Mg, and K, and higher levels of extractable Al. However, there was no detectable increase in nitrification within the fertilized WS despite the fact that stream water NO_3 concentrations in the fertilized WS are currently 2-4x greater than those in either reference WS (WS 3 are $150 \mu\text{M}$, those in WS 4 are $\sim 50 \mu\text{M}$ and those in WS 7 are $\sim 75 \mu\text{M}$). In contrast with NO_3 , sulfate has been strongly retained by soil layers and increased more gradually in stream water. Stream and soil solution chemistry data suggest that base cation mobilization and depletion from the soil exchange sites has occurred, and that ecosystem acidification has taken place. Increased base cation concentrations in stream water also were linked closely with high solution levels of nitrate. Some changes in growth rates of vegetation have been detected, and their implications are being further evaluated in the context of any shifts in long-term processes and nutrient budgets.

[O3C-4] Acidity and nutrient constraints on the soil organic matter balance

Presenter: Filip Oulehle, Czech Geological Survey and Global Change Research Centre, filip.oulehle@geology.cz

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Sulphur (S) and nitrogen (N) deposition are important drivers of the terrestrial carbon (C) and N cycling. It is clear that acidic atmospheric deposition has impacted on the wider biogeochemical cycle of forest ecosystems, including the ecosystem C balance. In 2013, we established two experimental plots in spruce and beech forest stands of the same elevation (784 m a.s.l.), bedrock and deposition history in the Ore Mountains (Czech Republic) to manipulate S and N inputs. In spring 2014 we started to apply S and N treatments and combination of both in randomised block design (eight doses per year, NH_4NO_3 50 kg N ha^{-1} yr^{-1} ; H_2SO_4 50 kg S ha^{-1} yr^{-1} , control included). Soil water chemistry (soil water collected from forest floor and - 30 cm depth) responded to altered element inputs (after 1st year). Soil water pH decreased in acid treatments (S and S+N), no pH change was measured in N treatment. Soil water pH decreases were followed by decreases of DOC concentrations. N treatment induced some NO_3^- leaching, but substantially lower than expected. Field soil respiration did not change significantly yet. N addition stimulated activities of all measured enzymes in beech stand while only the cellulolytic activity (beta glucosidase and cellobiosidase) was enhanced in all treatments of spruce stand. Besides the field measurements, we have undertaken controlled soil incubation experiment (one week) with organic soils from spruce stand exposed to altered pH (acidification and alkalization) and DOC availability (direct DOC addition). The results have shown pH control on DOC availability – DOC concentration decreased in acidic treatments and DOC concentration increased in alkaline treatment. Heterotrophic soil respiration was stimulated in treatments exposed to alkalisation and DOC addition. Altered soil respiration was probably a direct result of DOC bioavailability for microbes under different treatments, rather than direct pH effect on soil microbial communities.

[O3C-5] Health Consequences of Acid Rain in South West Sweden

Presenter: Ingegerd Rosborg, Division of Land and Water Resources Engineering, School of Architecture and the Built Environment, KTH Royal Institute of Technology, 10044 Stockholm, Sweden.

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Acid rain leads to loss of essential elements and increases the concentrations of toxic elements in drinking water. 75 private wells from acid regions (pH < 6.5) were compared with 75 from alkaline areas (pH > 7.0) in southern Sweden. Women, drinking the water for at least 5 years, were interviewed about their health and water and hair samples were collected. The concentrations of about 40 elements in water and hair were analyzed, most by ICP-OES. The concentrations of essential elements such as Ca, Cr, Mo, Se and K, as well as the body's buffering agent HCO_3 were significantly lower in acid than in alkaline water. The median Ca concentration was 6 times lower in acid waters and hair compared to alkaline, and HCO_3 14 times lower in acid waters. Mg was similar in both populations, since the Swedish bedrock in general has low Mg content. The levels of toxic metals such as Cd and Pb were significantly higher in acid well water, causing mineral imbalance in the body, as mirrored in hair. High Cu concentration, causing especially diarrhea, is a serious acidification problem. Water elements were mirrored in hair, e.g. Ca and Mo. The concentrations of especially Ca, Cr, HCO_3 and SO_4 , peaked at pH 7.0–8.0, due to precipitation of carbonates and sulfates in alkaline soils and leaching from acid soils. Women living in the acid area reported more negative health changes during the time they had been drinking their well water. Thus, the number of reported heart, intestinal, muscle, and skin problems were between 2 and 9 times more frequent among women drinking acid than alkaline well water.

**BREAKOUT SESSION 4 (BLOCK A):
ATMOSPHERIC MODELING OF AIR
POLLUTANTS**

Session Chair: Donna Schwede, US EPA

*Session Co-Chair: Leiming Zhang, Environment
Canada*

[O4A-1] Modeling Atmospheric Composition Matters: To Air Quality, Weather, Climate and More

Presenter: Gregory R. Carmichael, University of Iowa,
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Author(s): Gregory Carmichael, Pablo Saide, Negin Sobhani, Sarika Kulkarni, and Meng Gao, Center for Global and Regional Environmental Research, The University of Iowa

The composition of the atmosphere plays important roles in climate, weather forecasting, human health, terrestrial and aquatic ecosystems, agricultural productivity, aeronautical operations, renewable energy production, and more. This is exemplified by air pollutants such as ozone and aerosols, which have adverse human health impacts, and which are also strong radiative forcing agents with impacts on weather and climate. These air pollutants when deposited on the surface through dry and wet processes also can have adverse impacts on ecosystem health and agricultural productivity. In order to meet societal needs for expanded services related to weather, air quality and climate, researchers around the globe have been developing a goal of seamless prediction across spatial and temporal scales. This has helped drive the development of numerical models that couple atmospheric chemistry, aerosol dynamics and meteorology within integrated model systems. Such models have undergone rapid evolution in recent years. In this paper we explore the needs for, and advances in, modeling atmospheric composition and deposition. We also discuss recommendations for improvements in modeling and observing systems to increase prediction skill and to reduce uncertainties in atmospheric composition and deposition related impact assessments.

[O4A-2] Sensitivities of simulated PM2.5 health effects and source contributions to aerosol models

Presenter: Yu Morino, National Institute for Environmental Studies, morino.yu@nies.go.jp

Author(s): Yu Morino¹, Kayo Ueda², Akinori Takami¹, and Tatsuya Nagashima¹ (¹National Institute for Environmental Studies, ²Kyoto University)

Chemical transport models are a useful tool to evaluate health effects and source contributions of PM_{2.5} in the atmosphere. However, model results generally include large uncertainties, because of problems with their input data (e.g., meteorological, boundary, and emissions data), the parameterization of each process, and missing science elements. Thus, evaluations and improvements of model performance are critical for model applications. In this study, we used PM_{2.5} chemical composition data measured simultaneously over several regions of Japan in winter, spring, and summer 2012 to evaluate sensitivity simulations, one based on a secondary organic aerosol (SOA) yield model and two based on a volatility basis set (VBS) model. It was found that concentrations of organic aerosol were better reproduced by a VBS model than a two-products SOA yield model. In addition, concentrations of aerosol nitrate were better reproduced by a model with dry-deposition velocities of nitric acid and ammonia enhanced by a factor of five, as was done in a previous study. We also evaluated sensitivities of simulated PM_{2.5} health effects and source contributions to these model setups. As compared to the standard simulation, simulated excess mortality due to organic aerosol was higher by a factor of two and excess mortality due to nitrate aerosol was lower by a factor of three in the improved simulation. Differences in PM_{2.5} source contributions to the model setups are also discussed.

[O4A-3] Long-term variation of the ratio of nitrate to non-seasalt sulfate in precipitation over East Asia during 2000-2011

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Growing in anthropogenic emissions in East Asia will cause substantial changes in the precipitation chemistry. In particular, the effects of Chinese emissions, where NO_x emissions have been rising continuously and SO₂ emissions peaked in 2005–2006, are important. The absolute chemical concentration in precipitation is inherently linked to the amount of precipitation; therefore, the ratio of nitrate (NO₃⁻) to non-seasalt sulfate (nss-SO₄²⁻) concentration in precipitation with equivalent basis (hereinafter, Ratio) was used. We analyzed the long-term behavior of Ratio in precipitation over East Asia during 2000–2011 and investigated the factors responsible for variations of Ratio in precipitation by using a model simulation with sensitivity analysis of emission changes in China. Ratio over Japan, Korea, and China decreased slightly or remained constant during 2000–2005 (first 6 years of 2000–2011) and subsequently increased during 2006–2011 (last 6 years of 2000–2011). Linear regression analysis of the observations showed the increases in Ratio during 2006–2011 were +3.4±1.0%/year, +13.2±4.1%/year, and +9.8±2.5%/year for Japan, Korea, and China with a statistical significance level of $p < 0.05$, respectively. These variations in Ratio corresponded closely to the changes in the NO_x/SO₂ emission ratio in China. Model simulations for 2000–2011 and their reproducibility were validated by comparison with ground-based observation; capturing the observed features well. Sensitivity analysis of emissions from China in the model simulation for 2009–2011 clarified that the increment in NO_x emissions from China contributed to 55–60% of the increase in Ratio in China and around 50–55% in Korea and Japan; the contribution of the increment in NO_x emissions was smaller in the region downwind of China. In contrast, the decline in SO₂ emissions from China contributed below 40% in China and around 40–45% in Japan; the effect was larger in the region downwind of China.

[O4A-4] Estimates of Acid Deposition in Alberta and Saskatchewan Using A Chemical Transport Model

Presenter: Paul Andrew Makar, Air Quality Research Division, Environment Canada,
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Two configurations of the on-line chemical transport model GEM-MACH were used to predict annual and short-term acidifying deposition in the provinces of Alberta and Saskatchewan.

A two-bin aerosol size distribution configuration was used to estimate annual aqueous, gas-phase and particulate deposition of four sulphur and eleven nitrogen containing species. The relative importance of different species towards total deposition and their spatial variation was shown: dry deposition of $\text{SO}_2(\text{g})$ and wet deposition of $\text{HSO}_3^-(\text{aq})$ contribute the greatest share of total sulphur deposition close to the sources; the wet deposition of $\text{SO}_4^{2-}(\text{aq})$ contributes the greatest share further downwind. Nitrogen deposition was dominated near the sources by dry deposition of $\text{NH}_3(\text{g})$ and $\text{NO}_2(\text{g})$, and dry deposition of $\text{HNO}_3(\text{g})$ and wet deposition of $\text{NH}_4^+(\text{aq})$ and $\text{NO}_3^-(\text{aq})$ dominated further downwind. Particulate deposition and dry deposition of other gases had a relatively minor impact. Deposition totals were used to estimate exceedances with respect to different estimates of critical loads of acidity, for forest, lake, and lake catchment ecosystems. The model predictions indicate exceedances with respect to all three receptor ecosystems, for a large region of northern Saskatchewan, mainly associated with oil sands related emissions sources in northern Alberta.

A 12-bin aerosol size distribution configuration was used to evaluate the model deposition estimates against estimates of total sulphur deposition derived from aircraft observations of individual plumes in the oil sands region. The aircraft flight path was aligned to intersect the plumes at specific points downwind, with cross-sectional "wall" flights perpendicular to the plume axis being used to estimate the total sulphur at successive downwind locations. Differences in observed total sulphur were used to estimate losses due to deposition. The resulting estimates will be compared to model estimates for the same region, and the potential of the aircraft methodology for estimating deposition of other species will be discussed.

[O4A-5] Deposition of acidifying species in the Waterberg of South Africa in response to expanding coal-fired power generation

Presenter: Stuart Piketh, Unit for Environmental Science and Management, North-West University, Potchefstroom

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South Africa has experienced severe power shortages over the past 7 years with devastating impacts on economic growth. Currently the country operates 13 coal fired power stations, many of which have a generating capacity of 3600 MW. In order to address the power shortages two new coal fired power stations (4800 MW each) are under construction, one on the Mpumalanga Highveld, the other in the Waterberg district, close to the town of Lephalale. Lephalale is isolated and up wind of the Highveld stations. Matimba, the existing PS has been operating since the early 1990's, while Medupi, a new PS, is slowly being brought online. In order to assess if a distinctive change in the acidifying potential of the increased emissions can be observed, six passive monitoring stations were established in 2006. SO₂, NO₂ and O₃ have been measured on a monthly basis. These measurements are based on the molecular diffusion of gaseous species to an impregnated filter unique to each pollutant.

Concentrations of SO₂ showed current values range between 5µg.m⁻³ and 16.45µg.m⁻³. NO₂ concentrations vary between 8 µg.m⁻³ and 14.5µg.m⁻³. In this paper dry deposition will be calculated using the inferential method for the sites surrounding the two power stations. Previously unpublished data of wet deposition monitoring around Lephalale will also be presented. Use will also be made of a dispersion model (CALPUFF) to estimate the deposition rates for operating a one and both power stations. Comparisons will be made between the observed and the modelled data.

**BREAKOUT SESSION 4 (BLOCK B):
BIOGEOCHEMICAL MODELS APPLIED TO
ACIDIFICATION AND RECOVERY**

*Session Chair: Filip Moldan, IVL Swedish
Environmental Research Institute*

*Session Co-Chair: Tim Sullivan, E&S
Environmental*

[O4B-1] Biogeochemical Models Applied to Acidification and Recovery: Where We've Been, How We've Done, and Where We're Going

Presenter: Jack Cosby, Centre for Ecology and Hydrology, Bangor, Wales, UK

Author(s): Jack Cosby, Centre for Ecology and Hydrology, Bangor, Wales, UK

Biogeochemical models of acid deposition effects were first developed in the late 1980's at the peak of sulphur deposition. Process understanding and data collection at the time were focused on acidification responses. Evaluations of these models were limited to assessing how well acidification could be simulated. Except for a few experimental reversals of acidification, modelling recovery was a matter of forecast and prediction. With the large reductions of S deposition in Europe and the U.S. in the last decades, the abilities of the models to simulate recovery can now also be assessed. Recent data have highlighted the important roles of nitrogen and dissolved organic carbon (DOC) in acidification and recovery, with new process understanding being incorporated in the models.

MAGIC (Model of Acidification of Groundwater In Catchments) is but one of many biogeochemical models used to assess catchment acidification and recovery. For more than 30 years MAGIC has been applied at locations around the world in both site specific and regional analyses. Here the history MAGIC is used to illustrate the iterative nature of model development involving evaluation of model performance, modification of model processes, and testing of the new features. Simulations of acidification made in the 1980's are compared to historical records and experimental results in Europe and the US. Projections of recovery from acidification made in 1995 are compared to observed recovery in 2010 for 202 sites in 10 regions in Europe. New formulations using decomposer dynamics to link nitrogen (N) cycling to carbon (C) turnover in soils are evaluated by application to 15-30 years of data from sites in the Czech Republic. Finally, the importance of incorporating effects of climate change and land use change in future biogeochemical models of acidification and recovery, and the relevance of acidification/recovery processes for Earth System Modelling are discussed.

[O4B-2] Assessing anthropogenic impact on boreal lakes with historical fish species distribution data and hydrogeochemical modeling

Presenter: Salar Valinia, Swedish University of Agricultural Sciences, salar.valinia@slu.se

Author(s): Göran Englund, Umeå University
Filip Moldan, Swedish Environmental Research Institute
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Quantifying the effects of human activity on the natural environment is dependent on credible estimates of reference conditions to define the state of the environment before the onset of adverse human impacts. In Europe, emission controls that aimed at restoring ecological status were based on hind casts from process-based models or paleolimnological reconstructions. For instance, 1860 is used in Europe as the target for restoration from acidification concerning biological and chemical parameters. A more practical problem is that the historical states of ecosystems and their function cannot be observed directly. Therefore, we (i) compare estimates of acidification based on long-term observations of roach (*Rutilus rutilus*) populations with hind cast pH from the hydrogeochemical model MAGIC; (ii) discuss policy implications and possible scope for use of long-term archival data for assessing human impacts on the natural environment and (iii) present a novel conceptual model for interpreting the importance of physico-chemical and ecological deviations from reference conditions. Of the 85 lakes studied, 78 were coherently classified by both methods. In 1980, 28 lakes were classified as acidified with the MAGIC model, however, roach was present in 14 of these. In 2010, MAGIC predicted chemical recovery in 50% of the lakes, however roach only recolonized in five lakes after 1990, showing a lag between chemical and biological recovery. Our study is the first study of its kind to use long-term archival biological data in concert with hydrogeochemical modeling for regional assessments of anthropogenic acidification. Based on our results, we show how the conceptual model can be used to understand and prioritize management of physico-chemical and ecological effects of anthropogenic stressors on surface water quality.

[O4B-3] Recovery of acid-impaired streams in Great Smoky Mountains National Park from acid deposition

Presenter: Habibollah Fakhraei, Syracuse University, hfakhrae@syr.edu

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Great Smoky Mountains National Park (GRSM) receives elevated levels of atmospheric acid deposition compared to many national parks, raising concerns on the biological function of stream ecosystems due to decreases in pH and acid neutralizing capacity (ANC). Twelve stream-watersheds in the GRSM were identified by the state of Tennessee as acid-impaired under Section 303(d) of the Clean Water Act. We investigated pre-anthropogenic condition and potential recovery of these sites in response to recent and future projected declines in atmospheric deposition using a biogeochemical model, PnET-BGC. As important inputs of the model, spatial and temporal patterns of atmospheric deposition and climatic drivers were estimated by empirical models developed from data at the monitoring stations inside and near the Park. The PnET-BGC model parameters were calibrated to the observed stream chemistry. Long-term simulation of stream chemistry indicates that the deterioration of surface water quality resulting from acidic deposition was substantial and none of the impaired streams can be recovered to their pre-anthropogenic condition by year 2050. All the 12 listed streams had pre-anthropogenic ANC greater than 41 $\mu\text{eq/l}$ (up to 66 $\mu\text{eq/l}$), but acid deposition markedly decreased stream ANC (ranging from 3 to 32 $\mu\text{eq/l}$) currently. However decreasing current atmospheric deposition to the pre-anthropogenic condition (i.e., 100% reduction of sulfur and nitrogen deposition) by year 2020, is projected to improve stream ANC to a range between 14 and 34 $\mu\text{eq/l}$ by 2050. Accuracy of model simulations in the presence of uncertainties in the estimated model parameters and inputs was assessed using three uncertainty and sensitivity techniques: Sensitivity Index (SI), Monte Carlo (MC) and Morris One-factor-At-a-Time (MOAT) approaches. The uncertainty and sensitivity analyses identified precipitation, Ca^{2+} and Na^{+} weathering rates and SO_4^{2-} and NO_3^{-} wet deposition as the most critical inputs of the model which their uncertainties impact model outcomes.

[O4B-4] Modeling the impact of climate change on the acid-base status of a forested, upland watershed in Shenandoah National Park, Virginia

Presenter: Todd M. Scanlon, University of Virginia, tms2v@virginia.edu

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Although recovery of watersheds from acidification has occurred on a widespread basis across eastern North American and Europe, upland watersheds in the southern Appalachians of the U.S. remain an exception largely because high sulfate (SO_4^{2-}) adsorption has prevented significant acid-base recovery. Projecting the future status of these systems is complicated by climate change, which can act as a major biogeochemical driver altering biological, chemical, and physical watershed processes. The integrated biogeochemical model PnET-BGC and three general circulation models were used to evaluate the potential effects of future climate scenarios on watershed biogeochemistry at White Oak Run in Shenandoah National Park (SHEN), Virginia. A sensitivity analysis was performed to measure the relative influence of changes in temperature and precipitation on the projections of watershed biogeochemistry. Discharge is projected to increase, stream concentrations of SO_4^{2-} and base cations are predicted to decline, and stream NO_3^- , pH, and DOC are projected to remain relatively constant over the next century. Altogether, the decline in base cations is projected to outpace that of SO_4^{2-} , reducing stream alkalinity. The effects of changes in temperature and precipitation relative to these chemical constituents are primarily manifested through dilution of soil and surface waters, increased plant demand for nutrients, and increased rates of mineralization and decomposition. Overall, the loss of alkalinity resulting from a moderate climate change scenario is projected to offset alkalinity gains provided by the Clean Air Act and associated amendments by 65%, representing a considerable setback from desired outcomes. Using estimates of SO_4^{2-} deposition and export from watersheds in SHEN and other locations throughout the Eastern U.S., we also evaluate how well PnET-BGC and other models represent SO_4^{2-} adsorption/desorption process in watershed soils.

[O4B-5] Exploiting a long-term dataset to make even longer-term model predictions of the acidification status of soils and waters: Possibilities and limits

Presenter: Richard Skeffington, University of Reading, UK,
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In the 1970s, the Tillingbourne Catchment in S. England had the most acidic measured bulk precipitation in the UK, and the most acidic throughfall in the world (mean pH < 2.9). Stream pH was < 4.0, and soil acidification had reduced the pH_{water} under conifers to < 2.7. In the following 25 years, large reductions in S and (to a lesser extent) N emissions and hence deposition led to some recovery. The MAGIC Model demonstrated that stream recovery was smaller than it would have been if all the deposition reduction had been transferred to surface waters, whereas soil recovery was greater. The catchment has unusual features which allow spatially-varying processes to be identified and separated. Hence stream recovery was being delayed by sulfate desorption from some soils, but also by an increase in nitrate outputs due to N accumulation in soil organic matter, and an increase in strong acid anion fluxes from groundwater. Conversely, recovery was accelerated because the catchment wetlands became more effective in reducing nitrate, and biological processes reduced soil acidity. These results were used to re-parameterise the model and make further predictions. A naïve application of the model suggested that recovery of the stream would only be temporary given current and likely future deposition, and the soil would continue to acidify. Incorporating the various spatially-variable processes altered these predictions, so that the range of outcomes widened to include both a faster return to acidified conditions and a continued slow recovery. These responses have long timescales, but measurements 15 years later can be used to provide some validation of the catchment trajectory. Long-term modelling also requires consideration of land management and rare events (e.g. fires). The catchment's responses to extreme changes allows a test of current understanding of acidification and recovery processes, and suggests a research agenda.

**BREAKOUT SESSION 4 (BLOCK C):
LINKAGES OF ACID RAIN TO CLIMATE
CHANGE AND THE CARBON CYCLE**

*Session Chair: Christine Goodale, Cornell
University*

*Session Co-Chair: Chris Evans, Centre for
Ecology & Hydrology,
Environment Centre Wales*

[O4C-1] Temperature, Precipitation and Nitrogen Effects on the Terrestrial Carbon Cycle

Presenter: Tara Greaver, National Center for Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC (Greaver.Tara@epamail.epa.gov)

Author(s): Emmi Felker-Quinn, 2Oak Ridge Institute for Science and Education, National Center for Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC (Felker-Quinn.Emmi@epamail.epa.gov)

In the absence of S deposition, N deposition to ecosystems may initially stimulate carbon captured by autotrophs, however higher levels of N will cause the toxic conditions associated with acidification. The threshold for the onset of acidification changes across the landscape depends on geochemical sensitivity and historical loading of acidifying deposition. N deposition occurs in many ecosystems concurrently experiencing multiple stressors, including those associated with human-driven climate change. Two important aspects of climate affecting ecosystem function are temperature and precipitation. How these aspects of climate factors alter the ecosystem response to nitrogen deposition is an active area of research.

There are many processes that contribute to the terrestrial carbon cycle, these may be categorized into above and below ground pools. Understanding how each of these is influenced by N, temperature and precipitation can help to characterize the most vulnerable processes. However there is also utility in understanding the net flux of carbon into or out of a system. Estimates of how much N stimulates C storage vary widely; one unit (kg/year) of N input may cause an additional 24.5 to 177 unit C uptake. Currently, there is strong evidence that N, temperature and precipitation as individual stressors have substantial effects on C storage. However, few empirical studies evaluate the interactive or cumulative effects of these stressors.

To gain insight on stressor interactions from single stressor response studies, we have synthesized existing meta-analyses of empirical observations of terrestrial ecosystem response to N, precipitation, and temperature. Interactions between single stressors are identified on multiple components of the carbon cycle, including above and below ground metrics. Thresholds and research needs are discussed.

Disclaimer: The views expressed in this abstract are those of the author and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency.

[O4C-2] Attributing spatial and temporal changes in soil C and pH in the UK to acid deposition and other environmental drivers

Presenter: Amy Thomas, Centre for Ecology and Hydrology,
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Acid deposition and associated soil acidification has been a significant problem in the U.S. and Europe, and is an emerging concern in Asia. Whilst controls on emissions have reduced deposition for some regions, levels remain high in parts of Asia. Here we explore relative importance of drivers of changes in soil C and pH using data from the UK Countryside Survey (CS), a national soil survey across England, Scotland and Wales repeated 1978, 1998 and 2007, giving a total of 3725 data points. A mixed model approach was used to model soil C concentration change over each survey period based on drivers including atmospheric deposition, climate variables and internal soil properties.

Understandings of variation in soil response to ongoing deposition and recovery from acidification in the UK based on these models can be used to help predict and manage recovery elsewhere. Given that soil C represents the largest terrestrial carbon pool there is significant interest in improving our understanding of how soil C responds to atmospheric deposition, and how this interacts with other drivers of change (e.g. land use and management and climate change) and how these responses are modified by inherent soil properties.

Data indicate that as acid deposition in the UK declined from the 80s to 2000s, soil acidity also decreased, across all surveyed habitats. Deposition was important for modelling change in pH, and pH was important for modelling soil carbon change. The importance of pH was reduced in the models when soil N and moisture change variables were included in the models, complicating interpretation of cause and effect. Correlations between changes in pH and changes in deposition are low, which may reflect importance of soil buffering processes, as well as the difference in scales of measurement between deposition (5km) and pH (point sample).

We believe this is the first evidence of acid deposition contributing to soil C change at a national scale. This work also suggests that models which seek to explain or include soil C change need to include both historic and ongoing effects of acid deposition as well as climate change and land use.

[O4C-3] Widespread forest recovery across the central Appalachian Mountains (U.S.) following reductions in pollutant emissions

Presenter: Richard Thomas, West Virginia University, rthomas@wvu.edu

Author(s): Justin Mathias, West Virginia University

State-of-the-art climate models require a mechanistic understanding of how simultaneous changes in key environmental variables affect carbon cycling across diverse forest ecosystems. Using dendroisotopes, we examined the effects of acid deposition on two tree species growing in the central Appalachian Mountains that differ in their sensitivity to acid deposition. Red cedar is a tree species with low sensitivity to acid deposition, whereas red spruce is highly sensitive to acid deposition. Despite these differences, tree growth estimated from tree cores indicates growth rates by both species increased after the Clean Air Act of 1970 compared to growth rates before this legislation. Basal area increment and carbon isotopes in tree rings confirm recovery of both species after decades of acid deposition, but provide strong evidence for differences in their sensitivities to acid deposition. First, isotopic discrimination in tree rings showed a nonlinear trend that indicates a shift in gas exchange of both species before and after the Clean Air Act, but the critical year for this change was 7-10 years later for red spruce (1989-1992) compared to red cedar (1982), indicating a more prolonged recovery time for red spruce. Second, simulated changes in integrated photosynthesis and stomatal conductance using isotopes and measurements of gas exchange indicate sharper reductions of both parameters for red spruce before the critical years. Partitioning reductions in stomatal conductance between effects of increased atmospheric CO₂ and effects of acid deposition indicate that effects of acid deposition were greater than that of atmospheric CO₂. We estimate that acid deposition from 1944-2014 reduced aboveground biomass per hectare by 19% in stands dominated by red spruce in West Virginia, US. Thus, this study shows that the influence of acid deposition varies for these two species and that timing of recovery from acid deposition depends on the resilience of the tree species.

[O4C-4] Assessing the rates of recovery from acidification under climate change in the Northeastern USA

Presenter: S. Belyazid ⁽¹⁾, J. Phelan ⁽²⁾, C. Clarck ⁽³⁾

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Long term ecosystem monitoring and manipulation experiments provide unique sets of data to understand ecosystem processes. We used an integrated ecosystem model to simulate the biogeochemistry, tree growth and ground vegetation communities in three intensively studied forestsites of the North-Eastern USA (Hubbard Brook, Bear Brook East and Bear Brook West). The model was successful in capturing the levels and trends of ecosystem indicators at all levels (trees, soil solution chemistry, ground vegetation composition). Thanks to the high quality of input data and good understanding of ecosystem processes, model calibration was kept to a minimum. However, the model failed to predict or explain tree dieback at the Hubbard Brook site, a phenomenon not fully understood empirically. The model was used to forecast the responses of the studied ecosystems to global changes, taking into account the wide variability of climatic conditions and deposition levels expected in the remainder of the century. The forecasts indicate that elevated nitrogen deposition can dominate the future behavior of the studied ecosystems, even reversing the trend of recovery from historical acidification at Hubbard Brook.

[O4C-5] Achieving the Swedish environmental quality objective "Natural acidification only" in a world of changing climate, forestry practices and air pollution

Presenter: Filip Moldan IVL Swedish Environmental Research Institute, Box 53021, SE-400 14 Gothenburg, Sweden

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In 1998 the Swedish Government formulated a challenge: to leave to the next generation a society in which all the major environmental problems have been solved. The overall goal is that by the year 2020 the pressures placed on the environment must be reduced to sustainable levels. Today Sweden has 16 environmental quality objectives, of which one is "Natural Acidification Only". This objective has been defined as: "The acidifying effects of deposition and land use must not exceed the limits that can be tolerated by soil and water".

The CLEO (Climate Change and Environmental Objectives) research program investigates how climate change and forestry practices affect the possibilities to achieve this objective. Within CLEO two GCM projections were downscaled for Sweden and combined with three future forestry scenarios (with increasing intensity of harvest); business as usual, medium biomass removal, and high biomass removal. The MAGIC model (Model of Acidification of Groundwater in Catchments) was used to simulate the future development of lake waters and catchment soils. Differences between scenarios were evaluated for years 2030, 2050 and 2100 at 2 631 Swedish lakes.

By the year 2030 the differences in simulated lake- and soil acidification status were small. While the rate of change is slow, the business as usual scenario resulted in continued recovery from acidification with gradually diminishing numbers of acidified lakes in 2030, 2050 and an even lower number in year 2100. On the contrary, the medium biomass removal scenario resulted in little further recovery beyond 2010, and the high biomass removal scenario on average caused a slow re-acidification despite the very low levels of air pollution. Thus in the longer perspective the differences were substantial.

Climate change is the major source of uncertainty in the model predictions. Extreme events such as storms causing sea-salt deposition episodes, increased mineral weathering due to warmer and more humid climate or reduced forest productivity due to pests are difficult to predict but could change both the rate and the direction of the recovery from acidification.

**BREAKOUT SESSION 5 (BLOCK A):
LINKAGES OF SULFUR AND NITROGEN WITH
OTHER AIR POLLUTANTS**

Session Chair: Christopher Lehmann, NADP/CAL
Session Co-Chair: Andy Johnson, Maine DEP

[O5A-1] The Forest's Perception of Multi-Air Pollutant Stressors in the 21st Century

Presenter: I.J. Fernandez, University of Maine, School of Forest Resources, Climate Change Institute, and School of Food and Agriculture, Orono, Maine 04469

Author(s): I.J. Fernandez, University of Maine, School of Forest Resources, Climate Change Institute, and School of Food and Agriculture, Orono, Maine 04469

Over the past 25 years we have witnessed relatively rapid and dramatic declines in atmospheric S and N deposition. This has heralded in an era of recovery and the scientific pursuit of evidence for these successes. Many can be found. For students of the forest as an air pollutant receptor in the northeastern US and eastern Canada, acid rain has always represented a paradox since both S and N are essential plant nutrients, and N typically limits growth. Indeed, N fertilization often results in improved forest growth. Adding to this complexity, forests exhibit few direct negative effects of acid deposition, as most effects represent indirect response mechanisms. Forests also modify the flux of atmospheric pollutants, typically enhancing ecosystem exposure.

Forests are also responding to these declines in S and N deposition during a novel period in our modern times of a rapidly changing environment. As forests have been experiencing declines in 'acid rain', they have also been experiencing accelerating rates of change in both the chemical and physical climate. These include (1) secondary influences of air pollution on ecosystem acid/base chemistry, (2) declining dry deposition, noteworthy for heavy metal burdens and base cation supply to soils, (3) declining tropospheric ozone, (4) escalating fumigation with CO₂, (5) rising air temperatures, (6) increased precipitation, (7) increased frequency and intensity of storms, and (8) a shifting seasonality. Together these escalating rates of change, coupled with others not listed here, challenge simple single pollutant paradigms of exposure response and recovery. Forests no longer are largely considered a source of specific forest products, but providers of a broad array of ecosystem services. It is increasingly important to consider the interactions of multiple atmospherically derived stressors on the environment in research, management and policy, which will often take us beyond the capabilities of existing numerical models.

[O5A-2] Dry and wet deposition of air pollutants in North China

Presenter: Yuepeng Pan, Institute of Atmospheric Physics, Chinese Academy of Sciences, panyuepeng@mail.iap.ac.cn

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Atmospheric deposition is known as a major removal process of pollutants from the atmosphere and an important input of nutrients and contaminants for the ecosystems. Despite public concerns of that, the quantified knowledge of deposition from the atmosphere to ecosystems remains scarce. The wet and dry deposition was measured simultaneously under a network of ten sites across Northern China operated during a three-year period from December 2007 to November 2010. This is to our knowledge the first long-term direct measurements of atmospheric wet and dry deposition flux of crustal and anthropogenic pollutants on a regional scale across China. The dataset can be served as a basis for the validation of regional emission inventories and biogeochemical or atmospheric chemistry models. This presentation will focus on the atmospheric deposition flux of carbon, nitrogen, sulfur and heavy metals in the target area.

[O5A-3] The sensitivity of summer time surface ozone concentrations to dry deposition in the United States

Presenter: Sarah Kavassalis

Author(s): Sarah Kavassalis and Jennifer Murphy, Department of Chemistry, University of Toronto

Dry deposition of ozone to the Earth's surface is an important atmospheric process that can regionally exhibit control on surface ozone concentrations. In areas with large leaf area indices (LAI), the loss of ozone to vegetation through stomatal conductance is the principle mechanism for dry deposition during the growing season. In daylight hours, stomatal conductance is primarily controlled by soil water potential and vapour pressure deficit (VPD), which can vary significantly day-to-day. To understand the influence of deposition variability on surface ozone, we looked at 25 years of CASTNET and AQS ozone and meteorological data in conjunction with observationally derived stomatal conductance relationships and box modelling results. We found that variability in deposition could account for more than 10 ppb of the day-to-day differences in peak ozone concentration under average climatic conditions. During years that exhibited large scale droughts, regional peak ozone excesses greater than 10 ppb can be attributed to a complete shut-off of the ozone vegetation sink. This is the first report of such a coincidence in North America, and is consistent with observations and modelling results performed in Europe. This coupling of ozone concentration to meteorologically sensitive deposition helps explain a portion of the ozone relative humidity negative correlation commonly observed in surface measurements in the American Southeast and Northwest, but under-reproduced in chemical transport models. We will also present our work on updating the deposition scheme in the GEOS-Chem global chemical transport model and the improvement to predicted ozone concentration-meteorology coupling.

[O5A-4] Analysis of Meteorological conditions of a persistent haze process in Yangtze River Delta

Presenter: Rui Han, NMIC, hr12@mails.tsinghua.edu.cn

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The Yangtze River Delta area (YRD), which is located on the eastern coast of China, is one of regions with economically developed, densely populated, large pollutant emission. In recent years, Along with faster industrialization and urbanization, in the process of those, a large amount of waste residue, waste water, waste gas and other be put into the atmosphere directly or indirectly. At the same time, most city densely clustered, thus reduce the pollutant buffer which originally existed in urban-rural fringe. And pollution is not easy to diffuse. Then air pollution has become more serious in the region, severe haze weather get more frequent (Fig.1).

According to meteorological data, take Nanjing as an example, in the 64 years spanning from 1961 to 2014, haze days increased from 4.2 days to 194 days, an increase of 6.3%. in which, the 2012 has risen 226 days, which means nearly 62% days are controlled by the haze weather in 2012. Especially in December 2014, extremely severe and persistent haze occurred in the Yangtze River Delta area from the north to the south area. The record-breaking high concentrations of particulate matter (PM_{2.5}) have increased more than 400 $\mu\text{g}/\text{m}^3$ on hourly average, and haze weather has lasted about a week. It is harm to people's health, serious impact on the normal production and life. To improve the air quality in YRD area, has become one of the key problems to realize sustainable development. In fact haze is formed as the result of all these meteorological conditions. So this paper combined meteorological data (including hourly data of temperature, pressure, wind, relative humidity, precipitation, and visibility, analyzed the haze weather process in the boundary layer meteorological factors and structure, spatio-temporal distribution of aerosol concentration, explained the mechanism of haze formation, transmission and deposition. That will help to understand the mechanism and changing law of haze weather in this area. Finally, corresponding views to control the air pollution based on the conclusion has been proposed, and it gave evidences to achieve sustainable.

[O5A-5] Measurements of atmospheric hydroperoxides over a rural site in Japan using a helicopter

Presenter: Koichi Watanabe, Toyama Prefectural University, nabe@pu-toyama.ac.jp

Author(s): Koichi Watanabe, Chinatsu Yachi, Miyuki Nishibe, Serina Michigami, Yukiko Saito, Nagisa Eda, Nobuhiro Yamazaki, Taiki Hirai, Toyama Prefectural University

Measurements of the concentrations of hydroperoxides (hydrogen peroxide (H_2O_2) and methyl hydroperoxide (CH_3OOH , MHP)) as well as the concentrations of SO_2 , NOX and O_3 in the higher atmosphere over a suburban site near the coast of the Japan Sea, Toyama Prefecture, Japan were performed using a helicopter (Robinson R44 helicopter) from 2010 to 2015. Hydroperoxides were collected by a mist chamber every 2,000 ft. height, up to an altitude of 10,000 ft (about 3,000 m) during the horizontal turning flight. After each sampling of hydroperoxides, the helicopter descended immediately near the ground level at Toyama Prefectural University. A small polyethylene bottle which contained the sampling solution was thrown down and transported to our laboratory. The solution was analyzed by a HPLC system at once. We could measure the concentrations of hydroperoxides in the higher atmosphere within 5-10 minutes after the sampling. After the transport, the helicopter immediately ascended to the next altitude and the collection of hydroperoxides was performed again. The sampling air was not affected by the helicopter exhaust. The H_2O_2 concentrations were lowest near the surface and highest in the upper boundary layer. In summer, the concentrations of H_2O_2 were usually higher than those of SO_2 above a 4,000 ft height where potential capacity of SO_2 oxidation in the aqueous phase was large. On the other hand, the concentrations of SO_2 were higher than those of H_2O_2 in a cold season. The results showed the oxidation of SO_2 was suppressed in cloud particles when clouds occur. The concentrations of hydroperoxides and O_3 in the summer of 2013 were significantly higher than those in the summer of the other years. The high concentrations in 2013 were due to air pollutants long-range transported from the Asian continent.

**BREAKOUT SESSION 5 (BLOCK B):
ATMOSPHERIC NITROGEN DEPOSITION II:
BIOLOGICAL EFFECTS**

*Session Chair: Pamela Templer, Boston
University*

*Session Co-Chair: James Sickman, University of
California, Riverside*

[O5B-1] Terrestrial ecosystem responses to N deposition: The effect of site and climate on critical loads of nitrogen for forests in the northeastern U.S.

Presenter: Linda H. Pardo, USDA Forest Service, Northern Researchy Station, Burlington, VT lpardo@fs.fed.us

Author(s): Molly Robin-Abbott, ERC, Burlington
Claire B. O'Dea, USFS, Washington, DC
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Nitrogen (N) deposition in the US continues to cause detrimental changes to the structure and function of terrestrial ecosystems. In order to prevent these detrimental effects, it is necessary to define a threshold level of deposition below which harmful effects do not occur. This level is called the critical load (CL). For this project, we developed a GIS-based tool to evaluate the impact of multiple stressors (N deposition, climate change, pests) simultaneously for species of management concern on public and private forest lands. In addition to calculating species-specific critical loads, the GIS-tool is designed to take into account the impact of site abiotic factors on the response of trees to N deposition. The abiotic modifying factors include elevation, precipitation, temperature (e.g., min winter T, max summer T), and soil characteristics. The impact of each abiotic modifying factor on the response to N deposition for a given species is determined based on the certainty associated with the data and response reported. Output from the GIS-tool allows us to evaluate which tree species are most susceptible to impacts from N deposition and the geographic distribution of these sensitive species. It also allows us to determine the CL and exceedance (Actual Deposition- CL) for different management scenarios. Using the tool we can assess the area impacted at current deposition levels; we can also explore future deposition scenarios to determine how the area impacted and species most affected shift with declines (or increases) in N deposition. The GIS-tool will contribute to management and policy efforts to mitigate detrimental impacts from N deposition on terrestrial ecosystems in the US.

[O5B-2] Continental Scale Analysis of Tree Growth, Mortality, and Recruitment Responses to Nitrogen Deposition Reveal Regional and Species-specific variability that May Enhance and Concentrate Mitigation Efforts

Presenter: Kevin Horn, Virginia Tech, kjhorn@vt.edu

Author(s): Kevin J. Horn¹, R. Quinn Thomas¹, Linda H. Pardo², Erica A.H. Smithwick³, Doug Baldwin³, Gregory B. Lawrence⁴, Scott W. Bailey⁵, Sabine Braun⁶, Christopher M. Clark⁷, Mark Fenn⁸, Annika Nordin⁹, Charles H. Perry¹⁰, Jennifer N. Phelan¹¹, Paul G. Schaberg², Sam St.Clair¹², Richard Warby¹³, Shaun Watmough¹⁴ and Steven S. Perakis¹⁵

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Nitrogen deposition is a significant component of acid rain. Nitrogen itself however typically influences plant responses where N is a limiting nutrient. As N increases the growth rate of individuals plants potentially increases; however, under high N deposition soil N levels saturate and even cause leaching of cations and acidification of soils. Plant responses to N have regional and species-specific variation base on site conditions and genetic plasticity respectively. Continental-scale analysis of the associated effects of N-deposition on growth, recruitment, and mortality help to reveal these regional and species-specific influences.

Continuous response curves for the associated effects of N-deposition on growth, mortality, and recruitment rates for 111 tree species were made possible through the expansive and detailed FIA (Forest Inventory and Analysis) database in conjunction with modeled climate and N-deposition datasets (PRISM, TDEP, and CMAQ). Of these 111 tree species 28 experienced decreased growth rates, 33 increased growth rates, and 22 species showed clear threshold responses across their ranges of exposed N-deposition. Similarly 13 species increased in mortality, 2 decreased, and 8 showed clear threshold responses. Recruitment rates were also significantly influenced by N-deposition.

Regional effects of N-deposition on tree growth, mortality, and recruitment are a combination of site conditions and species present on the site. In general, the northern regions in the US experience more deleterious effects of increased N-deposition while the southern regions are experiencing enhancing effects to tree growth within their current N-deposition exposure. Dry western regions also trend towards negative effects with increased N-deposition. Site and species-specific responses vary within these generalizations however, and are likely a combination of temperature and precipitation influences as well as presence of specific species. The use of continuous response curves and regional identification of these tree responses are being and can further be used to validate regional emission levels and concentrate mitigation efforts.

[O5B-3] A biodiversity indicator for the assessment of nitrogen deposition

Presenter: Wieger Wamelink, Alterra, Wageningen UR,
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Author(s): Wieger Wamelink*, Janet Mol-Dijkstra*, Ger Jan Reinds*, Luc Bonten*, Max Posch#, Wim de Vries* & Paul Goedhart^

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In Europe the assessment of critical loads for acidity and for nitrogen (N) has in the past mainly focused on abiotic parameters such as a critical Al/Bc ratio or critical nitrate concentration in the soil solution. Since it became clear that N deposition has a large impact on species composition, the need emerged for a critical load for N deposition based on vegetation composition as a proxy for biodiversity. The effect of N deposition on vegetation composition is indirect. The N input to the soil changes the C/N ratio and the competitiveness of species. Especially fast growing grasses profit, and species adapted to nutrient poor circumstances suffer.

To assess the effect of N deposition on plant species composition, several models have been developed, e.g. MADOC-GBMOVE in the UK, ForSAFE-VEG in Sweden and VSD+-PROPS in the Netherlands. The latter is now also being adapted for use in the USA. All these models contain a soil process model that calculates soil chemistry such as soil pH, nitrate concentration and C/N ratio based on e.g. deposition of S and N. Simulated soil chemistry is then used as input for model predicting plant species responses either in a process-oriented way (VEG) or by statistical relationships between climate and soil chemical indicators and plant species occurrence (GBMOVE, PROPS). The PROPS model is calibrated using a European data set with vegetation relevés with calculated pH and C/N ratio using a species indicator system, modelled nitrogen deposition, and temperature and precipitation obtained from meteorological databases. These environmental data are linked to the species in the relevés to obtain response curves per species. Changes in occurrences probability of wanted species in response to N and S deposition and climate change are then used as an indicator for changes in biodiversity.

[O5B-4] Modelling soil and vegetation response to atmospheric nitrogen deposition and climate change in French forests

Presenter: Simon Rizzetto, Toulouse University, INP, UPS, CNRS, EcoLab (Laboratoire écologie fonctionnelle et environnement), ENSAT, Avenue de l'Agrobiopole F-31326 Castanet-Tolosan

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Anthropogenic activities highly contributed to increase nitrogen and sulfur atmospheric emissions since 1880. Nitrogen deposition is known to severely impact ecosystem functioning by influencing soil biogeochemistry, nutrients balance and, consequently, tree growth, forest health and biodiversity. Since the 1980's, within the Geneva Convention on Long-Range Transboundary Air Pollution, European countries have joined their efforts to abate atmospheric pollution. Because the ongoing global changes affect the ecosystem processes, climate change and atmospheric deposition must be conjointly taken into account to assess the evolution of forest ecosystem status over time.

The purpose of this study was to predict forest vegetation response to the combine effects of nitrogen atmospheric deposition and climate change by using the dynamic coupled biogeochemical-ecological model (ForSAFE). The output results computed with the biogeochemical model were used as inputs to a vegetation table compiling reference ecological parameters for more than 480 understory plant species that are representative of the main French forest ecosystems. After performing necessary steps of calibration and validation for both biogeochemical and ecological modules on intensively studied sites, we run the coupled model for various climatic and deposition scenarios on several temperate French forest sites, from nowadays to 2100. We present the results of the biogeochemical response namely the changes in soil parameters, and illustrate the response of the vegetation groups regarding vegetation cover for three forest sites from the french ICP Forest network. The first simulations, for the next hundred years, showed a long-term impact of N deposition and climate change scenarios on plant species abundance and diversity depending on the species and their ecological affinity, whereas forest management was identified as the responsible of short-term impacts.

[O5B-5] The nitrogen fingerprint in European forest vegetation

Presenter: Thomas Dirnböck, Environment Agency Austria,
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Author(s): Ulf Grandin, Swedish University of Agricultural Sciences
Martin Forsius, Finnish Environment Institute
Maria Holmberg, Finnish Environment Institute

Chronic nitrogen (N) deposition is a threat to biodiversity that results from the eutrophication of ecosystems. Many local to regional studies have shown that chronic N deposition leads to a shift in the plant species composition of the forest floor and eventually to diversity loss. However, so far there is no unequivocal evidence that elevated nitrogen deposition is a broad-scale driver behind the eutrophication signal in forest plant communities. We have studied long-term monitoring data from 28 European forest sites with a total of 1335 permanent forest floor vegetation plots from northern Fennoscandia to southern Italy to assess temporal trends in vascular plant species cover and diversity. We found that the cover of plant species which prefer nutrient-poor soils (oligotrophic species) decreased the more the measured N deposition exceeded the critical load ($p = 0.002$). Although species preferring nutrient-rich sites (eutrophic species) did not experience a significant increase in cover ($p = 0.440$), in comparison to oligotrophic species they had a marginally higher proportion among new occurring species ($p = 0.091$). The observed gradual replacement of oligotrophic species by eutrophic species as a response to N deposition seems to be a general pattern, as it was consistent on the European scale. In a next step, dynamic soil-vegetation models are applied which will be driven with deposition scenarios in order to explore possible future pathways of nitrogen driven changes in forest ecosystems.

**BREAKOUT SESSION 5 (BLOCK C):
ROLE OF FORESTRY AND LAND MANAGEMENT**

*Session Chair: Kevin Bishop, Uppsala University
and SLU*

[O5C-1] Critical biomass harvesting: Applying a new concept for Swedish forest soils

Presenter: Cecilia Akselsson, Department of Physical Geography and Ecosystem Science, Lund University, cecilia.akselsson@nateko.lu.se

Author(s): Salim Belyazid, Centre of Environmental and Climate Research, Lund University

Emission reductions of sulphur have been successful and recovery of soils and surface waters has started. However, the recovery is slow and problems with acidified soils and waters are predicted to remain for many decades. Whereas the importance of acidifying emissions for acidification has decreased, the acidification effect of forestry has increased, due to increased demand of renewable energy. High concentrations of base cations in branches, tops and needles mean substantially increased losses of base cations at whole-tree harvesting compared to stem harvesting.

Critical load of acidity has been an important tool in adjusting policies to reduce emissions of sulphur and nitrogen oxides. Calculations of critical loads of acidity are based on acidity mass balances. The aims of this study were to put forward a policy tool for sustainable harvesting based on the critical load of acidity concept, "Critical biomass harvesting", and to test it on the Swedish national critical load database.

The study demonstrated that critical biomass harvesting could be estimated in a similar way as critical load of deposition, using the same national databases. The calculations for Sweden showed that critical biomass harvesting was exceeded in the southern half of Sweden already at stem harvesting in spruce forests. Whole-tree harvesting expanded the exceedance area, and increased the exceedance levels in southern Sweden. In pine forests the exceedance was lower, and affected smaller areas. The areas with exceedance coincide with the most acidified soils from acid deposition, where recovery is slow. Whole-tree harvesting, without wood ash recycling, especially in spruce forests in southern Sweden, can be expected to further slow down recovery.

[O5C-2] Acidic Deposition and Timber Harvesting Will Continue to Reduce Essential Nutrients Needed for Healthy Watersheds

Presenter: Bill Jackson, USDA Forest Service, Asheville, NC,
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Author(s): Bill Jackson, USDA Forest Service, Asheville, NC and Claire O'Dea, USDA Forest Service, Washington, DC

Calcium, magnesium, and potassium are essential base cations for healthy terrestrial and aquatic biota. Unfortunately, both acidic deposition and timber harvesting remove these base cations from ecosystems and the biogeochemical cycle. In sensitive watersheds, this loss of base cations from acidic deposition or timber harvesting can result in reduced soil base saturation and stream acid neutralizing capacity (ANC) to levels of biological concern, leading to a variety of negative ecosystem effects.

Land managers within the USDA Forest Service do not have authority to regulate the amount of acidic deposition on National Forest ownership, but they do have control over the location and intensity of timber harvests. Land managers are therefore interested in the potential effect of timber harvesting on watershed health, specifically:

- 1) What future stream ANC category is attainable without timber harvesting?
- 2) What affect, if any, will timber harvesting have on the ANC category for a catchment?

The Ecosystem Management Decision Support (EMDS) software includes a simple mass balance equation to estimate steady state critical loads for Southern Appalachia. It estimates the strength of evidence that a watershed catchment will attain or maintain a desired stream ANC. We used EMDS to evaluate and compare the impact of sulfur deposition and timber harvesting scenarios on stream ANC. At current levels of sulfur deposition, timber harvesting may result in large areas with stream ANC above 50 ueq/L, including catchments above 100 ueq/L, and a small percentage below 20 ueq/L. Areas with constant sulfur deposition and no timber harvesting are predicted to have higher stream ANC than areas where sulfur deposition is reduced by 50 percent but harvesting is ongoing. Stream ANC below 20 ueq/L could occur over large portions of our national forests in Southern Appalachia if whole tree harvesting occurs over a wide area.

[O5C-3] Comparison of current and long-term Ca weathering rates in the White Mountains of New Hampshire

Presenter: Ruth D. Yanai, SUNY College of Environmental Science of Forestry, rdyanai@syr.edu

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Long-term soil weathering can be estimated by comparing concentrations of mobile elements in parent materials with those in soil profiles, referenced to immobile elements such as titanium. These rates are much slower than current watershed denudation rates estimated from input-output budgets. The difference might be attributable to contemporary influences such as acidic deposition or biological demand following forest harvesting.

We compared the net hydrologic flux of calcium at the Hubbard Brook Experimental Forest (HBEF) with weathering rates calculated from soil profiles in 14 other stands in the White Mountain National Forest. We estimated uncertainty in both methods. Uncertainty in ecosystem weathering estimates are rarely reported but are essential to establishing confidence in the results.

The net hydrologic flux of Ca in the reference watershed of the HBEF was 7.1 kg/ha/yr, with a 95% confidence interval of 0.5 kg/ha/yr, based on a Monte Carlo sampling of uncertainty in the measurements. Uncertainty in Ca inputs in precipitation was greater than that of Ca losses in runoff. In contrast, the long-term weathering rate estimated from soil profiles averaged only 0.5 kg/ha/yr, with a range of -0.2 to 1.1 kg/ha/yr across the 14 sites. This approach involves estimating the time for soil development and assuming that there is no loss or gain of material, that the C horizon represents the parent material, and that Ti is immobile during weathering. Even with these uncertainties, current rates of Ca loss are undoubtedly higher than the average over 14,000 years of soil formation. Calcium loss was accelerated by 3.0 kg/ha/yr in the first 26 years after harvesting a watershed at the HBEF. This difference could be due to biological demand for nutrients (including phosphorus in apatite, a Ca mineral) or to other changes associated with forest disturbance and regrowth, such as acidification. Clearly, current rates of Ca loss are variable, affected by forest management, and high relative to the long-term average over past millennia.

[O5C-4] Changes in catchment biogeochemistry under future scenarios of acid deposition and forestry practices in Central Europe

Presenter: Jakub Hruška, Global Change Research Center, Academy of Sciences of the Czech Republic, Brno, Czech Republic, jakub.hruska@geology.cz

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During the 20th century forest ecosystems in Central Europe have been seriously damaged and soil pools of major nutrients significantly depleted due to long-term deposition of sulphur (S) and nitrogen (N) compounds from the atmosphere. The problem is exacerbated by forest harvesting, which removes additional amounts of nutrients from the ecosystems, and by elevated leaching of nitrates (NO₃) and base cations (mostly Ca, Mg, K) from deforested areas. On the other hand, harvesting has decreased dry and occult deposition of S and N onto forest canopies. At the Uhlířská catchment (Jizera Mts., northern Czech Republic) high S and N deposition resulted in forest dieback with deforestation of 50% of catchment area in the 1980's. Concentrations of SO₄ in streamwater decreased rapidly, but NO₃ as well as dissolved organic carbon (DOC) concentrations increased. The pH rose, because the SO₄ decline was larger than the increase of NO₃ and DOC. In the 1990's atmospheric deposition decreased by 60-70% due to power plant desulfurization; streamwater has continued to recover from acidification. Regrowth of Norway spruce in deforested areas (plantation from late 1980's) has changed catchment biogeochemistry by several ways during last decade: (i) streamwater NO₃ has declined dramatically, (ii) S dry deposition on newly developed canopy has increased, and (iii) uptake of base cations (Ca, Mg, K) by the trees has increased. As a result, recovery in the catchment has slowed, and streamwater pH has decreased slightly during last three years.

Application of the biogeochemical model MAGIC suggests further slow re-acidification of this sensitive granitic catchment until 2050 as a result of intensive regrowth of Norway spruce plantations. The driving mechanisms are enhanced base cation uptake and S dry deposition. Also the observed DOC increase contributes to rising streamwater acidity.

[O5C-5] Acidity and base cations in forest soils as affected by deposition reduction and whole-tree harvesting: Application of the HD-MINTEQ model

Presenter: Jon Petter Gustafsson, Department of Soil and Environment, Swedish University of Agricultural Sciences, Box 7014, 750 07 Uppsala, Sweden, jon-petter.gustafsson@slu.se

Author(s): Jon Petter Gustafsson, Stefan Löfgren and Ulf Skyllberg, Swedish University of Agricultural Sciences

There is still considerable uncertainty as regards the soil chemical effects of whole-tree harvesting in relation to those caused by decreasing deposition levels. Here we present work in which we applied a mechanistically based dynamic model, HD-MINTEQ, to assess mechanisms behind long-term chemical changes for three different Swedish forested sites. The model suggested that deposition reductions caused pH increases but also decreases in dissolved base cations. This is in agreement with what is predicted also by other models (e.g. MAGIC, ForSAFE). The effect of whole-tree harvesting on the pH of the soil water was predicted to be moderately negative after 80 years, with the largest change for the B horizon. However, in inland areas where seasalt input is low, the export of acidity to runoff water was generally small. In the long term, shortage of Ca²⁺ rather than the pH decrease is suggested to be a potential problem for tree growth. Again these conclusions are much the same as would be obtained with other models. However, the interpretation of the mechanisms involved is different. The HD-MINTEQ model results emphasize that salt-dependent proton dissociation of soil organic matter, rather than cation exchange (which is predicted by the other models), is a predominant process behind short- and medium-term soil chemical responses to changes in the infiltrating water, with sulphate adsorption/desorption reactions being of additional significance in areas with spodic B horizons. This could change our view on how and why soil acidification occurred in the past, as well as how deposition reduction and forest management affect soil acidity and exchangeable cations in the future.

**BREAKOUT SESSION 6 (BLOCK A):
LINKAGES OF ACID RAIN WITH THE MERCURY
CYCLE**

Session Chair: Dave Schmeltz, US EPA

[O6A-1] Current and Past Sulfate Inputs Control Methylmercury in a Boreal Peatland

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Methylmercury (MeHg) is a neurotoxic compound that is detrimental to the health of humans and wildlife. MeHg production is mediated by bacteria that are ubiquitous throughout aquatic systems. Therefore its presence in the environment is a reflection of the availability of inorganic mercury and other compounds that influence the rate of bacterial MeHg production. A number of sulfate-reducing bacterial (SRB) species are well-known mercury methylators, and studies have demonstrated the stimulatory effect that elevated sulfate inputs can have on MeHg production in, and export from, sulfur-limited aquatic systems. The influence of sulfate availability on SRB-activity makes the reduction of sulfate inputs to natural systems a promising mechanism for lowering MeHg production in certain environments.

The effects of long-term increases and decreases in atmospheric sulfate deposition on MeHg production were measured through experimental manipulation of sulfate loads to a boreal peatland in northern Minnesota. Between 2001 and 2008 sulfate was added through simulated rainfall events to half of a 2.0-ha peatland at a rate representative of deposition rates in the northeastern US prior to the 1990 Clean Air Act Amendments. MeHg production, export, and bioaccumulation in the system increased by 2-6X over control levels and the zone of highest net MeHg production moved from the peatland margins to the center. In the spring of 2006 sulfate addition was halted in a portion of the experimental treatment. MeHg concentrations in the porewaters and peat of this new recovery treatment declined to near control levels by the end of the study. However, the legacy of elevated sulfate deposition was apparent following drought when higher levels of MeHg and sulfate were released into porewaters from resaturated peat. These findings suggest that reduction of sulfate inputs may result in lower MeHg in some systems, but that complete recovery may be slowed by climatic variability.

[O6A-2] Stream mercury at five Czech catchments across a Hg and S deposition gradient

Presenter: James B. Shanley, U.S. Geological Survey, jshanley@usgs.gov

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The Black Triangle area in the northern Czech Republic suffered forest dieback from extreme levels of acid deposition from local combustion of high-sulfur coal. Emissions peaked in 1982 but with pollution controls they declined precipitously in the 1990s to current levels at only 10% of peak. Although mercury (Hg) was not measured, analysis of peat cores show that Hg deposition paralleled S deposition, as would be expected from the close association of Hg with S in coal. To investigate the fate of Hg in this highly acidified landscape, we studied dissolved (filtered) stream water Hg and dissolved organic carbon (DOC) concentrations at five catchments with contrasting Hg and S deposition histories in the Bohemian (western) part of the Czech Republic. The sites spanned a gradient of Hg and S deposition with 3 sites in the Black Triangle, one near Prague, and one in the relatively unpolluted Bohemian Forest in the south. Our hypothesis was that stream Hg concentrations and fluxes would align strongly with the gradient in Hg deposition. However, Hg deposition history appeared to be only one of several factors affecting current stream Hg dynamics. Two of the sites within the Black Triangle had filtered Hg concentrations and output fluxes that were among the highest reported in the literature. However, Hg concentrations at the most polluted Black Triangle site were near typical background levels for forested streams and were indistinguishable from those at the unpolluted Bohemian Forest site. Stream Hg/DOC ratio more closely tracked the gradient, suggesting that the Hg export was limited by DOC availability. Stream Hg/DOC, in turn, was positively related to soil C/S, which implied a role for legacy S deposition by formation of solid phase Hg-S under low pH and more soluble Hg-S complexes under high pH, and/or S inhibition of soil organic matter decomposition.

[O6A-3] Anthropogenic Mercury Accumulation in Forested Watersheds of Pennsylvania

Presenter: Elizabeth Boyer, Penn State University, ewb100@psu.edu

Author(s): E. Boyer, J. Grimm, D. Lawler, K. Eklof, P. Drohan, C. Grant, and D. DeWalle, Penn State University

Atmospheric deposition of mercury (Hg) is a critical environmental stress that affects ecosystems and human health. Mercury emissions to the atmosphere from coal-fired power plants and other sources such as waste incineration can be deposited over large geographic areas to downwind landscapes in precipitation and in dry fallout. The northern Appalachian Mountains are downwind of major atmospheric mercury emissions sources. Some mercury reaches watersheds and streams, where it can accumulate in sediments and biota. Human exposure to mercury occurs primarily through fish consumption, and currently mercury fish eating advisories are in place for many of the streams and lakes in the region. Here, we explored mercury accumulation in forested landscapes - in air, soils, water, and biota. To quantify atmospheric mercury deposition, we measured both wet and dry mercury deposition at 10 forested locations, from which we present variation in mercury deposition and initial assessments of factors affecting the patterns. To quantify mercury accumulation in terrestrial environments, we measured soil mercury concentrations within and surrounding 12 vernal pools spanning various physiographic settings in the region. Given that vernal pools have large inputs of water via precipitation yet do not have any stream discharge outflow, they are likely spots within the forested landscape to accumulate pollutants that enter via wet atmospheric deposition. To quantify mercury accumulation in aquatic environments, we sampled mercury concentrations in streams draining 35 forested watersheds, spanning gradients of atmospheric deposition, climate and geology. Mercury concentrations were measured in stream water under base-flow conditions, in streambed sediments, aquatic mosses, and in fish tissues from brook trout. Results indicate that wet and dry atmospheric deposition is a primary source of mercury that is accumulating in watersheds of the Northern Appalachian Mountains.

[O6A-4] Controlling Factors of Long-Term Trends in Mercury Wet Deposition and Precipitation Concentrations at Huntington Wildlife Forest

Presenter: Zhuyun Ye, State University of New York College of Environmental Science and Forestry, zye01@syr.edu

Author(s): Zhuyun Ye, State University of New York College of Environmental Science and Forestry, Huiting Mao, State University of New York College of Environmental Science and Forestry, and Charles T. Driscoll, Syracuse University

The Adirondacks, as a “biological Hg hot spot” and “the bull’s eye of North America’s acid rain problems”, was changed by the deposition of mercury and acids from combustion of fossil fuels for more than a century. The present study aimed to investigate the meteorological factors that influenced the decadal pattern in Hg wet deposition in upstate NY. Long term observational data were analyzed from the Mercury Deposition Network (MDN) at Huntington Wildlife Forest (HWF, located in the Adirondacks). Volume weighted mean (VWM) Hg concentrations in precipitation were found to be decreasing at a rate of $0.12 \text{ ng L}^{-1} \text{ yr}^{-1}$ ($r^2 = 0.34$, $p = 0.03$) from 2000 to 2013. The decline was linked to Hg emission decreases in the United States, especially in the Northeast and Midwest. Yet Hg wet deposition was found to have remained fairly constant over the past two decades. Simultaneously, strong positive correlation ($r^2 = 0.89$, $p < 0.0001$ for spring; $r^2 = 0.58$, $p = 0.002$ for summer) of Hg wet deposition with precipitation was found in spring and summer, while significant positive correlation ($r^2 = 0.61$, $p = 0.0009$ for fall; $r^2 = 0.33$, $p = 0.03$ for winter) of Hg wet deposition with VWM Hg concentration in precipitation was found in fall and winter. This indicates different predominant factors controlling Hg wet deposition in different seasons. Considering higher Hg wet deposition in spring and summer than fall and winter, increases in precipitation during the two seasons could offset the decreasing trend of Hg concentration in precipitation. Significant springtime positive correlation ($r^2 = 0.35$, $p = 0.02$) between precipitation and the North Atlantic Oscillation (NAO) index together with geopotential height and wind speed analysis indicated that large-scale dynamical forcing was likely an important factor influencing the long term trend in springtime Hg wet deposition at HWF.

[O6A-5] Wet Deposition Monitoring Networks of Mercury and Acid Rain in Taiwan

Presenter: Guey-Rong Sheu, National Central University,
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Author(s): Guey-Rong Sheu, National Central University
Neng-Huei Lin, National Central University

East Asia is the largest anthropogenic emission source region of atmospheric mercury (Hg) globally. Southeast Asia, a region with numerous small-scale gold mining and intense biomass burning activities, also contributes significant amount of Hg to the atmosphere. Due to seasonal monsoon activities, Taiwan is located on the transport paths of Hg and other air pollutants emitted from these two regions. Moreover, model simulations suggested that Taiwan and the surrounding oceans could receive high Hg input via wet deposition. Therefore, a wet Hg deposition monitoring network, consisting of 11 sampling sites in Taiwan and a remote islet site in subtropical Northwest Pacific Ocean, was established upon the existing acid rain monitoring network to collect weekly rainwater samples for Hg analysis since 2009. The purpose of this network is to develop information on spatial and seasonal trends in wet Hg deposition and to evaluate the contribution of regional/long-range transport. Here we reported rainwater Hg data collected in 2009-2013. Annual volume-weighted mean (VWM) Hg concentrations of all the sampling sites ranged between 5.6 and 21.7 ng L⁻¹, close to the range of values reported by NADP/MDN. Annual wet Hg deposition fluxes ranged between 11.0 and 63.4 $\mu\text{g m}^{-2}$, usually higher than the values reported by NADP/MDN. This is mainly due to the higher annual rainfall at the sampling sites in Taiwan (1022-5206 mm). Geographical distribution of wet Hg deposition flux mimicked the distribution of accumulative rainfall amount, indicating precipitation depth is the primary factor in determining the magnitude of the wet Hg deposition flux. Correlations between major ions and Hg varied with sites.

**BREAKOUT SESSION 6 (BLOCK B):
CYCLING OF BASE CATIONS IN ECOSYSTEMS**

*Session Chair: Scott Bailey, University of New
Hampshire*

*Session Co-Chair: Stephen Norton, University of
Maine*

[O6B-1] Dynamics of calcium and magnesium in forest ecosystems assessed by a multi-isotopic tracing experiment

Presenter: Gregory van der Heijden, INRA-BEF Champenoux France,
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Many forest ecosystems grow on nutrient poor soils that have been depleted of their calcium and magnesium exchangeable pools due to past acid deposition. In the context of decreasing atmospheric inputs and increasing biomass exportation, the sustainability of forest soil fertility is major concern. However, many studies have observed discrepancies between measured and predicted soil fertility change or soil nutrient pools and tree nutrition indicators. These discrepancies suggest that trees access nutrient sources which are not currently correctly taken into account.

To better understand how forests may cope with very low mineral resources, in April 2010 a multi-isotopic tracing experiment (^{26}Mg , ^{44}Ca) was carried out in a 35-yr old beech stand growing on a very nutrient poor soil in Burgundy, France. A tracing solution (dissolved salts: Mg^{2+} and Ca^{2+}) was sprayed on the forest floor (80 m^2). The isotopic tracers have been monitored in the soil, forest floor and trees. The results from this on-going experiment have been published in recent articles. We present here a synthesis of the major findings.

The vertical transfer of Mg and Ca in the soil profile was very slow. Two years after the application of tracers, 8% of ^{26}Mg and 35% of ^{44}Ca were still retained in the litter layer (ion exchange), only 15% of ^{26}Mg was found below 15cm depth and 9% of ^{44}Ca was found below 5 cm depth. 27% and 20% of ^{26}Mg and ^{44}Ca were taken up by trees in the first two years but no tracers were found in the canopy compartment. The transport of Mg and Ca from the roots to the canopy was very slow and probably governed by ion exchange along the xylem sap flow. A novel approach using the isotopic dilution of tracers was developed to test the validity of input-output Mg and Ca budgets.

[O6B-2] Ecosystem Alkalization from Oil Sands Emissions

Presenter: Shaun Watmough, Trent University, swatmough@trentu.ca

Author(s): Andrew McDonough, Trent University
Adam Bird, Trent University
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Shanti Berryman, Integral Ecology
Justin Straker, Integral Ecology
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The Athabasca Oil Sands in Alberta, Canada is one of the largest point sources emitters of NO_x and SO₂ in Canada and there have been widespread concerns over potential ecosystem acidification owing to the acid sensitivity of the base-poor, sandy soils in the region. In this study we compared atmospheric deposition and ecosystem response at a jack pine (*Pinus banksiana*) stand adjacent to one of the largest mines in the region with a site approximately 15 km from the mine. At the site closest to the mine, deposition of S and N in throughfall exceeds 3000 eq/ha/y compared with <300 eq/ha/yr at the more distant site. However base cation (Ca, Mg + K) deposition in throughfall at both sites exceeds combined S and N deposition and base cation levels in tissues of several plant and lichen species (naturally occurring and transplants) are significantly higher at the site adjacent to the mine. Surface soils and soil solution show greatly elevated base cation levels at the site close to the mine despite similar soil characteristics and base cation weathering rates. There is no difference in species richness or diversity between sites but herbaceous cover and biomass is several fold higher and lichen cover is several fold lower at the site closest to the mine. Tree health is also impaired at the more impacted site. This work indicates that despite high acid emissions from oil sands activities, ecosystem alkalization may be of greater concern than acidification owing to large dust emissions from the mines and the Acid Deposition Management Framework for the region should be modified accordingly.

[O6B-3] Do soil weathering rates in south-central Ontario protect forests from acidification under current deposition?

Presenter: Grant Stott, Trent University, grantstott@trentu.ca

Author(s): Grant Stott, Trent University
Julian Aherne, Trent University
Hazel Cathcart, Trent University

Acidification of forest soils is still a prevalent issue across north-eastern North America, despite significant reductions in the emissions of sulphur and nitrogen oxides during the past few decades. Critical loads of acidity is widely used to quantify ecosystem sensitivity to sulphur and nitrogen deposition, and exceedance, i.e. where deposition is greater than critical load, is the indicator of long-term risk to ecosystem health. Soil base cation weathering rates are a key determinant of critical loads, but few studies have incorporated high-resolution regional weathering rates derived from observed soil properties. The objective of this study was to develop high-resolution critical loads of acidity for forest soils in the acid-sensitive Muskoka River Catchment (MRC; area = 4,660 km²) in south-central Ontario, a region characterized by thin, poorly-buffered soils. Soils were sampled at 84 sites across the region, and weathering rates were estimated using PROFILE, a steady-state soil geochemical model. Estimated base cation weathering rates in the upper 50 cm of the soil ranged from 45 to 1254 eq/ha/yr, averaging 461 eq/ha/yr across the MRC, which is low when compared to estimates in other regions. Further, estimated weathering rates are similar in magnitude to average base cation deposition across the MRC (422 eq/ha/yr). The point estimates of base cation weathering rates were interpolated to produce a continuous prediction map. Critical loads of acidity were determined using the simple mass balance model in conjunction with continuous data layers of land cover, weathering rate, nutrient uptake by vegetation, base cation deposition and nitrogen immobilization to calculate critical loads. Total (wet and dry) sulphur and nitrogen deposition, ranged from 1114 to 1340 eq/ha/yr, suggesting widespread exceedance of critical loads across the MRC.

[O6B-4] Influence of windblown dust on snowpack chemistry and snowmelt timing in mountains of the western U.S.

Presenter: David W. Clow, U.S. Geological Survey, dwclow@usgs.gov

Author(s): D.W. Clow¹, M.W. Williams², and G.P. Ingersoll¹

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Widespread dust deposition events are common in the Rocky Mountains, and there is concern that dust deposited on snow may contribute to earlier snowmelt by decreasing snowpack albedo. However, direct measurements of dust in snow are difficult and rarely made. In this study, dust and snowpack chemistry were measured in a dust-rich layer of snow after a major dust event in February 2006 at 13 sites in Colorado. There was a strong positive correlation ($r^2 \geq 0.95$) between dust, calcium, and alkalinity concentrations, reflecting dissolution of eolian carbonate dust within the snowpack. These results have two implications: (1) dust has a strong neutralizing effect on snowpack acidity, and (2) calcium and alkalinity can be used as proxies for dust, enabling us to make inferences about dust deposition across space and time based on snowpack chemistry.

Depth-integrated snowpack samples have been collected annually just prior to maximum snow accumulation at 57 sites in the Rocky Mountains since 1993 as part of a regional snow chemistry monitoring program operated by the USGS. Data from these samples show strong upward trends in calcium and alkalinity concentrations ($p < 0.03$), with trend magnitude increasing from north to south. These results indicate an increase in dust deposition in the southern Rockies over the past two decades, and may partly explain declining precipitation acidity in the region.

The influence of dust deposition on snowmelt timing was investigated by regressing climate variables and snowpack chemistry against snowmelt timing indices derived from SNOTEL data. Results indicated that snowmelt tends to begin earlier in years with substantial dust deposition or warm air temperatures, and later in years with deep snowpacks. Thus, dust deposition to mountain snowpacks can have a range of effects, some positive (acid neutralization), and some negative (earlier snowmelt timing).

[O6B-5] The importance of water residence time distributions for the flux of weathering products

Presenter: Martin Erlandsson, Uppsala University,
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Soil mineral weathering is one of the major sources of base cations, which play a dual role for a forest ecosystem; they function both as plant nutrients, and for buffering against acidification of catchment runoff. On a long-term basis, the soil weathering rates will determine the highest sustainable forest productivity without causing acidification. It is believed that the hydrologic residence time play a key role in determining weathering rates on a landscape scale. In this study, we investigate the significance of the water residence time (WRT) distribution for the transport of base cations to catchment runoff.

By modelling hillslope flowpaths with different residence times, using the geochemical computing code PHREEQc, we demonstrate different relationships between the WRT-distribution and different concentrations of weathering products. Elements mostly associated with minerals which never reach supersaturation (Ca^{2+} , Mg^{2+}), display a linear relationship between concentration and WRT. In contrast, elements associated with minerals which do reach supersaturation (Na^+ , K^+) display a non-linear relationship with WRT, and elements associated with a secondary phase (Si) can show a negative relationship between concentration and WRT.

We also demonstrate how the width (i.e. standard deviation) of the WRT distribution affects the transport of weathering products – as the transport of Na^+ , K^+ and Si is limited by supersaturation and precipitation of secondary phases, the tails of “old water” of the WRT-distribution will not contribute to any extra transport of these elements. In contrast, the transport of Ca^{2+} and Mg^{2+} will only be dependent on the average WRT, and not the shape of the distribution.

Finally, we use the derived relationships to estimate the transport of weathering products from a forested hillslope, given the modelled WRT distribution.

**BREAKOUT SESSION 6 (BLOCK C):
CLEAN AIR POLICIES**

*Session Chair: Rocci Aguirre, The Adirondack
Council*

*Session Co-Chair: John Sheehan, The
Adirondack Council*

*Session Co-Chair: Mandy Warner, Environmental
Defense Fund*

[O6C-1] The Rocky Mountain Park Initiative: A Unique Approach to Reducing Nitrogen Deposition

Presenter: Lisa Devore, Colorado Department of Public Health and Environment, Lisa.Devore@state.co.us

Author(s): Lisa Devore, Air Pollution Control Division, Colorado Department of Public Health and Environment

The Colorado Department of Public Health and Environment (CDPHE), the Environmental Protection Agency (EPA), and the National Park Service (NPS) formed the Rocky Mountain National Park (RMNP) Initiative in 2005 to address air pollution issues within RMNP. This collaboration focuses on monitoring the effects and trends of nitrogen deposition and addresses other air quality issues impacting ecosystems and visibility within RMNP. The three agencies, through a joint Memorandum of Understanding (MOU), work collaboratively with interested stakeholder groups to understand the status of nitrogen deposition and ecosystem impacts at the park, sources of emissions, and approaches to resolve the nitrogen deposition issue in RMNP.

In 2007, the three agencies issued the Nitrogen Deposition Reduction Plan (NDRP), with milestones for achieving nitrogen deposition reductions that protect RMNP resources over time. The NDRP documents how ecosystem health first began to decline at high-elevation areas on the east side of RMNP between 1950 and 1964 as indicated by a shift in aquatic biota from a natural to a disturbed condition. The beginning of this shift corresponded to a critical load of wet nitrogen deposition of 1.5 kg N/ha/yr. This threshold has been designated the resource management goal for restoration of healthy ecosystems at high elevation areas of RMNP. The NDRP relies on a “glidepath” approach to achieve the resource management goal by the year 2032 with interim milestones at five-year intervals. Subsequently, other reports have been issued to document progress and innovative approaches including the 2012 Milestone Report which assesses a variety of monitoring data and statistical analyses using a ‘weight of evidence’ approach to determine whether the first milestone had been reached.

[O6C-2] Social and economic impacts of the acidification and potential recovery of Adirondack ecosystems

Presenter: Colin M Beier, SUNY College of Environmental Science and Forestry, cbeier@esf.edu

Author(s): Jesse D Caputo, SUNY College of Environmental Science and Forestry, jcaputo@esf.edu

Sustaining recent progress in acid rain mitigation requires continued declines in emissions that will likely give rise to real or perceived tradeoffs between healthy ecosystems and cheap energy. Because most impacts of acid rain affect ecosystem functions that are poorly understood by policy-makers and the public, an ecosystem services framework can help to identify and quantify how these functions benefit society. Otherwise, ecosystem recovery will seem to have few tangible impacts on our economy, health, or quality of life. Focusing on the Adirondack region, our research quantifies how the acidification and potential recovery of the region's terrestrial and aquatic ecosystems will shape the ecosystem services that they provide to multiple beneficiaries. We draw upon the Adirondack region's lake and stream surveys, soil and vegetation inventories, and deposition monitoring efforts, among other data sources. We focus on key 'biological receptors' of deposition in forests and lakes that are acid-sensitive, economically and culturally important, and relevant for regulatory efforts such as the identification of critical loads. Our analyses consider the interplay between ecosystem acidification and local management actions, such as forest harvesting or fish stocking, and how such interactions will shape long-term outcomes. We also evaluate scenarios of changes in ecosystem services resulting from different future emissions pathways, based on ecosystem simulation models. Overall our findings elucidate some of the economic and cultural impacts of acid rain in the Adirondacks, and suggest that both natural and human-mediated pathways for ecosystem recovery are needed to restore ecosystem services that have been degraded or lost due to acid rain.

[O6C-3] Evidence-based impacts of SO₂ policies 1990-2012: A Swedish case study

Presenter: Stefan Åström, IVL Swedish Environmental Research Institute Ltd and Chalmers University of Technology, stefan.astrom@ivl.se & astrom@chalmers.se

Author(s): Stefan Åström, Katarina Yaramenka, Ingrid Mawdsley, Helena Danielsson, Peringe Grennfelt, IVL Swedish Environmental Research Institute Ltd, Annika Gerner, Statistics Sweden

Since 20 years European ecosystems are under recovery from acidification damages. To solve the remaining acidification problems in Northern Europe, additional policy measures are most likely needed. Knowledge on the impact of previous policies is important for such policy decisions.

In this study the objective was to identify if it is possible in retrospect to verify the impact of individual policy measures affecting SO₂ emissions. The study was performed for Sweden as a case and the time period 1990-2012. Official emission inventory data was used for the analysis.

In the analysis we first decomposed reported SO₂ emission reductions into reductions due to: structural changes; fuel shifts; or emission factors. Secondly we performed an ex-post policy analysis comparing SO₂ policy measures with observed emission reductions.

Our results show that SO₂ policies were linked to at least 48% of the national SO₂ emission reductions for the period. For the remaining reduction the impact of policies could not be clearly distinguished due to too many plausible explanations. Factors complicating the ex-post analysis were: the timing of policy measures and emission reductions; the multitude of measures implemented; the multiple impacts of several measures; and the multiple impacts of autonomous changes in the economy. Validation of individual policy measures was achievable only for specific cases. Impacts of emission limit values were more clearly visible than impacts of market instruments.

Policy-specific conclusions are limited despite that Sweden is a country with large amounts of official data collected and processes leading to SO₂ emissions are well known. However, if the goal is to have evidence-based policy we suggest that emission data inventories are complemented with data on the installment of emission-abatement technologies and economic data. Given the current state, studies that focus on only one specific policy measure are likely to misrepresent the impacts of the measure.

[O6C-4] The effects of China's control policies on historical and future trends on atmospheric pollutant emissions

Presenter: Yu Zhao, Nanjing University, yuzhao@nju.edu.cn

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To examine the effects of China's national policies of energy conservation and emission controls, inter-annual emission trends of air pollutants (SO₂, NO_x, CO, PM, PM₁₀, PM_{2.5}, black carbon, organic carbon, and calcium) are estimated with a bottom-up framework from 2000 to 2014 and the future emissions are projected through 2030 based on available energy scenarios and emission control strategies. Despite fast growth of the economy and energy consumption, reduced SO₂ and primary PM emissions are respectively found from 2007 and 2006, respectively, suggesting successful emission control of those species. However, the NO_x emissions are estimated to keep growing until 2012. The emission control strategies are expected to have more effects than the energy paths on the future emission trends. While emission trends determined by bottom-up methods can be generally verified by observations from both ground stations and satellites, clear discrepancies exist for given regions and seasons, indicating a need for more accurate spatial and time distributions of emissions. The estimated emission trends raise concerns about current pollution control strategies. Compared with total PM, there are fewer gains in control of fine particles and carbonaceous aerosols, the components most responsible for damages to public health and effects on radiative forcing. A much faster decrease of calcium in primary PM than that of SO₂ may have raised the acidification risks to ecosystems, indicating further control of acid precursors is required. Moreover, with relatively strict controls in developed urban areas, air pollution challenges have been expanding to less-developed neighboring regions, and the potential for emissions abatement in key sectors may be declining due to the near saturation of emission control devices use. A more comprehensive emission control strategy targeting a wider range of pollutants (volatile organic compounds and NH₃, etc) and taking account of more diverse environmental impacts is urgently needed.

[O6C-5] Measuring the Value of Acid and Mercury Pollution in New York State through Property Values (In progress)

Presenter: Chuan Tang, Clarkson University, chutang@clarkson.edu

Author(s): Chuan Tang, Institute for a Sustainable Environment, Clarkson University;
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Thomas M. Holsen, Civil & Environmental Engineering Department, Clarkson University

The water bodies of New York State have been severely impacted by deposition of airborne pollutants including acid rain and mercury generated primarily by emissions from electrical generating units (EGUs) located upwind of New York State. These pollutants have degraded the ecosystem services provided by these water bodies, including the amenity service. In this study, links between water quality and water quality as a result of acid and mercury deposition in New York State is established through hedonic analysis. Hedonic analysis is an environmental economics approach that uses regression techniques to estimate a hedonic price function which represents the impact of observable property characteristics, including environmental amenities and spatial factors, on the equilibrium prices of parcels.

Specifically, more than 180,000 property transactions data over a 10 year period (i.e., 2004 to 2013) in 34 counties (including the Adirondacks and Finger Lakes Regions) are collected and used to estimate the property value effects of water quality measures. Accordingly, valid data for explanatory variables in terms of the change of water quality (e.g., lake water acidity and trophic status) for more than 150 lakes in the study area are used. An example of latest regression analysis suggests that, comparing to normal pH level (i.e., 6.5 ~8.0) in lakes, the property value was significantly depreciated by approximate 4.67% in terms of poor lake pH level of nearest big lakes which are greater than 282 ha. Furthermore, comparing to low fish mercury (<0.26 ppm), there is approximate 1.12% reduction in property price due to higher fish mercury (0.26 ~0.4 ppm) in nearest big lakes. This research helps partially quantify air pollution impacts on northern New York State property values and could be used to justify additional Clean Air Act regulations to further restrict sulfur and mercury emissions which are negatively impacting this area.

**BREAKOUT SESSION 7 (BLOCK A):
ADVANCES IN QUANTIFYING TOTAL
ATMOSPHERIC DEPOSITION**

*Session Chair: Kristi Morris, National Park
Service*

Session Co-Chair: Gary Lear, US EPA

[O7A-1] A Hybrid Approach for Estimating Total Deposition in the United States

Presenter: Gary Lear, USEPA, lear.gary@epa.gov

Author(s): Gary G. Lear, Clean Air Markets Division, U.S. Environmental Protection Agency, Washington, DC, USA and Donna B. Schwede, U.S. Environmental Protection Agency, Research Triangle Park, NC, USA

Atmospheric deposition of nitrogen and sulfur causes many deleterious effects on ecosystems including acidification and excess eutrophication. Assessments to support development of strategies to mitigate these effects require spatially and temporally continuous values of nitrogen and sulfur deposition. In the U.S., national monitoring networks exist that provide values of wet and dry deposition at discrete locations. While wet deposition can be interpolated between the monitoring locations, dry deposition cannot. Additionally, monitoring networks do not measure the complete suite of chemicals that contribute to total sulfur and nitrogen deposition. Regional air quality models provide spatially continuous values of deposition of monitored species as well as important unmeasured species. However, air quality modeling values are not generally available for an extended continuous time period. Air quality modeling results may also be biased for some chemical species. We developed a novel approach for estimating dry deposition using data from monitoring networks such as the Clean Air Status and Trends Network (CASTNET), the National Atmospheric Deposition Program (NADP) Ammonia Monitoring Network (AMoN), and the Southeastern Aerosol Research and Characterization (SEARCH) network and modeled data from the Community Multiscale Air Quality (CMAQ) model. These dry deposition values estimates are then combined with wet deposition values from the NADP National Trends Network (NTN) to develop values of total deposition of sulfur and nitrogen. Data developed using this method are made available via the CASTNET and NADP websites. Issues remain in incorporating results from the CMAQ 5.0 ammonia bidirectional flux module, providing meaningful information for base cations, and incorporating data from 1-in-3 monitoring networks (e.g., IMPROVE and CSN).

[O7A-2] Trends over 30 years in the mass budgets of sulphur, oxidized and reduced nitrogen and ozone over the UK and their implication for residence times, linearities, and understanding the wet and dry deposition processes

Presenter: Prof David Fowler
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The air chemistry of the 1980s in Northern Europe was dominated by sulphur dioxide (SO₂) and nitrogen oxide (NO_x) emissions, which oxidized to their respective acids during long range transport. The transport and deposition processes for sulphur were strongly influenced by the acidity of aerosols and cloud and relative amounts of ammonia (NH₃) and SO₂ in the air, while oxidation of nitrogen dioxide (NO₂) to nitric acid (HNO₃) was oxidant limited. Dry deposition to terrestrial surfaces was controlled by chemistry in surface water films. By 2015 the sulphur compounds are now the minor fraction while nitrogen compounds often dominate the anthropogenic pollutants. Ozone (O₃) is an important atmospheric oxidant whose mixing ratios over Europe have changed substantially over the last 30 years, contributing to the observed changes in atmospheric processing of the primary pollutants.

The process knowledge from field measurements and the long term monitoring data can now be compared with models which reproduce these changes over the 30 years in which SO₂ and NO₂ emissions have declined by 90% and 50% respectively. The paper compares the observed trends in sulphur and nitrogen budgets with models, quantifies the extent of the non-linearities in emission deposition footprints, and infers changes in the residence times in the atmosphere and transport distances.

[O7A-3] Quantification of atmospheric nitrogen deposition across China based on a nationwide monitoring network

Presenter: Xuejun Liu, China Agricultural University, liu310@cau.edu.cn

Author(s): Xuejun Liu, Wen Xu, Xiaosheng Luo, Aohan Tang and Fusuo Zhang, China Agricultural University at Beijing; Yuepeng Pan, Institute of Atmospheric Physics, Chinese Academy of Sciences; Lin Zhang, School of Physics, Peking University; Kaihui Li, Xinjiang Institute of Ecology and Geography, CAS; Ying Zhang, Beijing Forestry University; Enzai Du, Beijing Normal University; Anthony J. Dore and Sim Tang, Centre for Ecology and Hydrology at Edinburgh UK; Jeffrey L. Collett, Jr., Colorado State University at Fort Collins; and Keith Goulding, Rothamsted Research, UK.

Global atmospheric reactive nitrogen (Nr) deposition to terrestrial ecosystems has increased dramatically since the industrial revolution and contributed largely to global acidification. This is especially true in China, due to continuous economic growth and substantial anthropogenic Nr emissions. However, there were no comprehensive reports on both measured wet and dry Nr deposition across China. We therefore conducted a five-year study (from 2010 to 2014) to quantify atmospheric dry and wet deposition of Nr and estimate its contribution to ecosystem acidification. Monthly atmospheric concentrations of five Nr species (NH_3 , NO_2 , HNO_3 , pNH_4^+ and pNO_3^-) in air and two inorganic N forms (NH_4^+ and NO_3^-) in precipitation were measured, based on our Nationwide Nitrogen Deposition Monitoring Network (NNDMN) containing 43 sites. Dry deposition fluxes of Nr species were estimated by using inferential models (dry deposition) while wet deposition fluxes of Nr were the products of precipitation amount times NH_4^+ or NO_3^- concentration in rainwater. Our observations reveal large spatial variations of atmospheric Nr concentrations and dry and wet deposition of Nr. The annual average concentrations ($1.4\text{--}47.0 \mu\text{g N m}^{-3}$) and dry plus wet deposition fluxes ($3.3\text{--}75.2 \text{ kg N ha}^{-1} \text{ yr}^{-1}$) of inorganic Nr species ranked based on land use as urban > farmland > coastal > forest > grassland. Annual mean dry, wet and total Nr deposition fluxes were 19.0, 19.3 and $38.3 \text{ kg N ha}^{-1}$ across China, respectively. Our results suggest atmospheric Nr dry deposition is of equal importance of wet deposition at the national scale and should be taken into account when considering the ecological impacts such as cropland, grassland and forest soil acidification as reported previously in China.

[07A-4] EADN Advances in Measurements of Atmospheric Ozone, Nitrogen, Sulphur Compounds in Dry Deposition across Equatorial African Great Lakes

Presenter: Vincent O. Madadi, University of Nairobi, Kenya, vmadadi@uonbi.ac.ke

Author(s): Vincent O. Madadi, University of Nairobi; Eric O. Odada, University of Nairobi, Shem O. Wandiga, University of Nairobi; Daniel Olago, University of Nairobi; Godfrey Wafula, University of Nairobi; Corrine Galy-Lacaux, 4Laboratoire d'Aérodologie, Université Paul Sabatier (CNRS/UPS), Observatoire Midi- Pyrenees, Toulouse, France

The Sub-Saharan Africa has suffered from the negative effects of unsustainable land use practices for long time. This has contributed to the increased atmospheric levels of pollutants such as SO_x, NO_x, Ozone, oxides of phosphorus and dust that have negatively impacted on productivity of both terrestrial and aquatic ecosystems. Airborne SO₂ and NO₂ are also key acid rain precursors, while tropospheric ozone is mainly a secondary pollutant. Historical data from sediment cores show that nutrient loading has been increasing in the surface waters within the African great lakes, whereas preliminary studies on atmospheric deposition have suggested that atmosphere is the leading source of nutrients. The existing data is inadequate, and whether atmospheric deposition or direct discharge is the major contributor of nutrients has remained a subject of great debate. Inadequate scientific data remains the major impediment towards delineating the primary sources of pollutants for appropriate mitigation measures.

Equatorial Africa Deposition Network (EADN) was established to determine the major sources of nitrogen (N) and phosphorous (P) and atmospheric gases deposited in the African Great Lakes and their transport fluxes across the tropical latitudes, to reveal whether N and P atmospheric loading is mainly as wet or dry deposition. EADN has established 12 sampling sites across 11 Sub-Saharan Africa countries to provide wet and dry deposition data to determine the spatial and temporal patterns of atmospheric nutrient transport and their relationship to land use patterns, and their integration in regional dispersive models to estimates deposition at regional and catchment levels.

This paper presents the data that collected over the previous 24 months of sampling of airborne concentrations of NO₂, HNO₃, SO₂, O₃, and NH₃ across the region to evaluate their deposition into the lakes. The paper further discusses the temporal and spatial changes in the concentrations of these gases in dry deposition.

[O7A-5] Comparison of Various Approaches for Estimating Total Nitrogen Deposition to Forests and other Ecosystems

Presenter: Mark E Fenn, USDA Forest Service, PSW Research Station,
mfenn@fs.fed.us

Author(s): Andrzej Bytnerowicz and Susan Schilling, USDA Forest Service, PSW Research Station;
James Sickman, Amanda James, Robert Johnson, and G. Darrel Jenerette, University of California, Riverside;
Leiming Zhang, Environment Canada, Toronto;
Ignacio Gonzalez-Fernandez, CIEMAT, Madrid, Spain

Four approaches for estimating total N deposition will be considered. The first is an empirical inferential method (EIM), demonstrated using 2002-2006 monitoring data collected on a network of sites in the San Bernardino Mountains (SBM) of southern California. Empirical data consists of ambient concentrations of NH_3 , HNO_3 , NO and NO_2 from passive samplers and surface deposition conductance for NO_3^- and NH_4^+ based on branch rinsing. Stomatal conductance values for NH_3 , NO , NO_2 and HNO_3 for key tree and shrub species are literature-based, while LAI data are from MODIS satellite images. We showed that $\sim 2/3$ of dry deposition is to plant surfaces, while $\sim 1/3$ is taken up through stomata. Summer-season Nr deposition ranged from $<3 \text{ kg ha}^{-1}$ on the eastern side of SBM to $>60 \text{ kg ha}^{-1}$ on the western side directly exposed to the Los Angeles Basin. Our estimates of N deposition compared well with those based on throughfall collected with ion exchange resin (IER) collectors and the big-leaf micrometeorological inferential method. By comparing EIM results with CMAQ modeled deposition and extrapolating summer data to annual values, we developed maps showing large areas of the SBM exceeding critical loads for nutrient Nr in chaparral and mixed conifer forests. On a statewide scale CMAQ was found to underestimate annual N deposition in montane sites receiving moderate or high levels of N deposition. Throughfall-adjusted CMAQ, based on an IER collector throughfall network, was used to partially correct for this underestimate. A third approach at estimating N deposition at forested sites across the U.S. was based on S:N ratios in wet or bulk deposition, and assuming the ratio also held for total deposition. Finally, total N deposition was calculated to shrubs or tree seedlings using a ^{15}N pool dilution technique, and compared to inferential and branch rinsing calculations.

BREAKOUT SESSION 7 (BLOCK B):
CONTROLS ON DOC IN SURFACE WATERS

*Session Chair: Jakub Hruska, Czech Geological
Survey*

Session Co-Chair: Salar Valinia, NIVA / SLU

[O7B-1] Trends in DOC in northern surface waters in North America and Europe

Presenter: Heleen A. de Wit, Norwegian Institute for Water Research, heleen.de.wit@niva.no

Author(s): Don.T. Monteith, Centre for Ecology & Hydrology, Lancaster, UK and John L. Stoddard, US Environmental Protection Agency

Concentrations of DOC in boreal surface waters have increased to levels that create challenges for water treatment plants and that may affect ecosystem services. Increased organic matter solubility in response to reduced acid deposition appears to be the dominant mechanism behind the DOC increase. As deposition declines to low levels, variation in climate is expected to become increasingly important for DOC trends and variability.

Here, we present trends in DOC from circa 500 lakes and streams in subarctic, boreal and temperate headwater catchments in America and Europe from 1990 until 2012. We test 1) if DOC responds to changes in the rate of decline in acid deposition, and 2) if the importance of climatic and biogeochemical factors that drive trends and variability in DOC is changing.

For 1990 to 2012, the median ($\pm 2.5\%$ quartile) of the absolute and relative DOC trends was $+0.06$ ($+0.36$ to -0.02) mg C/L/yr and $+1.4$ ($+4.7$ to -0.9) %/yr, respectively. 67% of all trends was significant ($p < 0.05$). The largest relative changes were found in the UK ($+2.8\%$), while DOC in the Czech republic, and the south of Finland, Sweden and Norway all increased with $+1.8$ to $+2.1\%$. The mean trends in regions of North America ($+0.6$ to 1.4%) were similar to the mean changes in northern Scandinavia ($+1\%$), and lower than in the remainder of the Nordic region, the UK and the Czech Republic. In southern Sweden and Vermont/Quebec, DOC trends appeared to grow stronger.

Preliminary results indicate that seasalt deposition adds to the variation in DOC trend strength. A large proportion of the variation in DOC trend is still explained by trends in SO_4 . We will test if these different regional and temporal patterns can be explained by climatic drivers and/or atmospheric chemistry.

[O7B-2] Millennial-scale changes in lake-water carbon cycling in northern European boreal lakes: Teasing apart the competing roles of climate, land use and acidification

Presenter: Richard Bindler, Umeå University, Sweden, richard.bindler@umu.se

Author(s): Carsten Meyer-Jacob, Sofia Jonsson, Julie Tolu, Johan Rydberg, and Richard Bindler, Umeå University, Sweden

Understanding current trends in lake-water TOC and predicting future effects in response to ongoing environmental changes requires that we recognize what natural reference values were, quantify how much TOC has changed over timescales beyond monitoring, and identify the important long-term drivers of observed changes. As shown in previous work on lake acidification and metal pollution, lake-water TOC in N Europe has changed in response to human impacts not only over decadal but also centennial to millennial timescales.

Analyses of sediment records from several boreal lakes in Sweden using a suite of analytical tools (WD-XRF, Hg, FTIRS, pyrolysis-GC/MS, VNIRS-inferred lake-water TOC) reveal important changes in geochemistry, organic matter composition, pollen and lake-water TOC (Meyer-Jacob et al. 2015). Lake-water TOC increased parallel with the rapid landscape development in the millennia following deglaciation, and thereafter changed only slightly over ~9000 years in response to significant long-term natural changes in climate (Holocene Thermal Maximum) and forest vegetation (spruce establishment). However, 500–1000 years ago lake-water TOC levels began an unprecedented decline by ~50% in conjunction with an increase in the extent, if not necessarily intensity, of human landscape utilization, which in Scandinavia included slash-and-burn agriculture, outfield and forest grazing, haymaking on mires and exploitation of forest resources. In southern Sweden the TOC decline coincided with a period of mixed land use that led to a cultural alkalization in acid-sensitive lakes (Rosén et al. 2011), while in humic lakes in central Sweden the decline was associated mainly with widespread forest grazing and haymaking on mires, which reduced terrestrial C pools and C export to lakes. Although acidification recovery is one important factor for the ongoing TOC increase in Sweden, a significant part of the increase is coupled with changes in landscape utilization.

References:

Meyer-Jacob et al. 2015. PNAS 112:6579-6584
Rosén et al. 2011. Biogeosciences 8:2717-2727

[O7B-3] Stoichiometric and Isotopic Evidence for Drivers of Inverse DOC-Nitrate Loss Patterns in Forested Catchments

Presenter: Christine L. Goodale, Cornell University, clg33@cornell.edu

Author(s): Christine L. Goodale, Cornell University

Nitrate loss from forested catchments varies greatly across sites and over time, with few reliable predictors. Yet, one of the few recurring patterns is the negative nonlinear relationship between surface water nitrate (NO_3^-) and dissolved organic carbon (DOC) concentrations: that is, NO_3^- declines sharply as DOC increases, and high NO_3^- occurs only at low DOC concentrations. Several hypotheses have been proposed to explain this pattern but its cause has remained speculative. It is broadly attributed to C or N limitation of some biological process but the identity and location of these processes are not known. We examined whether variation in surface soil C content drives both DOC and NO_3^- loss across nine catchments selected from long-term monitoring networks in New York State. We measured forest floor C and N content and water-extractable NO_3^- and DOC, as well as DOC quality and NO_3^- isotopic composition for a subset of samples. These measurements showed that forest floor C stock drives DOC production while forest floor C:N ratio controls NO_3^- production, reflecting microbial stoichiometry and carbon-use efficiency. Isotopic measurements supported the interpretation that NO_3^- derived primarily from nitrification, with fractionation to produce isotopically light NO_3^- , especially in the forest floor. Yet, these processes of NO_3^- and DOC production did not suffice to create the inverse DOC- NO_3^- curve for soil extracts, as was observed at the catchment scale. Rather, the stoichiometry of denitrification and its limitation by bio-available DOC appear to control stream NO_3^- losses. Persistent enrichment in ^{15}N - NO_3^- between forest floor extracts and streamwater support the inference of partial consumption of NO_3^- by denitrification. Overall, stoichiometric and isotopic constraints indicate that catchment-scale DOC- NO_3^- patterns may be governed by N immobilization in high-C:N soils and NO_3^- production when heterotrophic microbes become C-limited, with subsequent NO_3^- consumption by denitrification limited by the supply of bio-available DOC.

[O7B-4] Dissolved organic carbon changes since the pre-industrial period redefine the extent of Swedish surface water acidification and help resolve a classic controversy

Presenter: Kevin Bishop
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Over 30 years ago, there was a suggestion that acid deposition would not acidify lakes and streams, but merely replace the natural organic acidity with strong acids of anthropogenic origin. A new regional understanding of how dissolved organic carbon has changed since the mid 1800's across Sweden is cause for reconsidering that controversial claim. Recent decadal increases in DOC are actually a recovery to pre-acidification levels. Thus more recent, higher DOC concentrations better represent pre-industrial reference conditions than the lower DOC levels during the height of acidification. The choice of DOC reference level is a critical step when assessing acidification status. Here we show that since the pre-industrial reference levels for DOC are higher than they were previously thought to be, the actual extent of surface water acidification in Sweden is substantially less than previously reported, if still far from unimpacted. We classified the acidification status of 66 lakes with long-term observations which represent a population of c:a 12,700 acid sensitive lakes in nemoral/boreal Sweden. While it is clear that suppression of organic acids by anthropogenic acidifying deposition was much less than a 1:1 replacement of acidity, the degree of compensation is sufficient to dramatically change the assessment of acidification in S. Sweden. Our findings emphasize the need to establish reference levels for DOC, which influences so many aspects of aquatic ecosystems, including acidity. This finding also points to the need to thoroughly test alternative hypotheses about complex environmental issues, even if they are controversial at the time.

[O7B-5] DOC concentrations of New England (USA) lakes: Is there a response to changing atmospheric deposition?

Presenter: William H. McDowell, University of New Hampshire,
bill.mcdowell@unh.edu

Author(s): William H. McDowell, University of New Hampshire
Sarah J. Nelson, University of Maine
Jody D. Potter, University of New Hampshire

Increases in DOC concentrations have been observed over time in many surface waters of Europe and North America, primarily from streams and rivers. A variety of drivers have been proposed to explain the observed increases, including increased temperature, atmospheric CO₂, and atmospheric deposition. Our past work in New England shows that some lakes have changed in DOC concentration over the past 25 years, and that year-to-year variability in runoff events is one of the drivers of changing DOC concentrations. In this paper, we address the role of atmospheric deposition, land use change, and weather extremes in driving regional variation in lake DOC concentrations. We use the spatially extensive data sets available from the Long Term Monitoring (LTM), Temporally Integrated Monitoring of the Environment (TIME) and High Elevation Lakes in Maine (HELM) monitoring programs. Each of these programs targets a different population of lakes in New England, from which we can draw conclusions about the regional changes in lake DOC concentrations and likely drivers of change.

**BREAKOUT SESSION 7 (BLOCK C):
STATUS AND TRENDS OF AQUATIC
BIOLOGICAL COMMUNITIES**

*Session Chair: Kerstin Holmgren, Swedish
University of Agricultural Sciences*
*Session Co-Chair: Barry Baldigo, U.S. Geological
Survey*

[O7C-1] Hindered, stubborn or confused? Explaining the patchiness of biological responses to the declining acidity of surface waters.

Presenter: Don Monteith, NERC Centre for Ecology & Hydrology, donm@ceh.ac.uk

Author(s): Don Monteith, NERC Centre for Ecology & Hydrology, Lancaster Environment Centre, UK.

Rick Battarbee, Environmental Change Research Centre, UCL, UK.

Alan Hildrew, Queen Mary University of London, UK

Iain Malcolm, Freshwater Laboratory, Pitlochry, UK.

Ewan Shilland, Environmental Change Research Centre, UCL, UK.

Chris Evans, NERC Centre for Ecology & Hydrology, Bangor, UK.

Martin Kernan, Environmental Change Research Centre, UCL, UK.

Large reductions in sulphur emissions have resulted in marked declines in surface water sulphate and labile aluminium concentrations and increases in pH and Acid Neutralising Capacity across most of the 22 sites on the UK Upland Waters Monitoring Network. However, comparison of the composition of algal (diatom) remains in contemporary lake sediments collected annually in traps with those taken from the bottom of lake sediment cores, suggest that, at the very least, some key biological characteristics of chemically recovering lake ecosystems remain very different from pre-acidification states. Furthermore, a 27 year long continuous record of benthic diatoms, macrophytes, macroinvertebrates and fish from all UWMN lakes and streams, indicate highly variable responses that differ between biological groups and sites. Here we review evidence for ecological change and assess its consistency with observed patterns of chemical change. A range of hypotheses are considered that might account for the apparent patchiness or delay in ecological recovery. These include insufficient chemical improvement (including the continued occurrence of acid episodes), biotic resistance - resulting from the consolidation of robust acid tolerant communities, and distance from non-acidified refugia. It is possible that other trends in the physical and chemical environment in recent decades, most notably relating to changes in climate and enrichment from atmospheric nitrogen deposition, may also provide checks in the return to formerly non-acidified states or may even constitute a permanently altered environmental baselines, but it is too early to rule out strong hysteretic responses. Our observations provide a unique, and spatially replicated, insight into the character, extent and limitations of ecological recovery in the wake of the partial removal of a major and regional scale long term environmental disturbance.

[O7C-2] Status and trends in stream ecosystems in limed, acidic or neutral waters (benthic diatoms, benthic fauna, fish)

Presenter: Cecilia Andrén, Stockholm University, cecilia.andren@aces.su.se

Author(s): Cecilia Andrén, Stockholm University, Björn Bergquist, Swedish University of Agricultural Sciences and Amelie Jarlman, Jarlman Konsult AB,

While there are numerous studies of the effects of acidification and the mitigation by liming on water quality, the biological effects and interactions are less well understood. The main focus in this study is on status, trends and interactions in stream diatom, benthos and fish communities. Within ISELAW (Integrated Studies of the Effects of Liming Acidified Waters) 42 acidic, neutral, limed or previously limed Swedish streams have been monitored for 8-25 years. Water was sampled at least monthly, sampling of benthic diatoms, benthos and electrofishing were performed every fall. Species abundances and relevant biological indices were used to assess status and trends in the stream communities, and their relationship to water quality, here represented by 12-month means of pH, Ca, TOC and Al. Benthic diatoms were tightly correlated to water acidity (pH-ACID, Spearman's ρ 0.74). Benthic fauna was less closely linked to water quality (pH-MISA, ρ 0.50) and more to the habitat, while brown trout showed the weakest correlation with water quality (pH-VIX, ρ 0.35) but a stronger relationship with habitat and hydro-morphology. Acidity (pH, Ca) distinguishes (Tukey's HSD) acidic streams from other stream categories, together with several biotic indices (NoT-diatoms; ACID; NoT-EPT/-Plechoptera; MISA; VIX). TOC and Al differed among acidic, neutral or limed streams, as did the diversity of benthic diatoms and fauna, Medin's index, NoT-benthic fauna/-Ephemeroptera/-Trichoptera, and abundance of YoY and older brown trout. There was no significant trend (Kendall/Theil) for the whole dataset or for the different stream categories, and only a few significant trends for individual streams.

The interactions in biota are further examined using multivariate ordination and clustering. A current challenge is to adapt the liming strategies to the decreased acidification; mainly to sustain stream communities comparable with those in reference streams and above all - when liming is stopped pass on vital ecosystems.

[O7C-3] Response of fish assemblages to changing acid-base chemistry in Adirondack long-term monitoring lakes, New York, USA

Presenter: Barry Baldigo, US Geological Survey, bbaldigo@usgs.gov

Author(s): Barry Baldigo, US Geological Survey, bbaldigo@usgs.gov and Karen Roy, New York State Department of Environmental Conservation, karen.roy@dec.ny.gov

Fish assemblages and water chemistry in 52 Adirondack Mountain lakes were sampled by the Adirondack Lakes Survey Corporation and the New York State Department of Environmental Conservation (NYSDEC) during three periods (1984-87, 1994-2005, and 2008-12) to document regional effects of acidic deposition and to assess recovery associated with the 1990 Clean Air Act Amendment (CAAA). The US Geological Survey and NYSDEC recently assessed standardized data from the three periods to quantify the response of community richness, total abundance, and brook trout abundance to changes in ANC (and assess effects of the CAAA) between 1984 and 2012. The median ANC of 43 lakes increased significantly from 3 to 30 ueq/L; yet median species richness, total catch-per-unit-effort (CPUE), and brook trout CPUE remained unchanged. Regression analyses indicate that fishery metrics were not directly related to the degree of chemical recovery and that brook trout CPUE may actually decline with increasing ANC. Although fish assemblages have improved in several lakes with increasing ANC, no consistent shifts in composition of fish communities were detected across all study lakes. Improvements in water quality associated with the CAAA have failed to yield concurrent improvements in fish communities of recovering lakes and suggest that more proactive efforts may be needed to restore native fish assemblages in acidified lakes across the Adirondack region.

[O7C-4] Recovery of young brown trout (*Salmo trutta*) in acidified streams: What are critical values for acid-neutralizing capacity?

Presenter: Trygve Hesthagen, Norwegian Institute for Nature Research, trygve.hesthagen@nina.no

Author(s): Trygve Hesthagen, Peder Fiske and Randi Saksgård, Norwegian Institute for Nature Research

We studied threshold values for the recovery of young (e.g. age 0+ and 1+) allopatric brown trout (*Salmo trutta*) in acid-sensitive streams in a Norwegian watershed by annual sampling by means of electrofishing during a 24-year period (1987-2010). Most sites typically had pH of 5.0-5.5, Ca of 0.3-0.7 mg L⁻¹, inorganic toxic Al (Ali) of 15-35 µg L⁻¹ and acid-neutralizing capacity (ANC) of -15 to +30 µeq L⁻¹. The water quality has improved during the study period, but has levelled off in recent years. The abundance of young brown trout was low and highly affected by acidification during late 1980s and early 1990s. However, it has since increased to a large extent. We recognized three stages in the fish density/ANC relationship; (i) low densities with 10-20 specimens 100 m⁻² at ANC -15 to -5 µeq L⁻¹, (ii) a transition stage with increased but unstable recruitment, e.g. 20 to 30 specimens 100 m⁻², at ANC -5 +10 µeq L⁻¹, and (iii) a pronounced recovery stage at ANC +10 to +25 µeq L⁻¹, to 40-50 specimens 100 m⁻². The transition stage coincided with high sea salt deposition. Principal component analysis recognized conductivity, Mg, Ca, Na, alkalinity and TOC as the variables with highest loadings, explaining 51 % of the variation among the eight variables included. Principal component 2 included pH, Ali and ANC, explaining 31 % of the variance. Coefficients for multiple regression analysis showed that the two components explained 41 % of the variance in total fish density. The brown trout populations in this area does not seem to be fully recovered, due to an unstable water chemistry.

[O7C-5] Long-term observation of biological and chemical recovery in the Ore Mountains` stream Grosse Pyra (Saxony, GERMANY)

Presenter: Martina Keitel, Saxon State Company for Environment and Agriculture, martina.keitel@smul.sachsen.de

Author(s): Martina Keitel, Saxon State Company for Environment and Agriculture, martina.keitel@smul.sachsen.de

From the 1960s to the beginning of 1990s the situation regarding acidic inputs substantially worsened in the Saxon Ore Mountains. The cross media effects in the causal chain air – soil – water resulted in an alarming acidification of stagnant and flowing waters causing severe ecological damage.

Over the last two decades drastic decline of atmospheric sulphur-input into vegetation and soil, along with systematic soil protection liming resulted in recovery of benthic macroinvertebrate assemblages in the formerly strongly acidified mountain brook Grosse Pyra. By means of a four stages biological assessment the effects of chronic acidification on macroinvertebrate communities are determined over a 25 years period. Although stream water alkalinity and pH did not markedly increase during that period, the number of water organism more than tripled and the acidity class of biological assessment has significantly developed from “continuously very acidic” (acidity class 4) to “periodically critically acidic” (acidity class 3).With long-term trends for corresponding relevant chemical parameters characterizing the process of water acidification and affecting aquatic communities can be solved the putative contradiction. Elevated dissolved aluminum concentrations associated with acidic spates have been recognized as important drivers for ecological change in acidified streams, resulting in the loss of species from those environments. With beginning of the 1990s during two decades, dissolved aluminum in Grosse Pyra dropped dramatically from an extremely high annual mean concentration of 1700 $\mu\text{g L}^{-1}$ to an annual mean value of ca. 500 $\mu\text{g L}^{-1}$.

There is proof of a remarkable biological recovery that was slowly starting to take effect in the 1990s. It has continued to increase in the last decade when even relatively acid-sensitive species sporadically appeared. According to different vulnerability to acidification similar positive long term changes in head waters are also observed in several other Ore Mountains` catchments.

STUDENT POSTER SESSION

IN ALPHABETICAL ORDER BY AUTHOR (POSTER LOCATION IS [P- #])

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

Student posters will also be available in the regular poster sessions P2 and P3.

[P-1] Monitoring Soil Response to Decreasing Acidic Deposition in a Western Adirondack Watershed over a 16-Year Period

Presenter: Michael Antidormi, University at Albany NY & USGS,
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Author(s): Michael Antidormi, University at Albany and
Greg Lawrence, United States Geological Survey and Andrei Lapenas,
University at Albany and Alex Buyantuev, University at Albany

The northeastern United States has been identified as one of the most heavily affected areas by acidic deposition. Acids deposited through acid rain leach away beneficial cations such as Ca^{2+} and Mg^{2+} . These cations act as nutrients for vegetation and buffers to acidic deposition. Long-term deposition monitoring has indicated that acidic deposition has continued to decline. Even after measured declines in both sulfur and nitrogen oxides, surface water studies in the northeast have signaled a delay in recovery response. The close relationship between soils and surface waters causes the recovery of water to be highly dependable on the current state of soil health. A lack of adequate soil data for the area has made it difficult to gain a full understanding of the dynamic and complex recovery processes. In order to disentangle these intricate soil processes to allow an accurate assessment of soil response trajectories, repeated soil measurements along with proper archiving are necessary.

To help evaluate soil recovery a western Adirondack watershed, originally sampled in 1998, was resampled in the summer of 2014. Soil sampling and analyses were run with supervision of the investigator who conducted the original sampling. Reanalysis of the original 1998 soils was done on archived samples. The objective of the study was to 1) assess soil data for changes that may indicate recovery over a 16 year sampling time period and 2) assess changes in the mobilization of toxic Al from the Buck Creek tributary. Exchangeable Al decreased in the Oe and Oa horizons ($P < 0.05$) and increased in the upper B horizon. Increases in Ca^{2+} and Mg^{2+} in the Oe horizon were observed. These results suggest recovery from acidic deposition has started in the O horizon, but increases of Al observed in the upper B horizon make the response for mineral soils unclear.

[P-2] Hillshade Analysis as A Method to Predict Patterns in Acidic Deposition

Presenter: Stephen Boucher, Syracuse University, sebouche@syr.edu

Author(s): Stephen Boucher, Syracuse University and Mario Montesdeoca, Syracuse University

Geographic information systems (GIS) is a powerful tool for analyzing, interpreting, and understanding spatially distributed data. GIS analysis has been used for many years to advance the knowledge surrounding acidic deposition in the Adirondack Park in New York. Understanding the spatial characteristics of deposition is of importance when considering the region as a whole. On a watershed to watershed basis, certain functions within the realm of GIS can be used to gain insight into the deposition patterns for individual watersheds. A hillshade analysis was done using a digital elevation model (DEM) of the Adirondack Park. During a typical hillshade analysis the user manually indicates the position of the 'sun'; selecting a radial position as well as an angular position relative to sea level. This ability to control the position of the light source lends itself to being utilized as a surrogate for wind direction. The results of these analyses depict a shaded region that may fall within the delineation a watershed. This shaded region theoretically will see a reduced amount of acidic deposition compared to windward sides of elevation rises. Soils within the shaded region may be less acid impacted than soils outside this region. Work needs to be done to establish the validity of this tool for predicting regions of lower acidic deposition. If this method proves to be viable, then using hillshade analyses to predict patterns of acidic deposition will aid in guiding research efforts and spatial selections of sampling locations.

[P-8] Reactive nitrogen emissions from unconventional natural gas well pads and implications for regional NO_x emission inventories

Presenter: Justin G Coughlin, University of Pittsburgh - Pittsburgh, jgc23@pitt.edu

Author(s): Lucy Rose, Department of Energy and Emily M. Elliott, University of Pittsburgh - Pittsburgh

According to the U.S. EPA National Emission Inventory, electric generating unit (EGU) emissions of NO_x (NO + NO₂) have declined by ~75% since 1995. However, recent advancements in shale gas extraction technology may counteract the substantial air quality improvements realized under the Clean Air Act and Amendments. Unconventional natural gas (UNG) extraction activities—including those in the Marcellus Shale play—represent one such emerging technology that threatens to offset gains in EGU NO_x emission reductions.

While existing wet and dry deposition monitoring networks effectively capture the regional impact of EGU NO_x emissions, it is currently unknown whether existing monitoring networks can capture increasingly prevalent UNG emissions. To determine whether current monitoring data reflect the increased UNG activity, we compared wet and dry reactive nitrogen (Nr) deposition (NO₃⁻, HNO₃ and NO₃-p from NTN and CASTNET sites) and ambient NO₂ concentrations (EPA Urban Air Database) throughout Pennsylvania to modeled NO_x emissions estimates from Marcellus UNG well pads. NO_x emissions estimates were based on both industry-reported values and published emissions factor estimates. We examined correlations between atmospheric HNO₃, NO₃⁻, and NO₂ measurements and estimated UNG NO_x emissions at several distances from atmospheric monitoring sites.

In 2013, industry-reported UNG NO_x emissions were ~10% of EGU NO_x emissions in Pennsylvania, while emissions factor estimates ranged from 2 to 29% of EGU NO_x emissions. From 2011 to 2013, Marcellus well pads within 25 km of monitoring sites were negatively correlated with Nr deposition ($R^2 = 0.42$, $p \leq 0.02$) and were also negatively correlated with ambient NO₂ concentrations ($R^2 = 0.38$, $p \leq 0.001$). These preliminary results suggest that current monitoring locations are not sensitive to UNG NO_x emissions. These results, existing knowledge gaps, and model uncertainties will be presented.

[P-7] Has resource extraction in western Canada led to higher deposition of heavy metals and nitrogen? Biomonitoring using *Pleurozium schreberi* and *Hylocomium splendens*

Presenter: Phaedra Cowden, Trent University, phaedracowden@trentu.ca

Author(s): Phaedra Cowden, Trent University and Julian Aherne, Trent University

Canada is a country rich in natural resources, such as oil, gas and minerals. However, the extraction and processing of these resources can lead to significant emissions of atmospheric pollutants. Monitoring the concentrations of these pollutants is integral to the management of resource development and the assessment of the effects on surrounding ecosystems. Bio-monitoring using mosses, while uncommon in North America, is widely used elsewhere as an effective method to assess the atmospheric deposition of heavy metals. Since 1990, moss bio-monitoring surveys have been carried out at regular intervals across Europe, by the International Cooperative Programme for Vegetation to evaluate the spatial patterns and temporal trends of atmospheric pollutants. The objective of this study was to evaluate the relative deposition of atmospheric pollutants in background regions compared with areas of active resource extraction activities: the Athabasca Oil Sands Region, Alberta and the Kitimat Valley, British Columbia (where an aluminium smelter is located). Two species of moss (*Pleurozium schreberi* [PI] and *Hylocomium splendens* [Hs]) were collected from 55 study sites across northern Alberta (11), British Columbia (10), Saskatchewan (16) and the Northwest Territories (8), and analysed for heavy metal and nitrogen concentrations. The dominant moss in the Alberta and Saskatchewan sites was PI, while Hs dominated in the Northwest Territories and British Columbia. The co-occurrence of both species at 10 sites throughout the sampling regions allowed interspecies concentrations and the variability in interspecies ratios (PI:Hs) to be evaluated. A study of this scale, incorporating multiple Canadian provinces, provides a unique opportunity to evaluate atmospheric deposition across a large geographical area, and the efficacy of bio-monitoring to support management decisions in resource rich regions.

[P-11] Assessing the sensitivity of macroinvertebrates to acid deposition in South African streams

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The burning of fossil fuels releases Sulphur and Nitrogen oxides into the atmosphere which are returned to the earth's surface as acid deposition. More than 60% of South Africa's energy demands are met by coal resources. Recently Eskom has embarked on a project to build two new coal power stations of 4 800MW each. It is hypothesised that the addition of these coal power stations might increase the current atmospheric output of sulphur and nitrogen oxides, and possibly exacerbate the issue of acidification. In this study, GIS has been used to identify three regions (Mpumalanga, Waterberg & the South-western Cape) of South Africa that have been shown to have natural acid sensitive soils and freshwaters and are therefore, vulnerable to acidification. The 3 regions have been categorised to represent high, moderate and low acid deposition loads, respectively. A total of 79 study sites (i.e. streams) within these regions have been identified of which 30% have pH values <5.5. The degree of damage caused by acidification on the aquatic ecosystem has been classified in European countries using macroinvertebrate indices. There are several factors that influence species tolerance to changes in pH such as the content of calcium, aluminium, bicarbonates and organic material. This study aims to establish a classification system for South African macroinvertebrates by looking at species presence and absence in relation to ANC (Acid Neutralising Capacity) and pH and potential differences in these relationships depending on DOC concentration. A total of 55 sites suitable for carrying out macroinvertebrate studies have been identified, 59.0% (n=22), 56.0% (n=27), and 90% (n=30) of sampled streams in each region respectively.

[P-6] Quantifying Rates of Atmospheric Dissolved Organic Carbon Deposition in the Northeastern United States

Presenter: Lidiia Lavorivska, Penn State University

Author(s): Lidiia Lavorivska, Elizabeth Boyer, Jeff Grimm, and Jose Fuentes, Penn State University

Organic matter which is usually expressed through measurements of dissolved organic carbon (DOC) is ubiquitous in atmospheric water. It plays an important role in cloud formation processes, and contributes to organic acidity of precipitation. Rain and snow deposited to the landscape is a source of nutrient enrichment to ecosystems and water bodies, and is especially important as an input of carbon in coastal regions. Since DOC is highly chemically reactive and bioavailable it influences rates of primary and secondary productivity in aquatic ecosystems. Despite the significance of DOC to many ecosystem processes, knowledge about its contributions to landscapes in precipitation remains limited. Here, we quantified the removal of DOC from the atmosphere via precipitation over space and time in order to assess the magnitude of wet deposition as a link between terrestrial and aquatic components of the carbon cycle. Further, we consider the predictability of organic matter in precipitation as a function of hydro-chemical and climatic variables. We measured DOC concentration and composition in storm events both sequentially (hourly during events) and seasonally (weekly over the year) at locations in Pennsylvania. Data on the chemical composition of precipitation, along with meteorological back-trajectory analyses help clarify how an interplay between emission sources, atmospheric transport and climatic conditions determine the abundance of rainwater DOC.

[P-9] Microbial Communities under Chronic Nitrogen Deposition: Effects on Decomposition of Various Litter Types

Presenter: Charlotte Levy, Cornell University, crl222@cornell.edu

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The relationship between nitrogen (N) inputs and decomposition rates is essential to understanding carbon (C) turnover in forest ecosystems. Prior studies of forest leaf litter decomposition have demonstrated divergent impacts on decomposition rate, dependent on litter “quality”. Litter with little lignin and low C:N ratios may decompose more rapidly following N addition, while litter with higher lignin contents and lower C:N ratios may experience delayed decomposition. Nitrogen addition affects microbial communities and processes, reducing microbial activity, altering community composition, and reducing production of exoenzymes. One hypothesis is that microbial species that specialize on high-quality litter proliferate in the nutrient-rich environment provided by nitrogen deposition. Another is that access to abundant nitrogen may be reducing microbial investment in exo-enzymes that break down low quality litter. One way to determine how microbial decomposition is affected by nitrogen addition is to compare microbial communities and enzyme production over a range of litter types and over multiple timescales of nitrogen addition.

Here, we have developed a two-year litterbag decomposition experiment for four litter substrates that differ in C:N ratio and lignin content based on both species (maple and oak) and litter part (leaf and petiole). Three time scales of nitrogen addition were tested by leveraging established experiments from four years of addition (Ithaca, NY, n=2), eight years of addition (Petersham, MA, n=1) and 26 years of addition (Petersham, MA, n=1). We will provide preliminary data on relative decomposition rates from the first year of the study, representing two collections of litterbags. We will provide C:N ratios from collected litterbags. Additionally, we will provide enzymatic activity measurements from six hydrolytic enzymes and two oxidative enzymes for all litterbags so far collected. Later work will delve into microbial community composition via PLFA and DNA analysis of collected litter.

[P-16] Response of the mercury cycle in an Adirondack, USA lake watershed to recovery from decreasing acid deposition and lime application

Presenter: Geoffrey Millard, Syracuse University, gmillard@syr.edu

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Acid-impacted lakes in northern Europe and northeastern USA are beginning to recover in response to decreases in acid deposition. Resultant increases in pH in these lakes have coincided with increases in dissolved organic carbon (DOC), which is positively correlated with total mercury and methylmercury concentrations. Methylmercury is a neurotoxin, which strongly bioaccumulates and biomagnifies. Thus, understanding how the mercury dynamics of watershed ecosystems respond to recovery from acid deposition has important implications for wildlife and human health. Honnedaga Lake is one of seven lakes in the Adirondack Park of New York State with a heritage brook trout (*Salvelinus fontinalis*) population. Though this ecosystem has been impacted by acid deposition, it is beginning to show signs of recovery. A demonstration watershed-liming project in a chronically acidified tributary of Honnedaga Lake is being conducted to evaluate mitigation of acid deposition in this critical brook trout spawning habitat. We are utilizing this experiment to investigate the changes in watershed mercury dynamics associated with recovery from acidification. During the 12 months after lime addition, the stream draining the treated watershed maintained a pH level above 5, which was significantly higher than reference and pre-treatment values. Total mercury concentrations in stream water were strongly correlated with DOC concentrations (treatment $R^2=0.90$, reference $R^2=0.63$), with a strengthening of this relationship after liming. Time-series analysis of aqueous mercury concentrations reveals a first flush effect of significantly elevated levels for six months after treatment. After the first flush, there was no significant difference in methylmercury concentrations from reference values ($p=0.524$), while total mercury remained significantly higher ($p=0.004$). This pattern suggests that elevated mercury is leaching from the treated watershed but is not being readily methylated before exiting the tributary. Further study is required to determine the long-term impacts of reduced acidification on mercury transport and bioavailability.

[P-14] Has heavy metal deposition in background regions responded to two decades of emissions regulations?

Presenter: Emily Olmstead, Trent University in Peterborough, Ontario, emilyolmstead@trentu.ca

Author(s): Emily Olmstead, Trent University in Peterborough, Ontario and Julian Aherne, Trent University in Peterborough, Ontario,

It is well established that heavy metal emissions from industrial sources and combustion processes can bioaccumulate and biomagnify within an ecosystem leading to acute and chronic toxic effects. Accordingly, protocols such as the 1998 Aarhus Protocol have been adopted to reduce heavy metals emissions. In concert, European-wide monitoring surveys were established to assess the effectiveness of these policy regimes. Bryophytes are ideal biomonitors for heavy metals as they are abundant and readily uptake nutrients from the atmosphere through precipitation and dry deposition. Since 1990, the International Cooperative Programme (ICP) on Vegetation has primarily used two moss species, *Hylocomium splendens* and *Pleurozium schreberi*, as biomonitors of atmospheric heavy metal deposition. The most recent survey reported reductions in lead (77%), iron (52%), cadmium (51%), vanadium (57%), chromium (43%), zinc (34%), nickel (33%), copper (11%), arsenic (26%), and mercury (23%) concentrations from mosses across continental Europe between 1990 and 2010.

Ireland is a well-established background reference region for atmospheric research owing to its location on the western periphery of Europe and dominant prevailing Westerlies. During 1996, heavy metal concentrations in moss were analyzed for 27 lake catchments across Ireland. Heavy metal concentrations were similar to Nordic regions of Europe; e.g., lead in Ireland was 5.2 µg/g, compared with 5.7 µg/g in Finland, and 5.8 µg/g in Norway, and zinc in Ireland was 25.0 µg/g, compared with 37.5 µg/g in Finland, and 37.7 µg/g in Norway. The objective of this study was to evaluate if metal deposition in background regions has responded to emissions regulations consistent with continental regions in Europe. Moss sites were resurveyed in Ireland and analyzed for 22 elements, including seven heavy metals (Pb, Zn, Cu, Cd, V, Co, and Ni). Observed changes in Pb and Cd between surveys were also compared to EMEP (Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe) modeled deposition estimates for Ireland.

[P-15] Concentration of heavy metals in precipitation registered at monitoring stations in Pribaikalye (East Siberia, Russia)

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Long-term observations were performed at two atmospheric monitoring stations in Pribaikalye (East Siberia). Both stations Irkutsk (52.3 N, 104.4 E – an urbanized area) and Listvyanka (51.9 N, 104.7 E – a rural area) have been included in the International EANET Program. Samples of rain and snow water were filtered through 0.45 μm filters. Concentrations of heavy metals (HM) were measured using inductively coupled plasma-mass spectrometry and synchrotron radiation X-ray fluorescence.

Seasonal variability of HM concentrations (V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, and Pb) was recorded at both stations with their maximum in spring despite different levels of anthropogenic load. A large amount of terrigenous material accumulated in atmosphere in spring due to snow melting, rise of air temperature, increase of wind velocity, and minimal precipitation. At that time, forest fires were also an additional source of HM presence in atmosphere. In winter, mainly undissolved HM fractions were registered in precipitation. Fossil-fuel power plants were the main sources of heavy metals. The content of dissolved HM fractions in precipitation was minimal at that period, except V and Co whose concentrations were maximal in winter. The minimal HM concentrations were attributed to large amount of precipitation (up to 70% of total amount) during summer-spring periods. Significant correlation coefficients (0.62-0.98) between major ions in precipitation and HM were calculated for vanadium and manganese with sulfates and nitrates. High coefficient (0.98) was estimated for Co, nitrate and other HM at station Listvyanka. At this station, mean long-term pH was 5.11 for snow and 4.77 for rain. Precipitation was acidified, thus increasing the content of dissolved HM fractions.

[P-4] Critical load exceedances of sulphur in the Muskoka River Watershed of south-central Ontario, Canada: Impacts of proposed forest harvesting on acid-sensitive surface waters

Presenter: Carolyn Reid, Environmental and Life Sciences Graduate Program, PhD candidate, Trent University, Peterborough, Ontario, K9J 7B8.

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Despite large reductions in atmospheric sulphur (S) deposition in North America, long-lasting consequences of acid rain are challenging the recovery of surface waters in acid-sensitive areas of the Canadian boreal shield. Slow weathering rates, low atmospheric base cation deposition and land use change are typical of this area. The potential risk of re-acidification is an emerging issue in the Muskoka River Watershed (MRW) which is located on the edge of the boreal shield in south-central Ontario, Canada. This risk is associated with the cumulative effects of acid rain base cation depletion in soils amplified by tree harvesting biomass removals. Dominant trends show that coincident with declining SO₄ concentrations, mean lake calcium (Ca) and magnesium (Mg) concentrations in 104 lakes across the MRW have decreased by 30% since the 1980's with limited improvement in pH in recent years. Predictive modelling that included harvesting losses, indicated that up to 38% of 364 lakes could go below critical Ca levels for keystone biota compared to 8% under a no harvest scenario. The need for further reductions to acid deposition was assessed using steady-state critical load models. Critical loads estimations included Ca and Mg losses resulting from predicted forest management plan biomass removals. Exceedances of critical loads for acidity (S) using the most recent S deposition estimates were examined and additional reductions are recommended to promote recovery in the majority of lakes in the study area. Ongoing base cation addition trials indicate holistic mitigation efforts through wood-ash addition could further aid both soil and surface water recovery.

[P-12] Staggering reductions in atmospheric nitrogen dioxide across Canada in response to emissions regulations

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It is well established that atmospheric nitrogen dioxide (NO₂), associated mainly with emissions from transportation and industry, can have adverse effects on both human and ecosystem health. Specifically, atmospheric NO₂ plays a role in the formation of ozone, and in acidic and nutrient deposition. As such, international agreements and national legislation, such as the Canada-US Air Quality Agreement) and the On-Road Vehicle and Engine Emission Regulations (SOR/2003-2) have been put into place to regulate and limit oxidized nitrogen emissions. The objective of this study was to assess the response of ambient air concentrations of NO₂ across Canada to emissions regulations. Long-term annual and seasonal trends in atmospheric NO₂ concentration at 66 continuous monitoring stations from British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, and Newfoundland were assessed during the period 1975–2013. Sites were limited to those that had at least 15 years of monitoring data. A non-parametric Mann-Kendall test (Z values and Sen's slope estimates) was used to determine monotonic trends. The annual air concentration of NO₂ decreased significantly at 89% of the stations (59 of 66), and decreased non-significantly at 8% (5 of 66). The concentration decreases ranged from 1.3–27.0 ppb; a 9.4–77.8% decrease in ambient NO₂. Concentrations only increased (non-significantly) at 3% (2 of 66) of the sites; one site was located in Oakville, Ontario, where data collection stopped in 2000, and the other site was Fort McMurray, Alberta, where the recent oil sands extraction methods have likely contributed to increasing NO₂ levels. Nitrogen dioxide emissions in the US have decreased 30-40%, and emissions in Canada have decreased by 34%, between 1990 and 2009, largely because of changes in environmental policies and technologies in both countries. The introduction of nitrogen limiting legislation, mainly from power plants and on-road vehicles, has lead to dramatic decreases in NO₂ levels nationwide.

[P-5] Simple Models to Estimate Historical and Recent Changes of Total Organic Carbon Concentrations in Lakes

Presenter: Salar Valinia, Swedish University of Agricultural Sciences, Norwegian Institute for Water Research

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Quantifying human impacts on the natural environment is dependent on credible reconstructions of reference conditions. For instance, effects of anthropogenic acidification of surface waters are strongly influenced by total organic carbon (TOC) concentrations. Since both the degree of acidification and recovery are dependent on historical TOC concentrations, simple models to estimate changes in surface water TOC between reference conditions (1860) and the present day (2012) are needed. We used Visible Near Infrared Spectroscopy (VNIRS) of lake sediments to reconstruct reference condition TOC and long-term monitoring data to predict recent changes. Two empirical models were developed to predict: (i) historical TOC trends between reference conditions (1860) and peak acidification (1980) and (ii) trends in TOC between 1988-2012. The models were statistically robust with R^2 of (i) 0.85 and (ii) 0.71 respectively. Models were driven by lake and catchment area, wetlands, historical sulfur deposition and water chemistry. Present day TOC concentrations are similar to VNIRS-reconstructed and modelled reference condition TOC in Swedish lakes. The results are valuable for understanding drivers of TOC changes in lakes and for more credible assessments of reference conditions needed for water management in Europe and elsewhere.

[P-10] Phytoplankton responses to nitrogen enrichment within high elevation lakes at Mount Rainier, North Cascades, and Olympic National Parks

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Atmospheric nitrogen (N) deposition can have a fertilizing effect on Western U.S. high elevation lakes because phytoplankton growth in such lakes is often limited by N. We conducted in situ nutrient enrichment experiments in 9 lakes across three National Parks in Washington State to simulate increases in lake N associated with deposition, and evaluated phytoplankton biomass, taxa, and community responses. At the biomass level, phytoplankton chlorophyll-a growth in all 9 lakes was limited by N or co-limited by N and phosphorus (P). In lakes with N-limited chlorophyll-a growth, dissolved inorganic nitrogen (DIN) concentrations of 13 $\mu\text{g N/L}$ or higher stimulated a chlorophyll-a increase, and DIN concentrations on 25 $\mu\text{g N/L}$ were required to increase chlorophyll-a beyond typical lake chlorophyll-a inter-annual variation. At the taxa level, N enrichment stimulated growth of a variety of taxa, but responses were strongest for diatoms and chlorophytes. Across lakes, multiple monod N growth-response curves were quantified for diatom species of the genus *Fragilaria*, *Aulacoseira*, and *Discostella*, and for chlorophyte taxa. Lake N concentrations required for half-saturation of diatom growth were similar to those quantified for increases in chlorophyll-a. Within each lake, nutrient limitation varied across taxa, and N enrichment stimulated taxa-level responses in both lakes where biomass growth was N-limited and co-limited by N and P. While addition of N and P altered phytoplankton community composition when added separately, they elicited greater change when added simultaneously. When compared to N concentrations in park lakes, taxa and biomass level response thresholds quantified in experiments indicate N concentrations in approximately 30-50% of high elevation lakes at Mount Rainier and North Cascades National Parks exceed experimentally-defined thresholds, suggesting many park lakes remain sensitive to deposition-induced N increases.

[P-13] Baseline Ozone in the Northeast U.S. Over 2001–2010

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Emissions of NO_x have been reduced since the 1990s through concerted efforts via the Clean Air Interstate Rule (CAIR), the Acid Rain Program (ARP), and the nitrogen oxide (NO_x) Budget Trading Program (NBP). Ozone (O₃) is formed through reactions between NO_x and volatile organic compounds (VOCs) in the presence of sunlight. Hence NO_x emission reductions can contribute to control of ambient O₃ mixing ratios. Baseline O₃ was studied for seven rural sites in the Northeast U.S. during varying periods in the 2000s decade. Baseline O₃ did not display a significant long term trend at any of the seven sites, resulting probably from the decreasing NO_x emissions in North America and Europe, increasing NO_x emissions in Asia, and global relatively constant mixing ratios of CH₄ in the 2000s. Springtime and wintertime baseline O₃ at Thompson Farm (TF), located near the sea level (18 asl), increased significantly at a rate of 2.4 ppbv yr⁻¹ and 2.7 ppbv yr⁻¹, respectively, which were most likely related to the decrease in NO_x emissions over urban areas. In summer 2003, long-range transport of O₃ and its precursors from wildfires in Russia contributed to the highest baseline O₃ at Appledore Island (AI), Castle Spring (CS), Mount Washington (MWO), TF, and Whiteface Mountain (WFM). In summer 2009 when there were most frequent cyclone activities in the Northeast U.S. and the lowest biomass burning emissions in Russia and Canada, mixing ratios of baseline O₃ were found to be the lowest of the decade at AI, Pack Monadnock (PM), and Pinnacle State Park (PSP). The findings of this study suggested impacts of increasing Asian emissions, NO_x emissions from the urban corridor, biomass burning emissions, and meteorological conditions should be considered when evaluating the air quality at rural sites and developing emission control strategies in the Northeast U.S.

[P-3] Significant forest soil acidification in China since 1980s

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Significant acidification in major croplands and grasslands were reported recently in China in response to either intensified fertilizer application or acidic deposition. It is likely that Chinese forest soils have also significantly acidified since both acidic deposition and wood production has increased substantially since the 1980s. We therefore gathered all soil pH data from the Second National Soil Inventory of China and publications from the China National Knowledge Infrastructure (CNKI) database in 1981-1985 and 2006-2010, respectively, to evaluate the long-term change of pH values in forest soils. Wood element concentration information, forest growth and atmospheric deposition data in period 1981-2005 were also gathered from publications from CNKI database to analyse reasons for forest soil acidification. We found that soil pH decreased on average by 0.37 units in the past 25 years (2006-2010 vs 1981-1985), with most serious acidification occurring in southwest China (0.64 pH units decline). On average, soil acidification induced by atmospheric deposition was estimated at $1.23 \text{ kmolc H}^+ \text{ ha}^{-1} \text{ yr}^{-1}$, and elements uptake (due to forest wood growth and harvest) further contributed $0.52 \text{ kmolc H}^+ \text{ ha}^{-1} \text{ yr}^{-1}$. In conclusion, atmospheric deposition was the major driver for significant forest soil acidification across China. Further work is needed to slow down Chinese forest soil acidification rate through strict acidic deposition control measures.

POSTER SESSION #2

IN ALPHABETICAL ORDER BY AUTHOR (POSTER LOCATION IS [P- #])

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

[P-30] Atmospheric sulphur trends from regional monitoring networks and global

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The trend in SO₂ emission has a strong spatial variability on global scale. In North America and Europe there has been a continuous decline in emissions for several decades. As a result, more than 50% reductions in the atmospheric concentration of sulphate are observed in these regions since 1990. In East Asia on the other hand, there was a strong increase in the SO₂ emissions up to around 2005 followed by a relaxation and declining trend last years. These large changes in global SO₂ emissions over the last decades have changed the atmospheric composition on a regional and global scale, and with an impact on both air quality and radiative forcing of aerosols.

The impact of aerosols both directly on the radiative balance, and indirectly on clouds and precipitation are important, while the uncertainties in the radiative forcing estimated over the industrial era are large (Myhre et al 2013). In this work, we address the question whether global climate models are able to reproduce the recent observed changes in atmospheric sulphate cycle and distribution. Reproduction of historical atmospheric sulphate levels based on the known emission changes is crucial to enable future scenario analysis and impact on climate and air quality.

In this study, monthly average mean concentrations of SO₂, and SO₄²⁻ in aerosols and precipitation are compiled from major regional networks: EMEP; NADP, AIRMoN, MAP3S, CAPMoN, EANET, IDAF from 1990 onward (or later for sites with shorter time series) until 2012. The measurement sites are carefully selected to ensure regional representativity, sufficient quality and completeness. The data are included in the AeroCoM database (<http://aerocom.met.no/>) for thorough comparison and visualization with the AeroCom models, which include aerosol chemistry. The models are further evaluated employing the already available global datasets of inorganic ions in precipitation (Vet et al., 2014).

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[P-6] Atmospheric nitrogen deposition budget in a subtropical hydroelectric reservoir (Nam Theun II case study, Lao PDR)

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With 490 km² at full level of operation, Nam Theun 2 (NT2) is one of the largest hydro-reservoir in South East Asia. NT2 is a trans-basin hydropower project that diverts water from the Nam Theun river (a Mekong tributary) to the Xe Ban Fai river (another Mekong tributary). Atmospheric deposition is an important source of nitrogen (N), and it has been shown that excessive fluxes of N from the atmosphere has resulted in eutrophication of many coastal waters. A large fraction of atmospheric N input is in the form of inorganic N. This study presents an estimation of the atmospheric inorganic nitrogen budget into the NT2 hydroelectric reservoir based on a two-year monitoring (July 2010 to July 2012) including gas concentrations and precipitation. Dry deposition fluxes are calculated from monthly mean surface measurements of NH₃, HNO₃ and NO₂ concentrations (passive samplers) together with simulated deposition velocities, and wet deposition fluxes from NH₄⁺ and NO₃⁻ concentrations in single event rain samples (automated rain sampler). Annual rainfall amount was 2500 and 3160 mm for the two years. The average nitrogen deposition flux is estimated at 1.13 kgN.ha⁻¹.yr⁻¹ from dry processes and 5.52 kgN.ha⁻¹.yr⁻¹ from wet ones, i.e., an average annual total nitrogen flux of 6.6 kgN.ha⁻¹.yr⁻¹ deposited into the NT2 reservoir. The wet deposition contributes to 83% of the total N deposition. The nitrogen deposition budget has been also calculated over the rain tropical forest surrounding the reservoir. Due to higher dry deposition velocities above forested ecosystems, gaseous dry deposition flux is estimated at 4.0 kgN.ha⁻¹.yr⁻¹ leading to a total nitrogen deposition about 9.5 kgN.ha⁻¹.yr⁻¹. This result will be compared to nitrogen deposition in the African equatorial forested ecosystems in the framework of the IDAF program (IGAC-DEBITS-Africa).

[P-42] Precipitation chemistry based on sample analysis from 1 mm precipitation increments – Washout/rainout processes, and interaction between raindrop and ambient particulate sulfate

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Datasets of precipitation chemistry at a precipitation resolution of 1 mm from three sites were studied to determine whether the washout and rainout mechanisms differed with site type (urban, suburban, rural). In addition, we will report the relation among a size and number of raindrops, SO_4^{2-} concentration of rainwater, and SO_4^{2-} concentration in ambient air, if possible.

[P-34] Recovery from acidification under the influence of climate-related events: Sea salt episodes, wind throws and insect attacks

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Emission reductions of sulphur have been successful, and recovery from acidification has been demonstrated in both soil water and surface water. The rate of recovery in a forest catchment is highly dependent on the forest status. Thus, different kind of disturbances can have an impact on the recovery process. The aim of this study was to investigate how sea salt episodes, wind throws and insect attacks affect soil water chemistry, and to analyze the results in the context of climate change.

The study was based on the SWETHRO network, an environmental monitoring program with long time series of deposition and soil water chemistry. In this dataset, several sites were affected by a number of sea salt episodes in the beginning of the 1990:ies. Furthermore, in 2005 and 2007, several sites were subject to severe storm damage. In one other site the spruces were damaged by bark beetles in 2008, and finally killed. The effect on nitrate leaching and the acidification indicators pH, ANC (acid neutralizing capacity) and inorganic aluminum were studied on these sites.

Sea salt episodes caused in many cases increased acidification, with reduced pH, reduced ANC and/or increased concentrations of inorganic aluminum. The effect was, however, temporary. The effect of storm damage was in many cases increased nitrate leaching, and thus acidification. The site with bark beetle attacks showed similar results.

It was concluded that the recovery progress is highly dependent on the frequency of sea salt episodes, as well as on the forest status. Sea salt episodes, storm damage and insect attacks may be affected by climate change. It is important to take acidification episodes caused by these factors into account when trying to predict future recovery from acidification in a changing climate.

[P-58] Wet deposition at the base of Mt Everest (5050 m asl, Nepal Himalaya): Seasonal evolution of the chemistry and isotopic composition.

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Perceived as one of the most uncontaminated places of the Earth, the Himalayas host a unique ecosystem with a high degree of biodiversity, but characterized by a recognized fragility that makes this region most sensitive to any environmental change. Recent studies in the southern slopes of Mt. Everest revealed a significant temperature increase in post monsoon period and a substantial weakening of rainfall during monsoon season, with important consequences on glacier shrinkage.

In this context, the chemistry of wet deposition was investigated at the Pyramid International Laboratory in the northernmost portion of the Khumbu Valley, at 5050 m asl, during 2007-2008, and 2012-2013, within the GAW programme. The main hydro-chemical species and the stable isotopes of oxygen and deuterium were determined on monsoon and snow samples.

Precipitation contents for all ions were the lowest ones among those measured in high elevation sites around the world suggesting that these values can be considered as the regional background concentrations in the depositions. During the monsoon periods the depositions were not substantially influenced by anthropogenic inputs. However, in the late monsoon phase the ionic content in precipitation increased; possibly due to a change in the moisture source. The analysis of snow samples supports this hypothesis, revealing SO_4^{2-} and NO_3^- concentrations 15 and 5 folds those measured in rain samples.

low nitrogen concentrations associated with very small amounts of precipitation have produced nitrogen loads considerably lower than those measured in the most remote regions of the world (e.g. European and North American mountain environments, Northern Africa dry savanna, Central Amazonia tropical rain forest). These results will be discussed further considering the nitrogen level in the surface water collected in the high Khumbu valley catchment.

[P-69] Nitrogen Deposition, Urban Development, and Invasive Plant Species Act Synergistically to Reduce Habitat Quality of Sensitive Avian Species

Presenter: Michael D. Bell, National Park Service, Air Resources Division, michael_d_bell@nps.gov

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Urbanization has contributed to the disruption of wildlands through fragmentation, changes in fire regimes, increased nitrogen deposition, and invasion of exotic plant species. These anthropogenic disturbances act independently and additively to disrupt environmental processes and community interactions even within protected wildlands. Here we incorporate these stressors into Mahalanobis D2 species distribution models to measure the impact of multiple anthropogenic stressors on potential species distributions in Western Riverside County with an emphasis on the California gnatcatcher (*Polioptila californica californica*) and least Bell's Vireo (*Vireo bellii pusillus*). Species occurrence data from 1990 to 2014 were used as inputs to develop a Habitat Suitability Index (HSI) for each species. Potential species distributions were then modeled at a scale of a 250 m grid using terrain, climate, and vegetation community indices. We modeled the changing patterns of HSI across a landscape when anthropogenic stressors were added, individually and in combination. The changes in HSI of the rare and threatened species were compared to a common species from each group. Model outputs for endangered and threatened species show that there is a consistent decline in the HSI in cells with high nitrogen deposition and cells near urban development. The spatial shift in habitat suitability moved away from the environmental stressors and there was a reduction in the size high suitable habitat patches within protected open space boundaries suggesting that the minimum habitat requirements for the species are reduced. There were not large changes in the distributions of the common species modeled. These results suggest that understanding future changes in nitrogen deposition or urban expansion will help identify shifts in species distribution through time without extensive surveys. The impacts of stressors are occurring rapidly and will help determine where active management must take place to maintain critical habitat in our national and region parks.

[P-15] A New Tool for Presenting Critical Loads and Exceedance Information to Parks

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Many park ecosystems are sensitive to nitrogen deposition. Atmospheric inputs of excess nitrogen can stress ecosystems by reducing biodiversity, disrupting nutrient cycling, and causing acidification of soils and water. Critical loads are a tool the National Park Service uses to help inform policy decisions meant to protect these parks. They are used to assess and understand the impacts of nitrogen deposition to park ecosystems by determining the nitrogen deposition level (critical load) at which harmful effects are expected.

The National Park Service has developed a web-based tool to identify areas where critical loads may be exceeded and air pollution damage to ecosystems may be occurring. The tool uses critical load data for five indicators (forests, herbaceous plants, lichen, mycorrhizal fungi and nitrate leaching) in 12 ecoregions, obtained from USFS scientists (Pardo et al. 2011). These critical loads are then compared to the 2010-12 three-year average estimated total-N deposition from the NADP total deposition model. The maps and tables produced allow users to identify NPS lands that may be experiencing N deposition that exceeds a critical load, and where ecosystems may be at risk. This information will assist parks in assessing the risk to ecosystems from nitrogen deposition and can be used in park planning, NEPA analyses, and interagency work to influence emissions reductions.

[P-65] Assessing the fate of experimental areal nitrogen deposition on a *Pinus banksiana* forest in the bituminous sands region of Alberta, Canada

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In this study, experimental applications of nitrogen (N) (as NH_4NO_3) were applied above a jack pine (*Pinus banksiana*) forest canopy via helicopter at N deposition values of 5, 10, 15, 20 and 25 $\text{kg N ha}^{-1} \text{yr}^{-1}$ reflecting projected ranges in current and future N deposition in the bituminous sands region of Alberta, Canada. Applications were conducted over 4 years with 4-5 applications per year. Throughfall analysis indicated that approximately 20 – 30% of N was retained by the canopy favouring NH_4^+ over NO_3^- . Calcium (Ca^{2+}) and dissolved organic carbon (DOC) increased in throughfall at the higher N treatments. Stemflow contributions of N were negligible but approximately 50% were converted to organic N. The N concentration of jack pine needles did not increase with treatment but there was a significant increase in the N content of epiphytic lichens. The largest increases in N concentration in response to N treatments were observed in terricolous lichens *Cladonia mitis* and *Cladonia stellaris* and the bryophyte *Pleurozium schreberi*. However, after four years of application, there were no significant responses in soil net N mineralization, NO_3^- leaching, litter decomposition, vascular plant community composition, tree health or foliar N concentrations in three common vascular plants (*Vaccinium vitis-idaea*, *Vaccinium myrtilloides* and *Arctostaphylos uva-ursi*). We conclude that after 4 years of experimental N application rates up to 25 $\text{kg N ha}^{-1} \text{yr}^{-1}$ the majority of the N is immobilized in the canopy or in the ground mosses and ground lichen. The capacity of these organic pools to store N will ultimately determine the long-term fate and biological impact of elevated N deposition in these traditionally N-limited ecosystems.

[P-78] Organic matter in rain: An overlooked influence on mercury deposition

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The importance of Hg emissions for deposition will be scrutinized during coming years as new legislation to control Hg emissions to the atmosphere comes into effect. We show that mercury (Hg) concentrations in rainfall are closely linked to organic matter (OM) with consistent Hg/TOC-ratios over large spatial scales decreasing from that in open field (OF, $1.5 \mu\text{g g}^{-1}$) to that in throughfall (TF, $0.9 \mu\text{g g}^{-1}$). The leaf area index was positively correlated with both TF [Hg] and total organic carbon ([TOC]), but not the Hg/TOC-ratio. This study shows that the progression in the Hg/TOC-ratio through catchments starts in precipitation with $\text{Hg/TOC}_{\text{bulk dep}} > \text{Hg/TOC}_{\text{soil water}} > \text{Hg/TOC}_{\text{stream water}}$. These findings raise the intriguing question as to what extent it is not just atmospheric [Hg] but also OM that influences the [Hg] in precipitation. This question should be resolved to improve the ability to discern the importance of changing global Hg emissions for Hg deposition at specific sites.

[P-57] Temporal and seasonal trends in gaseous NH₃ and precipitation NH₄⁺ concentrations in several regions of the USA

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An examination of NH₃ concentration data derived from bi-weekly passive samplers from 18 of the longest operating NADP/AMON sites (many operating from the Fall of 2007) shows that increasing trends (p -value < 0.05) in concentration have been occurring over most regions of the country. This trend is occurring at a seasonal and annual level of aggregation. Using a random coefficient model, the mean slope and standard error, for the 18 sites combined show an increase of NH₃ concentration of 7% \pm 1% (s.e.) per year and significant differences (p -value <0.05) among the seasons. Aggregating the sites to 5 regions (Northeast, Southeast, Midwest, Tex-Ok, and Mountain West) does not show a statistical difference between regions, probably because there are too few sites in each region, and the record for most sites is only 8 years long.

During a comparable period (2007 to 2014) NADP/NTN and NADP/AIRMoN co-located precipitation chemistry sites (or if no co-location, the nearest NADP site) show significant regional and seasonal differences in NH₄⁺ concentrations and a statistically significant overall increasing trend for all sites combined of 5% \pm 1% (s.e.) per year in NH₄⁺ concentrations.

[P-66] Isotopic Evidence of Over-Winter Nitrification in a Northern Hardwood Forest Floor

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Nitrogen cycling during winter remains poorly understood, but may have important consequences for water quality since that is when most N is exported in stream water. Previous research at the Hubbard Brook Experimental Forest in New Hampshire, USA has shown that NO_3^- in spring runoff is primarily from nitrification, rather than directly from snowpack meltwater, as indicated by $\delta^{18}\text{O}-\text{NO}_3^-$. However it is unclear whether the NO_3^- exported in stream water during winter is from stored NO_3^- produced during the previous fall or from overwinter nitrification. It is also unclear how the production and retention of N during winter is influenced by snow depth and soil frost, having implications for winter climate change. To improve understanding of N cycling beneath the snowpack during winter and associated effects of climate change, we established three low (less snow, more frost) and three high (more snow, less frost) elevation plots in northern hardwood stands at Hubbard Brook. We added 99% enriched $^{15}\text{N}-\text{NH}_4\text{Cl}$ to the forest floor immediately prior to snowpack development. Results showed that the added $^{15}\text{N}-\text{NH}_4$ was nitrified during winter beneath the snowpack, as indicated by elevated $\delta^{15}\text{N}-\text{NO}_3^-$ and low $\delta^{15}\text{N}-\text{NH}_4^+$ in soil leachate. Enriched $\delta^{15}\text{N}-\text{NO}_3^-$ was observed in both high elevation and low elevation plots; however, concentrations of NH_4^+ were slightly higher during late winter in the low elevation plots, perhaps indicating reduced nitrification in the colder soils. These differences in concentrations of NH_4^+ during winter were minor compared to differences during the growing season, when significantly higher concentrations of NH_4^+ and NO_3^- were observed in the low elevation plots. Disentangling influences on N cycling across seasons will enhance our understanding of factors regulating N export and improve predictions of N responses to future climate change.

[P-68] An overview of rainwater composition in a Brazilian region heavily impacted by agricultural biomass burning

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Brazil is the world's largest producer of sugar cane, and the second largest producer of ethanol fuel. São Paulo State alone accounts for ~60% of the national production, which has tripled in the last 20 years. This trend is likely to continue due to increasing global demand for ethanol fuel, as well as the imminent availability of cellulosic ethanol. Sugar cane cultivation is especially important as a regional source of anthropogenic emissions, because manual harvesting requires that the crop be first burned to remove excess foliage. The introduction of mechanized harvesting is progressively eliminating the burning practice in São Paulo State, and therefore, regional emissions are going through a great shift, with unforeseeable consequences in terms of aerosol composition, gas emissions, cloud formation, and ultimately rainfall patterns. The aim of this work is to investigate how regional agricultural practices have affected rainwater composition in the past decade. Rainwater samples were collected on an event basis from 2003 to 2014, using an automatic wet-only collector at the University of São Paulo campus in the municipality of Ribeirão Preto (a city with 680,000 inhabitants). Despite the phasing out of foliage burning, dissolved organic carbon and most of the major ions in rainwater showed very clear seasonality, with higher concentrations in the sugar cane harvest period. Annual (2003-2014) rainwater VWM pH ranged from 4.7 to 5.1 and did not vary significantly between harvest and non-harvest periods. Although emissions of acid species such as SO₂ and NO_x are greater during the harvest season, extensive soil resuspension (due to the use of heavy vehicles and machinery) can neutralize precipitation acidity. The largest annual changes were observed for the concentrations of acetate and formate, which doubled from 2005/06 to 2013/14, coinciding with an equivalent increase in the number of vehicles in the municipality and consequent increase in ethanol usage.

[P-7] Have emissions from the Athabasca Oil Sands Region acidified lakes and soils in northern Saskatchewan and Alberta?

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The largest point source of sulphur (S) and nitrogen (N) oxide emissions in Canada is the Athabasca Oil Sands Region (AOSR) in northern Alberta. While deposition in northern Alberta and Saskatchewan is low, there is concern that acid sensitive lake catchments downwind of the AOSR may undergo long-term changes in soil and water chemistry as a result of elevated acidic S and N deposition. However, in remote northern Alberta and Saskatchewan, temporal monitoring of lake and soil chemistry has only recently begun.

A novel model framework was developed to assess whether catchments downwind of the AOSR are undergoing acidification using minimal soil and water chemistry data. The framework chained the normative mineralogy model A2M, the weathering rate component of PROFILE, the hydrological model MetHyd, and the Very Simple Dynamic (VSD) model together to simulate changes in soil base saturation and lake Acid Neutralizing Capacity (ANC). Observations from 18 lakes chosen from regional monitoring networks were used to calibrate the models; two soil pits per catchment were also sampled for soil data.

Simulations suggest that changes to base saturation and ANC are slight at both the pit and catchment scale. Base saturation at the pit scale shows only a ~ 1% decrease, while lake ANC concentrations show a decrease of ~ 2.5% between 1850 and the calibration year, 2012. Under a scenario wherein emissions (scaled to 2006 deposition levels at each lake) peak between 2010-2020 and decline, all sites return to pre-acidification (1850) levels by the end of the simulation period (2100). However, most catchments have low to intermediate weathering rates (estimated between 0.002 to 0.170 eq m² yr⁻¹ at the soil pits and 0.007 to 0.48 eq m² yr⁻¹ at the catchment scale) and simulations suggest they are sensitive to even slight increases in acidic deposition.

[P-29] ADAGIO (Atmospheric Deposition Analysis Generated by optimal Interpolation of Observations): Project plans and status

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Progress to date on a new project, Atmospheric Deposition Analysis Generated by optimal Interpolation of Observations (ADAGIO), is described. The goal of the ADAGIO project is to improve maps of wet, dry and total annual deposition of nitrogen (N) and sulphur (S) in Canada and the United States by combining observed and modeled data. Established measurements of wet deposition and/or air concentrations of deposited compounds provide the most accurate atmospheric deposition values in regions with dense coverage, but are too sparse to provide reliable regional estimates of deposition for large areas of the continent. On the other hand, atmospheric models that include meteorology, emissions, transport, chemistry and deposition of key N and S compounds provide complete spatial coverage and the ability to account for non-linear effects of meteorology and chemistry, but have varying degrees of uncertainty in their predicted concentrations and fluxes. This project will use optimal interpolation techniques to combine the different advantages of measurements and models. Gridded precipitation amounts will be obtained for North America using the Canadian Precipitation Analysis (CaPA), in which all available precipitation data sets are used to adjust precipitation amounts predicted by Environment Canada's Global Environmental Multiscale (GEM) model. Concentrations of N and S in precipitation will be separately optimized using precipitation chemistry measurements from multiple Canadian and U.S. networks to perform optimal interpolation on concentration fields predicted by the in-line air quality model GEM-MACH (-Modelling Air quality and Chemistry). Similarly, surface air concentrations of particulate and gaseous N and S species will be optimized based on GEM-MACH output and network data. Dry deposition velocities will be obtained from GEM-MACH. Future directions may include the incorporation of satellite measurements in the concentration analysis, and integration of ADAGIO methods and results with the USEPA's Total Deposition (TDEP) program.

[P-59] Assessment of long-term trends in atmospheric deposition chemistry along the Italian-Swiss border: An example of transboundary cooperation

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The subalpine and alpine areas in North-Western Italy and Southern Switzerland (Canton Ticino) receive high deposition of atmospheric pollutants transported from emission sources in the Po Valley, one of the most urbanised and industrialised areas of Europe. Long-term studies, covering a 30-year period, on atmospheric deposition and its effects on surface water bodies have been performed in this area in the framework of the ICP WATERS and of national projects. Studies on both deposition and surface water chemistry have been performed since the beginning (early 1980s) through a cooperation between Swiss and Italian research institutions. In total, 15 atmospheric deposition sampling sites (wet-only) operate in this area. Sites span a wide latitudinal and altitudinal range, from the subalpine sites of Pallanza, in Italy, and Lugano, in Switzerland (about 200 m a.s.l.) to the high-altitude sites of Devero and Robiei (1640 and 1890 m a.s.l., respectively).

The analysis of the data at a spatial level highlighted a gradient in the deposition of acidity, sulphate and nitrogen compounds, with decreasing values in the northern part of the area. Deposition also varies locally, depending on geographical and morphological attributes of the sampling sites. Deposition data show a high interannual variability, due to the highly variable precipitation amount affecting this area (from 1200-1300 mm in dry years up to 3000 mm). The analysis of long-term trends revealed a substantial reduction in sulfate deposition, which almost halved since the 1980s. On the other hand, deposition of oxidised and reduced nitrogen has not changed to the same extent, showing a slight tendency to decrease only in the most recent period. However, nitrogen deposition is still high, also at the alpine sites (32 and 27 meq m⁻² y⁻¹ at Devero and 42 and 48 meq m⁻² y⁻¹ at Robiei for ammonium and nitrate, respectively). The NH₄:NO₃ ratio in atmospheric deposition has increased in time at most of the sites, from about 1.2 in the 1984-2002 period up to 1.4-1.5 in recent years, indicating an increasing importance of NH₄ deposition, especially at the southern, more polluted sites.

[P-33] Watershed leachate potential in lakes of northern Wisconsin

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Terrestrial inputs of dissolved organic matter (DOM) have changed substantially in recent years and are potentially linked to decreases in acid rain deposition. Dissolved organic matter may also play an important role in transporting nutrients, trace metals, or other materials, as well as influencing hydrologic or ecologic processes, within receiving lakes. However, loadings and sources of allochthonous materials in lakes are often not well understood. Seepage lakes may be particularly vulnerable to shifts in DOM loads due to their small catchment areas and dominance of precipitation. The objective of this study is to characterize potential allochthonous loads of DOM to seepage lakes of the Chequamegon-Nicolet National Forest in northern Wisconsin, USA. We present data on water soluble organic matter leachates of forest floor, sediment, and soil samples from lakes that span a range of DOM concentrations (4.5 - 39 mg C/L). For soil samples, absorbance at 254 nm was positively correlated with saturation state, while the E2/E3 index tended to be highest in saturated peatland soils and lowest in unsaturated soils. These results suggest that changes in watershed characteristics or hydrology may shift DOM transport to the lakes.

[P-9] Nitrogen Deposition Trends, Critical Loads, and Resources at Risk at Ten Sites in the U.S. National Park Service's Pacific West Region

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The U.S. Clean Air Act, as well as other legislation and agency directives, provide the basis for protection of air quality in areas managed by the National Park Service (NPS). In order to effectively maintain good and improve poor air quality in parks, the NPS determines air pollution levels, identifies thresholds or critical loads of pollution that adversely affect sensitive resources, and supplies this information to state and federal agencies for consideration in regulatory and other activities that influence air quality. The NPS also uses this information to develop planning documents that set park air quality goals and describe management actions which can be taken to achieve them. The adverse effects of nitrogen deposition, specifically effects associated with nutrient enrichment, are of concern in the Western U.S. The NPS Pacific West Region (PWR) encompasses more than 60 sites in six western states and the Pacific Islands. These parks include a number of ecological communities with known or suspected sensitivity to nitrogen deposition. 2003-2012 National Atmospheric Deposition Program (NADP) data showed an improving trend in nitrogen concentration in precipitation at three of the ten PWR park monitoring sites, while there was no significant trend at the other seven sites. Nevertheless, modeled 2010-2012 3-year average total (wet plus dry) nitrogen deposition suggested critical loads for nutrient enrichment were still exceeded for at least one ecological indicator at all ten PWR parks with NADP monitors. At six of those parks, modeled critical loads were exceeded for all current nitrogen nutrient critical loads indicators. Studies are needed to verify to what extent the nitrogen nutrient enrichment effects predicted by models are occurring in PWR parks.

[P-28] Surface atmosphere exchange of nitrogen compounds in a sahelian rangeland in Senegal

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Three field studies were carried out in a semi natural sahelian rangeland in Dahra (Ferlo, Senegal) in July 2012 and July 2013 at the beginning of the wet season, and in November 2013 at the end of the wet season. The objective was to explore surface atmosphere exchanges of nitrogen compounds in contrasting ecosystems conditions (soil moisture, vegetation cover), and when gaseous emissions from soils are supposed to reach high values.

In semi arid regions, the short wet season (3-4 months) gathers the necessary moisture conditions for starting microbial activity in the soil, growing of vegetation and N release to the atmosphere. During the three field campaigns, NO fluxes from soils as well as NH₃ bidirectional exchanges were measured by dynamic chambers, while N₂O fluxes were measured by static chamber. Concentrations of NO and NH₃ in ambient air were also measured on a 2 hours basis.

Soil N content (nitrate and ammonium), soil texture and pH were measured occasionally during the field campaigns. Soil temperature and moisture were measured throughout the year by an automatic meteorological station in the field.

Measured pH and ammonium concentration in soils allowed the quantification of soil emission potentials at different moments of the year, with values ranging from 270 (dry soils) to 6628 (recently wetted soils), indicating the soil capacity to emit NH₃.

NO emissions were equivalent at both seasons (around 3 ng.m⁻².s⁻¹), whereas NH₃ exchange fluctuated between emission and deposition depending on meteorological parameters and ambient NH₃ concentration (from 0.97 to -1.75 ng.m⁻².s⁻¹).

The presence of litter and standing straw in November 2013 played a great role in emitting N compounds, compared to July 2012 and 2013 when the herbaceous strata was sparse and emissions were dominated by microbial processes in the soil leading to N release to the atmosphere.

[P-8] Recent Advancements in the Adirondack Long-Term Monitoring Program

Presenter: James E. Dukett, Adirondack Lakes Survey Corporation

Author(s): James E. Dukett, Sue Capone, Phil Snyder, Nathan Houck; Sara Burke, Monica Schmidt; Adirondack Lakes Survey Corporation

The Adirondack Lakes Survey Corporation (ALSC) was established in 1983 to undertake comprehensive biological and chemical surveys of Adirondack waters, to study the water quality and the effects of acid rain, and to disseminate this information and contribute to scientific understanding through studies and outreach. The ALSC's primary program is its collaborative participation in the Adirondack Long Term Monitoring Program (ALTM) with key researchers and government agencies.

The ALTM program evaluates the effectiveness of acid deposition controls called for under the Federal Clean Air Act Amendments of 1990. The ALSC has provided critical data to ALTM researchers, which enables policy makers to design and evaluate the effectiveness of acid deposition and mercury control policies. Results of the ALTM program efforts have shown that, although there have been improvements to Adirondack lake chemistry, the trends have slowed recently. Recovery for many of these lakes will be in the order of decades at current deposition levels. Critically high levels of aluminum continue to occur, particularly during spring snowmelt causing adverse impact to both aquatic and terrestrial ecosystems.

While the monitoring of lake waters remains a top priority for the ALTM, in recent years, resources have been shifted into new projects to further help evaluate the effects of fossil fuel combustion on the Adirondack ecosystem. For example, in 2014 the ALTM added more stream monitoring to address weaknesses in our understanding of episodic acidification. This additional work will be valuable in supporting the EPA's Secondary NAAQS development. Ultimately these changes have reduced costs while improving the understanding of spatial and temporal trends in surface water quality in New York's Adirondack Park. This poster will highlight the recent advancements in the ALTM.

[P-67] Nitrogen dynamics in the dormant season: An inter-watershed comparison

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Although atmospheric nitrate deposition in eastern North America has declined in recent years, the threat of nitrate-induced acidification and/or eutrophication remains a concern. The majority of annual nitrate export in seasonally snow-covered catchments occurs during the dormant season (i.e. winter-spring), and recent studies in Ontario, Canada have shown that a substantial proportion of dormant season nitrate export occurs in association with rain-on-snow (ROS) events, and these events cause both episodic acidification and increases in aluminum (Al) concentrations in streams. As winter rain events are more common in warmer winters, future increases in winter temperature may result in more frequent ROS events and acid pulses during the dormant season. This study compared long-term (25+ year) winter-spring stream flow and N export patterns across forested catchments located in southeastern Canada and the northeastern United States, to determine the presence of (a) regional patterns, and (b) long-term trends in winter-spring hydroclimatology and nitrate dynamics across the region. We evaluated the contribution of winter rain events to annual nitrate export and pulses of acidity and Al, and the relationship between winter climate and nitrate dynamics across the region.

[P-1] Surface water quality trends from EPA's LTM Network

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Author(s): Clara Funk, US Environmental Protection Agency and Jason Lynch,
US Environmental Protection Agency

Surface water chemistry provides direct indicators of the potential effects of anthropogenic impacts, such as acid deposition on the overall health of aquatic ecosystems. Two EPA-administered monitoring programs provide information on the effects of acidic deposition on headwater aquatic systems: the Long Term Monitoring (LTM) program and the Temporally Integrated Monitoring of Ecosystems (TIME) program. Here we present regional variability of long term trends in surface water quality in response to substantial reductions in atmospheric deposition.

Water quality trends at acid sensitive LTM sites exhibit decreasing concentrations of sulfate at 100% of monitored sites in the Adirondack Mountains and New England, 80% of Northern Appalachian Plateau sites, but only 21% of sites in the Central Appalachian Mountains over the 1990-2013 period of record. Across all regions, most LTM sites exhibited constant or only slightly declining nitrate concentrations over the same time period. Acid Neutralizing Capacity (ANC) levels improved at most sites in the Adirondack Mountains, New England, and Northern Appalachian Plateau, but few sites showed ANC increases in the Central Appalachian Mountains because of lagging improvements in base cation concentration and sulfate adsorption. The ANC of northeastern TIME lakes was also evaluated from 1991 to 1994 and 2010 to 2012. The percentage of lakes with ANC values below 50 $\mu\text{eq/L}$, lakes of acute or elevated concern, dropped by about 41% in New England and 22% in the Adirondack Mountains, indicating improvement in all sensitivity classes. Despite some ecological recovery, many sensitive lakes and streams in these regions remain at risk due to current acid deposition levels. The TIME/LTM programs, along with other monitoring networks, will continue to monitor surface water trends for effects of acid deposition and other anthropogenic impacts.

[P-91] Visualization of Science Supported by NADP Measurements

Presenter: Ray Knighton¹

Author(s):

Ray Knighton¹, Susan Braxton², David A. Gay², and Noor Syahira Nasarudin²

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A semantic analysis was performed on recent scientific publications that cited the use of NADP measurements. Google Scholar was used to identify works (> 1000 documents identified 2007-2014), which in most cases required mining within full text for references to NADP programs and data, as bibliographic citation is not consistently used for data. Scopus was used as the primary source of the bibliographic metadata used in the analysis of the publications found using Google Scholar (>950 Scopus records). Scopus is a citation database of peer-reviewed literature, and includes extensive metadata (e.g., abstracts, subject terms and author affiliations). The National Institute of Food and Agriculture of USDA has semantically modeled approximately 130,000 projects to create approximately 700 subject matter concepts from the project documents that describe a wide range of scientific disciplines. The words in the title and abstract of over 900 NADP related publications were used to infer/model NIFA subject matter concepts and associated those concepts with the publications to visualize the documents in 2-D space. The scope of science supported by NADP data, publication trends over time, and the relationships of authors and institutions to the bibliography will be discussed.

[P-32] Ethanol in rainwater from an agro-industrial region of São Paulo State – Brazil

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Cars running on ethanol and ethanol-blended fuels emit significant quantities of ethanol and acetaldehyde to the atmosphere. The latter - a highly toxic species- can also be photochemically formed in the atmosphere via oxidation of ethanol by OH radicals. The increasing use of ethanol as a fuel may lead to health and climate consequences that needs to be better understood. The aim of this work is to investigate ethanol behavior in rainwater from Ribeirao Preto (São Paulo State, Brazil), a city with 680,000 inhabitants and 490,000 cars. Samples were collected on an event basis, using an automatic wet-only collector at the University campus from September 2012 to March 2014. Ethanol concentrations determined via head-space gas chromatography ranged from 1.2 to 13 $\mu\text{mol L}^{-1}$ with a VWM ($5.9 \pm 0.6 \mu\text{mol L}^{-1}$; $n = 104$) which was ca. 30 times higher than concentrations reported for Wilmington (NC-USA) rainwater. This large difference is most likely due to the intense use of ethanol fuel in Brazil since the 1980's. The average gas phase ethanol concentration was 290 ppbv ($n=3$), leading to a theoretical concentration of 52 $\mu\text{mol L}^{-1}$ in equilibrium with water. Washing out behavior for ethanol was not observed, confirming the equilibrium was not reached during a rain event. Higher ethanol concentrations were observed in spring/summer period when compared to autumn/winter. There are higher atmospheric ozone concentrations in winter which could imply more efficient oxidation processes, however, the correlation between ethanol and acetaldehyde was positive, suggesting photochemical processes are not dominant. Contrary to what was observed for several other species in rainwater, there was no clear correlation between ethanol concentrations and agricultural activities in the study region. Also, no correlation was observed with air mass back trajectory, suggesting ethanol concentrations in atmospheric waters are ruled by more localized car emissions.

[P-21] Sensitivity of early life stages of *Lepomis* fishes to episodic exposure to acid

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Author(s): William G. Hagar, Quan Xu and John P. Ebersole, Department of Biology, University of Massachusetts Boston

Despite the good news of recent reductions of acidic deposition, episodic acidification of freshwater environments remains a substantial threat to aquatic wildlife in the world. These acid spikes are particularly harmful to early stages of fish development. We have studied the effects of pH spikes on *Lepomis* sunfish eggs at different stages of development. *Lepomis* sunfish eggs were collected from rocks on nests in a freshwater pond and three early life stages -- eggs, pre-swim-up larvae, and post-swim-up fry -- were tested for their susceptibility to transient acid spikes by exposing them to different levels of acidity for various lengths of time. Compared to "no acid" controls, transient acidity resulted in significant mortality in all three early life stages, despite the absence of leachates of aluminum or other heavy metals from soils. Greater reductions in pH and longer exposure to acid conditions resulted in more mortality. Although all three early life stages were affected by episodic acidity, some stages were affected more than others. Acid sensitivity followed development stages with no significant difference between eggs and pre-swim-up larvae, and the greatest sensitivity in the post-swim-up fry that are free swimming with gills. Exposure to various levels of acidity for different lengths of time showed that Post-Swim-Up fry incur high mortality across a wide range of acid conditions. Although 77 per cent of Post-Swim-Up fry survived 6 hours of exposure to water at pH=5, at pH=4 less than 40 per cent of Post-Swim-Ups survived six hours of exposure -- and less than 10 per cent survived 12 hours. This laboratory data supports earlier field studies that demonstrated the effects of transient acid spikes on *Lepomis* hatching profiles by finding an association between episodic acid spikes and under-represented day-classes in freshwater ponds of Massachusetts. (Stallsmith B.W., Ebersole J.P., & Hagar W.G. (1996) *Freshwater Biology* 36, 731-744.)

[P-52] Evolution of Passive Cloud Water Collector from Manual to Fully Automated

Presenter: Eric Hebert, Environmental Engineering & Measurement Services, Inc., eric.hebert@ee-ms.com

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Cloud water chemistry measurements have been made at the summit of Whiteface Mountain in Wilmington, NY since 1978 (Volker A. Mohnen³). Early efforts to collect cloud water samples were labor intensive and limited to periods of visual confirmation of cloud events. The passive sampler was deployed with a hand-powered winch when conditions were determined to be conducive for collection by personnel stationed at the summit. Among the goals of the first researchers were to compare, evaluate, and refine the types of collectors, and measure cloud chemistry.

The Mountain Cloud Chemistry Project (MCCP) was in operation from 1986 to 1989 and was implemented by the Forest Response Program of the National Acid Precipitation Assessment Program (NAPAP) and sponsored by the Environmental Protection Agency. Sample collection was still done manually during this period.

The Mountain Acid Deposition Program (MADPro) was a multi-year study of the deposition of air pollution to high elevation forests in the eastern U.S. MADPro was a part of the Clean Air Status and Trends Network (CASTNET). Cloud water samples were collected at Whiteface Mountain from 1994-2000 under MADPro. The collector design was improved and automated for MADPro to include refrigerated sample bottles for automatic hourly sample collection, automatic deionized water rinse of collector, and electric (garage door) motor to deploy the sampler. Daily site visits were still required to change sample bottles.

From 2001 the cloud water collection system has been operated by the Adirondack Lake Survey Corporation (ALSC). Environmental, Engineering & Measurement Services (EEMS) has been responsible for system improvements and upgrades from 2005. This poster outlines and summarizes the system advancements which include pneumatic collector deployment, real-time measurement of sample volume as it is collected, and sample collection control to reduce sample bottle use and site visit requirements.

[P-36] Evidence of Acidification of Terrestrial Systems Reviewed in the United States Environmental Protection Agency's Integrated Science Assessment for Oxides of Nitrogen and Sulfur

Presenter: Jeffrey D. Herrick, U.S. Environmental Protection Agency, herrick.jeffrey@epa.gov

Author(s): Jeffrey D. Herrick, U.S. Environmental Protection Agency, Jennifer Phelan, RTI International, Meredith Lassiter, U.S. Environmental Protection Agency and Tara Greaver, U.S. Environmental Protection Agency

The U.S. Clean Air Act requires periodic review of the National Ambient Air Quality Standards (NAAQS) for criteria air pollutants, including oxides of nitrogen (NOX) and oxides of sulfur (SOX). In 2013, the EPA initiated the current NAAQS review of NOX and SOX and is currently developing an Integrated Science Assessment (ISA) which is a synthesis and evaluation of policy-relevant science that forms the scientific foundation for review. Here we discuss preliminary findings on the effect of acidifying total N (NOX and reduced forms of N [NHX]) and SOX deposition on terrestrial ecosystems from the current NAAQS review.

Evidence presented in the 2008 ISA showed that impacts of acidifying deposition on biological receptors in terrestrial ecosystems were generally attributable to Al toxicity, decreased ability of plant roots to take up nutrient cations, and elevated leaching of Ca²⁺ from conifer needles. The Ca/Al ratio in soil solution was an indicator of the negative impacts of soil acidification on terrestrial vegetation.

In the current review, we have considered 130 new references (published since 2008) and have included over 55 in the draft materials. In general, the new references support the causal relationships identified in the 2008 ISA. Additional findings in the current literature include: consistent relationships between soil chemical indicators of acidification and tree physiology and growth; relationship between soil chemical indicator threshold values and tree responses; effects of acidifying deposition on sugar maple and red spruce can be ameliorated by Ca²⁺ additions; negative relationship between richness of foliose lichen species and air quality in a hardwood forest; soil acid-base chemistry as a potential predictor of understory species composition. The views expressed in this abstract are those of the authors and do not necessarily represent the views or policies of the US EPA.

[P-38] The Aging of Black Carbon under Polluted Atmosphere Enhanced Positive Radiative Forcing

Presenter: Min Hu, Peking University, minhu@pku.edu.cn

Author(s): Min Hu, Peking University; Jianfei Peng, Peking University; Song Guo, Peking University; Zhuofei Du, Peking University; Jing Zheng, Peking University; Dongjie Shang, Peking University; Don Collins, Texas A&M University; Renyi Zhang, Texas A&M University

Direct radiative forcing of Black carbon is one of uncertainty for climate change. In order to assess the aging of BC particles under ambient conditions in terms of the enhancement of mass absorption cross-section (MAC), the measurements conducted by using a novel quasi-atmospheric aerosol evolution study (QUALITY) chamber under polluted conditions in Beijing, China. Monodisperse fresh BC particles produced from incomplete combustion were introduced into the QUALITY chamber and exposed to sunlight and aerosol precursor gases same as ambient conditions.

The measurements showed that (1) The growth rate of soot particles were measured to be 11-47 nm/h in each experiment in Beijing. The majority of secondary constituents were SV-OOA. (2) The microscopic morphology of soot particles switches from loose chain-like structure to compact spherical structure during the aging process when Dme increased by 50%. (3) The hygroscopicity increased during the aging process. κ_{HTDMA} agreed with κ_{CCN} very well. (4) The enhancement factor of MAC was calculated up to 2.4.

Our experimental results suggest that the current climate model may underestimate the direct radiative forcing of soot particles by underestimating the MAC.

Acknowledgements

This work was supported by the National Natural Science Foundation of China (21025728 and 21190052), the National Basic Research Program of China (2013CB228503).

[P-47] Characteristics of Atmospheric Carbonaceous Components in Precipitation and Particle

Presenter: Mingqun Huo, Asia Center for Air Pollution Research,
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Katsuyuki Takahashi, Japan Environmental Sanitation Center

The carbonaceous aerosols in the atmosphere could have a regional climatic impact as well as harmful health effects, but data on particulate carbon concentration in precipitation are still sparse in comparison with those obtained for aerosol phase. The methodology for collection and analysis of particulate carbonaceous components including OC and EC in precipitation was established in this study. Field monitoring for particulate carbonaceous components and other ions in precipitation and particle including PM_{2.5} was carried out at Niigata (rural), Sado Island (remote), and Tokyo (urban) sites in Japan from 2011 to 2014. Deposition amount, seasonal variation, long-range transportation, and scavenging ratio were discussed in this study.

The wet deposition amounts and concentrations of OC and EC both in precipitation and particle at Tokyo site were highest. The high concentrations of EC in precipitation in winter and spring at Sado Island in the sea of Japan were mainly due to transportation from Northeast Asian continent, whereas at Tokyo site that the high level of EC concentration was mainly from domestic emission. The major source for high EC concentration in precipitation at Sado site in winter was probably due to the fuel combustion in Northeast Asian Continent, but in spring maybe result from the biomass burning. The values of scavenging ratios implied that OC was more easily to be removed from the atmosphere than EC. The scavenging ratio of EC was highest at Tokyo site due to wash-out process and the ratio of OC was highest at Sado site because of rain-out process during transportation.

[P-46] Emission, transboundary transport, and deposition of particulate PAHs in Northeast Asia

Presenter: Yayoi Inomata, Asia Center for Air Pollution Research,
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Several polycyclic aromatic hydrocarbons (PAHs) are considered as carcinogenic compounds. It is recognized that East Asia is largest PAHs emitting region in the world. In this study, we investigated emission, transboundary transport, and deposition of particulate 10-PAHs (fluorene, pyrene, benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[ghi]perylene, indeno[1,2,3-cd]pyrene, 1-nitropyrene) in Northeast Asia from 2005 to 2013, using the aerosol chemical transport model, Regional Air Quality Model for Persistent Organic Pollutants (RAQM2-POP ver2). The emission inventory, Regional Emission Inventory in Asia for POPs version (REAS-POP ver2), which is developed by ourselves, was used for the period from 2000 to 2008. The 10-PAHs variations after 2009 were simulated by using the inventory at the year of 2008.

In Northeast Asia, China was the largest particulate 10-PAHs emission country, which contributes to more than 95% of total emission. The emission of 10-PAHs was rapidly increased with clear seasonal variation, low in summer and high in winter in China. The areas of highest emissions were in China, especially in eastern China, Chongqing, Sichuan province. The increased emission was significant in eastern China. Annual emissions of 10-PAHs were increased to 1.4 times during the period from 2000 to 2008. Emission in winter season (December) was 1.3-1.5 times higher than those in summer season (July).

Transboundary transport of particulate 10-PAHs is observed at the Noto monitoring site in coastal sites in the Sea of Japan. Particulate 10-PAHs concentrations are clear seasonal variation with high in autumn-spring and low in summer. The highest concentration of 10-PAHs was observed in March 2008 during this period. It appears that high concentrations result with long range transport under the stable atmospheric conditions.

We will discuss about the dry and wet deposition of particulate 10-PAHs in the Sea of Japan in the presentation. Several polycyclic aromatic hydrocarbons (PAHs) are considered as carcinogenic compounds. It is recognized that East Asia is largest PAHs emitting region in the world. In this study, we investigated emission, transboundary transport, and deposition of particulate 10-PAHs (fluorene, pyrene, benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[ghi]perylene, indeno[1,2,3-cd]pyrene, 1-nitropyrene) in Northeast Asia from 2005 to 2013, using the aerosol chemical transport model, Regional Air Quality Model for Persistent Organic Pollutants (RAQM2-POP ver2). The emission inventory, Regional Emission Inventory in Asia for POPs version (REAS-POP ver2), which is developed by ourselves, was used for the period from 2000 to 2008. The 10-PAHs variations after 2009 were simulated by using the inventory at the year of 2008.

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Transboundary transport of particulate 10-PAHs is observed at the Noto monitoring site in coastal sites facing to the Sea of Japan. Particulate 10-PAHs concentrations show clear seasonal variation with high in autumn-spring and low in summer. The highest concentration of 10-PAHs was observed in March 2008 during this period. It appears that high concentrations result with long range transport under the stable atmospheric conditions.

We will discuss about the dry and wet deposition of particulate 10-PAHs in the Sea of Japan in the presentation.

[P-22] Assessing the sensitivity of macroinvertebrates to acid deposition in South African streams

Presenter: Londiwe Khuzwayo, University of the Witwatersrand at Johannesburg, 384746@students.wits.ac.za

Author(s): Chris Curtis, University of the Witwatersrand at Johannesburg, Christopher.Curtis@wits.ac.za
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The burning of fossil fuels releases Sulphur and Nitrogen oxides into the atmosphere which are returned to the earth's surface as acid deposition. More than 60% of South Africa's energy demands are met by coal resources. Recently Eskom has embarked on a project to build two new coal power stations of 4 800MW each. It is hypothesised that the addition of these coal power stations might increase the current atmospheric output of sulphur and nitrogen oxides, and possibly exacerbate the issue of acidification. In this study, GIS has been used to identify three regions (Mpumalanga, Waterberg & the South-western Cape) of South Africa that have been shown to have natural acid sensitive soils and freshwaters and are therefore, vulnerable to acidification. The 3 regions have been categorised to represent high, moderate and low acid deposition loads, respectively. A total of 79 study sites (i.e. streams) within these regions have been identified of which 30% have pH values <5.5. The degree of damage caused by acidification on the aquatic ecosystem has been classified in European countries using macroinvertebrate indices. There are several factors that influence species tolerance to changes in pH such as the content of calcium, aluminium, bicarbonates and organic material. This study aims to establish a classification system for South African macroinvertebrates by looking at species presence and absence in relation to ANC (Acid Neutralising Capacity) and pH and potential differences in these relationships depending on DOC concentration. A total of 55 sites suitable for carrying out macroinvertebrate studies have been identified, 59.0% (n=22), 56.0% (n=27), and 90% (n=30) of sampled streams in each region respectively.

[P-53] Deposition and transport of Acidic Constituents of Precipitation affecting Himalayas

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Himalayan region which is considered as very sensitive ecosystem in terms of acidic deposition is affected by local and long range transport (LRT) of pollution sources. Local sources such as tourist activities, transport and other human activities have significant effect on snow chemistry further having adverse impacts on ecosystems. In spite of its sensitivity, Himalayan region of India has not been investigated from the view point of fresh snowfall chemistry research. Hence, the present study was carried out at two sites i.e. Kothi and Mukteshwar in Himalayan region of India. The results showed that the average pH of snowmelt was lower at Kothi (5.69) than Mukteshwar (6.37). Such relatively high pH of precipitation at both the sites is mainly due to the interference of CaCO₃ rich atmospheric dust in Indian region. However, the concentrations of acidic species such as NO₃⁻ and nssSO₄²⁻ were noticed significantly higher due to anthropogenic sources. This study suggested that there is an urgent need to formulate a regional network to monitor the deposition of acidic species in precipitation over Himalayas in order to protect this ecosensitive region.

[P-35] Evidence of Eutrophication of Estuarine/Marine and Freshwater Systems Reviewed in the United States Environmental Protection Agency's Integrated Science Assessment for Oxides of Nitrogen and Sulfur

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The U.S. Clean Air Act requires periodic review of the National Ambient Air Quality Standards (NAAQS) for criteria air pollutants, including gas-phase and deposited oxides of nitrogen (NOX) and oxides of sulfur (SOX). In 2013, the EPA initiated the current NAAQS review of NOX and SOX and is developing an Integrated Science Assessment (ISA), which is a synthesis and evaluation of policy-relevant science that forms the scientific foundation for review. The effects of deposition include N-driven eutrophication of marine and freshwater systems.

In the 2008 ISA, biological indicators of N deposition in aquatic systems included alterations to N:P nutrient ratio, alterations to limiting nutrient dynamics, phytoplankton biomass (measured as chlorophyll a concentration), periphyton biomass, and trophic status indices. Causal relationships were inferred between N deposition and alterations to the C cycle and biodiversity. The contribution of N deposition to total N load varies among ecosystems. In estuarine and freshwater systems that are N-limited, atmospheric and non-atmospheric N sources contribute to increased phytoplankton and algal productivity, leading to eutrophication.

In the current review, we have considered 540 new references (published since 2008) and have included approximately 120 in the draft materials to date. New findings for freshwater eutrophication include studies that support causal findings in the 2008 ISA, as well as new potential biological indicators (enzymes, diatoms) and biological thresholds. In estuarine systems, dynamics of nutrient limitation have been further characterized. Coastal eutrophication continues to result in numerous adverse effects including hypoxic zones, species mortalities, and harmful algal blooms. Changes currently observed in US aquatic systems in response to elevated N deposition can have profound effects on ecological structure and function.

The views expressed in this abstract are those of the authors and do not necessarily represent the views or policies of the US EPA.

[P-25] Acidic Deposition along the Appalachian Trail Corridor and its Effects on Acid-Sensitive Terrestrial and Aquatic Resources

Presenter: Gregory Lawrence, U.S. Geological Survey, glawrenc@usgs.gov

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The Appalachian National Scenic Trail (AT) spans 3,500 km from Georgia to Maine. Over its length, the trail passes through a corridor with wide variations in climate, bedrock type, soils, and stream water quality. These factors create a diverse range of ecosystems. The health of these ecosystems is a cause for concern because the AT passes through the heavily populated eastern U.S. with its many sources of sulfur (S) and nitrogen (N) emissions that produce acidic deposition. To address concerns about the health of the AT, a study was designed to evaluate the condition and sensitivity of the AT corridor with respect to acidic deposition. Collections of stream water (265 sites), soil (60 sites), tree cores (15 sites) and atmospheric deposition samples (4 sites) were made along with understory and overstory vegetation measurements (30 sites) over the full trail length within a 40 km-wide corridor. Existing data on atmospheric deposition, geology, vegetation, stream chemistry, and soil chemistry were also used in the analysis. Mean acid-neutralizing capacity (ANC) was lowest in the streams in the North section, intermediate in the Central section and highest in the South section, despite the South having the highest acid rain levels. At least 40% of the study streams exhibited pH and/or Al³⁺ measurements that indicated potential harm to biota. Approximately 70% of the soil sites had values of base saturation under 20%, the threshold below which acidic deposition can mobilize inorganic aluminum (Al³⁺), the form harmful to terrestrial and aquatic life. Compositional similarity of understory and canopy species was positively correlated with acidic deposition, suggesting that during past decades, species poorly adapted to acidic deposition were replaced with tolerant species. Target loads modeling indicated that exceedance of sulfur target loads to achieve stream ANC = 50 µeq/L by the year 2100 occurred throughout the trail corridor.

[P-39] Analyzing of precipitation below pH4.0 in the Anmyeondo

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We have observed and analyzed the pH, Electric Conductivity, ions species of precipitation in Anmyeondo(36.53°N, 126.32°E), background air monitoring site, Korea. It is located down wind area from Asia Continent under the westerly belt.

In this study, we analyzed pH, Electric Conductivity and 9 ion species from 20 samples of precipitation, which were below pH 4.0, during the period from 2012 to 2014 in Anmyeondo with pathway of airmass with precipitation.

Analysis result of 20 samples showed that mean average precipitation was 3.2 mm indicating it was lower compared to the mean value of 2012~2014 (14.3 mm). For anion species, it showed high concentration in order of Cl(266.6 ueq/L) > SO₄(266.2 ueq/L) > NO₃(234.5 ueq/L) while it was NH₄(230.0 ueq/L) > Na(229.9 ueq/L) for cation species. Mean pH value of 20 samples was 3.71 and those of Electric Conductivity was 161.4.

Especially, 11 samples were involved in cases of trough passing through the central or northern China. Meteorologically, one of the major pressure system is the trough of 500 hPa goes by the Korean peninsula after passing through the central or northern China. It was also observed that low pressure develops to the Korea through the Gulf of Pohai.

In the same cases, mean value of pH (3.62) was lower than 20 samples while major ion concentrations were 284.1 ueq/L for NO₃ and 292.8 ueq/L for SO₄ as showing that they are higher than those of 20 samples.

Consequently, it was assumed that precipitation with low pH value below 4.0 were observed by the airmass which was derived from industrial complexes in the Asia continent.

[P-19] Vermont's Acid-Impaired Lakes Show Decreasing Critical Load Exceedances Based on Analysis of Recent NADP Gridded Deposition Maps

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Author(s): Heather Pembroke, Vermont Department of Environmental Conservation and Jim Kellogg, Vermont Department of Environmental Conservation and Rich Poirot, Vermont Department of Environmental Conservation

The National Atmospheric Deposition Program (NADP) recently released annual total deposition values for the various wet and dry sulfur and nitrogen species, from 2000 through 2013. The Vermont Department of Environmental Conservation extracted these values from gridded deposition maps for its acid lake watersheds and compared them to the high-resolution distributed model (HRDM) values estimated by Ecosystems Research Group in 2002, as part of the Vermont Acid Impaired Lake Total Maximum Daily Load (TMDL). Critical Loads and their exceedances were originally calculated in 2003 and 2004 for that TMDL. In this present effort, critical load exceedances were recalculated for the Vermont acid impaired lakes based on the new NADP estimates. Critical load exceedances provide a means to gauge the extent of impairment and the level of reductions needed. Exceedances also demonstrate the present range of sensitivity of Vermont's acid impaired lakes. The number of lakes that no longer exceed their critical loads of acidity have increased, reflecting the large declines in atmospheric deposition. While critical loads are a steady state model, not intended to predict the actual dynamic conditions, these NADP deposition values give a fresh look at critical load exceedances in Vermont acid-impaired lakes and demonstrate that sensitive Vermont lakes are becoming less acidic.

[P-62] Acid Rain Attack on Outdoor Sculpture in Perspective

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Author(s): Richard A. Livingston, University of Maryland

A major concern motivating acid rain materials effects research has been the potential effects on materials used in cultural heritage, particularly marble and bronze. However, a combination of field and laboratory studies has failed to show that wet deposition is the dominant cause of weathering of these material compared to dry deposition and simple dissolution in rain water. This can be explained by geochemical modeling based on pH - SO_4 phase diagrams for marble (calcium carbonate) and bronze (copper) under Earth surface conditions. Reaction path modeling of the acid neutralization process using the pH range typically found in wet deposition (3.5-5.5) indicates that the amount of material that can be dissolved by this process is limited to relatively small values (1-4% of total ion in runoff) by thermodynamics. In contrast, dry deposition is limited only by kinetics related to the deposition velocity which depends upon the local microenvironment and the material's properties. Consequently dry deposition effects on bronze and marble have historically dominated over wet deposition. However, since the start of the acid rain era in the 1970s the atmospheric concentrations of sulfur dioxide has declined by over an order of magnitude in North America and Europe, and dry deposition attack would have decreased proportionately. Other dissolution processes have in turn become more significant. This includes the effect of natural acidity in rain due to atmospheric CO_2 . In marine coastal areas, hydrochloric acid vapor attack resulting from nitric acid/sea salt interactions has been detected. Finally, mass balance (runoff vs rainfall) studies have consistently found significant positive imbalances for both calcium and copper ions implying unidentified counter ions, which are probably organic acids. These considerations help explain the findings from field studies that the main variable for predicting materials loss is simply the quantity of rainfall rather than its chemical composition.

[P-77] pH sensitivity of Swedish forest streams related to catchment characteristics and forest status

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There is concern that whole-tree harvesting may acidify soils and surface waters. Based on the acid-base status during four seasons in almost 200 randomly selected headwater streams draining forest land and peat land in southwestern and central Sweden (Dalälven), landscape features most sensitive to acidification and potentially in need for protection from excessive biomass harvest or remedies such as ash treatment were identified. The pH sensitivity was defined from the relation between stream water pH and alkalinity/acidity (-0.2 to 0.2 meq Alk/Ac l⁻¹, reference pH=5.6) and was related to catchment characteristics (land cover, bedrock, soils, atmospheric deposition of sulfur and nitrogen and climate), forest status (tree species, forest biomass and production) and stream water chemistry during spring, summer, autumn and late autumn.

Because of regional variability in acidification history, sea salt deposition, amount and distribution of quaternary deposits, vegetation cover, etc. pH sensitivity is differently important in the two regions. The historically most acidified southwest Sweden is the least pH sensitive due to the high buffer capacity at the often low pH. Hence, high pH streams draining thin and coarse soils seems to be the most pH-sensitive. Total organic carbon (TOC) is negatively related to pH-sensitivity in southwest, while it is positively related to pH-sensitivity in the often bicarbonate buffered streams in the Dalälven region, where TOC adds acidity. Hence, streams draining wetlands and other peat areas are the most pH-sensitive in central Sweden. At base flow and more well-buffered conditions in summer, the streams in southwest show a similar pH-sensitivity pattern as the Dalälven region. The patchy spatial distribution of sensitive landscape types and the seasonal water chemical variation makes it difficult from an administrative point of view to develop simple guidelines for where e.g. forest slash harvest should be restricted or where ash applications should be recommended.

[P-75] Black cherry crown health and mortal status on the Allegheny Plateau: Unanticipated consequences of the clean air act?

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Since the early 2000s, foresters have reported that black cherry, *Prunus serotina* Ehrh., crown health has deteriorated while seed production, seedling establishment, and seedling growth have been poor or erratic. These anecdotal reports stimulated the initiation of studies to determine whether current conditions are anomalous. In 2014, 49 Forest Health Monitoring (FHM) plots on the Allegheny National Forest (ANF) were re-measured. All trees ≥ 12.7 cm were evaluated in four 7.3 m radius subplots and crown condition and mortal status of all trees was assessed. A preliminary analysis of standing dead stems revealed that overall mortality in these 49 plot clusters was approximately 15.1% (214 standing dead trees out of 1422). However, black cherry mortality accounted for almost 50% of the total number of standing dead trees with an overall mortality rate of 26.8% (105 standing dead trees out of 392 black cherry trees). Comparing black cherry mortality with that of all other species combined indicates a mortality rate of 10.6% for all other species (109 standing dead trees out of 1030). The percent black cherry basal area that was standing dead was 8.7 ft² per acre or about 17.2% of the total black cherry basal area averaged across all 49 FHM plot clusters sampled in 2014. During an earlier survey (1998-2001) with 168 plots, percent standing dead black cherry basal area was only 7.6% of total black cherry basal area. Other research has shown that black cherry growth is highly responsive to nitrogen (N) inputs. Numerous factors including increased susceptibility to crown injury from beech mortality gaps (beech bark disease), increased fall webworm and cherry leaf spot incidence and severity, and decreased atmospheric N inputs may be affecting black cherry health and regeneration in northwestern Pennsylvania.

[P-18] How will anticipated changes in tree species composition affect critical loads for nitrogen in the Northeastern US?

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Tree species strongly influence the carbon (C) and nitrogen (N) cycling of forest ecosystems through differences in nitrogen uptake, productivity, carbon allocation, litter quality, and other traits. In forests of the Northeastern US, tree species composition is changing rapidly because of invasive insects and diseases, climate change, and other factors. Using a new dynamic simulation model of C and N cycling in Northeastern forest stands, we ask the question: How do changes in tree species composition affect the predicted critical load for nitrate leaching? The model, called Spe-CN, is designed to allow user-defined scenarios of tree species change and is parameterized and tested with extensive field data from Northeastern forests. Model simulations predict that the amount and timing of nitrate leaching depends on the tree species present in the stand, and that changes in tree species composition will have a substantial effect on the predicted critical load for N in a 50-100y time horizon. For example, the decline of eastern hemlock (*Tsuga canadensis*) from an introduced insect pest and its replacement by birch (*Betula* sp.) forests will reduce the forest floor C and N pools, decrease soil N retention capacity, and cause an increase in N leaching following a time lag. Similarly, decline of American beech (*Fagus grandifolia*) due to an introduced disease and its replacement by sugar maple (*Acer saccharum*) will also result in declining forest floor C and N pools and a rapid increase in N leaching. We conclude that critical loads for N leaching are strongly dependent on tree species and that predictions of critical loads should account for anticipated changes in species composition. Though individual species are unique, their impacts on C and N cycles are predictable based on a limited set of species traits.

[P-83] Measurement Artifacts of Gaseous Oxidized and Particulate Bound Mercury in a Commercial Mercury Speciation System

Presenter: Winston Luke, NOAA Air Resources Laboratory

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The Tekran® 2537/1130/1135 mercury speciation unit is a robust analytical system which is routinely deployed in regional, national, and global monitoring networks to measure concentrations of gaseous elemental mercury (GEM), gaseous oxidized mercury (GOM), and particulate-bound mercury (PBM). Standard operating protocols have been developed to ensure the collection of uniform and high-quality monitoring data. However, recent published laboratory and field research has pointed to the underestimation of GOM using KCl-coated denuders in humid and/or ozone-rich environments. Under very dry conditions, contamination of the Tekran® regenerable particle filter used to collect PBM can lead to the conversion of GEM to PBM, and a subsequent overestimation of reactive mercury (RM) concentrations. In March 2015 we deployed a total mercury (TM)/GEM detector at NOAA's Mauna Loa Observatory (MLO: Elevation 3397 m) on the island of Hawaii, to calculate reactive mercury (RM = GOM + PBM) as the difference of TM – GEM. We also installed a second Tekran® speciation system to accompany an identical system operating at MLO since 2011. We will present side-by-side comparisons of ambient data collected by the three instruments under a variety of conditions, as well as measured performance parameters assessed using a GOM calibration device. Initial results confirm the degradation of GOM measurement under even moderate levels of humidity, but also suggest that current AMNet sampling and data reduction protocols can exacerbate the problem.

[P-12] Decreased Atmospheric Sulfur Deposition across the Southeastern U.S.: When Will Watersheds Release Stored Sulfate?

Presenter: Jason A Lynch, USEPA, Lynch.jason@epa.gov

Author(s): Karen C. Rice, U.S. Geological Survey & University of Virginia, Todd M. Scanlon, University of Virginia, and Bernard J. Cosby, Centre for Ecology and Hydrology

Emissions of sulfur dioxide (SO_2) to the atmosphere results in atmospheric deposition of sulfate (SO_4^{2-}), which is the dominant strong acid anion causing acidification of drainage waters and soils. Atmospheric deposition of SO_4^{2-} in the eastern U.S. has declined by over 80% since passage of the Clean Air Act and its Amendments of 1990. However, few corresponding decreases in streamwater SO_4^{2-} concentrations have been observed in unglaciated watersheds in part because many of these watersheds today retain SO_4^{2-} deposition, unlike their counterparts in the northeastern U.S. and southern Canada. Here we calculated SO_4^{2-} mass balances for 27 forested, unglaciated watersheds from Pennsylvania to Georgia, by using total atmospheric deposition (dry plus wet) and stream water quality measurements as inputs to identify factors controlling the retention and release of SO_4^{2-} in those watersheds. Our analysis indicate that many of these watersheds should convert from retaining to releasing SO_4^{2-} over the next two decades. The specific years when the watersheds crossover from retaining to releasing SO_4^{2-} correspond to a general geographical pattern of later net watershed release from north to south. The single most important variable found to explain the crossover year was the runoff ratio, defined as the ratio of annual mean stream discharge to precipitation. Percent clay content and mean soil depth were secondary factors in predicting crossover year. We might expect a decline in SO_4^{2-} concentrations within the next two decades, finally fulfilling one of the anticipated outcomes of the CAA and its Amendments.

[P-13] National Surface Water Assessment of Critical Loads across the U.S.

Presenter: Jason Lynch, USEPA, lynch.jason@epa.gov

Author(s): Clara Funk, USEPA

The Acid Rain Program (ARP), established under Title IV of the 1990 Clean Air Act Amendments, requires major emission reductions of sulfur dioxide (SO₂) and nitrogen oxide (NO_x) from the electric power industry with the intention to decrease acidic deposition to sensitive lands and surface waters, and allow waterbodies to recover from anthropogenic acidification. Implementation of subsequent USEPA regulations, such as the Clean Air Interstate Rule and, more recently, the Cross-State Air Pollution Rule, and others have further reduced emissions of SO₂ and NO_x. Here we complete a national assessment of the impact of acid deposition on surface waters by using critical loads for acidity from over 10,000 waterbodies across the U.S. that are included in the National Critical Load Database (NCLD). This approach provides a useful lens through which to understand the potential aquatic ecological benefits that have resulted from emission reductions and determine if current acid deposition loadings are sufficiently low to allow ecosystems to recover over time or if they will never recover under present loadings. Using methods from multiple approaches, steady-state mass-balance critical loads were examined to determine whether annual deposition loadings of sulfur and nitrogen to surface waters and their watersheds would support moderately healthy ecosystems. Emission reductions achieved since 1990 have contributed significantly to broad surface water improvements and increased aquatic protection. About 2/3 of the waterbodies examined exceeded their critical load in 1989-1991, but do not from 2012-2014. Sensitive surface waters along the Appalachian Mountains spline in the eastern U.S. remain the most threatened by acidic deposition. Areas in New England and eastern Adirondacks show the greatest improvement while many streams, particularly in the central Appalachian Mountains, show only moderate improvement and remain at risk despite reductions in acid deposition.

[P-70] Links between N Deposition and Nitrate Export from a High-Elevation Watershed in the Colorado Front Range

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Long-term patterns of stream nitrate export and atmospheric N deposition were evaluated over three decades in Loch Vale, a high-elevation watershed in the Colorado Front Range. Stream nitrate concentrations increased in the early 1990s, peaked in the mid-2000s, and have since declined by over 40%, coincident with trends in nitrogen oxide emissions over the past decade. Similarities in the timing and magnitude of N deposition provide evidence that stream chemistry is responding to changes in atmospheric deposition. The response to deposition was complicated by a drought in the early 2000s that enhanced N export for several years. Other possible explanations including forest disturbance, snow depth, or permafrost melting could not explain patterns in N export. Our results show that stream chemistry responds rapidly to changes in N deposition in high-elevation watersheds, similar to the response observed to changes in sulfur deposition.

[P-43] Long-term assessment of nitrogen deposition at EANET remote sites in Japan

Presenter: Kazuhide Matsuda, Tokyo University of Agriculture and Technology, kmatsuda@cc.tuat.ac.jp

Author(s): Satomi Ban, Tokyo University of Agriculture and Technology, Kazuhide Matsuda, Tokyo University of Agriculture and Technology, Keiichi Sato, Asia Center for Air Pollution Research and Tsuyoshi Ohizumi, Niigata Prefectural Institute of Public Health and Environmental Science

A long-term assessment of nitrogen deposition has been carried out in cooperation with the Acid Deposition Monitoring Network in East Asia (EANET). The assessment aimed to understand regional status and trend of dry, wet and total deposition of oxidized and reduced nitrogen based on the monitoring during 10 years from 2003 to 2012 at 8 remote sites in Japan (Rishiri, Tappi, Sado-seki, Happo, Oki, Yusuhara, Ogasawara, Hedo). At the sites, the concentrations of HNO_3 , NH_3 , particle- NO_3^- and particle- NH_4^+ , and the wet depositions of NO_3^- and NH_4^+ were measured by four-stage filter pack method every fortnight and by wet-only sampling daily, respectively. We used the inferential method to estimate the dry depositions of HNO_3 , NH_3 , particle- NO_3^- and particle- NH_4^+ by using parameterizations of deposition velocity on forest. Hourly data of wind speed, temperature, relative humidity, solar radiation and precipitation amount observed at the sites were used to calculate the deposition velocities. Each dry deposition value was valid if both at least 80% of the hourly meteorological values and the concentration were available for the 2 weeks, and 10-year dry deposition value was valid if at least 80% of the dry deposition values were available for the 10 years. 10-year wet deposition value was valid if both the percent precipitation coverage length and the percent total precipitation exceeded 80% for the 10 years. All of the sites, except the farthest site from the Asian continent (Ogasawara) and the northernmost site (Rishiri), had high total nitrogen deposition about $10 \text{ kg N ha}^{-1} \text{ year}^{-1}$ or more in 10-year mean annual value. At the high deposition sites, the depositions of reduced nitrogen were on the same level with those of oxidized nitrogen. Clear increasing or decreasing trend of total deposition was not found at the 8 sites during the 10 years.

[P-27] Comparison of National Trends Network Deposition Data to the Community Multi-scale Air Quality Model for United States National Park Sites

Presenter: April Maxwell, Oak Ridge Institute for Science and Education, maxwell.april@epa.gov

Author(s): April Maxwell, Oak Ridge Institute for Science and Education, Alexandra Ross, Oak Ridge Institute for Science and Education, and Joseph P. Pinto, U.S. Environmental Protection Agency

Oxides of nitrogen and sulfur damage human health and the environment. Elevated nitrogen and sulfur deposition originate from industrial emissions and other sources. Estimates of deposition across the United States are based on models and measurements. In this study, we compare National Trends Network (NTN) wet deposition data for five United States national park sites to output from the Community Multi-scale Air Quality (CMAQ) Model. CMAQ is used in geographic locations where NTN data is not available and the extent of agreement between modeled and measured data will allow better characterization of air quality impacts.

Total wet deposition of nitrate, ammonium, sulfate, and hydronium ions from 2000 to 2014 for Rocky Mountain National Park, Great Smoky Mountains National Park/southern Appalachia, southern California, Acadia National Park, and Tampa Bay were extracted from the NTN database. These sites were chosen as they are focus areas for which the effects of deposition on local ecosystems are examined for the U.S. Environmental Protection Agency's current review for a secondary standard for nitrogen and sulfur oxides. Data and model are compared for concentrations averaged over different time scales and for trends at each site.

This research was supported in part by an appointment to the Research Participation Program for the U.S. EPA, Office of Research and Development, administered by the Oak Ridge Institute for Science and Education through an interagency agreement between the U.S. Department of Energy and EPA. The study was reviewed by the National Center for Environmental Assessment, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the view and policies of the EPA, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

[P-71] Effect of intensified forest harvesting on critical loads calculation for Swedish lakes

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Many regions of Europe and North America are subject to an on-going legacy of surface water acidification related to historic acid deposition. While acid deposition is well below historical highs, modelling studies suggest that more intensive forest harvesting for bioenergy production may slow or counteract recovery. The European Renewable Energy Directive mandates that at least 20% of energy will be generated from renewable sources by 2020. Several countries including Sweden have interpreted the Directive to promote a greater reliance on forest bioenergy. The removal of base cations (BC; Ca + Mg + Na + K) in forest biomass will gradually reduce the buffering capacity of the landscape and may make surface waters more sensitive to acidification.

The static Critical Loads (CL) concept does not specify the consequences of any change in land management on allowable CL. Furthermore it does not specify neither the time at which ecosystem damage will occur after CL are exceeded nor timing of recovery once deposition decreases below the CL. Changes in land management such as more intensive forest harvesting will decrease CL as a smaller portion of soil buffering capacity is available to counteract acidification due to air pollution. We present 8 forestry scenarios with differing degrees of harvest intensity ranging from low preindustrial levels to those making full use of the potential of modern silviculture under which we modelled acid deposition impacts on catchment soils and lake water chemistry. On annual to decadal time scales, only minor differences in soil and water chemistry were simulated under the different forestry scenarios. However, the impact on estimated CL was substantial. More intensive forest harvest scenarios were associated with large reductions in CL and consequent increases in CL exceedances. This presents an unexpected policy challenge as more intensive forest harvesting to meet renewable energy targets may impact on allowable European scale air pollution emissions.

[P-79] An Investigation of Mercury Concentrations in Stream Water, Macroinvertebrates, and Juvenile Brook Trout in Response to Liming in an Adirondack Watershed

Presenter: Karen Riva Murray, U.S. Geological Survey, krmurray@usgs.gov

Author(s): Douglas A. Burns, U.S. Geological Survey; Charles T. Driscoll, Syracuse University; Geoffrey Millard, Syracuse University

Honnedaga Lake, a small (310 ha) lake located in the western Adirondacks, supports a heritage strain of brook trout (*Salvelinus fontinalis*). Although population density has increased in recent years, the rate of increase is much slower than expected due to the continued chronic or episodic acidification of many tributaries, which has reduced spawning success in those critical habitats. Since 2010, experimental in-stream and watershed liming of tributaries has been studied as a method for accelerating recovery and improving brook trout recruitment. Liming-related changes in stream water chemistry and trophic ecology, however, have major implications for mercury (Hg) cycling and bioaccumulation, and liming may have the unintended consequence of increasing the production, transport, and bioaccumulation of Hg. Samples of stream water, macroinvertebrates, and juvenile brook trout have been collected from limed and untreated tributaries, from reaches above and below in-stream liming, and before and after treatment, and analyzed for Hg species and related constituents such as DOC in streamwater and stable isotopes in biota. Pre-liming median methylmercury (MeHg) concentrations in crayfish (Cambaridae) varied widely among five sites sampled in July 2012 (i.e., 60 ng/g – 1,050 ng/g dry weight), and were related to concentrations of DOC and aqueous MeHg. Median concentrations of total Hg (assumed to be primarily MeHg) in young of year brook trout (n = 3 per tributary) from three tributaries ranged from 38 ng/g to 116 ng/g (wet weight), with the highest concentrations found in fish from the tributary with the highest DOC and aqueous MeHg concentrations. Post-liming data indicate that DOC concentrations increased in limed sites relative to those of nearby untreated reference sites. Post-liming MeHg data for water and biota will be used to evaluate potential effects of these changes on mercury cycling and bioaccumulation in these streams.

[P-3] Acid Rains Impact Assessment and Eutrophication

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Questions related to the acidification and eutrophication of rivers, water and soil have been a central research area for our Research team and according this research losses of fish populations attributed to the effects of acid deposition have received a great deal of public attention; however, the available evidence indicates that acidic waters also affect many other forms of aquatic life, from single-celled algae to large aquatic plants to amphibians such as frogs and salamanders. Adverse effects on aquatic plants and animals can affect the availability of food to other animals such as fish, aquatic birds, and mammals. Eutrophication is a result in algal blooms, which then cause oxygen depletion. Well known that Acid deposition, more commonly known as acid rain, occurs when emissions of sulphur dioxide and nitrogen oxides react in the atmosphere with water, oxygen, and oxidants to form various acidic compounds. Prevailing winds transport the acidic compounds hundreds of miles, often across state and national borders. These acidic compounds then fall to earth in either a wet form or a dry form. At certain levels, the acidic compounds, including small particles such as sulphates and nitrates, can cause many negative human health and environmental effects.

[P-14] Mapping Critical Loads of Atmospheric Nitrogen Deposition for Aquatic Ecosystems in the Greater Yellowstone Area, USA

Presenter: Leora Nanus, San Francisco State University, lnanus@sfsu.edu

Author(s): Leora Nanus, San Francisco State University, Jill McMurray, United States Forest Service, David Clow, United States Geological Survey, Jasmine Saros, University of Maine Orono, and Tamara Blett, National Park Service

Aquatic ecosystems at high-elevations in the Greater Yellowstone Area (GYA) are sensitive to the effects of atmospheric nitrogen (N) deposition. Current and historic N deposition has impacted aquatic ecosystems in the GYA and proposed emissions changes may further affect these sensitive ecosystems. Understanding the spatial variation in atmospheric N deposition is needed to develop estimates of air pollution critical loads for aquatic ecosystems across the GYA. In this study, high resolution maps of mean annual wet deposition (inorganic N, nitrate, ammonium) and Total N deposition (wet + dry) were developed to identify areas of elevated loading of pollutants. Total N deposition estimates in the GYA range from < 1.4 to $7.5 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ and show greater variability than inorganic N deposition. Spatially explicit estimates of critical loads of N deposition (CLNdep) for nutrient enrichment in aquatic ecosystems were developed using a geostatistical approach. CLNdep ranges from less than $1.5 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ to over $10 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ and variability is controlled by basin characteristics. The lowest CLNdep estimates occurred in high-elevation basins with steep slopes, sparse vegetation, and exposed bedrock, including areas within GYA Wilderness boundaries. These areas often have high inorganic N deposition ($>3 \text{ kg N ha}^{-1} \text{ yr}^{-1}$), resulting in CLNdep exceedances greater than $1.5 \text{ kg N ha}^{-1} \text{ yr}^{-1}$. The N deposition maps were used to identify CLNdep exceedances for aquatic ecosystems, and to explore scaling and boundary issues related to estimating CLNdep. Based on a NO_3^- threshold of $1.0 \mu\text{mol L}^{-1}$, inorganic N deposition exceeds CLNdep in 12% of the GYA, and Total N deposition is in exceedance for 23% of the GYA. These maps can be used to help identify and protect sensitive ecosystems that may be impacted by excess N deposition in the GYA.

[P-80] The Dragonfly Mercury Project: Linking surface water chemistry and landscape characteristics to biotic sentinels at a national scale

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In partnership with over 50 national parks across the U.S., and with citizen scientists as key field personnel, we are developing the use of dragonfly nymphs as bio-sentinels for mercury (Hg) in aquatic foodwebs. To validate the use of these sentinels, and gain a better understanding of the connection between biotic and abiotic pools of Hg, this project also includes collection of landcover/landscape data, surface water chemistry including Hg and Hg-relevant chemistry (pH, sulfate, dissolved organic carbon (DOC)), and most recently, sediment Hg. Because of the wide geographic scope of the research, the project also provides a nationwide snapshot of Hg in these diverse media, primarily in undeveloped watersheds. The project is able to cover this broad scale because of the participation of citizen scientist groups working in each participating park. Each park provides staff from their resource management or interpretive division, who then oversees and coordinates citizen groups that perform the sampling. Citizen groups range from formal education groups (i.e., middle school through University students), youth volunteers (i.e., Youth Conservation Corps), members of park volunteer programs, or visitor programs. Over 800 citizen scientists have participated in the project, contributing 4,000 hours of volunteer time to the research effort. Preliminary data highlight the importance of surface water chemistry, such as acidity and DOC, as well as site-specific landscape characteristics like geology and landcover, for identifying ecosystem conditions that have higher risk for Hg bioaccumulation in sentinel biota. Some regions generally have greater concentrations of Hg in biota; the Northeast, for example, tends to exhibit elevated dragonfly nymph Hg levels, which are likely related to ecosystem conditions favoring methylation and possibly due to a legacy of high atmospheric deposition in this region. However, some surprising observations made in areas such as the arid southwest suggest alternate sources and mechanisms that are also at play and responsible for driving elevated Hg in biota.

[P-50] Ozone Trends in Great Smoky Mountains National Park over the Past Two Decades: Good News for Plants and Evidence that the Clean Air Act Works

Presenter: Howard Neufeld¹

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Ozone (O₃) data from five locations in Great Smoky Mountains National Park and one outside the Park in NC were analyzed over the period 1989 to 2012. Locations ranged from 564 m at Cades Cove to 2030 m at Clingmans Dome in TN. Ozone concentrations [O₃] show an early morning minimum around 6 am at low elevations and a peak between 1 and 4 pm. High elevation sites have flatter profiles with minimum [O₃] occurring between 8 and 11 am and maxima at night. Exposures, measured as the W126 index, increase with elevation up to 800 m, after which they plateau. Sites in NC have lower exposures than similar sites in TN, reflecting scavenging and dilution as air moves over the Park. Seasonal W126 exposures increased from 1989 to 1999 but have dropped substantially after 2003, with near complete loss of [O₃] ≥ 100 ppb and a large decrease in the frequency of [O₃] ≥ 60 ppb, especially at high elevation sites. In the past decade, the maximum 3-month W126 index has shifted to earlier in the season (Apr – Jun), especially at low elevations and at high elevation in NC. Ozone episodes (defined as > 3 consecutive hours with [O₃] ≥ 60 ppb) have become less frequent and shorter, with lower mean [O₃]. Decreases in O₃ since 2002 are correlated with concomitant decreases in NO_x emissions from TVA Power Plants and coincident with reductions across the eastern United States. Lower NO_x emissions have resulted from implementation of the NO_x SIP call as required by the Clean Air Act and NC's Clean Smokestacks Act, as well as turnover in the motor fleet to less polluting vehicles. Plants and natural ecosystems in Great Smoky Mountains National Park are at much lower risk from tropospheric O₃ today than they were a decade ago.

[P-45] Dry deposition of reactive nitrogen oxides in Japan

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The concentrations and dry depositions of reactive nitrogen oxides (NO_2 , NO , HNO_3 , HONO, and NO_3^-) in the atmosphere were measured at eight sites in Japan during FY2008-2013. To estimate the depositions, the measured nitrogen oxide concentrations were multiplied by the calculated deposition velocities using the inferential method, assuming a forest, agricultural, and city area as the remote, rural, and urban sites, respectively.

The rural and urban sites showed high concentrations of NO_2 , and NO , while the coastal remote sites showed relatively high NO_2 , and NO_3^- concentrations as compared to the NO concentrations. Therefore, the contribution of NO_3^- to the deposition of all reactive nitrogen oxides (NO_y) was significant at the coastal remote sites, Rishiri (northern coastal remote site) and Cape Hedo (southern coastal remote site). NO hardly contributed to NO_y deposition, even though its concentration was high at most of the sites. Despite its low concentration, the contribution of HNO_3 to NO_y deposition was considerable owing to its deposition velocity being the highest. Moreover, the concentration of HONO was higher at the urban and suburban sites. In particular, the HONO concentration was higher than the HNO_3 concentration at Sapporo (northern urban site), while the HONO concentration was the same at all other sites. Despite its relatively small deposition in many cases, HONO was the second largest contributor to NO_y deposition at Sapporo and Kazo (rural site in Kanto region) in winter.

Concerning the effects of meteorological condition, the concentration of HNO_3 increased under high temperature conditions, because HNO_3 rapidly changes to NO_3^- under low temperature conditions. Therefore, an increase in the temperature at a given site may alter the nitrogen deposition amount because the deposition velocity of HNO_3 is high. Thus, global warming may cause changes in the composition of reactive nitrogen oxides and its deposition.

[P-81] The Correlation between Mercury, Ions, and Weather Conditions at PA-47

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Research conducted in the 1970s found that the emissions of SO₂ and NO_x proved to be a widespread problem through the formation of acid rain. In 2002, PA-47 was established to close an NTN/MDN measurement gap in south-central Pennsylvania, and sample collection conducted by Millersville University (MU) meteorology students has continued uninterrupted ever since. PA-47 is located approximately three kilometers from the MU Weather Information Center where a full suite of meteorological variables are recorded and archived. This research uses ion/mercury analyses and meteorological data from 2004 through 2013 to understand the correlation between the variability observed in the NADP record and the weather conditions that could have contributed to the variability. This period corresponds to the availability of trajectory analyses using the HYSPLIT – Hybrid Single Particle Lagrangian Integrated Trajectory Mode, which will be employed in this study.

Anomalies were found as deviations from the mean concentrations of mercury, sulfate, potassium, calcium, magnesium, sodium, ammonium, and chlorine. This resulted in the isolation of those weeks that exhibited anomalies that were one and two standard deviations outside the mean. The meteorological conditions were found for the anomalies and categorized according to wind direction and time of year, and HYSPLIT was used to obtain back trajectories to determine source regions for this air. Results suggest that weather conditions are well correlated with variability in the weekly ion and mercury data. Our preliminary data shows that highest concentrations are found when the wind direction is from the southwest in the summer seasons and in moderate precipitation events that occur after an extended period of dry conditions.

[P-4] Recovery from acidification in the Czech Republic between 1994 and 2014

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Over the last three decades, emissions of acidifying compounds into the atmosphere (SO₂, NO_x) decreased substantially across large parts of Europe. In 1994, network of 14 small forested catchments (GEOMON, GEOchemical MONitoring) has been established to provide evidence of the surface water recovery from anthropogenic acidification in one of the most polluted regions of Europe. Since 1994, bulk sulphur (S) deposition decreased (on average across sites) by 64%, dissolved inorganic nitrogen (DIN) deposition decreased by 36%, chloride (Cl) deposition decreased by 17% and calcium (Ca) deposition decreased by 24%. As a consequence the annual volume-weighted mean precipitation pH increased from 4.6 to 5.5. Spruce canopy throughfall flux of S decreased by 70%, DIN flux increased by 11%, Cl flux decreased by 23%. Throughfall precipitation pH increased from 4.1 to 5.3. Changes in precipitation chemistry were reflected in trends of the stream hydrochemistry. Stream water sulphate (SO₄) concentrations decreased (on average across sites) by 30%, nitrate (NO₃) decreased by 60%, Cl decreased by 19%, Ca decreased by 17%, aluminium (Al) concentrations decreased by 10% and corresponding annual discharge-weighted pH increased on average from 5.9 to 6.3. Nevertheless, changes in hydrochemistry were tightly related to the former extent of catchment acidification. Sites exhibited strongest S deposition decline demonstrated the largest declines in NO₃ concentrations. Sites with the lowest stream water pH (<≈5) demonstrated Al reduction by ≈ 60%. Sites with long-term dissolved organic carbon (DOC) measurements in stream water have shown increasing DOC trends. Despite clear deposition control over the decadal stream hydrochemistry, year to year weather variation impacted short-term stream water chemistry. For example, average annual North Atlantic Oscillation (NAO) index was significantly positively related to annual Cl stream water concentrations. Dry and hot year 2003 stimulated mobilization of sulphate from catchment soils in the following year.

[P-44] Lead isotope & sulfur isotope in sulfate: Identification of environmental contamination near the zinc smelter in South Korea

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To control emissions and to successfully remediate contaminated sites, the investigation tools to trace pollution sources and fate of pollutants is needed. The isotopic composition in pollutants can play the role to identify sources and transformation process. So the isotopic composition of a source has to be unique and processes causing additional isotopic fractionation during transport or deposition have to be well known.

This study was conducted to build up the inventories of Pb isotopic compositions of major Pb pollution sources in South Korea. Since non-ferrous metal smelters are one of major anthropogenic sources, four major nonferrous metal two smelters for zinc, each one of smelter for lead and copper smelters were selected for the study. The Pb concentrations and isotopic compositions of metal ores, wastewater, sludge, metal rod and produced sulfuric acid were analyzed to understand the Pb isotopic patterns in environment. The isotopic ratio, $^{206}\text{Pb}/^{207}\text{Pb}$, of zinc ores from zinc smelter were in the range of 1.179 ~ 1.198 and the ratio of waste, flue gas and products samples were 1.105 ~ 1.147. These results implied that the isotopic patterns of output samples showed mixing patterns between two distinct metal ore sources.

In addition, we evaluated the environmental impacts of industrial emissions on surrounding ecosystem near the zinc smelter in S. Korea by using Pb isotopes, sulfur and oxygen isotopes in sulfate as tracers. Samples from zinc smelter and environmental matrices such as atmospheric particles, precipitation, coniferous needles and soil were collected and analyzed for heavy metals, ionic compositions, $\text{SO}_4\text{-S}$ & O isotopes and Pb isotopes.

The results showed that Pb isotopic values of atmospheric particles were merged to those of emission gases as Pb concentrations in particles are increased. However isotopic values of sulfate in atmospheric particles showed little changes in $\delta^{34}\text{S}\text{-SO}_4$ as $4.34 \pm 0.77\text{‰}$ and $\delta^{18}\text{O}\text{-SO}_4$ as $9.12 \pm 0.57\text{‰}$, which implied the Pb and sulfate might have different transporting processes in the area. The isotopic values of precipitation and needle showed more averaged patterns than atmospheric particles.

[P-26] Poster Title: Life in mid-air: Monitoring air quality in Class I Wilderness Areas within the White and Green Mountain National Forests, USA, using epiphytic lichens

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Lichens are valued for monitoring air quality because: a) they can concentrate air- and precipitation-borne elements within the lichen thallus and b) species have different and characteristic responses to pollutants such as sulphur (S) and nitrogen (N). Lichens were collected in 1993 to assess the pollutant concentrations in the lichens residing in Class I Wilderness areas of White Mountain National Forest in New Hampshire (Presidential Range-Dry River Wilderness (DR), and Great Gulf Wilderness (GG)) and the Green Mountain National Forest in Vermont (Lye Brook (LB)), USA. In 2011-2013, we re-sampled for lichen chemical concentrations and surveyed for diversity and health of epiphytic lichens at 12 stands, four stands in each of the three Class I Wilderness Areas, DR, GG and LB.

Despite improvements in air quality, the lichens are still hampered by pollution effects at LB. At LB, the lichens had a significantly lower number of species per plot and poorer thallus health on average when compared to plots in the White Mountain Wilderness Areas (GG and DR). Overall, there is a strong relationship between lichen species richness and thallus health assessment, suggesting that the differences in species richness are linked to damaging of lichens by pollution.

[P-74] Stream DOM photochemical degradation rates during extreme flow regimes

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Photochemical degradation of dissolved organic matter (DOM) was measured in situ photochemical experiments with stream water. A series of one week experiments covered a period of two months. A highly variable discharge during this period enabled to conduct experiments with stream DOM representing different flow regimes from baseflow to extreme flood events. Concentrations of dissolved organic carbon (DOC) ranged from 8 mg L⁻¹ during baseflow to 26 mg L⁻¹ during the flood. Baseflow pH values of 6.6 decreased by 1.5 unit during the flood.

Water samples were filtered through 1- μ m glass fiber filters and exposed to solar radiation in quartz bottles in the stream just below the water surface for 7 days. Molecular weight fractions of DOM in the original samples and their changes during photochemical experiments were estimated by size exclusion chromatography. During experiments, the original DOC concentration decreased by 8 to 29 %, depending on intensity of solar radiation and DOM properties. During the DOM exposure to solar radiation, concentrations of high molecular weight fractions (> 4kDa) decreased while concentrations of low molecular weight fractions increased, confirming structural changes in DOM composition. Observed rates of photochemical DOM degradation depended on discharge due to higher terrestrial export of high molecular weight DOM fractions during elevated discharges than during baseflow as well as on solar insolation intensity.

Our results highlight important effects of weather and hydrological conditions (precipitation and runoff) on photochemical properties of DOM in streams and their fate during exposure to solar radiation.

[P-24] Impact of Acid Rain, Industrial Wastes, and Effluent on the Wetland Ecosystem and its Characterization for Productivity and Sustainability in Indian Sub-Continent

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Divergence of wetland ecosystem including coastal biosphere and uncounted scattered deltas of Indian subtropics possess high productive ecosystem, comprising assemblage of flora and fauna. The stability of this ecosystem in the regions is oftenly subjected to varying degrees of stresses and degradation caused by different man-made causative factors, acid rain, industrial affluent and natural degradation. A comprehensive investigation was made near and far away the industrial areas under different five agro-zones (NAZ, OAZ, Coastal & Saline zone) of West Bengal, India on the effect of emissions through various factories and thermal power plants on the soil characteristics (suspended particulate matters, pH, organic carbon, CEC, available S and NO₃-N content) and quality of water in lakes, tanks, ponds, even well-waters (pH, BOD, COD, SO₂-S, Cl⁻, NO₃⁻, Turbidity, Cd and F⁻) through project activities in relation to its use in the welfare of the society (agricultural use, psci-culture and other domestic uses). The results showed that intensity of acidity (water pH) as well as concentration of various soluble salts and BOD and COD in the vicinity of an industrial area (i.e. within 100 metres) was very low. A substantially higher acidity and ion concentration were recorded up to 1 km away from industry, where the growth of aquatic plants, organisms and the production of fish (in lakes and tanks) were severely affected. The results further indicated that the acidity of water gradually increases up to pH 5.5 and concentration of sulphates and chlorides (850 and 580 mg l⁻¹ respectively) between 1–2 km from the industry, suggesting that aquatic ecosystems and domestic, agricultural and fish production are less affected with increasing distance from industry. Integrated wetland management programmes suited to bio-diversity of the zone-specific, were thus imperative to make upliftment of rural economy as well, as the mounting pressure of this area poses a threat to the ecosystem and makes it vulnerable for their normal life support. Consequently, one of the important tasks was developed suitable for in situ rainwater conservation through watershed approach in different agro-ecosystem. Thus, it is imperative to utilize this vast wetland including coastal ecosystem integrately for different approaches of development with impetuously for food, fuel, fishes and other biological enterprises for maximum productivity and ultimately, economic stability of the people that are inextricably linked with rural sustainability in these sub-zones as well.

[P-82] Long-term Monitoring of Mercury Speciation at a Coastal Site in the Northern Gulf of Mexico

Presenter: Xinrong Ren, NOAA/Air Resources Laboratory

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Mercury speciation, including gaseous elemental mercury (GEM), gaseous oxide mercury (GOM) and particulate bound mercury (PBM), trace pollutants, including ozone, SO₂, CO, NO, NO_y and black carbon, and meteorological parameters have been continuously monitored since 2007 at an Atmospheric Mercury Network (AMNet) site in Grand Bay, Mississippi. Average concentrations and standard deviations were 1.40 ± 0.23 ng m⁻³ for GEM, 5.9 ± 11.4 pg m⁻³ for GOM, and 5.0 ± 10.8 pg m⁻³ for PBM. Diurnal variation of GEM shows slight increase in GEM concentration during the morning, likely due to downward mixing of higher concentrations from the residual layer. Seasonal variation of GEM shows higher levels in winter and spring and lower levels in summer and fall. Both diurnal variations of GOM and PBM show peaks in the afternoon likely due to photochemical oxidation of GEM. Seasonally, PBM measurements exhibit higher levels in winter and spring and lower levels in summer, while GOM measurements show high levels in early summer and late fall and low levels in winter. These data were analyzed using HYSPLIT back trajectory and principal components analysis in order to develop source-receptor relationships for mercury species in this coastal environment. Trajectory frequency analysis shows that high mercury events were generally associated with high frequencies of the trajectories passing through the areas with high mercury emissions, while low mercury levels were largely associated the trajectories passing through relatively clean areas. Principal components analysis reveals two main factors: combustion and photochemical process that were clustered with high GOM and PBM. This study indicates that the receptor site, which is located in a coastal environment of Gulf of Mexico, experienced impacts from mercury sources that are both local and regional in nature.

[P-10] Abiotic Modifying Factors of Critical Loads of Nitrogen: Critical load ranges for Class I Areas in the Northeastern United States

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Author(s): Molly Robin-Abbott, USDA Forest Service; Linda Pardo, USDA Forest Service; Jennifer Pontius, University of Vermont and USDA Forest Service; Claire O'Dea, USDA Forest Service

Multiple interacting factors, including climate change, pollution, pests, and pathogens threaten forest ecosystem health and sustainability. Pollution in the form of excess nitrogen (N) deposition can alter ecosystem structure and function; the level of N below which harmful effects do not occur over the long term is the critical load. We have developed a GIS tool to assess the effect of various factors (temperature, precipitation, elevation, and soil characteristics) on site-specific critical loads for N deposition. We first developed tables delimiting the effect of site modifying factors on critical loads for 23 species of management concern in the northeastern United States. These tables were then integrated with multiple GIS data layers- forest composition, elevation, January temperature, July temperature, precipitation, soil pH, soil permeability, available water capacity, and bedrock depth – to determine site-specific critical loads. Here we present critical load ranges for Class I areas in the northeastern United States.

[P-51] Long-term monitoring of acidification in sensitive areas of the Northern and Eastern United States: A new generation of research

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Author(s): (and several co-authors)

We present a description of six long term study regions in the northern and eastern United States that have been monitored cooperatively since the 1990 Clean Air Act Amendments and before. Each has over three decades of surface water chemistry, and surveys of selected biota. Associated intensive studies have elucidated the impact of acidification to surface waters, and illustrated declines in acidity across much of these areas. The present holds new challenges: sulfur (S) deposition and in-lake/in stream S concentration trends document declines in most regions, but not in western Virginia. Nitrate deposition has declined, but in-lake/in-stream concentrations have been inconsistent across regions. Buffering capacity has increased in some areas and on some waterbodies (but not all). New questions are arising due to a new generation of researchers and stressors; new methods and technologies are required. In light of climate change, what does “recovery” look like? What is the role of increasing dissolved organic carbon? The aquatic landscape continues to be altered by inputs and reductions both intentionally (reduced emissions) and unintentionally (reduced base cations and climate change). We are mining existing data for climate change indicators and making a comprehensive effort to refine inter-regional comparisons, and identify network sentinel sites that address current and future policy needs. Recent findings such as those above let us know that the narrative is still unfolding. In order to inform and affect policy, we need to follow and understand these dynamics.

[P-41] Long-term trend on stream water chemistry and sulfur budget in an acidified forested catchment in central Japan

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Ijira catchment is located in the downwind side of the Chukyo Industrial Area in central Japan and has been historically experiencing large-scale depositions of sulfur and nitrogen from the atmosphere. The catchment was acidified and nitrogen-saturated in the mid-1990s, according to previous studies. The stream water pH declined from 7.3 in 1994/1995 to 6.6 in 2003, and then promptly recovered to a value of approximately 7 thereafter. Simultaneously, the NO_3^- concentration increased until 2002/2003 and thereafter started declining in 2005. During the period of acidification with NO_3^- leaching, the SO_4^{2-} concentration reached the highest value in 1994 with a mean concentration of $210 \mu\text{molc L}^{-1}$, and then gradually declined to $127 \mu\text{molc L}^{-1}$ in 2013. In addition, the concentrations of dissolved organic carbon were high from the mid-1990s to the early-2000s. The mean annual SO_4^{2-} input from 2007 to 2012 was $0.9 \pm 0.1 \text{ kmolc ha}^{-1} \text{ year}^{-1}$, while the mean annual output from the stream for the corresponding period was $2.3 \pm 0.5 \text{ kmolc ha}^{-1} \text{ year}^{-1}$. Even after taking into account various uncertainties, the output of SO_4^{2-} exceeded the input. The mean sulfur isotopic ratios ($\delta^{34}\text{S}$) of SO_4^{2-} in rainwater and soil solution at 20 cm depth were 4.6‰ and 3.8‰, respectively, while that in the stream water was -13‰. Recent sulfur inputs appear to be retained in relatively shallow soil layers. The sulfur in shallow layers may have contributed to the high concentrations in the mid-1990s. Reports in the literature suggest the existence of geological sources with significantly low $\delta^{34}\text{S}$ values (from -14‰ to -8‰) near the study catchment. Therefore, it is possible that the SO_4^{2-} derived from geological sources contributes to the large discrepancy, although dendrochronology suggests certain effects of the atmospheric inputs with lower $\delta^{34}\text{S}$ (from -7‰ to +1‰) in the 1960s/1970s in the Chukyo Industrial Area.

[P-48] Atmospheric deposition of carbonaceous components at Japanese monitoring sites and its contribution to carbon budget in East Asia

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Black carbon has been recently paid attention as a “Short-Lived Climate Pollutant” (SLCP), which give adverse effect on climate change, human health, agriculture and ecosystems. Characterization of atmospheric carbonaceous aerosol including black carbon has been investigated in worldwide. On the other hand, atmospheric deposition of carbonaceous components were monitored only at a few sites in Europe, North America and Africa, which will obscure removal process and atmospheric concentration distribution of black carbon. In this study, carbonaceous components in precipitation and aerosol are monitored at remote, rural, urban sites in Japan, and atmospheric deposition amounts of carbonaceous components were evaluated.

Field observations have been implemented at Niigata (rural), Sado (remote), and Tokyo (urban) sites in Japan since April 2011 to June 2012. The amounts of elemental carbon (EC), equivalent to black carbon, and organic carbon (OC) in precipitation and aerosol were measured by the IMPROVE protocol using a DRI model 2001 carbon analyzer. Wet deposition amounts were calculated as the products of aqueous concentration and precipitation amounts, and dry deposition amounts were as the products of aerosol concentrations and deposition velocity estimated by the Inferential Method. Seasonal variations of wet and dry depositions were discussed.

Wet deposition amounts of carbonaceous components of OC and EC at Sado (May 2011 to Feb. 2012) and Tokyo (May 2011 to Feb. 2012) sites were 1355.93 mg/m², 18.30 mg/m² and 1668.08 mg/m², 51.09 mg/m², respectively. Emission inventories of EC and OC are dominant in China although the increment rate of EC and OC in China decreased in recent years. By using the obtained results, the contribution of wet and dry deposition of EC and OC to carbon budget in East Asia will be discussed.

[P-76] Long-term changes in ecosystem nitrogen availability and nitrate export in two neighboring watersheds in the Adirondack Mountains, New York (USA)

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This project seeks to describe and compare long-term changes in forest composition, terrestrial nitrogen (N) availability, and stream nitrate-N export in two neighboring USGS-gaged, forested watersheds in the Adirondack Mountains of New York (USA) during a period of declining acid deposition. Shifts in tree species composition were examined in 15 permanent plots at 5-year intervals from 2000 – 2015 using the importance value (IV) index. Long-term changes in terrestrial N availability (1980 – 2014) were assessed through $\delta^{15}\text{N}$ analysis of tree rings (20 trees per watershed). Wet atmospheric N deposition data were acquired from NADP/PRISM annual gradient maps (1986 – 2013) and combined with statistically modeled stream nitrate-N yields (1999 – 2012) to construct annual N input-output budgets.

We found pronounced differences in forest composition between watersheds; American beech had the highest IV in the southern watershed, and both American beech and red spruce had high IVs in the northern watershed. Both of these dominant tree species are generally understood to be in decline in the Adirondacks. Atmospheric N deposition has decreased by 40% since 1986, and the $\delta^{15}\text{N}$ data suggest that terrestrial N availability has also decreased over time in both watersheds, yet the two tributaries are showing divergent trends in stream nitrate-N export. These results point to the need to integrate regional (N deposition) and site-specific (forest composition) drivers to explain long-term changes in terrestrial N availability and stream nitrate-N export in forested watersheds.

[P-31] A new viewpoint of a fluorescent method applied to investigate hydrogen peroxide in rainwater from an agro-industrial region of São Paulo State-Brazil

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Hydrogen peroxide is one of the most important oxidants in the troposphere, engaging in redox reactions with a variety of organic compounds and sulfur dioxide, thus contributing to rainwater acidification. The aim of this work is to optimize a fluorescence method to determine H_2O_2 in environmental matrices, and to investigate the behavior of this species in rainwater of Ribeirão Preto (São Paulo State, Brazil). The city has 680,000 inhabitants and 490,000 vehicles, and due to the high use of ethanol fuel in Brazil, the lower troposphere is enriched with oxygenated volatile organic compounds. The role of H_2O_2 in the oxidation of these type of compounds is still unknown. Rain samples were collected on an event basis, using an automatic wet-only collector at University campus, from September 2014 to March 2015. The method is based on oxidation of 2',7'-dichlorodihydrofluorescein (DCFH) by H_2O_2 catalyzed by the enzyme horse radish peroxidase (HRP) forming the highly fluorescent compound 2',7'-dichlorofluorescein (DCF). The method's working range was up to 300 nmol L⁻¹ with good linearity ($r > 0.99$) and a LOD of 10 nmol L⁻¹. This system permitted, for the first time, rain samples to be stored for up to 48 h at -22 °C. Concentrations of H_2O_2 in rainwater ranged from 5.5 to 39 $\mu\text{mol L}^{-1}$ (VWM = $14.8 \pm 5.9 \mu\text{mol L}^{-1}$; $n = 14$), in agreement with the range found in São Paulo city (Brazil). Washing out behavior was observed suggesting peroxide is effectively scavenged from the gas phase by rainwater. A positive correlation was observed between ethanol and hydrogen peroxide in rainwater ($p < 0.01$), which is significant because it suggests H_2O_2 mediated oxidation is not a dominant sink for biofuel ethanol at this location.

[P-17] Associations between red spruce radial growth and pollution critical load exceedance values

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Author(s): Ben Engel, Gary Hawley, Shelly Rayback, Jennifer Pontius, Alexandra Kosiba, all the University of Vermont, and Eric Miller, Ecosystems Research Group

Acidic sulfur (S) and nitrogen (N) deposition depletes cations such as calcium (Ca) from forest soils and has been linked to increases in foliar winter injury that led to the decline of red spruce (*Picea rubens* Sarg.) in the northeastern United States. We used results from a 30 m resolution steady-state S and N critical load exceedance model for New England to better understand the spatial connections between Ca depletion and tree productivity. We examined how radial growth (basal area increment) of 441 dominant and co-dominant red spruce trees from 37 sites across Vermont and New Hampshire was related to modeled estimates of S and N critical load exceedance. As expected, climate-related sources of variation accounted for most of the differences in growth. However, exceedance was significantly and negatively associated with mean growth for the study period (1951-2010) overall, and particularly for the 1980s and 2000s – periods of numerous and/or severe foliar winter injury events. Because high winter injury reflects the convergence of predisposing (cation depletion) and inciting (weather) factors, exceedance alone appears insufficient to define associated patterns of growth reduction. Significant interactions indicated that exceedance had little influence on growth at low elevations (where intrinsic conditions for growth were generally good) or high elevations (where growth was uniformly poor), whereas exceedance was significantly associated with reduced growth at mid elevations over broad periods of time. Exceedance was also linked to reduced growth rebounds following a region-wide foliar winter injury event in 2003. Overall, our analyses suggest that modeled S and N critical load exceedance can help account for red spruce growth and rebound from injury in the field. Interestingly, recent growth for red spruce is above the average for the current dendrochronological record – indicating that the factors shaping growth may be changing.

[P-20] Assessment of lake acidification: Towards type-specific reference conditions for microcrustaceans (Cladocera and Copepoda)

Presenter: Ann Kristin Schartau, Norwegian Institute for Nature Research, ann.schartau@nina.no

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Based on a national dataset on 3100 Norwegian lakes, the sensitivity to acidification have been indicated for 31 species of Cladocera and 23 species of Copepoda, i.e. about 40% of the species recorded in Norway. According to the European Water Framework Directive, deviation from reference conditions are the basis for ecological status assessment. For most acidified lakes, data on microcrustaceans prior to acidification does not exist. Therefore, we have to establish reference values for pressure relevant indicators based on data from non-acidified lakes belonging to acid-sensitive lake types. For a dataset of 370 lakes with harmonized monitoring data of micro-crustaceans, we identified reference lakes by two different approaches. 1) For lakes with sufficient data on chemical parameters (approximately 150 lakes), we calculated pre-industrial ANC and pH using the F-factor model and compared these values with current monitoring data. We used two following criteria to identify non-acidified lakes: lakes with delta-ANC and delta-pH less than 10 $\mu\text{eq/L}$ and 0.2 pH-units, respectively. 2) For all other lakes, we made a geographical matching of each lake with grids of 12 x 12 km², for which acid-load exceedance have been calculated for five different periods. We also used information on other pressure data to exclude lakes with uncertain reference status. In total we identified 126 reference lakes, of which 44 lakes were considered as sensitive to acidification (alkalinity < 0.2 meq/L, Ca < 4 mg/L). These lakes represented two national lake types; very low alkalinity, clear lakes and low alkalinity, clear lakes. Most microcrustacean metrics discriminated between lake-types and/or categories of acidification status, whereas we found no significant interaction between lake-type and acidification category. Differences between lake-types as well as natural variation within lake-types have to be taken into consideration in the development of an assessment system for lake' acidification based on microcrustaceans.

[P-56] Thirty Years of Acid Rain Studies in Maryland

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The Power Plant Research Program [PPRP] was established in 1971 by the State of Maryland to ensure that demands for electric power would be met in a timely manner at a reasonable cost while associated environmental impacts would be acceptable. A goal of the program is to investigate the impacts of new and existing generating facilities. In particular, acid rain is called out as a specific item of study by PPRP and over the past thirty years has produced a number of reports based on studies of this concern. With the passage of the Clean Air Act Amendment (CAAA) in 1990, Congress established the Acid Rain Program and limited power plant emissions of sulfur dioxide and nitrogen oxides which contribute to acid rain. Further, Maryland passed the Healthy Air Act of 2006 that required in-state reductions of these acidifying emissions from the fossil-fueled generating fleet. This poster will cover results from two particular studies: the long-running Maryland Biological Stream Survey [MBSS] and the Maryland Synoptic Stream Chemistry Survey [MSSCS] that together show the benefits that the CAA and HAA have achieved in reducing stream acidification. MBSS is a routine, long term program sampling stream attributes including pH, major cations and anions, acid neutralizing capacity and alkalinity. MSSCS was a detailed 1987 study of streams across the state. In 2012, 25 years later, the most acid rain impacted streams were resampled under similar hydrologic conditions. The results from these two studies show trends to higher ANC and pH and a lower percentage of stream miles being categorized as “acidic” or “highly sensitive”. The efforts to control acid rain have been a clear benefit to Maryland.

[P-64] Acid rain on the Coast of the Gulf of Mexico

Presenter: Rodolfo Sosa, E. Universidad Nacional Autónoma de México, rodsosa@unam.mx

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The Coast of the Gulf of Mexico is a region that exhibits acid rain which has been detected since 2003 in four sampling sites, which are located in the State of Veracruz: “El Tajín” archaeological zone; “La Mancha” ecological station; “San Juan de Ulúa” fortress and “Universidad Veracruzana-Mocambo”. These sampling sites were continuously and simultaneously being operated from 2003 until 2005.

“La Mancha” site remains in operation and is considered a reference site. The measurements for wet deposition were made from 2003 to 2014. For the evaluation of acid rain, the collection of rainfall samples is performed daily. The pH and conductivity measurements are done in the laboratory, as well as the determination of ion concentration (Na^+ , NH_4^+ , K^+ , Mg^{2+} , Ca^{2+} , SO_4^{2-} , NO_3^- and Cl^-) by HPLC.

During the study period, the following ranges for values for the volume weighted mean were found per year: pH (4.81-5.44), sulfate (15.83-40.00 $\mu\text{eq/L}$), nitrate (3.55-26.45 $\mu\text{eq/L}$), among others.

“La Mancha” site shows an increasing trend in pH, which is significant throughout the period with 0.30% per year. A significant declining trend in NO_3^- was observed over the decade-long study period, averaging 4.16% increase per year.

The period of 2004 to 2009 shows an increase in NO_3^- , while since 2010 a small decline has been identified. It was also observed a significant increase in the trend over the SO_4^{2-} in the decade-long study period, with a 3.08% of average increase per year. The period of 2004 to 2009 shows an increase in SO_4^{2-} with a decline in 2010, followed by an apparent trend to remain constant. This shows the potential impact in the study area over different receptors: agricultural areas, water bodies, and buildings which are part of the cultural heritage (“El Tajín” presents a superficial recession of 4.2 micrometers per year), among others.

[P-63] Three Years of Continuous Wet Deposition Monitoring in Central Argentina

Presenter: Ariel Stein, NOAA's Air Resources Laboratory, ariel.stein@noaa.gov

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Measurements of wet deposition outside of the developed industrialized nations are scarce and discontinuous. In particular, the South American continent shows a lack of continuous measurements performed at regionally representative sites. In this presentation, we will show three years of rain water chemical composition concentrations and wet deposition data including Ca^{2+} , Mg^{2+} , K^+ , Na^+ , NH_4^+ , NO_3^- , Cl^- and SO_4^{2-} , obtained from a station located in central Argentina (30° 57' 26" S, 62° 49' 28" W) near Lago Mar Chiquita, part of a vast agricultural region planted primarily in soybeans. This site follows a modified National Atmospheric Deposition Program weekly sampling protocol, relying on bag sampling in order to minimize shipping of buckets and other expendable equipment. Samples are presently shipped to the NADP Central Analytical Lab for chemical analysis. A description of the site setting, costs incurred, and challenges encountered coordinating site management and data analysis between NADP and this site will also be presented.

[P-16] Forecasts for terrestrial ecosystem acidification development under air pollution, climate change and different types of forest management with the ForSAFE model

Presenter: Harald Ulrik Sverdrup
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Simulations with the ForSAFE-VEG model shows that including climate change and forest management changes in the model runs have significant effects for the results in terms of critical loads of acidification and the exceedances of critical loads. The difference seen by including climate change are large and profound in northern Sweden, significant in middle Sweden and insignificant in southern Sweden. Primary reasons are that both weathering rates and growth rates for trees, combined with increased intensity of harvest, affect the outputs significantly from earlier assessments. The calculations show that even if the large reductions in sulphur deposition during the last decades have given large positive results, that the problem of soil acidification and its effects are still significant in southern and middle Sweden, even if this is on a much milder intensity than earlier.

[P-49] Ozone-induced rice grain yield loss is controlled by ABBERANT PANICLE ORGANIZATION 1 gene

Presenter: Masanori Tamaoki, National Institute for Environmental Studies, mtamaoki@nies.go.jp

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Ozone is the main photochemical oxidant that causes leaf damage as well as decreases the productivity of crops. The tropospheric ozone concentration will continue to increase especially in Eastern Asia. Ozone will trigger 40% of crop yield loss at maximum in this area. Yield loss in ozone-exposed crops is thought to be occurred by a reduction in photosynthetic activity caused by leaf injury. However, the degree of visible ozone-induced leaf injury does not correlate with grain yield reduction among rice cultivars, suggesting that ozone-induced grain yield loss in rice may not be accounted for by the reduction in photosynthetic activity caused by leaf damage. In this study, we performed QTL analysis using chromosome segment substitution lines from Sasanishiki (no grain yield loss by ozone) and Habataki (decrease grain yield by ozone) to identify a gene involving in rice grain yield loss by ozone. Ozone-exposed Habataki showed decrease of grain yield as well as primary rachis number. The QTL analysis showed a locus located on chromosome 6, which includes ABBERRANT PANICLE ORGANIZATION 1 (APO1) gene, regulates grain yield loss and primary rachis number under ozone-exposed rice. The APO1 gene is known to control the number of primary rachis during panicle formation. We found the APO1 is the gene that affects grain yield loss in ozone-exposed rice by using of near-isogenic line, which contains Habataki-genotype of APO1 gene with Sasanishiki background. The transcript levels of APO1 gene in inflorescence meristem decreased remarkably in Habataki and increased in Sasanishiki by ozone, suggesting that APO1 plays important role for rice grain yield loss by ozone through controlling primary rachis number of panicle. Furthermore, we also showed that some phytohormones such as jasmonate and abscisic acid involve in ozone-induced grain yield loss through regulation of APO1 expression in inflorescence meristem.

[P-54] Spatial distribution of rainwater chemistry and sources of ionic species across the Indo-Gangetic Plains, India

Presenter: Dr. Suresh Tiwari, Indian Institute of Tropical Meteorology, Pune, New Delhi Branch, Prof. Ram Nath Vij Marg, New Rajinder Nagar, New Delhi-India, Email: smbtiwari@tropmet.res.in

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The spatial distribution of rainwater chemistry over the densely-populated and highly polluted Indo-Gangetic Plains (IGP) was investigated using samples (total= 687) collected during three consecutive summer monsoon seasons from 2009 to 2011. The concentrations of secondary ionic species (SO_4^{2-} and NO_3^-) were measured along with the other major ions (F^- , Cl^- , Na^+ , K^+ , Ca^{2+} , Mg^{2+} & NH_4^+) and pH and specific conductivity. The weighted mean pH (\pm std) and conductivity of rainwater were 5.73 (\pm 0.17) and 31.6 (\pm 31.0) $\mu\text{S cm}^{-1}$, respectively. Approximately 16% of rainwater samples were acidic (mean pH= 5.38 of acidic rain; H^+ = 5.38 $\mu\text{eq/l}$) and rest of them were alkaline (mean pH = 6.34 of alkaline; H^+ = 0.63 $\mu\text{eq/l}$) in nature. Specific conductivity was ~39% lower (20.6 $\mu\text{S cm}^{-1}$) for acidic rain compared to the more basic (33.6 $\mu\text{S cm}^{-1}$) samples. The mean sum of all measured ions is $351.6 \pm 130.1 \mu\text{eq L}^{-1}$ with maximum contributions of Ca^{2+} (30%) and SO_4^{2-} (15%). Mean [SO_4^{2-}] (52 $\mu\text{eq/l}$) and [NO_3^-] (29 $\mu\text{eq/l}$) were approximately five and ten times higher than the background hemispheric values. Secondary ions had the highest deposition fluxes (SO_4^{2-} : 25.2 kg/ha/y and NO_3^- : 18.3 kg/ha/y). The mean ratio of H^+ / ($\text{NO}_3^- + \text{SO}_4^{2-}$) was 0.02 indicating ~98% of the acidity was neutralized. Ca^{2+} , (57%), Mg^{2+} (25%), NH_4^+ (15%) and K^+ (4%) were important neutralizing species. Positive Matrix Factorization (PMF) was applied to the deposition fluxes. Five factors were identified as ammonia neutralized, sea salt, soil, biomass burning, and calcium neutralized.

[P-2] Long-term trends in water chemistry of acid-sensitive Swedish lakes show slow recovery from historic acidification

Presenter: Martyn N. Futter, Swedish University of Agricultural Sciences, martyn.futter@slu.se

Author(s): Salar Valinia, Swedish University of Agricultural Sciences, Stefan Löfgren, Swedish University of Agricultural Sciences, Stephan Köhler, Swedish University of Agricultural Sciences, Jens Fölster, Swedish University of Agricultural Sciences

Long-term (1987–2012) water quality monitoring in 36 acid-sensitive Swedish lakes shows slow recovery from historic acidification. Overall, strong acid anion concentrations declined, primarily as a result of declines in sulfate. Chloride is now the dominant anion in many acid-sensitive lakes. Base cation concentrations have declined less rapidly than strong acid anion concentrations, leading to an increase in charge balance acid neutralizing capacity. In many lakes, modeled organic acidity is now approximately equal to inorganic acidity. The observed trends in water chemistry suggest lakes may not return to reference conditions. Despite declines in acid deposition, many of these lakes are still acidified. Base cation concentrations continue to decline and alkalinity shows only small increases. A changing climate may further delay recovery by increasing dissolved organic carbon concentrations and sea-salt episodes. More intensive forest harvesting may also hamper recovery by reducing the supply of soil base cations.

[P-11] Establishing the critical load of nutrient nitrogen for northern Canadian Jack pine forests

Presenter: Nicole Vandinther, Environmental & Life Sciences, Trent University, Peterborough, Ontario, Canada, [nicolevandinther@trentu.ca]

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Large-scale development of open-face bitumen mining in the Athabasca Oil Sands Region (AOSR) has led to elevated emissions of nitrogen oxides (NO_x), with emissions totalling more than 90,000 tonnes in 2011. There is growing concern that chronic nitrogen (N) deposition may potentially impact plant species biodiversity in Alberta and neighbouring areas of Saskatchewan and the Northwest Territories. These regions are dominated in part by nutrient poor, upland Jack pine (JP) forests and are among the most sensitive to N deposition.

Terrestrial effects of increased N deposition have been widely quantified using empirical critical loads of nutrient nitrogen (CLemp(N)). Recommended European CLemp(N) values for coniferous forests fall between 5–15 kg N ha⁻¹yr⁻¹, a range tailored to protect soil and vegetation processes occurring within these stands. As European forests can experience N deposition up to 100 kg ha⁻¹yr⁻¹, this range may not be suitable for Canadian forests. Deposition values in the AOSR are estimated to range between 5 and 65 kg N ha⁻¹yr⁻¹ based on proximity to emissions sources and the recommended CLemp(N) for northern hardwood and coniferous forests in North America ranges from 3–8 kg N ha⁻¹yr⁻¹.

This study used observational data from forest vegetation plots in JP dominant stands across Alberta, Saskatchewan and the Northwest Territories. The objective was to assess N as a potential driver of plant community composition against both climate and sulphur deposition. A region-specific CLemp(N) range was derived by evaluating vegetative community change points using Threshold Indicator Taxa ANalysis (TITAN) against a modelled N deposition gradient.

The results of this study suggest that most taxa have not experienced adverse impacts from N deposition. However certain indicator species, including *Pinus banksiana*, lichen and moss species demonstrated greater vulnerability to increased N deposition. While CLemp(N) values exist for broad ecosystem classes, adjusting that range is critical to ensure sensitive ecosystem components are protected against N deposition for a specific region.

[P-23] Phytoplankton and Zooplankton Communities in Swedish Lakes Covering a Gradient of Inorganic Aluminum Concentrations

Presenter: Tobias Vrede, Swedish University of Agricultural Sciences, Department of Aquatic Sciences and Assessment, Sweden, tobias.vrede@slu.se

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Labile inorganic aluminum (Ali) is highly toxic to many aquatic organisms. Different studies exhibit a range in critical concentrations. This suggests that there is a complex relationship between Ali concentration and toxicity, possibly modulated by TOC and F concentrations as well as pH. We also hypothesize that there are differences in the responses on the species level. Here we present results on phytoplankton and zooplankton community composition in 177 and 51 lakes, respectively, from the Swedish National Monitoring and ISELAW (Integrated Studies of the Effects of Liming Acidified Waters) programs. These lakes have either measured or modeled Ali concentrations and cover large ranges in annual median Ali, pH and TOC of <3-780 $\mu\text{g/L}$, 4.2-9.3 and 0.4-50 mg/L, respectively. The colonization pattern of plankton species and the response of phytoplankton and zooplankton communities to long-term changes in Ali were investigated by time series analysis on 10 selected lakes with at least 15 years of plankton and chemistry data. These lakes have a median $\text{pH} < 6$ and are currently recovering from acidification as evident from positive trends in pH. To investigate the opposite scenario, the changes in the plankton communities in response to increasing Ali concentrations were also assessed in a few re-acidifying lakes where liming has been discontinued.

[P-85] Trends in Mercury Wet Deposition and Mercury Air Concentrations across the U.S. and Canada

Presenter: David A. Gay

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This study examines the spatial and temporal trends of mercury (Hg) in wet deposition and air concentrations in the United States (U.S.) and Canada between 1997 and 2013. Wet deposition data was obtained from the National Atmospheric Deposition Program (NADP) Mercury Deposition Network (MDN) and Hg air concentration data was obtained from NADP Atmospheric Mercury Network (AMNet), Environment Canada (EC), University of Nevada Reno (UNR), and other published and unpublished data sources. Multiple trend methods (Linear Parametric (LP) and Seasonal Mann-Kendall (SMK, primary method)) were used for individual sites, along with multiple methods for calculating regional trends in order to increase confidence in the results. Temporal trends over the period 1997-2013 in Hg concentration and Hg deposition were negative for 17 sites (-1.8 to 0.3% yr⁻¹) and 12 sites (-2.6 to 1.2% yr⁻¹), respectively, out of total 19 sites, mostly located in the eastern half of the U.S, which is in general agreement with findings from earlier studies. This is in contrast to the period spanning 2008-2013, which includes data from 81 sites, out of which only 24 had negative trends for both Hg concentrations and Hg deposition, while 57 sites had positive trends, and 24 and 21 of those sites had significant ($p < 0.05$) positive trends in concentration and deposition, respectively. Regional analysis revealed that 2008-2013 trends in both Hg concentration and deposition in the Rocky Mountains, Plains, and Upper Midwest regions were significantly positive ($p < 0.05$), while other regions displayed no significant trend and only California displaying a significant negative trend. Sulfate concentration trends in wet deposition were negative in all regions, more in-line with reductions in SO₂ anthropogenic emissions in the U.S. and Canada over the same time period. The trend in total gaseous Hg (TGM) from shorter term data sets taken as one continuous record was broadly consistent with trends in Hg concentration in wet deposition, with the early time period (1998-2007) producing significantly negative trends (-1.5% yr⁻¹) and the recent time period (2008-2013) producing a trend that was not significant (-0.3% yr⁻¹). We hypothesize that such a shift to a predominance of positive or less negative trends in atmospheric Hg could be the result of rising Hg emissions from regions outside the U.S. and Canada, changing atmospheric chemistry conditions due to rising background concentrations of ozone in the Western U.S., and/or changes in the Hg source from the oceans.

[P-60] Dry deposition of O₃ and SO₂ estimated from gradient measurements above a temperate mixed boreal forest

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Author(s): Zhiyong Wu, Ralf Staebler, Robert Vet, and Leiming Zhang, Air Quality Research Division, Science and Technology Branch, Environment Canada

Vertical profiles of O₃ and SO₂ concentrations were monitored at the Borden Forest site, Ontario from April 2008 to May 2013. A modified micrometeorological gradient method (MGM) was applied to estimate O₃ and SO₂ dry deposition fluxes using concentration gradients between a level above and a level below the canopy top. The calculated five-year mean (median) dry deposition velocity (V_d) was 0.35 (0.27) and 0.60 (0.55) cm s⁻¹, respectively, for O₃ and SO₂. V_d(O₃) exhibited large season variations with the highest monthly mean of 0.62 cm s⁻¹ in August and the lowest of 0.10-0.20 cm s⁻¹ in winter months. In contrast, seasonal variations of V_d(SO₂) were small with monthly means ranging from 0.60 to 0.80 cm s⁻¹. The different seasonal variations between O₃ and SO₂ were caused by the enhanced SO₂ uptake by snow surfaces in winter. Diurnal variations showed a peak value of V_d in early morning in summer months for both O₃ and SO₂. Canopy wetness impacted O₃ and SO₂ uptake. Canopy wetness can increase the non-stomatal uptake of O₃ while decreasing the stomatal uptake. This theory also applies to SO₂, but additional factor such as surface acidity may play even more important role on the overall uptake.

[P-40] Isotopic evidence for strong seasonality of dissimilatory sulfur reduction in a catchment of the Thai tropical dry forest

Presenter: Naoyuki Yamashita, Asia Center for Air Pollution Research, nyamashita@acap.asia

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In Southeast Asia an increase in emissions of S into the atmosphere may introduce new risks for the plant, soil and surface water through acidification. However, the effect of the atmospheric S deposition is poorly understood in tropical forests that have possible S sources and processes in the internal S cycle. S isotopic ratio ($\delta^{34}\text{S}$) could be a good indicator to identify the source of sulfate in surface water because only bacterial dissimilatory S reduction results in a large fractionation of S isotope. We assumed that the S reduction process was significant in tropical dry forest due to strong seasonality of the precipitation which may lead to a severe anaerobic/aerobic condition in deeper soil. Our objective is to demonstrate the presence of the S reduction process by measuring $\delta^{34}\text{S}$ in rainfall, soil, soil water and stream water in tropical dry forest catchment in Thailand. As a result, $\delta^{34}\text{S}$ in streamwater was 4-5 ‰ higher than rainfall during late-wet and dry season, whereas $\delta^{34}\text{S}$ in rainfall and streamwater was mostly comparable during early and middle wet season. In late-wet and dry season, $\delta^{34}\text{S}$ in sub-soil water was particularly higher in the riparian zone near the outlet of the study catchment than in the area near the headwater and on the slope. $\delta^{34}\text{S}$ of phosphate extractable sulfate was significantly higher for subsoil in riparian zone than for surface soil on slope. Sulfate enriched ^{34}S might be increased due to bacterial dissimilatory S reduction in late wet season and retained in the subsoil during dry season. Meanwhile, in early and middle wet season, streamwater sulfate could be directly affected by atmospheric S input. This heterogeneity of internal S dynamics should be considered to examine the effect of atmospheric deposition on ecosystems in tropical dry forest.

[P-72] The long-term impact of whole-tree harvest on the acidification recovery process in Swedish forest soils

Presenter: Therese Zetterberg, IVL Swedish Environmental Research Institute, therese.zetterberg@ivl.se

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Forest soils and surface waters are slowly recovering from acidification. However, increased forest biomass harvesting (whole-tree harvesting, WTH) depletes the soil of nutrients and buffer capacity more than conventional harvesting (CH), which may prevent this recovery. Our study focuses on the long-term impact of WTH in a Swedish wood-fuel experiment. Soil solution data showed that ANC and calcium (Ca^{2+}) concentrations were significantly lower (16 respectively 17 $\mu\text{eq l}^{-1}$) in WTH-plots than in CH-plots, 27-30 years after harvesting. pH was also slightly lower (-0.05 units). Hence, WTH caused long-term soil solution acidification. However, the largest treatment effects were found at the bicarbonate buffered northern site and of little ecological significance due to high ANC. At the two more acidic southern sites, the effects were not large enough to counteract the natural recovery. A couple of years later (32-35 years after harvest), the main treatment effects were gone, but still observable at the northern site. Soil samplings between 1990 and 2013 showed a decrease in exchangeable Ca^{2+} pools, independent of treatment. The greatest depletion occurred after CH (2.6-8.6 kmolc ha^{-1}) compared to WTH (0.2-5.0 kmolc ha^{-1}). With time, the Ca^{2+} pools have become more similar between treatments. However, the Ca^{2+} pools still remained lower after WTH. Losses of Ca^{2+} are unlikely to have caused reductions in tree growth due to the nitrogen limited conditions of these sites, and there are no signs of impaired tree vitality. Additionally, the largest losses were observed at the northern well-buffered site, less likely to be affected by soil acidification. At the two acid southern sites, CH and WTH harvest have not made them more acidic according to the Swedish soil acidity classification system. Our results suggest that WTH can be carried out in large parts of Sweden without causing significant acidification of soils and surface waters. Read more at Zetterberg et al. 2013. The effect of harvest intensity on long-term calcium dynamics in soil and soil solution at three coniferous sites in Sweden. For. Ecol. Manag., 302: 280-294.

[P-84] Relative contributions of gaseous oxidized mercury and fine and coarse particle-bound mercury to mercury wet deposition at nine monitoring sites in North America

Presenter: Leiming Zhang, Environment Canada, leiming.zhang@ec.gc.ca

Author(s): Irene Cheng, Environment Canada, Leiming Zhang, Environment Canada, Huiting Mao, State University of New York

Relative contributions to mercury wet deposition by gaseous oxidized mercury (%GOM) and fine and coarse particle-bound mercury (%FPBM and %CPBM) were estimated at nine North American locations. %FPBM and %CPBM were determined from scavenging ratios of particulate inorganic ions (K^+ , Ca^{2+} , Mg^{2+} , Na^+), atmospheric speciated Hg concentrations, and precipitation. A conservative estimation for FPBM and CPBM suggested they contributed 8-36% and 5-27%, respectively, depending on the location, to total wet deposition. The rest 39-87%, likely an upper-end estimation, was attributed to the contribution of GOM. The relative distributions of %GOM, %FPBM and %CPBM were influenced by Hg(II) gas-particle partitioning, urban and coastal site characteristics, and precipitation type. At the regional scale, %GOM dominated over %FPBM and %CPBM. However, the sum of FPBM and CPBM contributed to nearly half of the total Hg wet deposition in urban areas, which was greater than other site categories and is attributed to higher FPBM air concentrations. Higher %FPBM at coastal locations compared to other site categories is likely due to the wet scavenging efficiency of sea-salt aerosols. At four locations, %FPBM exceeded %GOM during winter in contrast to summer, suggesting the efficient snow scavenging of aerosols. The results from this study are useful in improving mercury transport models since most of these models do not estimate CPBM, but frequently use monitored mercury wet deposition data for model evaluation.

POSTER SESSION #3

IN ALPHABETICAL ORDER BY AUTHOR (POSTER LOCATION IS [P- #])

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

[P-83] Contribution of Industrial Sectors to Emission of SO₂ and NO₂ in Nigeria, the Case of Lagos and Ogun States

Presenter: Adebola A. Adeyi, University of Ibadan, Ibadan, Nigeria

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There is rapid growth in anthropogenic emissions of SO_x, NO_x, NH₃, dust particles and other materials. These air pollutants originate from the burning of fossil fuels, industrial and agricultural processes, soil re-suspension, sea spray and other natural processes. Emission data on air pollutants from industrial sectors in Nigeria are limited. This study was conducted to estimate the emission of SO₂ and NO₂ from industrial sectors and some selected industries under the top five most polluting industrial sectors in Lagos and Ogun States, Nigeria using Industrial Pollution Projection System (IPPS) Pollution Intensities with respect to employment and total output. Emission projection for 2020 and 2025 was also calculated and actual emissions of the gases were measured using auto sampler.

In Lagos, SO₂ and NO₂ emission by sectors showed that Food Beverage and Tobacco (FBT) (1,040,000 tons/yr.; 582, 000 tons/yr.) and Chemical and Pharmaceutical (CPH) (995,000 tons/yr.; 601, 000 tons/yr.) sectors were the highest emitter of these gases, respectively while in Ogun state, Non-metallic Mineral Products sector (227,000 tons/yr.; 129, 000 tons/yr.) was the highest emitter, followed by FBT sector (215,000 tons/yr.; 120, 000 tons/yr.). In most cases, SO₂ emission was higher than NO₂ emission. Emission projection showed that emission of these pollutants will increase markedly in the year 2020 and 2025.

In the selected industries, the range of SO₂ measured was 0.01-0.02 ppm while NO₂ was 0.01-0.08 ppm. Actual pollution loads of these gases were compared with the IPPS pollution loads with respect to employment and output using t-test at 95% confidence interval. There was no significant difference between the actual pollution loads and IPPS pollution loads. Thus, there is need to monitor and control emission of these gases into the environment from industrial sources to prevent the deposition of acid rain and its harmful implication on the entire ecosystem.

[P-54] SUSTAINABLE LIVELIHOOD IN INDIAN AGRICULTURE: THE SIMMERING CHALLENGE IN THE FACE OF GLOBAL WARMING AND CLIMATE CHANGE

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Agriculture provides food, shelter, and cloths to the civilization and now it is going to be heinously hit by the simmering impact of global warming and climate change. Across the world every sensitive mind and sensible organizations are really concern what could be done to mitigate and defend and incoming danger and probably the incoming disaster. It has been found that one degree centigrade change in night temperature will invite a reduction in wheat and rice yields to the tune of thirty per cent and twelve per cent respectively. Out of 7800 kilometers of coastal lines of India, thirty per cent may be submerged by the up surging sea levels by 2050 to create a drifting effect of population, occupation, and social balances too. Nevertheless the change of cropping pattern, mutant behavior of crops, erosion of crop bio-diversity, dramatic changes in behaviour of critical growth stages of crops and all have already been distinctively observable here in this part of World. The present paper examines the sustainable livelihood issues in terms of changing wage pattern, food intake value, health status and livelihood security of farming populates in the villagers of West Bengal, India. These all chaotic changes in the erstwhile balances of livelihood generating system is certain to make the issues of global warming more complex. It has been found that even the consequences of livelihood security and food intake value are being impacted conspicuously by factors like cropping intensity and crop spacing. The study further reveals that the variables like holding size and crop spacing have recorded significant regression impacts on the predicted variable like food intake value. The study was conducted in a classically changing village, Goragachha by name, over eighty respondents, mainly small and marginal farmers. Statistical tools like multistage regression analysis and path coefficient have been applied to isolate the discernable factors and also to delineate the interactive reticulate impact of some exogenous variables on the consequent character like sustainable livelihood system. As a method altogether fifteen predictor variables have been selected in this study to assess their interactive impacts of predicted character like livelihood security (Y1), food intake value (Y2), health status (Y3), wage (Y4) and sustainable livelihood (Y5). In a country like India where more than eighty percent populace are eking out their livelihood from a size of holding less than two hectors per capita, the impact of climate change on livelihood security is going to be the worst and most prominent too. So, the modeling of livelihood system as being managed in rural India has so far been the most urgent issue and responsibility to combat the deleterious impact of climate change.

Keywords: Sustainable livelihood, climate change, global warming, livelihood security, food intake value, health status.

[P-76] Recovery/Re-acidification in a previously limed humic stream

Presenter: Cecilia Andrén, Stockholm University, cecilia.andren@aces.su.se

Author(s): Cecilia Andrén, Stockholm University and Paul Andersson, Firma SBV-analys

Long-term studies of acidified and lime-treated waters (before, during and after liming) are scarce. Three sites in a small humic stream (catchment areas 2 to 7 km²) in the middle-east of Sweden were studied to follow the process. The acidic headwater Havssvalgssbäcken is located directly above where the lime-doser was operating. The stream flows down to a small lake (that balanced lime-dose with runoff). There are two sites further downstream in Örvallsbäcken; one 100 m and one situated 2.5 km from the lake. The watershed has been studied since before (1984), during liming (1985-2000) and continuing afterwards by electrofishing, benthos and water sampling. The acidic reference site represents temporal changes 1984-2014 and the two limed sites shows the liming process. As anticipated most significant trends were found for water quality. Organic carbon has increased in the whole watercourse, reflecting changes in the drainage area with decreasing acidification pressure and increasing temperatures. Though in the acidic headwater annual mean pH and calcium has decreased. In the lime-treated sites significant cubic trends were found with highest mean/min pH and mean calcium together with lowest mean total-aluminum during liming in the late 90ies. Since liming was terminated the watercourse is becoming more acidic, though still not as acidic as before. At the acidic site benthos (in contrast to pH) indicates enhanced conditions with improved acidity indices and increasing number of taxas (NoT) of Trichoptera and decreasing NoT of Plecoptera. After the termination of the liming total-, Plecoptera- and EPT-NoT has increased at the two treated sites and the benthos acidity index has improved in one site. The effect on fish of terminating liming was small and uncertain (nevertheless when liming began brown trout returned) but a few more young-of-the-year brown trout has been observed in one previously limed site.

[P-21] Reconstructing centuries of catchment weathering from paleolimnological records of pH and TOC

Presenter: Kevin Bishop, Uppsala University and Swedish University of Agricultural Sciences, kevin.bishop@geo.uu.se

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Weathering rates remain difficult to quantify, especially at the catchment scale in acidification sensitive areas. Here we present a novel method to estimate centuries of catchment weathering from the independent paleolimnological reconstructions of pH and TOC concentrations. We demonstrate this at Lake Lysevatten, (Southwestern Sweden) where a 12 000 year time-series of ANC was created from the pH and TOC records.

Using the assumption of constant runoff during the whole period, the area specific ANC produced by weathering in the catchment (ANC_w) has decreased from around $740 \text{ eq}\cdot\text{ha}^{-1}\cdot\text{yr}^{-1}$ after the glacial retraction, to a present value of around $430 \text{ eq}\cdot\text{ha}^{-1}\cdot\text{yr}^{-1}$. The numbers are in reasonably good agreement with weathering estimates from the PROFILE model for this region of $300 \text{ eq}\cdot\text{ha}^{-1}\cdot\text{yr}^{-1}$.

The total amount of ANC lost from the catchment during the cultural alkalinization was also calculated (865 – 1775 AD). The total amount of ANC lost during this 900 year period was 640 keq/ha . At the peak of alkalinization (around 1535 AD), the annual amount of ANC lost from the catchment was $1770 \text{ eq}\cdot\text{ha}^{-1}\cdot\text{yr}^{-1}$, i.e. an “extra” loss of $1330 \text{ eq}\cdot\text{ha}^{-1}\cdot\text{yr}^{-1}$ compared to the baseline.

[P-19] Relationships Between Long-term Atmospheric Wet Deposition and Stream Chemistry in Mid-Appalachian Forest Catchments

Presenter: Dave DeWalle, Penn State University

Author(s): Dave DeWalle, Penn State University; Elizabeth Boyer, Penn State University; and Anthony Buda, US Department of Agriculture

Improved understanding of the link between atmospheric deposition and surface water quality is critical to assessing the degree to which forested watersheds have recovered from acidification. This presentation draws upon long-term atmospheric wet deposition and stream chemistry data to study how changes in atmospheric chemical inputs have been propagated to stream waters. We used autocorrelation and lagged cross-correlation techniques to analyze monthly time series describing variations of chloride, sulfate and inorganic nitrogen concentrations for pairs of stream/deposition monitoring sites. Autocorrelation analysis revealed that individual atmospheric input time series of sulfate and inorganic nitrogen were strongly seasonal, while chloride inputs exhibited little seasonality. Stream chemistry time series exhibited gradually declining autocorrelation trends with increasing lag times suggesting that atmospheric input signals were variably damped by the forest ecosystems. Lagged cross-correlation between raw atmospheric and stream chemistry time series indicated gradual decreases in correlation within superimposed regular annual cycles of correlation over 10- 15 years of lag time. Pre-whitening of each atmospheric and stream time series using regression or ARIMA models removed the influence of long-term trends, seasonal cycles and other factors and revealed occurrence of relatively few and highly variable lag times with significant correlations. While lagged cross-correlation of raw time series data provided some useful insights into the long-term trend and seasonal nature of the linkages between atmospheric deposition and stream chemistry, cross-correlation of shorter-term residual variations after prewhitening did not produce a consistent pattern of lag times with significant correlations in our monthly time series data.

[P-45] Fluoride in UK precipitation: 2012-2014 and comparison with historic data

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Fluoride was not routinely measured in UK precipitation until after the 2010 Icelandic volcano eruption. From January 2012 fluoride in daily precipitation has been routinely analysed along with a standard suite of inorganic ions and cations at the two European Monitoring and Evaluation Programme (EMEP) UK Supersites. Auchencorth Moss is in southern Scotland and it rains ~50-60% days per year and ~1000 mm per annum, whereas Harwell in south-central England has precipitation 40-50% of the days in a year and ~800 mm rain. The DWOC dataset from 2012-2014 are presented here and discussed in terms of fluoride concentration and deposition. Fluoride deposition over the period 2012-2014 was in the range 3- 7.5 mg.m⁻² and was similar at both sites. The potential sources of the fluoride are discussed and the co-variation with other ions are explored. The fluoride levels are compared with short term measurements made over the spring and summer of 2010 during the Eyjafjallajökull eruption.

[P-36] 25 Years of Atmospheric Monitoring at Whiteface Mountain Observatory

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Long-term records of precursor trace gases and condensed-phase atmospheric constituents have been collected for over two decades at the Whiteface Mountain Observatory in the Adirondack Mountains of northern New York. Built in 1971 by the Atmospheric Sciences Research Center (ASRC) of the University of Albany, the observatory sits atop Whiteface Mountain (44.366°N 73.903°W) at 1483 m above sea level. At this altitude the bulk of the atmospheric constituents arrive from long range transport of regional sources. A second monitoring site is located on the eastern shoulder of Whiteface Mountain at ASRC's Marble Mountain Lodge (44.393° N and 73.859° W) at 604 m elevation that is collocated with a National Atmospheric Deposition Program (NADP) site. Both sites have very recently been added to the Clean Air Status and Trends Network (CASNET); Marble Lodge in 2012 and Whiteface Summit in 2015.

At Whiteface summit daily aerosol sampling began in 1978 including analysis for SO₄. Precursor trace gas measurements became routine in the early 1990's with warm season cloud water chemistry added in 1994. At Marble Lodge precipitation chemistry began in 1984. Trace gas observations were added in 2000 with sulfate and nitrate monitoring beginning in 2004. At the summit the SO₂ trend is very clearly decreasing over the roughly 25-year period of measurements. NO_y and NO₂ have more complicated trends; since the mid-2000's they have shown a sharp decrease. Cloud water pH has followed with a steady increase over the same period. Wind rose analysis shows the greatest contribution of precursor gases are from the west to south sectors. Precursor gases (SO₂ and NO_x) are higher at the lodge in all seasons, and highest in the winter months. These rich and often long running datasets provide a detailed view of the atmospheric chemistry at a remote location in the northeastern U.S.A.

[P-12] The last harvest? Soil acidification limits options for sustainable management of sugar maple (*Acer saccharum*) in Adirondack forests.

Presenter: Jesse Caputo, SUNY College of Environmental Science and Forestry, jcaputo@esf.edu

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Sugar maple (*Acer saccharum* Marshall) is among the most ecologically and economically important species in eastern forests of the US and Canada. Best management practices have been developed to sustain sugar maple (SM) in northern hardwood forests, where competitive interference and deer browsing can inhibit the advance regeneration needed to reestablish after harvest. Several other threats to the sustainability of SM have been identified, most notably the acidification and depletion of base cations from forest soils due to acid rain. Because SM is both highly valuable and vulnerable to acidification, we simulated the dynamics of sugar maple stands under different silvicultural prescriptions on acidified versus well-buffered soils in the western Adirondacks over a 100-yr period. Drawing on field observations of SM growth and recruitment to initialize FVS simulations, prescriptions included diameter-limit harvesting, shelterwood retention with understory cleaning, sugarbush, and an unmanaged reference. We observed a significant interaction between silvicultural prescription and base cation availability that determined the future of sugar maple in managed stands. Below a base saturation of 12%, sugar maple will not be regenerate after harvest, and is replaced by red maple (*Acer rubrum* L.) and American beech (*Fagus grandifolia* Ehrh.), regardless of whether the shelterwood or diameter-limit harvest method is used. On sites with greater base cation surplus, simulations indicate that SM can be sustained for future rotations, most effectively with the BMP-based shelterwood prescription. We quantified the potential economic implications of these acidification impacts on SM, with respect to timber, syrup and foliage, using the Forest Ecosystem Services Toolkit. Overall our results suggest that sugar production may be the only economically viable and sustainable management option for SM stands on culturally acidified soils.

**[P-6] Critical loads of acidity for 90,000 northern Saskatchewan lakes:
A novel approach for mapping acid sensitivity and critical loads**

Presenter: Hazel Cathcart, Trent University, hazelcathcart@trentu.ca

Author(s): Hazel Cathcart, Trent University and J. Aherne, Trent University

Point source emissions of sulphur and nitrogen oxides are the dominant contributors to acidic deposition in Western Canada, particularly in the Athabasca Oil Sands Region (AOSR) in northern Alberta. Northern Saskatchewan is home to nearly 90,000 lakes located downwind of the AOSR in ecosystems known to be sensitive to acidic deposition. The remoteness of this region has historically made high-resolution estimates of critical loads of acidity difficult; until recently, regional surveys of water chemistry have been extremely limited.

This study aimed to estimate exceedances of critical loads to determine the risk of long-term impacts on ecosystem health associated with AOSR emissions. A single-lake, catchment-scale regression-kriging approach was used to determine critical loads of acidity of the total lake population (89,947 lakes). Multiple linear regression models were created for sulphate, base cations, and dissolved organic carbon (DOC) using spatial data layers based on landscape characteristics (such as climate, topography, vegetation, geology, soil and deposition) in addition to observed lake chemistry. Spatial correlation was assessed and modeled for inclusion in the kriged results. The resultant maps were used to calculate and map predicted exceedances of critical loads of acidity under 2006 sulphate deposition levels.

Results show wide-spread exceedance, primarily on the Athabasca Basin. The Basin was predicted to have very low critical loads (5,938 lakes below $5 \text{ meq m}^{-2} \text{ yr}^{-1}$), with a larger region below $10 \text{ meq m}^{-2} \text{ yr}^{-1}$ (23,043 lakes). An estimated 12% to 15% of lakes are in exceedance of their critical loads; this amounts to a total lake area of $3,742 \text{ km}^2$, or 17% of the total lake area in northern Saskatchewan.

This study showcases the first use of regression kriging for regional critical loads calculations, and may be of interest to future assessments of acid sensitivity.

[P-1] Map of geochemical reactivity of rocks in the Czech Republic: Essential tool to define areas susceptible to acidification and nutrient degradation

Presenter: Tomas Chuman, Czech Geological Survey,
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Knowledge of geochemical background is essential for making informed landscape management decisions, as this information determines the areas with higher levels of susceptibility to soil acidification and/or nutrient degradation. The presented map of the geochemical reactivity of rocks in the Czech Republic at a scale of 1:1,000,000 is based on database of regional geological maps and data from the lithochemical database, which currently contains analyses of 15,170 samples, with more than 13,000 silicate rock analyses that were used in this study's classification. Each sample has its coordinates and a lithological description of the rock. Carbonate content and the coefficient of alkalinity were calculated for each sample from the lithochemical database. The coefficient of alkalinity was calculated as follows:

$$CAlk(\text{mol} \cdot \text{kg}^{-1}) = \frac{\text{Na} + \text{K} + \text{Li} + \text{Ca} + \text{Mg} + \text{Ba} + \text{Sr}}{\text{Si} + \text{Ti} + \text{Al} + \text{Fe} + \text{Mn} + \text{Na} + \text{K} + \text{Li} + \text{Ca} + \text{Mg} + \text{Ba} + \text{Sr}}$$

Carbonates were determined based on the content of calcium carbonates, magnesium carbonates or calcium-magnesium carbonates in the rock samples, calculated from the CO₂, CaO, MgO content (mol*kg⁻¹) in the silicate rock analysis. Rocks were classified into eight groups according to carbonate content and coefficient of alkalinity. Rocks in these groups were further subdivided according to the susceptibility to weathering, forming a total of 28 categories. The map shows chemical differences and reflects the chronostratigraphical, lithostratigraphical and lithological differences among rocks within the country. It is clearly identifiable which lithological units are rich in cations and which are cation poor, thereby providing land management practitioners with essential information on the susceptibility of soils and water to acidification and nutrient degradation.

[P-51] The NorthEast Comprehensive Acid Monitoring PRoject (NE-CAMPR) for enhanced monitoring in New York State

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New York has monitored the impacts of acid deposition across the state for decades, and was the first in the nation to establish aggressive, source-receptor based acid deposition control requirements aimed at protecting sensitive ecosystems. Recently, New York converted its original independent deposition network to the NADP/NTN to reduce measurement redundancies and improve access to wet deposition data. By 2013, three sites in the Adirondack Mountains and three in urban/suburban locations were converted to the NTN. A key component in this upgrade was the addition of passive NH₃ (NADP/AMoN) and continuous NO_y measurements at the existing Huntington Forest NADP/CASTNET site. Recently, New York also took over operation of the Moss Lake NTN site, moving the equipment to nearby Nick's Lake. To better characterize the spatio-temporal variability of deposition across this sensitive region, and to complement deposition monitoring at Underhill, VT and other sites in the Northeast, New York installed CASTNET and passive NH₃ samplers at two additional sites – Whiteface Mountain and Nick's Lake. Ambient sulfur and nitrogen concentrations and deposition measurements from the Northeast provide input for NADP's Total Deposition Maps, and valuable data for the review of the secondary ambient air quality standards for oxides of sulfur and nitrogen. Here we present preliminary analysis of the augmented air and deposition measurements from the NorthEast Comprehensive Acid Monitoring PRoject (NE-CAMPR), including comparisons of continuous and integrated SO₂ measurements, and seasonal patterns in wet and dry deposition of sulfur and nitrogen. These enhanced acid deposition monitoring efforts will allow New York to continue to protect sensitive ecoregions and track the effects of emission reduction programs. The Adirondacks are one of several sensitive regions in the northeastern US, and enhanced interaction with scientific stakeholders across the broader region will increase the likelihood that surrounding states will find benefit in these data improvements.

[P-7] Critical loads of a neglected ecosystem: Afromontane tarns in the Drakensberg Mountains of South Africa and Lesotho

Presenter: Chris Curtis, School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand, Johannesburg, South Africa.

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The problem of acid deposition linked to fossil fuel combustion has been recognized as an international problem for over 30 years. In Europe and North America, the critical loads approach has been successfully used for policy development to mitigate the effects of acid deposition on natural ecosystems including heathlands, forests and surface waters. Major reductions in emissions of acidifying sulphur and nitrogen compounds have been achieved allowing chemical and to a lesser degree biological recovery of freshwater ecosystems. In contrast, South Africa is building new coal-fired power stations and emissions are likely to increase in the short term.

In South Africa, very few studies into the ecosystem effects of acid deposition have been published, and have focused mainly on the Highveld industrial regions of relatively high sulphur and nitrogen deposition. However, the potential for ecosystem impacts has been recognized since early studies in mountain catchments in the 1980s. Inland standing waters are scarce in semi-arid South Africa, but the ephemeral and perennial upland tarns of the Drakensberg mountains are numerous and little studied. Their biota are poorly described but include endemic species of branchiopod crustaceans and aquatic macrophytes. We present hydrochemistry data and apply the SSWC model to demonstrate that there are extremely acid-sensitive tarns in the Drakensberg which are vulnerable to the impacts of acid deposition, although deposition is very poorly quantified for the region. Furthermore, critical load models as formulated in Europe do not perform well and will need to be adapted to South African conditions.

[P-64] Spatial boundary of urban 'acid islands' in southern China

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Elevated emissions of sulfur dioxide, nitrogen oxides and ammonia in China have resulted in high levels of sulfur and nitrogen deposition, being contributors to soil acidification, especially in and near large cities. However, knowledge gaps still exist in the way that large cities shape spatial patterns of acid deposition. Here, we assessed the patterns of pH, sulfate, nitrate and ammonium in bulk precipitation and throughfall in southern China's forests by synthesizing data from published literature. Concentrations and fluxes of sulfate, nitrate and ammonium in bulk precipitation and throughfall exhibited a power-law increase with a closer distance to the nearest large cities, and accordingly pH showed a logarithmic decline. Our findings indicate the occurrence of urban 'acid islands' with a critical radius of approximately 70 km in southern China, receiving potential acid loads of more than 2 keq ha⁻¹ yr⁻¹. These urban acid islands covered an area of 0.70 million km², accounting for nearly 30% of the land area in southern China. Despite a significant capacity to neutralize acids in precipitation, our analysis highlights a substantial contribution of ammonium to potential acid load in southern China. Our results suggest a joint control on emissions of multiple acid precursors from urban areas.

[P-68] Monitoring effect of SO₂ emission abatement on recovery of acidified soil water and stream water in southwest China

Presenter: Lei Duan, Tsinghua University, lduan@tsinghua.edu.cn

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Following Europe and North America, East Asia, mainly China, became the global hotspots of acid deposition, with very high deposition of both sulfur (S) and nitrogen (N) occurring in large areas in the southwest and southeast. Great efforts had been taken to fulfill the national goal of 10% reduction in total emission of sulfur dioxide (SO₂) during 2006-2010 in China. However, the total emission of nitrogen oxides (NO_x) in the same period kept increasing. In order to evaluate the effect of SO₂ emission abatement on acid deposition and soil acidification, a long-term monitoring on throughfall, soil water and stream water was carried out from 2001 to 2013 in a small, forested catchment near Chongqing city in Southwestern China. Results (Figure 1) indicated significantly a decreasing trend of S deposition but increasing trend of N deposition in recent years, which coincided well with the decreasing trend of SO₂ emission and increasing trend of NO_x emission in Chongqing respectively. As the net effect, acid deposition had been reduced by the emission control, and the significant acidification of soil water and surface water had leveled off. However, the recovery of soil water and surface water from acidification was delayed, due probably to desorption of previously stored sulfate (SO₄²⁻) and enhanced leaching of nitrate (NO₃⁻) from soil. Since soil acidification is still very serious, shown by quite low pH and high molar ratio of base cations to aluminum (Al³⁺) in soil water, future emission abatement of both SO₂ and NO_x should be strengthened.

[P-35] The Value of Cloud Chemistry from the Summit of Whiteface Mountain, New York

Presenter: James E. Dukett, Adirondack Lakes Survey Corporation,
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Whiteface Mountain is one of the highest peaks in the Adirondacks and also one of the first to intercept pollutant plumes from upwind long distance and regional anthropogenic emissions. Cloud chemistry of primary and secondary formed pollutants represent near real time capture of emissions combustion that are unfiltered by forest canopy, soil processes, and other ecosystem matrixes. The cloud water data collected at the summit has been valuable in understanding the transformation and transport of anthropogenic emissions. In addition, the value of cloud water has also recently been associated mercury, climate change, and dry deposition research interests as well. This poster will highlight historical and more recent cloud collection and monitoring projects. As well as new projects, via shared collaborative interests across multiple entities, to further help our understanding of the effects from emissions on atmospheric processes.

[P-77] Survey of limed streams in Sweden

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The Swedish liming program today includes around 6 000 lakes and 1 500 streams. The large-scale recovery due to emission reductions during the 1990's has led to questioning of the level of the liming program, and a reduction of the liming has started. In 2007-2008 a survey of 3000 limed lakes indicated that liming was not needed in almost half of the lakes.

Since 2010 a survey program of limed streams has been performed. Each year, one sixth of the 1 500 limed streams are sampled. For each limed stream, an unlimed reference stream is also sampled. The higher temporal variation of stream water chemistry compared to lakes is a major challenge. We found that a cost efficient strategy for characterizing stream acidification status was to sample three times on fixed dates and three times during high flow during one year.

The samples were analysed for pH, alkalinity, Ca, Mg, Na, K, SO₄, Cl, NO₃, Al and TOC. The water chemistry expected if the stream had not been limed was calculated by using the ratio of Ca and Mg (Ca/Mg) from non-limed references close to the limed sites. The acidification status was then assessed by a tool (MAGIC-library) according to the Swedish Ecological Quality Criteria using the flow-weighted mean water chemistry.

The results from the first three years supports the on-going reduction in the liming program and gives the county boards a basis for deciding about each individual stream with regards to further liming activities. However, the uncertainties due to the correction of liming effects on chemistry, acidification assessment by the MAGIC-library and the temporal variation has to be taken into consideration.

[P-80] Impacts of lime amendments on leaf decomposition and nutrient uptake dynamics in acid-stressed Adirondack Mountain streams.

Presenter: Randy Fuller, Colgate University, rfuller@colgate.edu

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The Adirondack Mountain region is particularly susceptible to the effects of acid deposition, and a potential mitigation strategy is to add pelletized limestone directly to stream channels or across entire drainage basins to neutralize incoming acid. We studied the impact of lime amendments in 5 streams, 2 chronically acidic and 3 episodically acidic. Lime has been annually applied directly to stream channels of 2 episodically acidic streams, and in 2013, we aerially applied lime to a whole drainage basin of a chronically acidic stream. We compared rates of leaf decomposition and microbial respiration as well as macroinvertebrate community composition in all streams for both summer and autumn in 2012 (dry year) and 2014 (wet year). In 2012 and 2014, leaf decomposition and microbial respiration rates were lower in chronically acidic than episodically acidic streams, and overall, decomposition rates were highest in summer. Macroinvertebrate densities were higher in leaf packs during summer 2012 as water levels decreased and were higher overall in summer than in autumn. Diversity was higher in episodically acid streams in part because of the presence of Ephemeroptera in these streams. Lime applications did not increase leaf decomposition and microbial respiration rates nor has there been any shift in macroinvertebrate community composition, suggesting that while acidity has decreased in lime-amended streams, the biotic community has been slow to respond. Similarly, ammonium and phosphorus uptake dynamics have shown no differences that could be related to levels of acidity despite lower microbial respiration rates in the chronically acid streams. We did observe shorter uptake lengths for phosphorus versus ammonium, but this was related to lower ambient phosphorus concentrations. Our results suggest that ecosystem functional metrics such as leaf decomposition and nutrient uptake are slow to respond to improved chemistry from lime amendments.

[P-41] Applications of Solid Phase Microextraction (SPME) and Gas Chromatography (GC) techniques in rainwater for determination of carboxylic acids

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The purpose of this study was to develop and validate an analytical technique that will make it possible to quantify the concentration of low molecular weight carboxylic acids (C2-C6) in rain water, the method is based on solid-phase microextraction (SPME) combined with gas chromatography (GC) as tracers of environmental pollution. In SPME, sorbent-coated silica fibers are used to extract analytes from aqueous samples. After extraction, the fibers are directly transferred to the injector of a gas chromatograph. Detection limits in the μM (100pmol/ul) range are reached, with relative standard deviation (RSD) less than 10% and linear response ($R^2 > 0.99$) over two orders of magnitude, this was demonstrated for the acetic, propionic, butanoic and hexanoic acids, where this effect enables one to have lower limits and thus quantify trace concentrations. Chromatographic problems associated with the carboxylic acids have been overcome by simultaneous in situ; the SPME of carboxylic acids from the headspace over water has also been investigated. The results demonstrate suitability of the SPME approach to analysis of polar compounds; the conditions were established the time, the temperature and the extraction of the fiber. The application of this technique is vitally useful in environmental studies with a view to determine the percentage contributed by this type of compounds to the formation of acid rain that directly affects the environment.

[P-91] Visualization of Science Supported by NADP Measurements

Presenter: Ray Knighton¹

Author(s):

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A semantic analysis was performed on recent scientific publications that cited the use of NADP measurements. Google Scholar was used to identify works (> 1000 documents identified 2007-2014), which in most cases required mining within full text for references to NADP programs and data, as bibliographic citation is not consistently used for data. Scopus was used as the primary source of the bibliographic metadata used in the analysis of the publications found using Google Scholar (>950 Scopus records). Scopus is a citation database of peer-reviewed literature, and includes extensive metadata (e.g., abstracts, subject terms and author affiliations). The National Institute of Food and Agriculture of USDA has semantically modeled approximately 130,000 projects to create approximately 700 subject matter concepts from the project documents that describe a wide range of scientific disciplines. The words in the title and abstract of over 900 NADP related publications were used to infer/model NIFA subject matter concepts and associated those concepts with the publications to visualize the documents in 2-D space. The scope of science supported by NADP data, publication trends over time, and the relationships of authors and institutions to the bibliography will be discussed.

[P-53] A PERSPECTIVE OF COAL AS PRIME ENERGY SOURCE AND ATMOSPHERIC INTERACTIONS OF POLLUTANTS CAUSING ACID RAIN

Presenter:

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The global energy requirement has grown at a phenomenon rate and the consumption of primary energy sources has been a very high positive growth. This paper focuses on the consumption of different primary energy sources and it identifies that coal will continue to remain as the prime energy in foreseeable future. It examines the energy requirement perspective for India and demand of coal as the prime energy source. Economic development and poverty alleviation depend on securing affordable energy sources and Indian coal mining industry offers a bright future for the country's energy security, It discusses the strategies to be adopted for growth and meeting the coal demand. But such energy are very much concerned with environmental degradation and must be driven by contemporary managerial acumen addressing environmental and social challenges effectively This paper highlights the emissions of acid forming gases due to burning of fossil fuels and gas- liquid interactions in the atmosphere causing acid rain. It focuses on the area at risk in India exposed to acid rain and predicted increase in area in future. It discusses sources of acid forming gases and formation of dry and wet deposits. Their effects on human health, soil, crops, vegetation and amenities, and control measures of acid rain are discussed.

Keywords: Exponential, consumption, oil equivalent, utility, power, greenhouse

[P-52] Nitrogen and Acidification Effects on Forest Carbon Balance

Presenter: Christine L. Goodale, Cornell University, clg33@cornell.edu

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Chronic deposition of nitrogen and sulfur may affect forest carbon balance in several ways, through effects on plant growth, decomposition, and loss of dissolved organic carbon (DOC), with some synergistic and some contradictory responses. The effects of N as a nutrient and as an acidifying agent are rarely separated. In 2011, we initiated treatments for an N x S-addition experiment in three primary (never-cleared, mean tree biomass = 161 t C/ha) and 3 secondary (90 years post-agriculture, mean tree biomass = 104 t C/ha) forest stands in central New York State. Each stand contains four plots, including a control, two plots receiving 50 kg N ha⁻¹ yr⁻¹ as either NaNO₃ to raise soil pH or (NH₄)₂SO₄ to lower it, or elemental sulfur to acidify at the same S application rate (57 kg S ha⁻¹ yr⁻¹) as the (NH₄)₂SO₄ treatment. After three years of treatment, water-extractable solutions from surface mineral soils had a lower mean pH in the (NH₄)₂SO₄ and sulfur plots (4.4) than in the control (4.7) or NaNO₃ plots (4.9) (P = 0.001). Treatment effects on mean extract DOC properties correlated with effects on pH, with lower mean DOC concentration and aromaticity (SUVA) in the acidifying treatments. Foliar litterfall after three years of treatment averaged 1.8 t C ha⁻¹ yr⁻¹ and did not vary by stand age (P = 0.09) or treatment (P = 0.40). Wood growth over four years of treatment averaged 2.2 t C ha⁻¹ yr⁻¹ and did not vary by stand age (P = 0.96) or treatment (P = 0.12), but trended toward a slight increase in response to NaNO₃ in the primary forests and to (NH₄)₂SO₄ in the secondary stands. Litter decomposition rates did not vary by treatment during the first two years of decomposition but showed suppression in year 3 in all three types of amendment.

[P-65] PRINCIPLES AND IMPLEMENTATION OF QUALITY ASSURANCE/QUALITY CONTROL ACTIVITIES OF INTERNATIONAL ACID DEPOSITION NETWORK IN EAST ASIA (EANET)

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Author(s): Ken Yamashita, Keiichi Sato, and Hiroyuki Sase, Asia Center for Air Pollution Research (ACAP), Niigata, Japan

Activity on Quality Assurance/Quality Control (QA/QC) of EANET monitoring had been organized from the start of network activities in 1998. The main principles were adopted from the well-operational networks of other regions such as EMEP, NDAP as well as in line with WMO recommendations, and the respective QA/QC programs were developed before EANET had started its regular phase in January 2001 (EANET, 2000). It consists from two main parts: quality assurance on sampling and analytical procedures in labs performed by countries, and whole network intercomparison projects on analytical performance of labs organized by Network Center (ACAP, Japan). The common principles of in-country's QA/QC procedures are presented in the set of Technical Manuals on monitoring measurements separately for the different environmental media, namely, air concentration (initially, atmospheric dry deposition), wet deposition (precipitation chemistry), inland aquatic (surface waters), and on soil and vegetation. Generally the related standard operation procedures (SOPs) have been developed by national respective QA/QC managers based on documents above.

The intercomparison projects on laboratory analysis of uniformly prepared samples by all participating laboratories in countries of network were established at the preparatory phase of EANET in 1999. They are performed annually and cover analytical instrumental measurements of chemical compounds in precipitation, inland aquatic and soil samples. The several constituents of air pollution are also included into comparison studies several years ago. The review of overall project results is presented in the views of progress in quality of analysis of whole network and problems need to be addressed. The brief additional overview is also provided with the results of some EANET laboratories participated in regular WMO Laboratory Intercomparison Studies.

Reference:

EANET, 2000. Quality Assurance/Quality Control (QA/QC) programs (<http://www.eanet.asia/product/>)

[P-29] Effects of elevated N deposition observed after two decades of monthly N-addition to a spruce forest at Klosterhede, Denmark

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Author(s): Per Gundersen, University of Copenhagen

The study of long-term effects of elevated N deposition onto forest ecosystems requires long-term experiments. I have maintained a N-addition experiment in a Norway spruce plantation at Klosterhede, Denmark since 1992. Elevated N deposition (35 kgN/ha/yr) was simulated by spraying NH_4NO_3 in monthly doses to a 500 m² plot surrounded by three control plots. Over the year 1992 a ¹⁵N tracer was added as well both to the N-addition plot and a control plot to study the long-term fate of a one-year cohort of N deposition/addition.

In the first decade, the effects of the N-addition on plant and soil parameters were minimal except for a decline in moss cover and some N enrichment of plant compartments. In the second decade, trees started to grow less (c. 25% less) possibly due to impaired nutrition (lower levels of needle contents of P, Ca and K compared to the controls) and effects on the mycorrhizal community. The C/N ratio of the LF layer decreased from 30 to 27 and added N was still (yr 23) largely retained in the ecosystem although the retention efficiency is slowly decreasing. Despite the retention of +700 kgN/ha/yr and a decrease in later-stage decomposition, repeated soil sampling could not reveal any increase in soil C stocks. The fate of the ¹⁵N tracer differentiate fast and slow N pools and show that added N mainly and increasingly over time ends up in soil organic matter.

In the presentation I will compare the results from the Klosterhede N-addition experiment with similar data obtained from local and Europe wide gradients in N deposition.

[P-2] Trends in soil percolate chemistry from two contrasting soils in response to declining S and N deposition at the Turkey Lakes Watershed

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Author(s): Paul Hazlett, Natural Resources Canada, Canadian Forest Service

The impact of declining inputs of atmospheric acids on soil chemical leaching was examined for two forested plots with contrasting soil chemical properties located in close proximity to each other at the Turkey Lakes Watershed in central Ontario, Canada. The watershed study is located on the Precambrian Shield in uneven-aged tolerant hardwood forest with 90% of the basal area as mature to over-mature sugar maple. Podzols (Spodosols) with mor organic horizons have developed in thin glacial till deposits over predominantly metamorphic silicate bedrock. Year to year variation in SO_4^{2-} , NO_3^- , Ca^{2+} , K^+ , Mg^+ , Na^+ , H^+ and Al^{3+} concentrations in forest floor and mineral soil percolate collected with zero-tension lysimeters were assessed for monotonic trends between 1984 and 2014.

Reductions in S and N emissions in eastern North America have resulted in declines in precipitation SO_4^{2-} and NO_3^- concentrations at Turkey Lake. Negative trends were detected in monthly forest floor percolate SO_4^{2-} and base cation concentrations during the 30-year measurement period on both plots, in contrast to NO_3^- which showed no trend. The plot with a relatively lower B horizon base saturation and extractable Fe and Al also showed decreasing trends in SO_4^{2-} and base cation concentrations in mineral soil percolate. The plot with higher base saturation and extractable Fe and Al in the B horizon did not exhibit these decreasing trends. N and S mineralization in these soils is strongly influenced by soil temperature and moisture content and air temperatures at the site have increased at a rate of 0.75°C per decade. In addition to decreased deposition, interactions between soil microbial processes and mineral soil S adsorption/desorption are controlling soil percolate chemistry at the site.

[P-74] Recovery of Arctic charr (*Salvelinus alpinus*) and their effect on the zooplankton community in a formerly acidified mountain lake in Southern Norway

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We assessed water quality, zooplankton and fish in Lake Rondvatn, an acidified high mountain lake in Southern Norway. Originally the lake was inhabited by a dense population of Arctic charr (*Salvelinus alpinus*), and a very small population of brown trout (*Salmo trutta*). In the 1960's their numbers started to decline, and they became extinct during the next decade. This was confirmed by test fishing in both 1986 and 1996. The lake is low in Ca (0.4 mg L^{-1}) and was highly acidified already in the 1970's. Monthly water chemistry monitoring started in 1980, showing a mean annual pH of 5.3. The pH stayed generally below 5.5 until 1995. Since the mid 1990's, SO_4 has decreased from about 2.0 mg L^{-1} to 0.5 mg L^{-1} at present, followed by a pH increase to about 6.0. In 1998, Arctic charr was re-introduced, and test fishing in 2004, 2008 and 2012 revealed a dense population of Arctic charr. Yearly analysis of the zooplankton community since 1997 have showed low diversity and density. The copepod *Cyclops abyssorum* have been the most abundant species. However, they increased slightly until 2003, but their numbers gradually decreased towards 2014 to a level below that in 1997. This was followed by increased densities of the cladoceran *Bosmina longispina*, which was rarely found before 2008. We consider that Lake Rondvatn has been fully recovered with regard to water chemistry and fish. Brown trout is still missing, however, they have always been very low in numbers due to marginal spawning streams. Further, we hypothesized that the changes in the zooplankton community was initially a direct effect of improved water quality. Later it followed by a cascading effect caused by increased predation on *Cyclops abyssorum* by Arctic charr, and reduced competition between the two most common zooplankton species.

[P-75] The relationship between water quality, crustaceans and fish in acidified and limed lakes in a Norwegian watershed

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Author(s): Bjørn Walseng and Trygve Hesthagen, Norwegian Institute for Nature Research.

We studied water chemistry, crustaceans and fish in 60 lakes > 1.0 ha in an acidified watershed in south-eastern Norway. Twenty six of these lakes have either been limed or affected by liming. The mean value \pm S.D. of pH in non-limed and limed lakes was 5.13 ± 0.55 (n=34) and 6.14 ± 0.64 (n=26), respectively. Most lakes were humic with $\text{TOC} = 10.59 \pm 5.73 \text{ mg L}^{-1}$, and low in nutrients with Ca of $1.63 \pm 1.39 \text{ mg L}^{-1}$ and tot-P of $5.47 \pm 5.02 \text{ mg L}^{-1}$. Altogether 87 species of crustaceans were recorded; 58 cladocerans and 29 copepods. Among crustaceans, *Acroporus harpae* and *Polyphemus pediculus* occurred in both limed and non-limed lakes. In non-limed lakes, *E. gracilis*, *B. longispina* and *Ceriodaphnia quadrangula* were the dominant species. *Bythotrephes longimanus* survived in the most acidified lakes. Three cyclopoids, *Cyclops scutifer*, *Mesocyclops leuckarti* and *Thermocyclops oithonoides* coexisted in 17 lakes, all favoured by liming. *Limnospira frontosa* and *Leptodora kindti* probably re-appeared after liming. Based on test-fishing with multi-mesh gill nets, we recorded 11 fish species. Perch (*Perca fluviatilis*) was the dominant species, being present in 46 lakes. Perch was lost in seven of the most acidified lakes. Northern pike (*Esox lucius*) and roach (*Rutilus rutilus*) were the sub-dominant fish species, with corresponding figures of total and lost stocks in 19 vs. 4 and 10 vs. 12 lakes, respectively. Other fish species were low in numbers. A DCA-ordination grouped the lakes on the basis of their crustaceans and fish species according to water quality, including pH, all the basic cations, the strong acid anions, inorganic Al and TOC. Perch occurred in different types of lakes, reflecting their high tolerance for acidified waters. In contrast, roach is more acid-sensitive, which was also reflected in the analysis.

[P-23] Recovery of acidified Bohemian lakes between 1984 and 2015 and prediction until 2050: The role of acid deposition and bark beetle induced forest disturbance

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Assessment of temporal trends, rates of change and modelling of future trends in hydrochemical parameters and forest cover has been conducted to elucidate key drivers of surface water acidification in five glacial lakes in the Czech Republic. Since 1984, the key driver in acidification reversal was sulphate concentration which fell in line with reductions in sulphur deposition. Reduction of nitrogen deposition was followed by proportional reduction in nitrate leaching although decline in NO₃ concentrations was more pronounced at two sites, the Čertovo Lake and Prášílské Lake until 2006. Coherent decline of chloride concentration was detected across all sites. The decrease of strong mineral acids was partly compensated by decrease of inorganic aluminium, especially at sites most acidified in the beginning of observations where sensitivity of pH to further reductions in acid anions may be expected. Concurrently, charge of weak organic acids (OAs) increased and partly balanced the strong mineral acid decrease as a consequence of (i) significant DOC increase and (ii) deprotonation of OAs caused by pH rise. Since 2000s, bark beetle induced forest decline accelerated NO₃ leaching at most of the catchments (by 200 % at three lakes). However, elevated N leaching was effectively neutralized by base cations (K, Mg, Ca) originating from decaying fresh litter, thus acidification recovery was not reversed, but slowed down. After cessation of NO₃ leaching we hypothesise that collapsed tree canopy across catchments (from 12 to 87 % compared to 1984) will cause lower total acid input in precipitation (S and N) and regrowth of vegetation may stimulate higher N immobilization (in biomass and soil); processes which could lead to further increase of ANC and pH, key indicators for biological recovery. MAGIC model was used to estimate future lake chemistry until 2050. Results suggest further slow recovery for most of the lakes.

[P-39] CASTNET 'Small Footprint' Filter Pack Only Sites

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The Clean Air Status and Trends Network (CASTNET) currently features 94 sites across the contiguous United States and Alaska. In recent years, CASTNET has taken the approach of expanding by adding new sites that are considered 'small footprint'. These sites do not have traditional CASTNET shelters but instead use small, tower-mounted equipment boxes. Small footprint sites only include a filter pack system for measuring ambient concentrations and an ambient temperature measurement for use in converting concentrations to local conditions. The equipment box, which houses the mass flow controller, pump, cellular modem, and data logger, is mounted at approximate chest height. The 10-meter tilt-down tower used is standard at traditional CASTNET sites. The first small footprint sites were installed in 2012 in the northeast, with two sites in the Adirondack Park in New York and one site in northern Vermont. Two additional small footprint sites were added in 2014. One site was installed in northeastern Kansas in February 2014 as part of the Kickapoo Tribe's air monitoring program, and the second site began operations in late summer 2014 at the Red Lake Nation of Minnesota. An alternative energy, 'off-grid' design for small footprint sites was developed and tested at the Amec Foster Wheeler field test site in Gainesville, Florida. This design uses a wind turbine and solar panel for generating electricity, which is stored in two 12 volt AGM (absorbent glass mat) deep cycle batteries, which are used to power the site. The first 'off-grid' site was installed in November 2014 at the Coweeta Hydrologic Laboratory in North Carolina as part of a transect study designed to characterize concentrations in an Appalachian valley. A second site will be deployed in late 2015. The 'off-grid' design makes it possible to do filter pack sampling in remote locations where electrical grid access is not possible or would be cost prohibitive.

[P-42] Cloudwater Monitoring Results at Clingmans Dome, TN 2000-2011

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Deposition of pollutants by cloud water exceeds deposition by precipitation and dry deposition in high elevation settings from North Carolina to Maine. To further examine the occult deposition affecting the Appalachians, the Mountain Acid Deposition Program (MADPRO) began in 1993 as part of EPA's Clean Air Status and Trends Network (CASTNET) and operated through September 2011. As a part of MADPRO, cloud water samples were collected beginning in 1997 at Clingmans Dome, TN (CLD303) in the Great Smoky Mountains National Park during the warm season and analyzed for their pollutant constituents. Cloud water analyte concentrations, cloud liquid water content, and various meteorological measurements were then used for estimation of cloud deposition of these pollutants. Weekly ambient pollutant concentrations, dry deposition estimates, and wet deposition data were obtained from the nearest CASTNET and NADP/NTN sites, and total deposition was estimated as the sum of cloud, wet and dry deposition fluxes.

Three-year mean concentrations of sulfate, nitrate and hydrogen for 2009-2011 were lower than concentrations measured in 1995-1997 by approximately 42, 62 and 60 percent, respectively. Likewise, seasonal deposition estimates for sulfate, nitrate and hydrogen from 2009-2011 were lower by approximately 77, 74, and 92 percent, respectively, from 1999-2001 estimates. Cloud water sulfur deposition accounted for 71 to 89 percent of the total (dry, wet, and cloud) sulfur deposition from 2000-2011. Cloud water nitrogen deposition contributed about 69 to 90 percent to the total nitrogen deposition for the same time period.

Back trajectories run using HYSPLIT and aggregated over the 2000-2011 period shows that days with H+ concentrations above the 90th percentile most often originated from eastern Kentucky, eastern Tennessee, or central Georgia. Concentrations below the 10th percentile most often originated from the Atlantic Ocean, Gulf of Mexico, or on a northward trajectory through central Ohio into southern Ontario. Additional trajectory analysis focusing on sulfate and nitrate high and low concentration days is currently underway.

[P-3] Chemical and mineralogical properties of agricultural loess soils in vitro acidified

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Agricultural loess soils of the Pampas show some evidences of an incipient acidification process, linked with both climatic conditions and N-fertilization. An in vitro study was developed to know how will be the future trends of soils if N-fertilization continues. An equivalent amount of H⁺ to those produced by a constant application of 84 kg N ha⁻¹ year⁻¹, the most frequent N dose applied in these soils, during 1, 10, 30 and 50 years were performed over samples from the topsoil of four Mollisols placed in a climosequence. Mostly H⁺ additions did not modify CEC nor the contents of both amorphous- and crystalline Al-, Mn- and Fe oxides. However, the most acidified treatments of soils placed in the transition zone of the climosequence (Hapludolls) showed decreases in phyllosilicates crystallinity. This effect was not so pronounced in soils placed in both the moist- and the driest extreme of the sequence, due to the abundance of buffer substances. Soils of the driest extreme (Haplustolls) will be the less affected soils by acidification because the presence of high amounts of both free lime- and soil organic matter as well as by the smectitic mineralogy of the soil-size fractions. Soils of the moist extreme of the climosequence (Argiudolls) are the soils with better neutralizing mechanisms, due to the high contents of both soil organic matter and soil-size fractions, though illitic. Hapludolls would be the soils with the highest risk to acidification if N-fertilization continues at similar doses as those was used in this study, because both the quantity- and the quality of the buffer substances prevailing.

[P-4] Chemical and mineralogical properties of N-fertilized loess soils with acidification evidences

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Empiric evidences indicate that N-fertilization linked with no-till decreased pH values of loess soils of the Pampas. On soil samples from the topsoil of four N-fertilized (F) and non-fertilized (NF) paired Mollisols within a climosequence (from ustic to udic moisture regimes) were measured the extent of pH decreases, their effects on some chemical- and mineralogical properties as well as their H⁺ buffering substances. Results indicated that both F- and NF soils showed, although incipient, acidification evidences, being differences between pH_W and pH_{KCl} higher than 1.0. Moreover, N-fertilization produced higher pH decreases, but particularly in soils with udic water regimes, in agreement with both their higher N-doses and the longer N-fertilization periods. F ustic soils showed both less crystallized illite- and kaolinite-like clay minerals as well as higher contents of amorphous Al oxides than the NF pairs. It remain unclear if the higher contents of amorphous Al coming from the denaturalization of phyllosilicates, from the transformation of the abundant volcanic glasses present in these soils or from both. Cation exchange capacity and the percent of base saturation showed no changes between fertilization treatments, probably due to the large influence of soil organic matter (SOM) on exchange properties of the studied soils. If pH decreases due to both N-fertilization and no-till continue, soils placed in both the moistest- (Argiudolls) and the driest extremes of the climosequence (Haplustolls) will be the less affected because their buffer substances. Udic soils content high SOM and illitic clays and silts, which have high capacity to neutralize H⁺ while ustic soils contain free lime and high density charged clay minerals. The most affected soils would be those placed in the transition zone of the climosequence (Hapludolls), which content low amounts of the substances with buffer capacity.

**[P-5] Spatial variations of acid-base properties in Swedish forest soils:
The impact of deposition and biomass growth**

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In this study, we compared the effects of tree growth and acidifying atmospheric deposition on the acidity of forest soils in Sweden. Soil data, from the time period 1993-2002, for the O (n=1990), B (n=1902) and C (n=1477) horizons from the Swedish Forest Soil Inventory and sulfur deposition data from the European Monitoring and Evaluation Programme were used. To investigate acidification by tree growth a relative age concept was used, taking into account that trees have different growth rates in different parts of Sweden. We did linear regression analyses of pH-H₂O, total acidity, exchangeable Ca and Al versus relative age and S deposition, respectively. Analyses were done for the whole country as well as for data grouped either in S deposition or temperature sum gradient classes in order to minimize effects of co-variance due to similarity in geographic gradients. Results show that S deposition is significantly correlated to lower pH, higher total acidity, lower Ca and higher Al in all soil horizons. The acidifying effect of S deposition is higher in the topsoil than in the subsoil. Regression lines of pH, total acidity and Ca versus S deposition have steeper slopes for regions in northern Sweden than for regions in the south. Tree growth is significantly correlated to lower pH and higher total acidity in the O horizon and B horizon but not in the C horizon. Regression lines of pH and total acidity versus relative age have fairly similar slope for regions throughout Sweden. Overall, the analyses indicate that the acidity of forest soils in Sweden during the 1990s was influenced more by atmospheric deposition than by tree growth.

[P-69] Sources and mechanisms of acidification of atmospheric precipitation in Baikal region (East Siberia, Russia)

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Elevated acidity ($\text{pH} < 5.0$) has been registered in atmospheric precipitation and snow cover in different areas of the Baikal region for many years. Acidity of atmospheric precipitation increases in the areas away from regional industrial sources.

Acidic precipitation has been more often registered (50-60% cases with $\text{pH} < 5.0$) at the monitoring station Listvyanka ($51^{\circ}9' \text{ N}$; $104^{\circ}7' \text{ E}$; Southern Baikal) operating within the EANET Program since 1998. Elevated acidity of precipitation recorded in the south of Lake Baikal is attributed to the formation of acidic components during transport of impurities from main regional sources located in industrial cities of Irkutsk and Angarsk 70-100 km off the lake. Large coal heating plants of these cities emit over 100,000 tons of SO_2 and approximately 60,000-80,000 tons of NO_x into the atmosphere annually. The ratio of major components emitted into the atmosphere, direct measurements of oxides of sulfur and nitrogen and chemical substances in aerosols, as well as balance estimates (emission/deposition) showed that precipitation acidification in Southern Baikal is caused mainly by the formation of nitric acid. Detailed analysis of chemical composition of snow sampled from the coast and the surface of Lake Baikal performed in 2011-2014 has confirmed this conclusion. Snow collected in the background areas of the Baikal region has low pH values (4.8-5.0) characteristic of the majority of alpine areas that are not affected by regional sources. So far the reasons and scales of elevated acidification of atmospheric precipitation have remained unclear. It is likely associated with both natural processes (deficit of neutralizing alkaline components in pure atmosphere) and long-range transport of sulfur and nitrogen oxides with air masses from large industrial sources.

[P-20] Long-term response of surface water acid neutralizing capacity in a western Maryland (USA) river basin to declining acid deposition

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The response of surface water chemistry to declining regional acid deposition in the predominantly forested Savage River watershed (area = 275 km²), located on the Appalachian Plateau in western Maryland, was examined through trend analysis of data from 20 repeating, synoptic stream surveys conducted at 40 randomly-selected stations between 1999 and 2014 under spring baseflow conditions. With the exception of one site, recovery in acid neutralizing capacity (ANC) was universal. Six sites exhibited a statistically significant positive trend ($p=0.10$). Due to confounding factors (e.g., road salt application) especially within the less forested watersheds, we have focused our trend analyses on the 24 sites with greater than 75% forest cover. The average overall recovery in ANC among these sites was $2.6 \pm 0.8 \mu\text{eq L}^{-1} \text{yr}^{-1}$, which is comparable to ANC recovery observed at two intensively monitored streams within the same basin. ANC recovery can be mostly attributed to declines in both surface water SO_4^{2-} and NO_3^- concentrations. Nineteen of the 24 stations exhibited a significant decreasing trend in SO_4^{2-} with a mean change of $-2.7 \pm 0.6 \mu\text{eq L}^{-1} \text{yr}^{-1}$, while 19 of the 24 stations demonstrated a significant downward trend in NO_3^- with a mean change of $-1.0 \pm 0.5 \mu\text{eq L}^{-1} \text{yr}^{-1}$. The fewer significant trends in NO_3^- are likely the result of forest disturbance in some of the watersheds from a gypsy moth defoliation outbreak, which has been shown to cause spikes in NO_3^- export. With the exception of Na^+ , base cation (K^+ , Mg^{2+} , and Ca^{2+}) concentrations also decreased, resulting in a small mean decline in the sum of base cations (SBC). Subtracting the average sum of acid anions (SAA) trends from the average SBC trends results in a computed ANC recovery of $2.2 \mu\text{eq L}^{-1} \text{yr}^{-1}$, which is very comparable to the observed recovery trend.

[P-60] Long-term Observations and Climate Change Indicators

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The Earth's climate is changing. Temperatures are rising, snow and rainfall patterns are shifting, and more extreme climate events—like heavy rainstorms and record high temperatures—are already taking place. One important way to track and communicate the causes and effects of climate change is through the use of indicators. An indicator represents the state or trend of certain environmental or societal conditions over a given area and a specified period of time. Indicators are designed to help better understand observed long-term trends related to the causes and effects of climate change.

EPA compiles a set of key indicators related to climate change into a report entitled: *Climate Change Indicators in the United States*. Together, these indicators present compelling evidence that climate change is happening now in the United States and around the world. EPA's indicators are based on observational data from various long-term monitoring networks. EPA partners with over 40 data contributors from various government agencies, academic institutions, and other organizations to compile and summarize these indicators. EPA is continuing to leverage monitoring data, analyses, and expertise to highlight additional indicators and more fully capture the range of impacts and effects associated with climate change.

[P-17] Patterns of base cations and aluminum in three geochemically contrasting catchments

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Three spruce catchments are situated 5-7 km apart in the Slavkov Forest Critical Zone Observatory, Czech Republic. They are underlain by differing silicate bedrocks, base-poor granite (Lysina-LYS), base-rich amphibolite (Na Zelenem-NAZ) and serpentinite (Pluhuv Bor-PLB) with extremely high Mg content and low K and Ca (Kram et al. 2012). Regular monitoring started in 1989 (LYS) or 1991 (PLB) and irregular sampling at NAZ started in 2001. Simultaneous monitoring of fluxes at all three catchments started in 2012. Three years (2012-2014) were evaluated in this contribution. Bulk precipitation, throughfall and soil water samples were collected monthly, stream water weekly (LYS, PLB) or monthly (NAZ). Soil water was collected from five depths (10, 20, 30, 60 and 90 cm). Water analyses included Al species and isotopes (²⁶Mg, ⁴⁴Ca). PLB exhibited very high resistance to acidification due to Mg supplied from chemical weathering. NAZ exhibited high resistance to acidification and well balanced concentration of base cations (BC). However LYS exhibited very low resistance to acidification due to low supply of BC from weathering and elevated concentrations of inorganic monomeric Al in deeper mineral soil (means 74-88 ueq/l), higher than corresponding concentrations of BC (68-80 ueq/l). Geological substrate influenced element fluxes in catchments including canopy throughfall. Internal circulation of nutrient BC in trees was calculated based on the assumption that Na is not involved (Bredemeier 1988). Mg exhibited the largest differences in internal circulation, with low flux at LYS (3 meq/m²/yr), intermediate at NAZ (10 meq/m²/yr), and high at PLB (29 meq/m²/yr). On the contrary, the lowest flux for K was at PLB (15 meq/m²/yr), only 52-54% recorded at LYS or NAZ. The largest Ca internal circulation was recorded as expected at NAZ (13 meq/m²/yr), 30-60% larger than at the other sites. A comparison of results from traditional approaches and isotopic methods is ongoing.

[P-58] Climate warming shifts carbon allocation from stemwood to roots in calcium-depleted spruce forests

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Increased greening of northern forests, measured by the Normalized Difference Vegetation Index (NDVI), has been presented as evidence that a warmer climate has increased both net primary productivity (NPP) and the carbon sink in boreal forests. However, higher production and greener canopies may accompany changes in carbon allocation that favor foliage or fine roots over less decomposable woody biomass. Furthermore, tree core data throughout mid- and northern latitudes have revealed a divergence problem (DP), a weakening in tree ring responses to warming over the past half century that is receiving increasing attention, but remains poorly understood. Often, the same sites exhibit trend inconsistency phenomenon (TIP), namely positive, or no trends in growing season NDVI where negative trends in tree ring indexes are observed. Here we studied growth of two Norway spruce (*Picea abies*) stands in western Russia that exhibited both the DP and TIP but were subject to soil acidification and calcium depletion of differing timing and severity. Our results link the decline in radial growth starting in 1980 to a shift in carbon allocation from wood to roots driven by a combination of two factors:

(a) soil acidification that depleted calcium and impaired root function and (b) earlier onset of the growing season that further taxed the root system. The latter change in phenology appears to act as a trigger at both sites to push trees into nutrient limitation as the demand for Ca increased with the longer growing season, thereby causing the shift in carbon allocation.

[P-81] A Fresh Look at Liming to Remediate Acidic Deposition Effects

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The only management option other than emissions reductions for remedying the effects of acidic deposition has been the application of lime to neutralize acidity after it has been deposited. For this reason, liming has been a part of acid rain science from the beginning. However, the practice of liming to remediate acidic deposition effects has always been controversial. Liming was first used as a stopgap measure to stem further degradation of aquatic ecosystems, but concern was raised that it would be used as a substitute for reducing emissions. More recently, the large reductions in emissions and trends of improving water quality have brought up the question of whether liming is needed. A large variety of liming approaches have been tried, which has led to an extensive literature on the subject. The first half of this presentation will provide an assessment of liming methods and their effectiveness. The second half of the presentation will focus on a specific study where liming is being investigated as a tool to improve ecosystem health by increasing the bio-availability of calcium in a watershed where calcium has been severely depleted by acidic deposition.

In the Adirondack region of New York, lakes are showing improved chemistry and evidence of incipient ecosystem recovery. However, the slow recovery of soils may be hindering regional ecosystem recovery. To determine if liming can accelerate the reversal of acidic deposition effects, high-calcium limestone has been applied to one 30-ha watershed and two streams outside this watershed. Two primary goals of the treatment are to increase soil base saturation in the rooting zone and eliminate toxic forms of aluminum in streams during high-flow episodes. Observations to date include reduced mobilization of aluminum in soil, decreased concentrations of toxic forms of aluminum in streams and increased concentrations of dissolved organic carbon in streams.

[P-47] Long-term Trends in Atmospheric Wet Deposition in the United States, 1976 – 2015

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The Multi-State Atmospheric Power Production Pollution Study (MAP3S) was established in the late 1970s to measure and predict changes in air pollutant concentrations and precipitation chemistry in response to large-scale power production from coal combustion. Samples were collected on an event basis in automated wet-dry collectors, which ensured that only wet deposition samples were collected. The MAP3S precipitation chemistry monitoring network initiated measurements in September 1976 with four stations established in the Northeastern U.S.

The MAP3S network expanded to a total of 9 stations by 1980, and measurements continued through 1990, with a transitional network operated by the Cary Institute for Ecosystem Studies through 1992. In October 1992, the MAP3S network was incorporated into the National Atmospheric Deposition Program (NADP), where it became the Atmospheric Integrated Research Monitoring Network (AIRMoN). The AIRMoN network has operated at a total of 12 locations, with six continuing to operate today. Measurement protocols for AIRMoN are very similar to the original MAP3S network, analyzing all of the same ion species with the exception of sulfite ion (SO_3^-). The original MAP3S sampling protocol was enhanced to ensure daily collection whenever precipitation was detected, with the stipulation that a blank sample was collected on Tuesdays following dry weeks.

The combined MAP3S and AIRMoN data sets represent the longest continuously operated precipitation chemistry network in the United States, and one of the longest operating networks in the world. This presentation evaluates long-term trends in atmospheric wet deposition, and evaluates the temporal periods of greatest change. These periods are linked to promulgation of significant air pollution emissions regulations, including the 1990 Clean Air Act Amendments. Sulfate and nitrate concentrations have decreased dramatically due to these regulations, particularly in the eastern U.S. where the highest emissions sources of SO_2 and NO_x are concentrated.

[P-62] Economic analysis of nitrogen oxides emission control for coal-fired power plants in China

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Coal provides around 65% of the electricity in China, more than any other source. Coal combustion and nitrogen oxides (NO_x) pollution are closely linked, and this relationship is particularly relevant in the largest coal consumer all over the world. The new national emission standards for coal-fired power plants was established in 2011 to limit the levels of NO_x. The economic analysis of NO_x emission control for coal-fired power plants is essential. NO_x control of coal-fired power plant normally includes technology routes about low nitrogen burner (LNB) and selective catalytic reduction (SCR). There will be a best technology investment plan which can distribute LNB and SCR "output". Based on the summary of the development and current situation of the large scale low nitrogen burner and selective catalytic reduction technologies and the air pollutant emission control policy, this paper establish scientific measures and reasonable technology route on "economic concentration" in the NO_x control and provides costs and benefits of NO_x pollution control strategies at coal-fired power plants in China.

[P-85] Recovery from acidification of Bohemian Forest lakes between 1984-2015: Evaluation of projections made with the MAGIC model in the 1990's

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The Bohemian Forest lakes are situated in Central Europe along the Czech-German-Austrian border. There are 5 glacial lakes at elevations between 918 and 1096 m, three of them were used in modeling study. Bedrock is formed from crystalline and metamorphic rocks (mica schist, gneiss, granite, and quartzite), sensitive to atmospheric acidification. All the lakes are acidic, with a depleted carbonate buffering system or low acid neutralizing capacity. Lake chemistry has been regularly monitored since 1984, covering period of highest acidic load (1980's) and followed by strong decline of acidic deposition. In 1999 the dynamic, process-based acidification model MAGIC (Model of Acidification of Groundwater In Catchments) has been used to project acidification of lakes, given implementation of the Gothenburg Protocol to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) in Europe. The model was calibrated for a set of experimental records of the lake water chemistry over the 1984-2000 period. Water and soil chemistry forecasts up to 2050 were based on reductions in S and N emissions presupposed by the Gothenburg Protocol. For two lakes (Cerne a Certovo), predicted surface water recovery from acidification for the year 2015 is very close to the actual recovery observed from measured data, as recovery is predominantly driven by reductions in sulfur deposition. Plesne lake has been strongly affected by catchment's deforestation after bark beetle outbreak in 2006. Thus observed elevated nitrate and associated increase of base cations and declined pH in lake water were not captured in MAGIC forecast, highlighting the importance of unexpected confounding factors for model predictions. But overall these results show that MAGIC successfully predicts future water chemistry given known changes in acid deposition.

[P-55] Climate Change Impacts in the United States: Benefits of Global Action

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A new EPA report, *Climate Change Impacts in the United States: Benefits of Global Action*, quantifies the physical effects and economic damages of climate change under two scenarios: a future with significant global action on climate change and a future in which greenhouse gas emissions (GHG) continue to rise. The report is designed to answer the question: What are the benefits to the U.S. of global climate action? These analyses are the product of the Climate Change Impacts and Risk Analysis (CIRA) project, an EPA-led collaborative modeling effort among a number of analytical teams within the federal government and scientists from a number of academic institutions and consulting firms. The CIRA project is among the first multi-sector studies to quantify the projected benefits (avoided climate change damages) in the U.S. of global-scale greenhouse gas reductions using a consistent set of assumptions. The peer-reviewed report estimates 20 specific impacts categorized into six broad sectors: health, infrastructure, electricity, water resources, agriculture and forestry, and ecosystems. Specific impacts examined include changes in suitable habitat for freshwater fish, forestry production, wildfire, water quality, water supply/demand, and air quality (ozone and fine particulates). While projecting decades into the future involves uncertainty, this report shows a substantial difference between a world with and without global climate action, making a clear case that reducing GHGs will provide substantial benefits to the U.S.

[P-13] Ecotoxicological Dose-Response Relationships from the Aquatic Acidification Literature

Presenter: April Maxwell, Oak Ridge Institute for Science and Education, maxwell.april@epa.gov

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The National Ambient Air Quality Standards (NAAQS) are implemented to protect human health and the environment from harmful effects of criteria air pollutants. This study will support the U.S. Environmental Protection Agency's review of the NAAQS for oxides of nitrogen and sulfur. Nitrogen and sulfur deposition from industrial emissions causes acidification of ecosystems. Deposition changes the chemistry of ecosystems by lowering the pH of soil and surface water, and these chemical alterations affect the biota of ecosystems. The purpose of this study is to evaluate ecotoxicological dose-response relationships by extracting biological responses from the freshwater aquatic acidification literature, including both laboratory and field studies. Survival and abundance are examples of biological response variables potentially influenced by aquatic acidification.

Data were extracted from the references of the 2008 Integrated Science Assessment for oxides of nitrogen and sulfur, the references of Biological Effects of Changes in Surface Water Acid-Base Chemistry (Baker, 1990), and keyword searches in Web of Science ranging from 1990 to 2015. We identified 54 species or groupings, and nearly half were fish. The most commonly studied dose-response relationship among five commonly studied fish species was pH versus survival. Preliminary results suggest dose-response relationships for pH versus survival for brook trout, Atlantic salmon, and rainbow trout.

This research was supported in part by an appointment to the Research Participation Program for the U.S. EPA, Office of Research and Development, administered by the Oak Ridge Institute for Science and Education through an interagency agreement between the U.S. Department of Energy and EPA. The study was reviewed by the National Center for Environmental Assessment, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the view and policies of the EPA, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

[P-24] The effects of reductions in acid deposition on stream and soil chemistry in the Catskill Mountains of New York

Presenter: Michael McHale, U.S. Geological Survey, mmchale@usgs.gov

Author(s): Michael McHale, Douglas Burns, and Jason Siemion, U.S. Geological Survey

The Catskill Mountain region of southeastern New York includes many streams that have been acidified by decades of acid deposition. The U.S. Geological Survey has monitored stream and soil chemistry in 4 headwater catchments (2 km² to 23 km²) and at the outlet of the Neversink River watershed (172.5 km²) since 1991. Soils in the Neversink watershed are sensitive to acid deposition because bedrock is composed of sandstone and conglomerate interbedded with siltstone and shale that provide little buffering capacity. The EPA's Acid Rain Program has documented significant decreases in USA emissions of SO₂ from 15 to 3 million tons and NO_x from 6.2 to 1.6 million tons from 1991 to 2014. Concomitant decreases in sulfate and nitrate wet deposition occurred during the same period at the National Atmospheric Deposition Program monitoring station in the Neversink River watershed (43.8 to 12.6 ueq/L sulfate; 25.7 to 13.5 ueq/L nitrate). Seasonal Kendall trend tests detected significant decreases in stream water sulfate concentrations at all 5 Catskill streams (an average of 2.5 ueq/L/yr), however there were no significant trends in nitrate concentrations. The biological control on nitrogen has a stronger influence on stream water concentrations than for sulfate because nitrogen is an essential macronutrient. Sulfur emissions have continued to decrease during the past 5 years, although the rate of decrease has diminished markedly. During that same 5 year period sulfate and nitrate wet deposition and stream water concentrations have not decreased. From 2001 to 2011 organic soil horizons showed signs of recovery as evidenced by an increase in base saturation, exchangeable calcium, and soil pH and a decrease in exchangeable aluminum. There were no indications of recovery in the mineral soil.

[P-73] Geochemical mass balance and risk assessment of heavy metals in El-Tebbin Catchment, Egypt

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The geochemical mass balance in in El-Tabbin region (Great Cairo, Egypt) is defined by elemental input and output fluxes of some toxic heavy metals such as As, Cd, Pb and Zn. The input-output mass balance, normalized to mass fluxes per unit area of the catchment per year, is the net difference between the input fluxes from weathering, dry atmospheric fallout (particulates), irrigation water, fertilization and output fluxes from biomass uptake and drain water. Geochemical mass balance of the studied toxic heavy metals indicates that the highest accumulation is due to Zn, Pb and Cd, respectively, while the depletion appears only for As.

Based on environmental risk assessment for potentially toxic elements in soils and sediments in more than 45% of total area disturbed environment (IER = 1–3) was documented and more than 13% of territory was characterized with highly disturbed environment (IER>3).

**[P-56] Long-term surface-water carbon trends beyond monitoring:
Progress in reconstructing past lake-water carbon levels from sediment
archives using infrared spectroscopy**

Presenter: Carsten Meyer-Jacob, Umeå University, Sweden, carsten.meyer-jacob@umu.se

Author(s): Carsten Meyer-Jacob, Julie Tolu, and Richard Bindler, Umeå University, Sweden

Increasing organic carbon concentrations have been observed in surface waters across parts of Europe and North America, but the interacting drivers causing this phenomenon are still debated. The lack of monitoring data beyond the last few decades inhibits disentangling the competing roles of proposed drivers such as climate change, land use or acidification and thus a reliable prediction of future trends in surface-water carbon levels.

Here, we present recent progress in modeling past lake-water total organic carbon (TOC) concentrations over decades to millennia from sediment records by using visible/near-infrared (VNIR) spectroscopy – a technique particularly sensitive to changes in organic matter (OM) composition. Qualitative and quantitative changes in lake-water OM ultimately leave their fingerprint in the lake's sediment and are consequently recorded in the sediment's VNIR spectrum. Rosén (2005) and Cunningham et al. (2011) originally developed a transfer function between VNIR spectra of surface sediments, the most recently accumulated material, and corresponding TOC concentrations in the water column to infer past lake-water TOC levels. We continue to develop this PLS regression model, which now includes 145 nemoral, boreal, and subarctic lakes across Sweden and a TOC gradient from 0.7-22 mg L⁻¹. Furthermore, initial results suggest that existing models for Sweden and Canada (also samples from Finland and Greenland) may be unified into one model for northern lakes.

We have also used pyrolysis-gas chromatography/mass spectrometry to better understand the biogeochemical information within the VNIR spectra. Pyrolysis-GC/MS provides molecular-level chemical information about OM composition. Thus far, we can identify 110 pyrolytic organic compounds in the TOC calibration samples including n-alkanes/alkenes, 2-ketones, carboxylic acids, carbohydrates, proteins, other N-compounds, (methoxy)phenols, (poly)aromatics, chlorophyll and steroids/hopanoids. Our aim is to identify the specific OM components that allow the transfer function for lake-water TOC.

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[P-25] Solution to acid rain pollution and the onset of eutrophication: A geochemical modelling explanation

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Today it's a well known environmental success story in regards to combating the acid rain pollution problem during 1970's-1980's in Scandinavia (Skjelkvåg et al., 2001; Odén, 1976; Brown and Sadler, 1981). Especially in southern Norway acid rain caused increased leaching of Al from forested soil, resulting in fish deaths due to toxic concentrations of labile Al in the aquatic environment (Gensemer and Playle, 1999; Rosseland et al., 2001). The initiative for gradual enforcement of regulations set to reduce SO₂ emissions in European countries (UNECE, 1979), has resulted in as much as a 70% reduction in anthropogenic SO₂⁻ deposition in southern Norway from 1986 - 2009. As a result, over the same period there has been a 3 times reduction in labile Al in lakes around southern Norway (Skjelkvåg et al., 2010). During approximately the same time period, Lake Vansjø located in south-eastern Norway, showed an increasing trend in the concentrations of total P resulting in eutrophication. Abatement actions directed towards reducing P runoff from agricultural area in the vicinity proved incapable of resolving the problem (Solheim, 2001). Though there are many possible explanations for the lack in improvement, one hypothesis is that the reduction in labile Al has resulted in more bioavailable P, a theory fundamentally supported by wastewater treatment and remedies for eutrophic lakes (Hsu, 1968; Auvray et al., 2006). In this study geochemical modelling with the software PHREEQC was used to simulate mixing of stream waters from a 100% forested (high conc. Al) and a 100% agricultural (high conc. P) catchment, located in close proximity to the lake, for present time and assumed 1986 conditions. Water chemistry for present time was attained via chemical analysis. 1986 water chemistry was adapted from present water chemistry, but in which Al and SO₂⁻ is 3 times higher for the forested catchment. Since it's difficult to assess the water chemistry in 1986 for an agricultural site, due to farming practices, i.e. liming and fertilizing, the water chemistry was left unchanged, except for SO₂⁻, which was increased 3 times. Based on equilibrium constants taken from the Minteq database and Ferguson and King (1977), it was found that given the right mix ratio, 9:1 - 5.7:1, for forest and agricultural water respectively during 1986, precipitation would occur as the generic formula Al_{1.4}PO₄(OH)_{1.2}. Based on present water chemistry no precipitation would occur for any mix ratio.

[P-26] Dynamic Modeling and Target Loads of Sulfur and Nitrogen for Surface Waters in Finland, Norway, Sweden and the United Kingdom

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During the last three decades, dynamic models (DMs) have been widely used to simulate the effects of the atmospheric deposition of sulfur and nitrogen on soils and surface waters. Model applications range from detailed studies at single sites to national-scale assessments of the impacts of multiple deposition scenarios. To facilitate the use of DMs in integrated assessment models (such as the GAINS model) – used in negotiating emission reductions under the Conventions on Long-range Transboundary Air Pollution and the European Union – the concept of a target load (TL) was developed. The TL concept adds the dimension of time to steady-state critical load models. A TL for a specified year (the ‘target year’) is the deposition, implemented in a specified (earlier) year, that does not violate a ‘critical chemical value’ for a receptor ecosystem, defined to protect a selected biological indicator, e.g., a fish species.

Here we applied the Model of Acidification of Groundwaters in Catchments (MAGIC) to 848 lake catchments in Finland (163), Norway (131), Sweden (234) and the United Kingdom (320) to simulate historical and future chemistry. Further, TLs in 2050 were computed for catchments where the critical limit of the chosen chemical criterion (ANC) was not achieved in 2050 under current deposition. The challenge in TL calculations lies in the fact that the DM has to be run in ‘inverse’ mode to determine the deposition needed to obtain a prescribed chemical value. Target loads were estimated for approximately 20% of the lake catchments to meet the critical ANC limit (average = 17 $\mu\text{eq L}^{-1}$) by 2050, the other 80% of the lakes being non-exceeded by 2050 under current emission reduction plans. The average maximum TL for sulfur (25.7 $\text{meq m}^{-2} \text{a}^{-1}$) was ~40% lower than the maximum critical load for sulfur (40.2 $\text{meq m}^{-2} \text{a}^{-1}$). Reducing emissions based on TL calculations instead of CL would lead to an average increase in ANC of 13.8 $\mu\text{eq L}^{-1}$ by 2050.

[P-34] Emission of Nitrogen compounds for Domestic Sewage Treatment Station Ponds (STS)

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Some aspects have been discussed as a contribution to the emission of greenhouse gases and acid rain by the Sewage Treatment Stations (STS). Among the most studied gases are CO_2 and CH_4 , we can not ignore the issue the emission of nitrogen compounds, which the most significant to ammonia (NH_3) and nitrous oxide (N_2O), both chemically reactive large interference in biogeochemical cycles. This study evaluated the emission of NH_3 and N_2O in sewage treatment ponds type Australian city of Lins ($22^\circ 21' \text{S}$, $49^\circ 50' \text{W}$) Sao Paulo State, Brazil. The NH_3 and N_2O were collected with the aid of an acrylic camera with float and movement of gases installed in the central part, in the final third of the facultative pond. The pH and temperature of the effluent were recorded by a probe fixed inside the camera. By means of Teflon tubing was connected to a gas collecting system for N_2O and Trapps system containing boric acid solution for retaining NH_3 . The collections of NH_3 were carried out throughout the day on three days in November 2014 and the collection of N_2O was carried out for 72 hours in June 2014. In the two days of NH_3 collections there was no change in climatic conditions predominating sun and few clouds on the third day prevailed clouds and light rain showers. In the first two days there was an increase in the emission of NH_3 between 10 and 14h, with higher emission 12h (223.63 mg/m².h). On the third day of collecting the issue was constant with an average of 50.14 mg/m².h, showing influence of the effluent temperature and solar radiation in the emission of NH_3 . The emission of N_2O was almost constant in the 72 hours with a mean of 2.49 mg/m².h, value close to the atmosphere, showing that facultative pond N_2O does not contribute to formation of acid rain.

[P-57] Tracking the impact of climate change and other pressures on UK surface waters recovering from acidification

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In the UK, as in many countries, acid deposition is decreasing but water temperatures are rising and rainfall patterns changing. Disentangling the relative roles of acid deposition and climate change in driving changes in water quality and freshwater biodiversity in the UK is hence now a priority for research. In this poster we describe the use of the Upland Waters Monitoring Network (UWMN), originally designed to track acidification recovery, to identify how climate change might affect upland freshwater ecosystems in the UK. Issues include changes to the thermal regime of lakes and streams, changes in biodiversity and geographical range of taxa, changes in the acidity of surface waters mediated by changes in precipitation and changes in pollutant fluxes related to the accelerated re-mobilisation of legacy pollutants from catchment soils.

[P-15] Ongoing acidification recovery and sensitivity in New Hampshire Class I and II Wildernesses

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Impacts of historic acid rain inputs and recovery post Clean Air Act (CAA) Acid Rain Program (ARP) emission reductions vary across landscapes due to differences in deposition rates, watershed features, and hydrology. One directive of the US Forest Service's 10-year Wilderness Stewardship Challenge was to monitor wilderness "air quality values", which includes water quality, to establish a baseline for those wilderness areas with limited information. The goal of this study was to provide the White Mountain National Forest with quantitative water quality information in four NH Class II Wilderness areas where limited monitoring had been done previously. Additionally, two NH Class I Wilderness streams were also sampled as continuation of a long-term summertime monitoring program allowing for an analysis of changes in base cations, acid anions, and acidity post 1995 CAA emission reductions.

Approximately every two weeks measurements of major anion and cation chemistry as well as pH were made in stream water grab samples from the Great Gulf and Presidential Range-Dry River upper elevation Class I Wilderness areas during the summer from 1995-1997 and from 2001-2014. Additional Class I and II stream sites at their lower Wilderness elevation boundary were sampled from 2012-2014 two to four times a year during the ice free period. The lower elevation watershed Wilderness boundary sample sites (240-550 m) ANC median values ranged from 18 to 114 across the WMNF. For the most recent sample year, 2014, three of the eight Class II stream sites had median ANC values <25 and all but three were <50 $\mu\text{eq/L}$, indicating continued sensitivity to acidification. The higher watershed elevation sites in Class I Wildernesses (1310-1406 m) had ANC values often <25 $\mu\text{eq/L}$. However, examination of the long-term base cation and acid anion concentrations at these sites indicate a continued trend towards recovery post CAA ARP reductions.

**[P-8] The Application of Critical Loads in Germany:
Now that the Sulfur problem is almost solved, the remaining great
challenge is posed by Nitrogen**

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The critical load approach has been used in Germany since the early 1990 to evaluate natural ecosystem risk via exposure to sulfur and nitrogen deposition. The Critical Loads approach computes thresholds for pollution and compares it with estimates of current deposition load. This has been done for approximately one third of Germany's territory. The share of ecosystems with no exceedance of the critical load acts as an indicator for the success of air pollution abatement measures. The measures taken to reduce acidifying effects due to sulfur seem to be effective: the share of ecosystems with critical load exceedance was reduced from 85% in 1990 to 5% in 2011. While the trend of 'no exceedance' looks promising, also the share of ecosystems showing a high exceedance (1000 eq ha⁻¹ yr⁻¹ and more) decreased significantly. In 1990 and 1995, about 60 % of Germany's ecosystems fell in to the category of 'high exceedance.' The most recent modeling year shows less than 1% in this category. A look at the effects of Nitrogen abatement measures shows a positive trend as well, but also reveals the challenges still ahead. While the share of highly polluted areas (more than 10 kg ha⁻¹ yr⁻¹) was reduced from 90 % in 1990 to less than 5 % in 2011, about half of the area is still at risk to suffer from eutrophication and acidification by Nitrogen. Notwithstanding that, the trend showing an increasing share of protected ecosystem is visible. In 1990, only 1 % of Germany's ecosystems showed 'no exceedance,' by 2007 the share had grown to 22.5 % and reached 55% in 2011. Still, a gap remains between the current status and Germany's environmental quality targets. A significant number of ecosystems remain at risk; the need for further emission reduction, especially of Nitrogen, is evident.

[P-28] Modeling the reactive ion dynamics in the rhizosphere of tree roots growing in acid soils: Upscaling of model results to field plot scale

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The effects of acid soil conditions on mineral nutrition and growth of forest trees are discussed controversially. It is hypothesized that approaches are needed which give an assessment of the risk of aluminum toxicity and the actual root nutrient acquisition rates as affected by the root-induced processes in the rhizosphere. A multi-ion rhizosphere model (MIM) has been developed which calculates the ion (Mi) concentrations in the inner rhizosphere (Rh; 2mm-around-the-root-volume), the Rh-to-Bulk concentration ratios (VMi-Rh), the actual rates of root nutrient uptake (UMi) and H/OH excretion (EH/EOH). The model is implemented for non-mycorrhizal long roots (Nietfeld and Prenzel, 2015; Ecological Modelling 307, 48-65) and mycorrhizal roots including emanating hyphae (in prep.). The model results have been corroborated by experimental data and rhizospheric field measurements. In a Monte-Carlo upscaling-procedure MIM-calculations present the heterogeneity of ionic Rh-concentrations and UMi-values of spruce trees growing on a long-term monitoring plot in Solling (F1-plot), Germany. The VMi-Rh-data comprise a range of about 0.5 up to 3.5 and agree with corresponding ratios of rhizospheric ion concentrations measured in 1991 (Nietfeld et al., submitted). The objective of this study is to present the modeled VMi-Rh values based on F1-bulk-soil ion-concentrations measured several decades ago and in the recent past. The high F1-concentrations in the 1980's and SO_4 as major anion produce high VAl-Rh-values exceeding the concentration threshold of toxicity which are caused by rhizospheric water flux, $\text{Al}(\text{OH})_3(\text{s})$ -dissolution and high EH-rates. In the recent past the reduced F1-ion-concentrations and the high availability of NO_3 result in extremely low UMi- and VAl-Rh-values due to high EOH-rates and rhizospheric $\text{Al}(\text{OH})_3(\text{s})$ -precipitation. It is concluded that the proceeding reduction of base cation (Mb) concentrations and a prospective NO_3 -saturation will lead to extreme low Mb/ NO_3 root uptake ratios and is supported by an increase of fine root biomass.

[P-16] Al, REEs, P, and DOC linkages in changing pH environments

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Four lines of evidence indicate mechanistic linkages between DOC, pH, and concentrations of dissolved and particulate Al, rare earth elements (REEs), and P:

(1) Paleolimnologic studies of post-glacial lake sediment from Sargent Mountain Pond, Maine (SMP), USA indicate that mobilization of Al from weathering of silicate minerals and REEs and P from apatite ($\text{Ca}_5(\text{PO}_4)_3(\text{OH})$) was enhanced by DOC ligands related to forestation. Secondary $\text{Al}(\text{OH})_3$, developing in soils, adsorbed REEs and P. Photo-oxidation of in-lake Al- and REE-DOC complexes in SMP caused precipitation of $\text{Al}(\text{OH})_3$, and adsorption of leached REEs and P in the water column to the $\text{Al}(\text{OH})_3$. Modern water chemistry is consistent with this mechanism.

(2) Batch weathering experiments with fresh granite bedrock from SMP released Al, P, and REEs rapidly but then Al was precipitated as $\text{Al}(\text{OH})_3$ that adsorbed P and REEs, as pH rose due to Ca release during “weathering”.

(3) Acid-leaching batch experiments, with periodic replenishments of the acid, on B- and C-horizon podzolic soils from Bear Brook Watershed in Maine (BBWM), showed rapid release of Al, REEs, and P. Release rates declined over 90% in 168 hours. REEs were released preferentially, relative to Al, early in the experiment, and the ratios among REEs changed systematically, suggesting fractionation during dissolution. C-horizon soils released higher concentrations of REEs during acidification but there was no detectable release of additional Ca, because of Ca:P and Ca:REEs molar ratios >100.

(4) High frequency water samples from the BBWM streams show declining REE concentrations with higher pH, but higher REE concentrations with higher DOC (typically at lower pH). DOC is more strongly correlated with REE concentrations than pH.

Recovery from acidic deposition will be complex, with concentrations of REEs impacted by changing DOC, altered Al mobility, and increased soil retention of the REEs as soil pH increases.

[P-10] Air Quality Portal for Land Management Planning: The application and use of critical loads for management and policy decisions

Presenter: Claire O'Dea, USDA Forest Service, cbodea@fs.fed.us

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National Forests and Grasslands are negatively impacted by the atmospheric deposition of sulfur and nitrogen. Acidification impacts include decreased soil nutrient availability, decreased growth/increased mortality of certain tree species, and decreased presence of fish species and macroinvertebrates. Nitrogen saturation impacts include eutrophication, algal blooms, and species community shifts/biodiversity loss. The term “critical load” describes the quantitative estimate of exposure to one or more pollutants below which these harmful effects are not expected to occur. The USDA Forest Service is using critical loads to assess the extent and severity of these potential impacts across our nation’s forests and grasslands, and to inform the land management planning and decision-making processes that serve to protect these lands.

The USFS developed the Air Quality Portal for Land Management Planning to serve as a decision support system for the implementation of critical loads into land management. Deposition estimates from the NADP Total Deposition Science Committee are compared with the NADP Critical Loads of Atmospheric Deposition Science Committee’s critical loads of acidity for surface waters and forested ecosystems, and empirical critical loads of nitrogen for lichens, mycorrhizal fungi, herbaceous plants and shrubs, forests, and nitrate leaching to determine where these critical loads are being exceeded, and therefore where anticipated associated ecosystem effects to national forests and grasslands are possible.

The USFS Air Quality Portal provides these critical load exceedance calculations, and outlines a process to assess the extent and severity of these exceedances. Monitoring and management recommendations are also provided, outlining actions that can be taken in an area concerned with critical load exceedances. The website also includes background information on atmospheric deposition and critical loads of air pollution, national maps, a glossary, sample land management plan components and assessments, and training materials.

The Air Quality Portal for Land Management Planning can be found here: <http://www.srs.fs.usda.gov/airqualityportal/index.php>

[P-71] Wind dependence of sea-salt and non-sea-salt components in precipitation and aerosol during winter seasons in Niigata Plain, Japan

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In a coastal area of the Sea of Japan, it has been reported that the concentrations of Na^+ and non-sea-salt SO_4^{2-} (nss- SO_4^{2-}) in precipitation tend to increase during winter. Northwesterly winter winds off the Asian continent bring sea-salt aerosols emitted from the Sea of Japan as well as long-range transported air pollutants to this area. The seasonally high concentrations of Na^+ and nss- SO_4^{2-} in precipitation would be attributed to scavenged sea-salt aerosols and particulate nss- SO_4^{2-} . However, not only the transport mechanism of the sea-salt and non-sea-salt aerosols and also the processes of precipitation scavenging of these aerosols are poorly understood.

In order to obtain information about the transport and the precipitation scavenging of sea-salt and non-sea-salt aerosols in a coastal area of the Sea of Japan during winter, a study was carried out on the wind dependence of sea-salt and non-sea-salt components of precipitation and aerosols in the Niigata Plain, located along the Sea of Japan, during winter seasons. Field sampling of precipitation and ambient aerosols was conducted at three sites in the Niigata Plain. At each site, a wet-only sampler was installed for the collection of precipitation samples. Aerosol samples were collected on a 47 mm Teflon filter by using a ten-line low-volume sampler. These samples were collected every 6 hours between December and March during the winters of 2008 - 2011. Samples of the precipitation and the filter extract were analyzed for the species: NH_4^+ , Na^+ , K^+ , Mg^{2+} , Ca^{2+} , Cl^- , NO_3^- and SO_4^{2-} . The electrical conductivity and pH of the precipitation samples were also determined.

In this presentation, the wind dependence will be discussed with respect to (a) the differences in the wind dependence between sea-salt and non-sea-salt components, and (b) the relationship between the wind dependence and the distance from the sea.

[P-70] Characterization of Multi-isotopic signatures of PM_{2.5} from Republic of Korea

Presenter: Yu-Mi Park, Chemicals Research Division, Environmental Health Research Department, National Institute of Environmental Research

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The origin of atmospheric particulate in the atmosphere has long been subject to debate and isotopic tools have been used to decipher the origin of particulate Matter (PM), which could help to design better management policies for its reduction. Recently, PM_{2.5} levels in China increased sharply due to rapid economic development of coal-based industries. Past studies have demonstrated that aerosol and other pollutants can be transported from China to other countries.

This study conducted at an urban site of Incheon and Seoul, and a background site of Baengnyeong Island to provide insights into the origin of PM_{2.5} in the area and to help define lead, sulfate and nitrate sources. The isotopic compositions of lead, strontium, sulfur in aerosol sulfate and nitrogen in aerosol nitrate were analyzed from May 2013 to December 2014. Back-trajectory analysis and Positive Factor Analysis (PMF) model using those isotopic data were also carried out to track its source contributions. The isotopic results of PM_{2.5} in Baengnyeong Island showed that PM_{2.5} originated from south-east part of Korean peninsula has higher value of 206Pb/207Pb than 1.177 and has a negative $\delta^{34}\text{S-nssSO}_4$ in some cases. The lead isotopic distribution of PM_{2.5} sampled in Incheon showed similar patterns of particles emitted from non-ferrous metal smelters in the country. $\delta^{15}\text{N-NO}_3$ and $\delta^{18}\text{O-NO}_3$ were 4.6‰ and 71.5‰ for Seoul PM_{2.5} (May-July, 2015), 0.4‰ and 77.7‰ for Baengnyeong PM_{2.5} (May-July 2015), and 6.2‰ and 75.8‰ for Baengnyeong PM_{2.5} (December 2014-January 2015). The highest value of $\delta^{15}\text{N-NO}_3$ in Baengnyeong PM_{2.5} was 11.8‰, which is similar to those of emission gas from the coal-fired power plant.

**[P-84] Nitrogen Wet Deposition and free acidity from Venezuela:
Assessing changes related to anthropogenic sources**

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Nitrogen is a key element in ecosystem functioning. Increment of fossil fuel combustion, soil inorganic fertilization and biomass burning in the past century have led to an increase of N trace gases and aerosols to the atmosphere. The changes produced in Nitrogen Wet Deposition (NWD) affect plant composition and distribution, soil physicochemical properties (pH, cation exchange capacity among others) and biodiversity. In order to assess the impact of Venezuela urbanization and industrialization growth on NWD and on the free acidity of rain, we measured the ionic composition of rain from a coastal urban (Catia La Mar) and suburban (Osma) cities and from a remote oceanic site in Venezuela (Margarita Island). We found that NWD and the relative contribution of inorganic acids to free acidity decreased in the following order Catia La Mar>Osma> Margarita Island. Remote continental and oceanic areas did not show statistically significant differences on NWD and acidity (derived mostly from organic acids) which suggests that industrialization in Venezuela has not been large enough to impact air quality on a regional scale. We show comparative analyses of relative increase of NWD and free acidity derived from inorganic acid related from urbanization. We also compare the temporal NWD shifts using the present study and previous published data (20 years ago) from other Venezuelan ecosystems.

[P-46] Operating a Long-Term Trends Monitoring Network

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The Clean Air Status and Trends Network (CASTNET) was established under the Clean Air Act Amendments to assess trends in ambient sulfur and nitrogen pollutants. CASTNET was uniquely designed to report estimates of dry deposition, one of the only national dry deposition networks in the world. CASTNET is managed by the Environmental Protection Agency, the National Park Service, and the Bureau of Land Management – Wyoming State Office. There are currently more than 90 monitoring sites throughout the contiguous US, Alaska, and Canada.

Assessing long-term trends using an ambient monitoring network requires consistent methods and thorough documentation to identify any unintentional step functions that might be introduced due to method improvements, changes in instrumentation, or variations in supplies and materials. CASTNET has measured gaseous SO₂, HNO₃, and particulate SO₄²⁻, NO₃⁻, NH₄⁺, base cations, and Cl⁻ using a 3-stage filterpack for more than 25 years. The network is operated following the SOPs and guidance written into the CASTNET Quality Assurance Project Plan (QAPP), which is updated annually or as needed.

To maintain financial and political support from stakeholders for a long-term network, operating partners must continue to adapt to changing agency goals and objectives while maintaining consistent methods. CASTNET has adapted to agency goals by installing regulatory O₃ monitors, adding tribal monitoring sites, decommissioning meteorological measurements at nearly half the monitoring sites and adding measurements used to reduce uncertainties in the nitrogen budget.

[P-33] Wet deposition, particulate, and gas-phase sulfur and nitrogen measurements in New York State: Long-term trends

Presenter: Oliver Rattigan, New York State Dept. of Environmental Conservation, Air Resource Div., 625 Broadway, 2nd Floor, Albany, NY 12233

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Over the past decades the New York State Department of Environmental Conservation (NYSDEC) has monitored air quality and wet deposition at urban and rural areas across the state. Such long-term measurements are critical in evaluating the impacts of federal, regional, and state pollution control measures. The NYSDEC wet deposition network complements the NADP program in the state by capturing the effects of local sources and roadways, providing deposition data across a wider range of landscapes. Here we present trends in sulfur and nitrogen species in ambient air and precipitation at urban and rural locations across New York. Consistent with emissions trends and national monitoring program data such as the NADP and CASTNet, huge decreases (50% or more) in ambient air (gas and particulate) and wet deposition sulfur and nitrogen species have been observed over the past decades.

[P-44] Protocol Changes to Address Low Level Contamination of Passive Sampler Bodies in NADP's Ammonia Monitoring Network

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Travel blanks are used for quality assurance (QA) purposes in the National Atmospheric Deposition Program's Ammonia Monitoring Network (NADP/AMoN). They provide an indication of potential contamination from handling, shipping and storage of the AMoN passive samplers. Since 2009, both the median ammonia concentration for the travel blanks and its standard deviation have increased. Efforts to identify and address the source of the contamination, though initially promising, did not resolve the problem. In 2008, packaging for the AMoN sampler bodies changed from a polypropylene jar to glass jar. The polypropylene jars were found to emit ammonia when exposed to elevated temperatures, such as those experienced during shipment in summer months. In early 2015, changes were made to the protocol for preparing the passive ammonia samplers in the laboratory. Those changes resulted in a decrease in both median ammonia concentration for travel blanks, and its standard deviation. Efforts to address the AMoN travel blank problem are described, and a timeline is presented for each item that resulted in a protocol change.

[P-78] Interaction between carbonate and ammonium in aqueous buffered solutions: Implications for the bidirectional exchange of ammonia

Presenter: Wayne Robarge, NC State University, wayne_robarge@ncsu.edu

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Improved mechanistic understanding of bi-directional exchange is needed to more accurately predict deposition of NH_3 to vegetation. Additional parameters, besides pH and temperature, have been demonstrated to enhance emissions of NH_3 from aqueous systems, specifically the presence of bicarbonate (HCO_3^-). In this study, time integrated measurements of ammonia emissions were made under controlled conditions (stirred glass reaction chamber, constant headspace air flow, depth of solution, pH (phosphate buffer), temperature, and ammonium ($\text{NH}_4\text{-N}$) concentration) in the absence and presence of HCO_3^- using annular denuder technology. Mass of NH_3 emitted from ammonium sulfate solutions increased with increasing air-flow (3-9 LPM), pH (5.5 – 8.0), temperature (10-30°C), and $\text{NH}_4\text{-N}$ concentration (5 - 100 mg N/L). In the presence of HCO_3^- (pH 7.5), the mass of NH_3 emitted increased from 20 – 50% as the concentration of $\text{NH}_4\text{-N}$ in solution increased (5 - 100 mg N/L). Enhancement in NH_3 emissions was not linear and plateaued at 100 mM HCO_3^- in solution. Application of a vapor-liquid equilibrium model suggests that the gas-liquid exchange rate of CO_2 may be limiting enhancement of NH_3 emissions at higher HCO_3^- concentrations. This suggests that the absolute magnitude of the enhancement of NH_3 emissions (and subsequent calculated mass transfer coefficients) in the presence of HCO_3^- is controlled to a large degree by the experimental apparatus. This work further documents the impact of CO_2 on NH_3 emissions and the potential impact of the partial pressure of CO_2 on the bi-directional exchange of NH_3 in terrestrial and aquatic systems. Delineating the mechanism by which the CO_2 - HCO_3^- equilibria impacts NH_3 emissions is important to properly describe the fate and transport of NH_3 in the environment.

[P-49] Atmospheric Sulfur and Nitrogen Concentrations along an Elevation Gradient in the Southern Appalachian Mountains

Presenter: John Walker, USEPA, walker.johnt@epa.gov

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Beginning in late 2014, EPA/ORD's National Risk Management Research Laboratory (NRMRL), with support from EPA/OAR's Clean Air Markets Division (CAMD) and the US Forest Service, began a transect study at the Forest Service Coweeta Hydrologic Laboratory in southwest North Carolina. Long-term atmospheric monitoring at Coweeta includes the National Atmospheric Deposition Program/National Trends Network beginning in 1978, Clean Air Status and Trends Network (CASTNET) beginning in 1987, and the NADP Atmospheric Ammonia Monitoring Network (AMoN) since 2011. Building on these efforts, the Southern Appalachian Nitrogen Deposition Study (SANDS) was initiated by EPA in 2014 to examine nitrogen and sulfur deposition processes in more detail using a combination of direct canopy-scale micrometeorological flux measurements and additional atmospheric concentration measurements targeting organic nitrogen compounds. This transect study examines differences in atmospheric sulfur and nitrogen concentrations along an elevation gradient to assess spatial variability within the Coweeta basin. Passive SO₂, HNO₃, and NH₃ samplers are deployed at five sites along a 4.5 km transect, increasing in elevation ≈ 750 m, to the southwest from the flux tower, which is near the NADP/NTN and AMoN (NC25) and CASTNET (COW137) monitoring locations. At the middle site, Screwdriver Knob, an off-grid, small footprint CASTNET filter pack was installed (designated COW005). Preliminary results from the five passive sites and the two CASTNET filter pack sites will be available by late summer 2015. In this presentation we examine spatial and temporal variability in air concentrations and discuss implications for the spatial representativeness of dry deposition fluxes measured at the eddy flux tower and long-term CASTNET site COW137.

[P-40] CASTNET's Continuous Ozone and NO_y Measurements

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The Clean Air Status and Trends Network (CASTNET) is a long-term monitoring network supported by the Environmental Protection Agency (EPA), the National Park Service (NPS), and the Bureau of Land Management (BLM) Wyoming State Office. The network was developed to assess regional trends in sulfur and nitrogen pollutant concentrations and deposition as a result of emission reduction programs under Title IV. Most CASTNET sites also measure ambient ozone concentrations to assess compliance with the National Ambient Air Quality Standard (NAAQS) and evaluate trends in air quality as a result of NO_x emission reduction programs. There are currently 94 CASTNET monitoring sites located in rural locations, including National Parks and Class I Areas, 80 of which feature ozone measurements.

CASTNET ozone sites are compliant with 40CFR Parts 50, 53 and 58 requirements and the EPA guidance outlined in the QA Handbook and are submitted to EPA's Air Quality System (AQS).

Preliminary analysis of the 2012 through 2014 data set shows that approximately three CASTNET sites have ozone design values greater than or equal to 75 ppb. An additional 15 sites have ozone design values greater than or equal to 70 ppb and less than 75 ppb.

Since 2012, CASTNET has established a network of continuous trace-level gas analyzers to develop a data set of NO_y measurements as well as measure ozone precursors. This network stretches from the east coast to the mountain west and features six EPA CASTNET sites. In addition, NPS, a primary sponsor of CASTNET, conducts NO_y measurements at two of their CASTNET sites. NO_y is defined as NO_x [nitrogen oxide + nitrogen dioxide] plus NO_z [nitric acid, nitrous acid, PAN, other organic nitrates, and nitrite]. Typical concentrations at the eight CASTNET sites measuring NO_y range from an annual average for 2014 of 1.0 part per billion (ppb) at Huntington Wildlife Forest, NY to 7.0 ppb at Beltsville, MD. Comparisons of NO_y with total nitrate measured by the CASTNET filter pack show consistent site-specific ratios over time. CASTNET NO_y data are used as part of the NCore program and provide information to atmospheric modelers, policy makers, and scientists studying environmental impacts.

[P-50] Enhanced Reactive Nitrogen Measurements Using Chemiluminescence

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The Clean Air Status and Trends Network (CASTNET) has a more than 25-year record of atmospheric nitrogen measurements at rural/remote locations in the United States. The routine nitrogen measurements made at CASTNET sites are HNO_3 , NO_3^- , and NH_4^+ . Most CASTNET sites are located at or near an NADP/NTN site, which provides measurements of NO_3^- and NH_4^+ in wet deposition. In 2007, CASTNET began participating in NADP/AMoN, which was established as a nationwide network of passive NH_3 samplers. Recent efforts have been made to expand measurements to enable a more complete assessment of contributors to the total nitrogen budget. Beginning in late 2014, an experimental total reactive nitrogen sampling system was developed using a commercially available reactive oxidized nitrogen system and deployed to analyze the components of the reactive nitrogen sample. The total reactive nitrogen system, deployed at the Beltsville, MD (BEL116/MD99) CASTNET site, consists of four converter boxes: a TNx stainless steel converter, two traditional molybdenum (moly) converters (one at 10m for NO_y and a second at the analyzer for NO_x), and an LED-based photolytic NO_x converter. Calculated parameters include NH_x , NO_2 from the moly converter, and NO_2 (true) from the photolytic converter. A solenoid sampling system diverts flow through the various converter boxes to allow for the detection of these species using a single analyzer. This approach reduces the expenses of inter-unit calibration and problematic biases or analytical drifts. Data comparisons have been made between the total reactive nitrogen sampler, CASTNET filter pack measurements, AMoN, and the MARGA, which have all been operating at the Beltsville site. Results show that the total reactive nitrogen sampler underreports NH_x as compared with the MARGA or CASTNET filter pack plus AMoN measurements. Additional research is being conducted to quantify the conversion efficiency of NH_3 by the NO_y moly converter. Other analysis shows that the NO_x moly converter is converting NO_z species making the moly-based calculated NO_2 concentrations higher than the NO_2 concentration calculated using the photolytic converter.

[P-32] NH₃ Conversion by Molybdenum NO_y Converters

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Beginning in 2012, Amec Foster Wheeler began installing Teledyne API NO_y analyzers as part of an initiative to create a sub-network within CASTNET of continuous trace-level gas analyzers. Goals for this network included support for the NCore program, measuring ozone precursors, and developing a data set of NO_y measurements for use in assessing potential evaluation tools for a future NO_x/SO_x secondary standard. This network stretches from the east coast to the mountain west and features six EPA CASTNET sites. During 2014, EPA directed Amec Foster Wheeler to develop and deploy and enhanced NO_y system to the Beltsville, MD CASTNET site. The enhanced system would utilize a single Teledyne API chemiluminescence NO_y analyzer with a variety of converters to measure total nitrogen, NO_y, NO_x, and NO permitting calculation of NH_x and NO₂. Part of the initial testing and ongoing routine QC checks involved challenging the system with NH₃ calibration gas. During this testing, results showed that the NO_y molybdenum converter also was converting a portion of the NH₃ gas, leading to an over reporting of NO_y and underreporting of NH_x, since that calculation is based on the difference between total reactive nitrogen and NO_y. The NO_x molybdenum used by the system did not show a similar response to the NH₃ calibration gas. Amec Foster Wheeler has conducted further testing of seven NO_y molybdenum converters with results ranging from 10% to 45% NH₃ conversion efficiency at 315 degrees C. Most were found to have efficiencies of at least 25% at 315 degrees C and conversion increased dramatically with increasing temperature. Solutions are currently being developed and discussed including the possibility of using a different molybdenum converter for NO_y, scaling the measurements, and/or installing a denuder at the NO_y inlet to remove NH₃.

[P-66] Ozone Reduces Grain Quality of Japonica Rice, even if It Does Not Cause Yield Reduction

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Tropospheric ozone concentration is expected to rise significantly throughout the 21st century. Ozone threat for food production is increasing in Asian countries. It is becoming clear that ozone affects not only grain yield, but also grain quality in rice, such as the increased protein and the decreased starch concentrations. However, biochemical mechanism responsible for an ozone-induced change in components or appearance quality is poorly understood. In this study, we conducted the analyses of appearance quality and starch composition in rice cultivars 'Koshihikari' (japonica) and 'Kasalath' (indica) under elevated ozone condition.

Ozone did not reduce the grain yield significantly in both Koshihikari and Kasalath. In contrast, the immature grains (mainly chalky) were increased significantly in Koshihikari grown under the elevated ozone, but not in Kasalath. SEM image of transverse sections of rice grains showed that the endosperm starch granules of Koshihikari ripened under elevated ozone were loosely packed with large spaces, and contained irregular round shaped granules. Furthermore, amylose content in the Koshihikari grains grown under the elevated ozone was higher than that in Koshihikari grains grown under the ambient air. The distribution analysis of amylopectin chain-length showed a decrease of long side chains of degree of polymerization (DP) more than 30, and alterations of short side chains of DP less than 20 in the grains of elevated ozone-treated Koshihikari. These alteration patterns of amylose and amylopectin are similar to those in starch synthase IIIa (SSIIIa)-deficient rice mutants (Fujita et al., 2009). Therefore, the increase of chalky grains in Koshihikari was suggested to involve in the decreased function of starch synthase by elevated ozone.

Reference:Fujita et al. (2009) Plant Physiol., 144, 2009-2023

[P-43] Demonstrating the Effectiveness of Utility SO₂ and NO_x Emissions Reductions Using an Integrated Clean Air Act Regulatory and Monitoring Strategy

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The U.S. Environmental Protection Agency's (EPA) implementation of Clean Air Act regulations such as the Acid Rain Program, Clean Air Interstate Rule (CAIR) and, more recently, the Cross-State Air Pollution Rule (CSAPR) has significantly reduced emissions of sulfur dioxide (SO₂) and nitrogen oxides (NO_x) from utility sources. These regulations require power plant stack-level continuous emissions monitors to provide SO₂ and NO_x hourly emissions data. Trend data and monitoring network tools (discussed here) help assess the effectiveness of these programs.

Using a novel integrated regulatory and monitoring strategy provides the ability to assess policy implementation and track environmental results. This poster describes the key elements of this assessment strategy, and provides valued results of Clean Air Act regulations regionally and nationally on emissions, atmospheric concentrations and deposition of pollutants, as well as the response of lakes and streams to changes in pollution levels.

Highlights include analysis of emissions data reported by facilities which EPA uses to track utility SO₂ and NO_x emissions changes; the Clean Air Status and Trends Network (CASTNET) which monitors nationally ambient sulfur and nitrogen concentrations and estimates dry sulfur and nitrogen deposition; the National Atmospheric Deposition Program (NADP)/National Trends Network (NTN) which complements CASTNET, monitoring sulfur and nitrogen in precipitation long-term across the U.S.; and the Long Term Monitoring (LTM) network which monitors lake and stream water chemistry in impacted areas in the eastern United States. Summary data, including national and regional trends from these networks featured here are available in progress reports on EPA's website <http://www.epa.gov/airmarkets/progress/progress-reports.html>.

[P-22] Twenty-five year trends in acid rain components in a well-buffered catchment

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Acid deposition is typically studied in landscapes with low buffering capacity, where the response of stream chemistry is relatively rapid and direct. As a contrast, we studied how a well-buffered catchment responded to the decreasing acid deposition inputs over the past 25 years. The Sleepers River Research Watershed in northeastern Vermont was established in 1959, but its strong infrastructure of 17 stream gages and 25 meteorological stations was largely overlooked in the acid rain research heyday of the 1980s, due to the high buffering capacity of its calcite-bearing bedrock and glacial till. The watershed fell into disrepair. In 1991, in the context of climate change, research resumed at the 41-ha forested W-9 catchment. Weekly precipitation and stream samples as well as more than 1000 high-flow event stream samples have been taken and analyzed for major solute chemistry since that time. We analyzed for trends (seasonal Kendall/Sen slope) in ANC, sulfate, nitrate, and DOC in the weekly dataset, and for flow-stratified trends in these solutes using the full weekly + event dataset. ANC and nitrate exhibited slight negative but non-significant trends. Sulfate had a strongly decreasing trend in the weekly samples and at all flow levels, despite a steady supply of sulfate (about half of the stream load) from weathering of sulfide minerals in the bedrock. The decrease in stream sulfate concentration was about $3 \mu\text{eq L}^{-1} \text{ yr}^{-1}$. DOC showed a slight, non-significant increasing trend of near $0.01 \text{ mg L}^{-1} \text{ yr}^{-1}$. Nonetheless, this positive DOC trend is consistent with the generally upward regional DOC trend, which is commonly attributed to decreased sulfate deposition. Given the near-surface source for DOC, Sleepers River may behave like more acidified watersheds because calcite has been weathered from the soils and shallow till.

[P-48] Biological Sensors for Measuring Integrated Total Nitrogen Input (ITNI) to Arid and Semiarid Regions

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In arid and semiarid regions, dry deposition is the major route for atmospheric N deposition to plants and soils, but these fluxes are difficult to quantify and are not always included in regional estimates of N deposition. In this study, we tested the ability of biological sensors consisting of a plant-sand-water hydroponic module to measure N deposition in coastal sage scrub ecosystems in southern California. The modules were isotopically enriched with ^{15}N and then deployed in the field where the rate of wet and dry loading of all N forms, was determined by the rate of dilution of the ^{15}N tracer. This integrated total nitrogen input (ITNI) method was compared to conventional measurements of wet deposition (NADP rain collector), bulk throughfall deposition (ion-exchange resin collectors (IER)) and the inferential method. The inferential method estimates dry deposition from atmospheric concentration measurements made by passive samplers and empirical deposition velocities. At the end of all deployments, the majority of the isotope tracer was confined to the plant, with lesser amounts in the sand and almost no tracer was left in the liquid reservoir. For a 207 day period between June 2013 and March 2014, the combined deposition measured was: i) inferential+rain method = 14.1 kg N/ha ; ii) IER method = 5.3 kg N/ha and iii) ITNI method = 13.6 kg N/ha . During the summer growing season, the ITNI method measured 60% more deposition than the inferential+rain method, likely because of active N assimilation by the plant. ITNI deposition was only 44% of the inferential+rain deposition during winter because the experimental plants were growing outside of their normal growing season. Our results demonstrate that the ITNI method produces comparable deposition rates to existing deposition methods, but care must be taken in the selection and growing of the plants.

[P-79] Long-term soil microbial responses to liming in a mixed hardwood forest

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The application of calcium carbonate (liming) to ecosystems impacted by acid rain generally increases soil pH and may alter a range of soil microbial processes. In measurements of soils 20 years after a watershed scale liming experiment at Woods Lake in the Adirondack region of the United States, Melvin et al. 2013 found that limed plots had more than twice the soil carbon stocks and up to 43% lower soil basal respiration than the control plots. We resampled these plots to examine whether changes in soil carbon stocks relate to changes in microbial processes and communities. We expected that the larger C stocks in limed soils could perhaps have resulted from reduced microbial biomass or carbon mineralization rates. Yet, we found that microbial mineralization of carbon from Oe and Oa horizons in a 60 day assay was not significantly different in soils from limed plots than from control plots. Moreover, microbial biomass in the Oe horizon, the soil horizon with the largest observed increase in soil pH, was significantly higher in the limed plots. Forthcoming analyses on extracellular enzyme activities will show us whether there are differences in microbial degradation of polymeric organic compounds in elevated pH soils. Soil DNA will be sequenced to identify shifts in fungal and bacterial abundance and diversity after liming.

[P-9] Assessing critical loads in Sweden for nitrogen under climate change based on chemical and biological indicators using the mass balance method and the ForSAFE-VEG model system

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The integrated dynamic ecosystem models SAFE and ForSAFE-VEG were used to estimate critical loads for nitrogen using different chemical and biological criteria, and attempting to account for possible effects of climate change. The study is based on a model application on a set of 640 sites earlier used for critical loads assessments in Sweden, focusing on the ecological effect of nitrogen pollution. To assess critical loads for nitrogen to ecosystems, two criteria were used for the critical loads estimates: 1: N leaching and 2: changes in plant community composition, and assessed using the models mentioned. We show that the model gives results consistent with earlier results using other methods such as the simple mass balance method. We show that the new model system is operational over the whole of the Swedish territory and may be used for policy development and policy outcome assessments. The critical loads are estimated both under the assumption of no change in climate from today's level and under the assumption that the steady state of climate will be comparable to the predicted levels of 2100 for temperature and precipitation under the IPCC-SRES A2 scenario (Formerly the "worst case" scenario, after 2011, the "medium case" scenario.)

[P-67] Acidic gas and aerosol concentration over Japan monitored using four-stage filter-pack method

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The Ministry of the Environment, Japan (MOEJ) has been monitoring atmospheric deposition, soil/vegetation and inland aquatic environment for the acid deposition problem in Japan since 1983. By 2000, it was already clarified that the amount of wet deposition of acidic substances had increased in the area along the Sea of Japan during winter season and transboundary air pollution from Asian continent was strongly anticipated. The MOEJ recommended the establishment of the EANET for promoting countermeasures against the acid deposition problem in East Asia. In 2001, countries participating in the EANET began monitoring acid deposition using unified methods. On the other hand, public environmental laboratories of local Japanese governments established an original nationwide network named "Japan Environmental Laboratories Association" and began monitoring acid deposition over Japan in 1991. They also developed a method for estimating concentrations of gas and aerosol in ambient air for monitoring acid deposition using a four-stage filter-pack and began implementing it in 1999. Based on the scientific knowledge accumulated thus far, the method was adopted as the standard for estimating gas and aerosol concentration in dry deposition monitoring by the EANET in 2003. As of 2012, monitoring of gas and aerosol concentration using the method were carried out at 43 sites (local: 31, EANET: 12) in Japan.

The four-stage filter-pack method is advantageous because it can simultaneously monitor particulate matter and gas components. However, it has a disadvantage in that artifacts occur because of the reactions between particulate matter and gas on the filters. Furthermore, chlorine loss occurs easily because Japan is enclosed by the sea.

We introduce gas and aerosol concentration over Japan based on the results of the monitoring using the four-stage filter-pack method, considering the effects of artifacts and chlorine loss.

[P-82] Atmospheric composition data: Introduction to the EBAS research infrastructure

Presenter: Kjetil Tørseth, NILU, kt@nilu.no

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Acid rain founded the basis for the most comprehensive database on atmospheric composition worldwide. Early in the 1970's, a European monitoring program on air and precipitation chemistry to understand transboundary fluxes of air pollutants was established. Results documented the relationships between emissions at distance and effects on ecosystems and later founded the basis of the Convention on Long-Range Transmission of Air Pollution under the UN-ECE, its Protocols and the long-term operations of the European Monitoring and Evaluation Programme (EMEP).

Having open access to data on concentration and deposition levels across Europe was essential to find political agreement between countries. This was possible even at a time of political dispute between Eastern and Western Europe, and its claimed that this was perhaps the most successful example of international collaboration in relation to environmental protection. NILU – Norwegian Institute for Air Research leads the EMEP Chemical Coordinating Centre, and has responsibility to archive the observational data. In early years, data was reported manually on paper, and subsequently typed into centralized computer systems for use in the assessments. Over the decades, this infrastructure has developed to serve a number of international frameworks/projects (WMO-GAW, AMAP, OSPARCOM, HELCOM, ACTRIS and others) as a centralized access point to atmospheric composition data. We claim that it anno 2015 represents the most comprehensive database in operation, and there are further several developments in the pipeline for the coming few years. More than 400 different chemical and physical variables, with data from about 50 countries and 300 ground sites, and measured by more than 70 different instrument types. Our poster will provide an introduction of the services offered by the EBAS-database (<http://ebas.nilu.no>), and list clients currently using it to secure the long-term archival and dissemination of data to the users.

[P-27] NUTSFOR a process oriented numerical model to simulate biogeochemical cycling and tree nutrition in forest ecosystems: Model development and testing using data from a multi-isotopic (Mg-26 and Ca-44) tracing experiment

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Numerical models are important and useful tools to help predict how forest ecosystems may respond to change in atmospheric deposition and/or silvicultural practices. They help forest managers and decision makers to ensure the sustainable management of forest ecosystems but they are also important research tools which help decipher the role of different processes in biogeochemical cycles. New tools such as stable isotope tracers (^{15}N , ^{87}Sr , ^{44}Ca , ^{26}Mg , etc.) have been developed in past decades to better experimentally study forest ecosystem biogeochemistry and nutrient sources for trees. Existing models have not yet integrated these isotopic tools to i) test the hypotheses and model concepts and ii) develop models to better simulate ecosystem processes.

NUTSFOR is a process oriented model based on model concepts from both the Nutrient Cycling Model (NuCM) and the ForSAFE model that simulates nutrient cycling of major cations (Ca, Mg, K, Al, NH_4 , Na) and anions (NO_3 , SO_4 , PO_4 , Cl,) and a stable isotope tracer for each element at the scale of an ecosystem. The ecosystem is represented as a series of vegetation and soil components or pools (soil adsorbed ions, soil mineral pool, soil solution, litter and tree biomass). NutsFor was calibrated over a 10-year period (2002-2012) period using the monitoring data from an experimental site in Burgundy France (35-yr old beech stand on a nutrient poor soil). NUTSFOR was able to reproduce correctly trends and intra-annual variability in throughfall, forest floor and soil solution chemistry at 15cm, 30 cm and 60cm depth. NUTSFOR was then used to simulate the multi-isotopic tracing experiment which was carried out in the experimental plot by spraying an isotopically enriched solution (^{26}Mg and ^{44}Ca) on the forest floor. The high similarity between simulated and measured distribution of ^{26}Mg and ^{44}Ca tracers in the ecosystem provided a unique and robust way to evaluate the hypotheses grounding the model.

[P-61] ACTRIS-Czech Republic: A unique research infrastructure for studying atmospheric chemistry in a changing climate

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Air pollution and climate are a linked system. Therefore, long-term research infrastructures covering both issues are of highest importance in the current changing world. The ACTRIS Czech Republic (ACTRIS-CZ) research infrastructure (RI) forms a unique platform for the long-term background air quality monitoring and research closely related to climate, environmental and health issues. The RI represents a national node of the existing ACTRIS RI (Aerosol, Clouds and Trace gases Research Infrastructure) and moreover, its capacity is integrated into pan-European research infrastructure ICOS (Integrated Carbon Observation System). Actually the Czech Republic is one of the first European countries where the ACTRIS and ICOS activities are coordinated at the same site. The potential of ACTRIS-CZ is formed by Košetice Observatory (operated by the Czech Hydrometeorological Institute), 250 m high atmospheric mast Křešín u Pacova (operated by Global Change Research Centre, Academy of Sciences of the Czech Republic) and by research and operating supplement of institutes implementing their research and monitoring activities. The Observatory was established in 1988 as a background station specialized in air quality monitoring and research and represents Czech Republic in long-term activities under CLRTAP (EMEP, ICP-IM) and WMO (GAW). Tall tower was opened in 2013. The most important research and monitoring activities include long-term measurement of greenhouse gases concentrations and their exchange dynamics. Tall tower is also used for investigating the impacts of global climate change on air quality and long-range transport of air pollution. The research will be focused on pollutants with a high potential for hemispheric transport (tropospheric ozone, ultra-fine particles, persistent organic compounds and mercury). RI ACTRIS-CZ has very good potential for successful participation in the pan-European Research Infrastructures (RIs) under ESFRI and other projects covering both climate and air quality issues.

[P-72] Concentrations of ionic constituents and formaldehyde in snow cover at Murododaira, Mt. Tateyama, Japan

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The large amount of snow cover formed (more than 6 m depth) in spring at Mt. Tateyama records the environmental signals in the high altitude during the cold months (6 months; from November to April). Measurements of the chemical composition of the snow pits at Murododaira (altitude, 2,450 m), Mt. Tateyama near the coast of the Japan Sea in Central Japan, have been performed each spring from 2004. The mean concentrations of nssSO_4^{2-} and NO_3^- are higher than those in the snowpack in 1990s. The mean nssSO_4^{2-} concentrations were highest in 2007 which might have been due to highest SO_2 emission in China in 2006. However, the concentrations of the anthropogenic ions are also highly affected by climatological conditions.

The nssCa^{2+} was usually high in the upper parts of 2- 3 m of snow deposited in the spring, when Asian dust (Kosa) particles are frequently transported. High concentrations of nssSO_4^{2-} were detected in both the spring and winter layers. The high nssCa^{2+} layers usually contained high concentrations of nssSO_4^{2-} . The results show that not only Kosa particles but also air pollutants might have been transported long-range from the continent of Asian. The peaks of HCHO corresponded to the high nssSO_4^{2-} layers above a 3.0 m depth. The concentrations of deposited HCHO might have been relatively well preserved in the spring layers. HCHO with sulfate aerosols may be transported to Mt. Tateyama from the Asian mainland.

[P-18] Impediments to Recovery from Acid Deposition

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Long-term (mid-1970s – present) measurements of bulk deposition and stream chemistry at small forested watersheds in central Ontario, Canada have enhanced our understanding of the impacts of acid-rain and subsequent recovery in acid-sensitive forested catchments. In response to large emission reductions, sulphate concentrations in precipitation and streams have declined markedly over the past 40 years. However, sulphate levels in streams are also greatly affected by climate, with high acid and metal pulses occurring in stream water following summer droughts. A decrease in atmospheric nitrate deposition has occurred more recently (from mid-1990s) and although most N is retained in catchments, streams draining predominately upland catchments have exhibited a decline in nitrate concentration as well. Despite large decreases in acid deposition, chemical recovery (increase in pH and decrease in Al) of surface waters has been much less than expected, primarily due to continued losses of base cations from the shallow, base-poor soils. The combined influence of soil acidification and climate-mediated biogeochemical changes is causing acid deposition related issues to persist long after emission reductions have occurred.

[P-38] Assessment of Wet-Deposition Sample Contamination for the National Atmospheric Deposition Program / National Trends Network

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The National Atmospheric Deposition Program (NADP) Field Audit program is one of several ongoing programs implemented by the U.S. Geological Survey to assess the quality of wet-deposition chemistry data. Established in 1997, the Field Audit quantifies potential sample contamination for the National Trends Network (NTN). Following a week without measureable precipitation at a sample-collection site, a portion of a quality-control (QC) solution is used to rinse the NTN sample-collection bucket. Both the rinse and unused portions of the QC sample are shipped as paired samples to the NADP Central Analytical Laboratory for analysis. Ion contamination, or loss, is calculated as the difference in concentration of each ion between the paired samples.

For comparison purposes, data collected during 1997-2014 were separated into two periods of record: 1997–2005 and 2006–14. Iso-concentration maps indicate consistent spatial patterns in the amount of contamination by crustal cations (calcium, magnesium, potassium and sodium) and of hydrogen-ion (from pH) loss for the two periods. Higher amounts of crustal cation contamination and hydrogen-ion loss were found in the arid Southwest and agricultural Midwest regions compared to other regions of the U.S. Hydrogen-ion loss is associated with base cation buffering from dust contamination. A Regional Kendall test indicated no significant trends in crustal cation contamination or hydrogen-ion loss over the 18-year Field-Audit record.

Replacement of Aerochem Metrics model 301 precipitation-sample collectors with the N-CON ADS 00-120 collectors³ may contribute to differences in crustal cation and hydrogen-ion concentrations. Ninety-seven N-CON collectors were installed during 2011 and 2013. A Kruskal-Wallis test indicated significant differences between the two collector types with respect to calcium and hydrogen-ion bucket-minus-bottle values. Differences in the effectiveness of collector lid seals is suspected as the cause for these results.

No spatial patterns for ammonium, nitrate, and sulfate contamination/loss were observed. Contamination with chloride in the Gulf of Mexico coastal region was consistent for both record segments.

[P-59] Related Changes in Snow Season Duration and Wet-Deposition Chemistry in the Contiguous USA

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Changes in the annual timing of precipitation type and measured wet-deposition chemistry maxima were evaluated for the study period 1979-2013 at 90 National Atmospheric Deposition Program / National Trends Network (NADP/NTN) sites that commonly report snowfall. Wet-deposition data with at least a 29-year record within the study period, collected coast-to-coast in the contiguous USA bounded by 35.7° (Tennessee) to 48.8° (North Dakota) north latitude, were analyzed using the Regional Kendall Test for trends for latitudinal and longitudinal regions. Trends and regional shifts in precipitation type, snow-season duration, and the timing of selected chemical concentration and wet-deposition annual maxima were identified and quantified.

During the 35-year study period, the snow season has shortened by one to three weeks. The fraction of annual precipitation falling as snow (S/P) has decreased slightly at the 90 sites, with a general pattern of decreasing S/P with increasing latitude. Results suggest that precipitation types identified as mixed snow and rain are increasingly comprised of a slightly greater proportion of rain in higher latitudes.

Latitudinal and longitudinal shifts in chemical wet-deposition maxima and changes in precipitation type are similar. Regional trends show maximum nitrate:sulfate concentration ratio and ammonium wet deposition occurs earlier now than in 1979. Washout of dust, represented by calcium, magnesium, and potassium (crustal-cations) wet deposition exhibited similar regional patterns.

Previous work by many researchers has documented trends in the magnitudes of both precipitation concentrations and wet deposition of atmospheric pollutants related to changes in emissions. This study evaluated how shifts in the annual timing of observed precipitation type and measured wet-deposition chemistry have also changed due to a warming climate. Possible ecological consequences of pollutant wet-deposition timing are suggested, including landscape nitrogen saturation and loss to surface water in forested ecosystems and ammonia emissions from agricultural areas due to changes in the growing season.

[P-11] Critical loads of acidity for boreal Saskatchewan, Canada

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Author(s): Aidan C. Mowat, University of Saskatchewan;
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Shaun A. Watmough, Trent University

Extraction of natural resources in boreal regions of western Canada forms an important part of Canada's economy. Emissions of SO₂ (and NO_x) are often concomitant with these industrial activities; most notable is the Athabasca Oil Sands industry which is among the largest national point sources of these pollutants to the atmosphere. Boreal regions of Canada are predominantly acid-sensitive, and northwestern Saskatchewan, which lies downwind of the Oil Sands industry, features some of the most acid-sensitive terrain in Canada. Terrestrial and aquatic critical loads of acidity were calculated for more than 100 sites in northwestern Saskatchewan using the Simple Mass Balance and Steady-State Water Chemistry models, respectively. Uncertainties associated with the critical load calculations, including base cation deposition to uplands and discharge from the lakes were identified as important. Critical loads of acidity (sulphur) are very low, with 5th percentiles of 12 and 1.9 mmolc m⁻² yr⁻¹, respectively for upland soils and headwater lakes. Current deposition of sulphur in the region is lower than for eastern Canada which has a legacy of acid rain, but is nonetheless comparable to critical loads. Atmospheric deposition monitoring data are scarce; however, and sulphur deposition estimates vary considerably. At present, determining the risk of acidification due to critical load exceedance is dependent on the choice of sulphur deposition estimate and the method of quantifying discharge used in calculating the aquatic critical load, highlighting the need for improved understanding of deposition and hydrology in the region.

[P-14] Vegetation community change points suggest that critical loads of nutrient nitrogen are too high

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It is widely accepted that elevated atmospheric nitrogen deposition can impact semi-natural ecosystems, leading to changes in plant species composition and potential biodiversity loss. The critical load approach has been used in Europe to set emissions regulations for nutrient nitrogen. In this study we explore vegetation community change, estimated by Threshold Indicator Taxa Analysis (TITAN), as an indicator of empirical critical loads. The plant species abundances for 15 different habitat types of conservation importance (i.e. Natura 2000 habitats) in Ireland were compared to mapped total atmospheric nitrogen deposition using TITAN, to determine the point along the nitrogen deposition gradient at which each habitat type demonstrated the most significant shift in community composition. This community level change point was compared with the recommended critical load range for nutrient nitrogen for each habitat. In essence, the community composition was used to represent a specified sensitive element of the environment, and the change point was used as the quantitative estimate of nutrient nitrogen. The community change points were all less than $10 \text{ kg N ha}^{-1} \text{ yr}^{-1}$, with habitats generally falling into one of two groups, <5 or $<10 \text{ kg N ha}^{-1} \text{ yr}^{-1}$. For all habitat types the change point fell below the recommended CL range; however, the relative rank of the change points followed the same pattern as the recommended CL ranges across the habitats. These results may reflect the lower total nitrogen deposition in Ireland, particularly along the west coast, compared with central Europe, where many of the studies informing current critical load recommendations were situated. Central European habitats have long been exposed to higher nitrogen deposition and so may have already lost the more sensitive species that influenced the community composition changes in this study.

[P-63] Effect of stimulated N deposition on N₂O emission in Inner Mongolia, China

Presenter: Hanyue Yang, Tsinghua University, Beijing,
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Author(s): Ting Zhang and Lei Duan, Tsinghua University, Beijing, Yongmei Huang, Beijing Normal University, Beijing

Mainly due to fast growing of agricultural and industrial activities, China became the highest N deposition zone in the world (Vet et al., 2014). N deposition had exceeded $3\text{g}\cdot\text{m}^{-2}\cdot\text{a}^{-1}$ in the temperate steppe (Zhang et al., 2013), which is a significant part of the Eurasia grassland, but possibly sensitive to N deposition. To study the effect of N deposition on N cycling in this ecosystem, N₂O emissions were measured from 18 plots of 6×3 m² on natural grassland enclosed from agriculture and grazing at Taipusi County, Inner Mongolia from June 2014 to May 2015. The plots were allocated to five simulated N deposition (by NaNO₃ addition) treatments with different doses, N2 (2 g N m⁻² a⁻¹), N5 (5 g N m⁻² a⁻¹), N10 (10 g N m⁻² a⁻¹), N25 (25 g N m⁻² a⁻¹) and N50 (50 g N m⁻² a⁻¹), and a reference without N addition (CK), with three replicates for each treatment. Results showed that N₂O emission was much relied on soil water content and soil temperature (Fig. 1). The estimated annual N₂O emission flux under ambient N deposition was 0.096 g N m⁻² a⁻¹, much higher than the previous study results. In addition, enhanced N deposition could significantly increase N₂O emission, especially under very high N dose (N25 and N50 treatment) (Fig. 2).

Reference:

Vet R et al. A global assessment of precipitation chemistry and deposition of sulfur, nitrogen, sea salt, base cations, organic acids, acidity and pH, and phosphorus. *Atmospheric Environment* 93 (2014) 3-100

Zhang J, Kang RH, Zhao B, Huang, YM, Ye ZX, Duan L, 2013. Monitoring Nitrogen Deposition on Temperate Grassland in Inner Mongolia. *Environmental Science*, 09, 3552-3556. (in Chinese)

2015 National Atmospheric Deposition Program Site Operator Awards

National Atmospheric Deposition Program Operator Awards

5 YEAR AWARDS

Site Code	Operator Name	Site Name	Funding Agency	Wet Start
FL11 - MDN/NTN	L. Phillip Navarro	Everglades National Park - Research Center	National Park Service - Air Resources Division	06/80
IL63 - NTN	Jim Kirkland	Dixon Springs Agricultural Center	University of Illinois-State Agricultural Experiment Station	01/79
MA01 - NTN	Krista Lee	North Atlantic Coastal Lab	National Park Service - Air Resources Division	12/81
NC06 - AMoN	Nathan Hall	Beaufort	U.S. Environmental Protection Agency - Clean Air Markets	04/10
PA13 - MDN	Kathy Penrod	Allegheny Portage Railroad National Historic Site	Pennsylvania Department of Environmental Protection	01/97
PA42 - MDN	Kevin Horner	Leading Ridge	Pennsylvania Department of Environmental Protection	03/10
PA60 - MDN	Kevin Horner	Valley Forge	Pennsylvania Department of Environmental Protection	11/99
PA90 - MDN	Kevin Horner	Hills Creek State Park	Pennsylvania Department of Environmental Protection	01/97
PA72 - MDN	Rebecca Philpot	Miford	Pennsylvania Department of Environmental Protection	09/00
SC19 - MDN	Michael Bates	Congaree Sw amp	South Carolina Department of Health and Environmental Control	03/96
SD18 - MDN	Misti Hebb	Eagle Butte	Cheyenne River Sioux Tribe Environmental Protection Department	03/07
TX43 - NTN	Brent Auvermann	Canonceta	Texas A&M Agricultural Experiment Station	07/07
UT97 - MDN	Andy Hale	Salt Lake City	Utah Department of Environmental Quality	05/07

10 YEAR AWARDS

Site Code	Operator Name	Site Name	Funding Agency	Wet Start
AZ06 - NTN	Charles Conner	Organ Pipe Cactus National Monument	National Park Service - Air Resources Division	04/80
CA66 - NTN	Valerie Nuttman	Pinnacles National Monument - Bear Valley	National Park Service - Air Resources Division	11/99
CA76 - NTN	Eric Olson	Montague	U.S. Geological Survey	06/85
IN34 - NTN	Laura Brennan	Indiana Dunes National Lakeshore	National Park Service - Air Resources Division	07/80
MD15 - NTN	Francis "Hoss" Parks	Smith Island	NOAA - Air Resources Laboratory	06/04
MD18 - NTN	Eric Sherry	Assateague Island National Seashore - Woodcock	Maryland Department of Natural Resources	09/00
MI53 - NTN	Mike Reilly	Wellston	U.S. Forest Service	10/78
MN16 - NTN	Deacon Kyllander	Marcell Experiment Forest	U.S. Forest Service	07/78
MN99 - NTN	Peter Harris	Wolf Ridge	Minnesota Pollution Control Agency	12/96
NY08 - NTN	Jeff Stayton	Aurora Research Farm	Cornell University	04/79
VA13 - NTN	Diane Reaver	Horton's Station	U.S. Environmental Protection Agency - Clean Air Markets	07/78
WY98 - NTN	Ted Porwoll	Gypsum Creek	Bridger-Teton National Forest	12/84

15 YEAR AWARDS					
Site Code	Operator Name	Site Name	Funding Agency	Wet Start	Wet Start
AL03 - MDN	Dennis Stripling	Centreville	Southern Company/Atmospheric Research & Analysis, Inc.	06/00	
FL14 - NTN	Tom Bolton	Quincy	U.S. Geological Survey	03/84	
20 YEAR AWARDS					
Site Code	Operator Name	Site Name	Funding Agency	Wet Start	Wet Start
NM07 - NTN	Kay Beeley	Bandelier National Monument	National Park Service - Air Resources Division	06/82	
VA00 - NTN	John Mabon	Charlottesville	U.S. Geological Survey	10/84	
25 YEAR AWARDS					
Site Code	Operator Name	Site Name	Funding Agency	Wet Start	Wet Start
IN22 - NTN	Angie Thompson-Hewitt	Southwest Purdue Agriculture Center	U.S. Geological Survey	09/84	
UT98 - NTN	Nolan Johnson	Green River	U.S. Geological Survey	04/85	

30 YEAR AWARDS

Site Code	Operator Name	Site Name	Funding Agency	Wet Start
IA23 - NTN	Jim Secor	McNay Research Center	U.S. Geological Survey	09/84

35 YEAR AWARDS

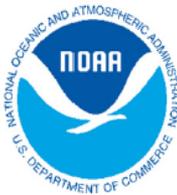
Site Code	Operator Name	Site Name	Funding Agency	Wet Start
FL03 - NTN	Larry Korhnak	Bradford Forest	U.S. Environmental Protection Agency - Clean Air Markets	10/78
ME02 - NTN	Peter Lowell	Bridgton	Maine Department of Environmental Protection/USEPA	06/97
OR10 - NTN	John Moreau	H.J. Andrews Experimental Forest	U.S. Forest Service	05/80

Proceedings Notes

The 9th International Acid Rain Conference was brought to you by:



This project was undertaken with the financial support of:
Ce projet a été réalisé avec l'appui financier de :



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