SAES-422 Multistate Research Activity Accomplishments Report

Project No. and Title:	NRSP-3, The National Atmospheric Deposition Program – A Long-Term Monitoring Program in Support of Research on the Effects of Atmospheric Chemical Deposition
Period Covered:	10-2012 through 4-2013
Date of Report:	June 16, 2013
Meeting Dates:	April 22-25, 2013

Participants

A listing of the attendees is provided.

Meeting Minutes

The NADP is comprised of a technical committee (all participants), an executive committee, several scientific committees, and a series of subcommittees focusing on specific areas of the ongoing project including operations, quality assurance, ecological response and outreach, and data management. All approved meeting minutes from our 2013 Spring Meeting (and all other meetings) are available on our website (http:// http://nadp.isws.illinois.edu/committees/minutes.aspx). Several of the subcommittee minutes are delayed for approval, but will be posted when approved.

The attachment is the minutes of the Joint Subcommittee Meeting (a meeting of all participants, with topics of interest to all).

(attachment..)

Accomplishments

The NRSP-3 provides a framework for cooperation among State Agricultural Experiment Stations (SAES), the U.S. Department of Agriculture, and other cooperating governmental and non-governmental organizations that support the National Atmospheric Deposition Program (NADP). The NADP provides quality-assured data and information on the exposure of managed and natural ecosystems and cultural resources to acidic compounds, nutrients, base cations, and mercury in precipitation

and through dry deposition of several of these compounds. NADP data support informed decisions on air quality and ecosystem issues related to precipitation chemistry.

Specifically, researchers use NADP data to investigate the impacts of atmospheric deposition on the productivity of managed and natural ecosystems; the chemistry of estuarine, surface, and ground waters; and the biodiversity in forests, shrubs, grasslands, deserts, and alpine vegetation. These research activities address "environmental stewardship," one of the Agricultural Experiment Station's research challenges (Science Road Map #6). Researchers also use NADP Mercury Deposition Network data to examine the role of atmospheric deposition in affecting the mercury content of fish, and to better understand the link between environmental and dietary mercury and human health. This fits with another research priority of "relationship of food to human health."

The NADP operates three precipitation chemistry networks: the National Trends Network (NTN), the Atmospheric Integrated Research Monitoring Network (AIRMoN), and the Mercury Deposition Network (MDN).

The NTN provides the only long-term nationwide record of basic ion wet deposition in the United States. Sample analysis includes free acidity (H^+ as pH), specific conductance, and concentration and deposition measurements for calcium, magnesium, sodium, potassium, sulfate, nitrate, chloride, bromide (new), and ammonium. We also measure orthophosphate ions (PO_4^{3-}, the inorganic form), but only for quality assurance as an indicator of sample contamination. At the end of April 2013, 256 NTN stations were collecting one-week precipitation samples in 48 states, Puerto Rico, the Virgin Islands, Canada, and a new site in Argentina. Additionally, there are multiple quality assurance and test sites. Complementing the NTN is the seven-site AIRMoN. AIRMoN sites are essentially NTN sites operated on a daily basis (i.e., single precipitation events), with samples collected to support continued research of atmospheric transport and removal of air pollutants and development of computer simulations of these processes.

The 107-site MDN offers the only long-term and routine measurements of mercury in North American precipitation. Measurements of total mercury concentration and deposition (and optional methyl-mercury) are used to quantify mercury deposition to water bodies, some of which have fish and wildlife mercury consumption advisories. Since 2008, every state and 10 Canadian provinces listed advisories warning people to limit fish consumption due to high mercury levels. Coastal advisories are also in place

for Atlantic waters from Maine to Rhode Island, from North Carolina to Florida, for the entire U.S. Gulf Coast, and for coastal Hawaii and Alaska.

The NADP operates two newer gaseous atmospheric chemistry networks: the Atmospheric Mercury Network (AMNet) and the Ammonia Monitoring Network (AMoN, NADP's newest network). In each case, the network goal is to provide atmospheric concentrations of these particular gases, and then to estimate the rate of dry deposition (without precipitation) of the gas. In many cases, dry deposition of the gas could far exceed the wet deposition of the same compound.

At the end of April 2013, 18 AMNet sites were collecting five-minute estimates of gaseous elemental mercury and two-hourly average concentrations of gaseous oxidized mercury and particulate bound mercury. The AMNet provides the only long-term region-wide record of basic atmospheric mercury concentrations in the United States.

The AMoN has 58 sites operating as of April 2013, where two-week averages of atmospheric ammonia gas are being collected with passive devices. This low-cost network is designed to provide long-running estimates of ammonia in the atmosphere. These data are particularly important to agriculture, since many sources of ammonia are agricultural in nature (Roadmap Challenge #6). Data from both gaseous networks support continued research of atmospheric transport and removal of air pollutants and development of computer simulations of these processes.

Short-term Outcomes and Outputs.

Samples Collected. NADP's principal objective and accomplishment/outcome is the collection and analysis of samples for precipitation and atmospheric chemistry. Briefly, the NADP processed a total of 7,980 samples from the NTN, including 561 quality assurance (QA) samples. The analyses included observations of 10 different analyte concentrations and precipitation volume, which allow for calculation of deposition flux for each analyte. These same data were collected daily (i.e., every day with measurable precipitation) from the AIRMoN network. AIRMoN collected and processed 611 precipitation samples, including 57 QA samples. The MDN collected and processed 3,901 weekly mercury-in-precipitation samples, including 1,332 QA samples. The AMoN collected and quality assured 1,034 ammonia samples, which included 561 QA samples. The AMNet collected, quality assured, and produced approximately 20,960 hourly and two-hourly averages.

NADP Database. Our second most important accomplishment/outcome is making data available to all for the support of continued research. Scientists, policymakers, educators, students, and others are encouraged to access data at no charge from the NADP website (http://nadp.isws.illinois.edu). This website offers online retrieval of individual data points, seasonal and annual averages, trend plots, concentration and deposition maps, reports, manuals, and other data and information about the program. As of today, 2011 calendar year data are complete and online, along with data through January 2013, and all of 2012 will be finalized within two weeks. Website usage statistics provide evidence that our data are being used. During FY2012, website usage continued to grow. More than 40,000 registered users accessed our information and records show over 27,800 data downloads from the site. The site annually receives well over 1.25 million "hits." We continually divide users into types, and for FY2012 about 40% were from federal and state agencies (somewhat higher than normal), 36% from universities, 16% from K-to-12 schools, and 8% from other individuals or organizations. The NADP website has registered users from more than 150 countries across the globe. These statistics demonstrate that NADP continues to be relevant to both the scientific and educational communities and continues to attract new users.

Map Summary. As with every year, the 2012 annual maps will be developed during June and available approximately September 2013. These maps are used widely and constitute one of the major products of the network. Individual maps are filed by network, year, and constituent, and can be downloaded in several formats (see examples at http://nadp.isws.illinois.edu/data/annualiso.aspx). Individual maps are compiled into annual Map Summary reports, and the 2011 Map Summary is also available for download (2012 will be available approximately on Sept. 15, 2013; http://nadp.isws.illinois.edu/lib/dataReports.aspx). We printed 2,000 copies of the 2011 Annual Summary, and about 50% of these have been distributed thus far.

Scientific Meeting (Fall 2012). At the end of each federal year, a combined business and scientific meeting is held to showcase some of the latest deposition research that occurred during the year. During FY12, the meeting focused on "The NADP Cooperative: State, Local, and Tribal Perspectives" with a goal of focusing more on the non-federal sites and uses of the NADP data (October 21 to 25, 2012 in Portland, Maine). The meeting attracted 130 registered participants, and included eight sessions, 41 oral presentations, and 20 posters. One session was devoted to ammonia monitoring with reference to agriculture, and another session focused on total nitrogen deposition in water bodies and western lands. All presentations, posters, and meeting proceedings are available on the NADP website (http://nadp.isws.illinois.edu/conf/2012/).

Scientific Meeting (FY13, Fall 2013). The next scientific meeting will be held in Park City, Utah (October 8-11, 2013). An agriculture/ammonia session is planned. All are welcome, with all presentations, posters, and meeting proceedings to be added to the NADP website.

These basic activities fulfilled the project objectives: (1) coordination of these networks; (2) quality assurance to ensure consistency; and (3) analytical, site support, and data validation services for the sites financed directly through this agreement.

Additional Operation Notes. The NADP continues to convert our precipitation gages to an all-digital network, originating with a Technical Committee decision in 2006 (http://nadp.isws.illinois.edu/newissues/newgages/newequip.aspx). Currently, the network is operating with approximately 85% new digital networks.

NADP's fifth network, the Ammonia Monitoring Network (AMoN), is an agricultural-focused network. Ammonia is of great concern regarding agriculture and air pollution. AMoN currently operates 58 sites, and (as of today) 12,000 observations of atmospheric ammonia concentrations are available. AMoN's cost-efficient passive measurements can be used to estimate ammonia dry deposition, a process which is being considered (nadp.isws.illinois.edu/AMoN/).

The Central Analytical Laboratory has begun to measure the concentration of bromide ion in all NADP samples as a routine analyte of the NTN and AIRMoN sites. Regular measurements will be released for the 2012 year. Bromide is important to agricultural users, given its fumigant usage in the agriculture industry.

During the 2013 calendar year (as of today, five months), 97 journal articles and reports were generated using the NADP data. These are listed in the Publications section. This is again evidence that NADP is producing data that are both valuable and useful.

At the Spring 2011 Meeting, the NADP committees voted to modify NADP maps from an earlier discrete contour map style to a new continuous color gradient map, and to incorporate much more additional precipitation data (using the Parameter-elevation Regressions on Independent Slopes Model, PRISM). The new map series is now available going back to 1994, and the older-style maps are also still available through 2010. These maps provide much more information to the depositional community by adding precipitation adjustments for elevation and locations. These maps were first published with the 2011 map summary in October 2012. These PRISM data are the result of a research collaboration between the PRISM Research Group at Oregon State University and the USDA's Natural Resource Conservation Service and Forest Service.

U.S. EPA scientists, with NADP, continued special studies to determine whether organic nitrogen deposition can be measured reliably and accurately. The results indicated that the measurements are reliable, and that organic N can be differentiated from inorganic N in our samples. This will add much needed information to the understanding of N deposition patterns and sources.

A new litterfall mercury monitoring initiative will measure mercury and methyl mercury in forest litterfall (leaves, twigs, etc.). These dry deposition estimates will complement the MDN wet deposition mercury monitoring. Initiation of the trial began in September 2012. Analysis and field support will be provided through the USGS (http://nadp.isws.illinois.edu/newIssues/litterfall/).

Impacts

As a National Research Support Project, the NADP's most important impact is that our data are used in research, per our research support mission. From January through May 2013, we identified 97 journal articles and reports that used NADP data, maps, and procedures in their own research, for modeling applications, and for comparison to NADP results, etc. These articles will be included in our online database of NADP publications.

Here is a short summary of 10 articles (and theses/dissertations) that are of particular interest to the agricultural community.

1. Brahney et al. used 17 years of calcium wet deposition from 175 NADP sites to show a continual scale increase in calcium deposition. The largest trends are increasing deposition to the intermountain West and to the agricultural Midwest (IA, KS, MO, IL, IN). For the Midwest, the increase was 24% over the 17 years. A decrease was noted across Texas and New Mexico. These observations are consistent with the current Southwest USA extended drought.

2. Blesh and Drinkwater (SAES, Cornell) used farm-scale interviews and a regional model of farm nitrogen usage to evaluate the nitrogen contribution to the Mississippi River nitrogen flux. This small-scale approach captures some of the variability, in part due to crop rotation and nitrogen source types that regional scale models miss. From this, they concluded that crop rotation (increased C availability) and nitrogen fertilizer reduction are necessary to significantly influence N movement to the Gulf of Mexico. The authors used NADP nitrate

and ammonia deposition rates over several years and four states for input of N to the particular farms and study areas.

3. Fleming (dissertation, Crop and Soil Environmental Sciences, Virginia Tech) evaluated irrigation techniques and N fertilization application rates to optimize both for the growth of fresh tomatoes. She used NADP seasonal deposition rates of nitrate and ammonia over three years from Maryland as input for her N fertilizer and fruit recovery balances. With her research, she provided improved production protocols for sustained yields, lower irrigation rates, and improved nitrogen application.

4. Guretzky et al. (several SAES scientists, Agronomy, Animal Sciences, UN-Lincoln) investigated the ecosystem response to grazing beef cattle diet supplements (corn, distillery grains) under different N inputs (unfertilized to heavily fertilized). They used NADP inorganic N deposition rates to their experimental lands over two study years, where in unfertilized lands the atmospheric N deposition was the only external N addition. Among other results, the authors concluded that the distillers grain feeding did not affect herbage accumulation over the long term without additional N fertilizer.

5. Jones (thesis, Crop and Soil Environmental Sciences, Virginia Tech) examined temporal changes of soil nutrient concentrations (soil pH, P, N, S, Ca, Mg, K, Fe, Zn, Cu and B) over five years in a beef cattle system, and developed a model to predict changes of these nutrients within herbage over time. He used NADP deposition rates of pH, N, S, Ca, Mg, K, etc. as external inputs to his system. He found higher concentrations of herbage N and K and soil P, K, Fe, Zn, and Cu over time, with lower variability in herbage P and K.

6. Nippert et al. (Kansas State University SAES site) examined the water sources and budgets of wild bison on Konza Prairie using isotopic analysis of their dung. They determined that the bison primarily used puddles and wallows (i.e., atmospheric precipitation) as their major water source. They confirmed this with isotopic analysis of onsite NADP precipitation samples. Implications of climate change to grazing animal primary water sources could have many different effects.

7. Bash et al. evaluated a U.S. EPA air quality model with respect to bi-directional ammonia exchange through incorporation of both NADP wet deposition data and the USDA Environmental Policy Integrated Climate (EPIC) agroecosystem model (soil nitrogen model). EPIC was used to improve the nitrogen/ammonia emissions, and NAPD data from the entire network (monthly and annual sums,

for 2002) were used to evaluate the model results. By incorporating the EPIC model, significant model improvement of N aerosol concentration and N deposition was seen.

8. Hale et al. developed a database of nutrient input to northeast ecosystems going back to the 1920s. Atmospheric deposition is a major nutrient source, and they used the full complement of NADP observations from our NE states (41 sites). Very large changes have occurred over these years, due primarily to the urbanization of the NE. The authors concluded that agriculture and particularly livestock were the most important inputs defining spatial nutrient patterns, and changes in these inputs over time changed the NE spatial patterns. Agriculture is still a major input to the nutrient cycling in the region.

9. Santhi et al. (SAES scientists, Texas A&M Univ.; ARS Scientists) developed a physically-based, regional-scale modeling approach to evaluate if agricultural conservation practices are improving the water quality conditions of rivers and streams as part of the USDA-initiated Conservation Effects Assessment Project (CEAP). They used NADP wet deposition inputs of N to their modeling (multiple sites over 18 river basins). Simulations indicated that current practices have the potential to significantly reduce the delivery of sediment, N, and P loads to the Ohio/Mississippi River by 15, 16, and 20%, respectively.

10. Zhu et al. relate values of atmospheric ammonia as a tool to improve the GEOS-Chem air quality model's performance in predicting ammonia transport, atmospheric chemical reactions, and deposition. By comparing model output to ground measurements from two NAPD networks (multiple years, all sites) for wet deposition (NADP/NTN) and for gaseous ammonia (NADP/AMoN), the authors significantly increased their precision in resulting ammonia and air quality output in certain months, but other monthly predictions were not improved. This work confirms that predictions of ammonia impacts on air quality still need more improvement.

Publications

Includes 96 publications that used NADP data or resulted from NRSP 3 activities in 2013 (as of May). A publically available online database that lists citations using NADP data is accessible at: http://nadp.isws.illinois.edu/lib/bibliography.aspx.

1. Barco, J., Gunawan, S., & Hogue, T. S., 2013. Seasonal controls on stream chemical export across diverse coastal watersheds in the USA. Hydrological Processes 27: 1440–1453, DOI: 10.1002/hyp.9294.

2. Bash, J. O., Cooter, E. J., Dennis, R. L., Walker, J. T., & Pleim, J. E., 2013. Evaluation of a regional air-quality model with bidirectional NH 3 exchange coupled to an agroecosystem model. Biogeosciences 10(3): 1635–1645.

3. Becker, C. J., 2013. Groundwater quality and the relation between pH values and occurrence of trace elements and radionuclides in water samples collected from private wells in part of the Kickapoo Tribe of Oklahoma Jurisdictional Area, central Oklahoma, 2011. U.S. Geological Survey Scientific Investigations Report 2012–5253, 47 p., 5 apps.

4. Bettez, N. D., & Groffman, P. M., 2013. Nitrogen deposition in and near an urban ecosystem. Environmental Science & Technology, dx.doi.org/10.1021/es400664b.

5. Bettez, N. D., Marino, R., Howarth, R. W., & Davidson, E. A., 2013. Roads as nitrogen deposition hot spots. Biogeochemistry, DOI: 10.1007/s10533-013-9847-z.

6. Blesh, J., & Drinkwater, L. E., 2013. The impact of nitrogen source and crop rotation on nitrogen mass balances in the Mississippi River basin. Ecological Applications, http://dx.doi.org/10.1890/12-0132.1.

7. Brahney, J., Ballantyne, A. P., Sievers, C., & Neff, J. C., 2013. Increasing Ca2+ deposition in the western US: The role of mineral aerosols. Aeolian Research, http://dx.doi.org/10.1016/j.aeolia.2013.04.003.

8. Buzzelli, C., Wan, Y., Doering, P. H., & Boyer, J. N., 2013. Seasonal dissolved inorganic nitrogen and phosphorus budgets for two sub-tropical estuaries in south Florida, USA. Biogeosciences Discussions 10: 2377–2413.

9. Cao, J., Tie, X., Dabberdt, W. F., Jie, T., Zhao, Z., An, Z., & Shen, Z., 2013. On the potential high acid deposition in northeastern China. Journal of Geophysical Research: Atmospheres 118: 1–13, doi:10.1002/jgrd.50381, 2013.

10. Chanat, J. G., Miller, C. V., Bell, J. M., Majedi, B. F., & Brower, D. P., 2013. Summary and interpretation of discrete and continuous water-quality monitoring data, Mattawoman Creek, Charles County, Maryland, 2000–11: U.S. Geological Survey Scientific Investigations Report 2012–5265, 42 p.

11. Chen, S. M., Qiu, X., Zhang, L., Yang, F., & Blanchard, P., 2013. Method development estimating ambient mercury concentration from monitored mercury wet deposition. Atmospheric Chemistry and Physics Discussions 13(5): 12771–12796.

12. Cheng, I., Zhang, L., Blanchard, P., Dalziel, J., & Tordon, R., 2013. Concentration-weighted trajectory approach to identifying sources of speciated atmospheric mercury at an urban coastal site in Nova Scotia, Canada. Atmospheric Chemistry & Physics Discussions 13: 4183–4219.

13. Cowles, M. K., 2013. Regression and hierarchical regression models. In Applied Bayesian Statistics (pp. 179-205). Springer New York.

14. Curtis, L. R., Morgans, D. L., Thoms, B., & Villenueve, D., 2013. Extreme precipitation appears a key driver of mercury transport from the watershed to Cottage Grove Reservoir, Oregon. Environmental Pollution 176: 178–184.

15. Cusack, D. F., 2013. Soil nitrogen levels are linked to decomposition enzyme activities along an urban-remote tropical forest gradient. Soil Biology and Biochemistry 57: 192–203.

16. Dodson, J., 2013. Draft TMDL Report: Springs Coast Basin, Weeki Wachee Spring and Weeki Wachee River (WBIDs 1382B and 1382F), Nutrients, June 2013.

17. Drenner, R. W., Chumchal, M. M., Jones, C., Lehmann, C. M., Gay, D., & Donato, D., 2013. Effects of mercury deposition and coniferous forests on the mercury contamination of fish in the south central United States. Environmental Science & Technology 47 (3): 1274–1279, DOI: 10.1021/es303734n.

18. Duarte, N., Pardo, L. H., & Robin-Abbott, M. J., 2013. Susceptibility of forests in the northeastern USA to nitrogen and sulfur deposition: Critical load exceedance and forest health. Water, Air, & Soil Pollution 224(2): 1–21.

19. Ellis, R. A., Jacob, D. J., Payer, M., Zhang, L., Holmes, C. D., Schichtel, B. A., ... & Lynch, J. A., 2013. Present and future nitrogen deposition to national parks in the United States: Critical load exceedances. Atmospheric Chemistry and Physics Discussions 13(4): 9151–9178.

20. Environmental Protection Agency, 2013. At a Glance, Environmental and Health Results Report: Clean Air Interstate Rule, Acid Rain Program, and Former NOx Budget Trading Program, http://www.epa.gov/AIRMARKETS/progress/ARPCAIR11_downloads/ARPCAIR11_environmental_health.pdf.

21. Fenn, M. E., Ross, C. S., Schilling, S. L., Baccus, W. D., Larrabee, M. A., & Lofgren, R. A., 2013. Atmospheric deposition of nitrogen and sulfur and preferential canopy consumption of nitrate in forests of the Pacific Northwest, USA. Forest Ecology and Management 302: 240–253.

22. Fleming, C. S., 2013. Nitrogen and Phosphorus Management in the Mid-Atlantic (Doctoral dissertation, Virginia Polytechnic Institute and State University).

23. Gall, H. E., Park, J., Harman, C. J., Jawitz, J. W., & Rao, P. S. C., 2013. Landscape filtering of hydrologic and biogeochemical responses in managed catchments. Landscape Ecology 28:651–664, DOI: 10.1007/s10980-012-9829-x.

24. Goodsite, M. E., Outridge, P. M., Christensen, J. H., Dastoor, A., Muir, D., Travnikov, O., & Wilson, S., 2013. How well do environmental archives of atmospheric mercury deposition in the Arctic reproduce rates and trends depicted by atmospheric models and measurements? Science of the Total Environment 452: 196–207.

25. Grant, R. F., 2013. Modelling changes in nitrogen cycling to sustain increases in forest productivity under elevated atmospheric CO 2 and contrasting site conditions. Biogeosciences Discussions 10(4): 6783–6837.

26. Grant, R. H., 2013. Atmospheric wet deposition relationships to season and precipitation in south western Indiana. In Proceedings of the Indiana Academy of Science 97: 497–508.

27. Guretzky, J. A., Schacht, W., Snell, L., Soper, J., Moore, S., Watson, A., & Klopfenstein, T., 2013. Nitrogen input effects on herbage accumulation and presence of pasture plant species. Agronomy Journal 105: 915–921, DOI:10.2134/agronj2012.0458.

28. Gichuki, S. W., & Mason, R. P., 2013. Mercury and metals in South African precipitation. Atmospheric Environment, DOI: 10.1016/j.atmosenv.2013.04.009.

29. Giese, M., Brueck, H., Gao, Y. Z., Lin, S., Steffens, M., Kögel-Knabner, I., ... & Han, X. G., 2013. N balance and cycling of Inner Mongolia typical steppe: A comprehensive case study of grazing effects. Ecological Monographs 83(2): 195–219.

30. Glibert, P. M., Hinkle, D. C., Sturgis, B., & Jesien, R. V., 2013. Eutrophication of a Maryland/Virginia coastal lagoon: A tipping point. Ecosystem Changes, and Potential Causes. Estuaries and Coasts, 1-19, DOI: 10.1007/s12237-013-9630-3.

31. Gustin, M. S., Huang, J., Miller, M. B., Peterson, C., Jaffe, D. A., Ambrose, J., Finley, B.D., Lyman, S.N., Call, K., Talbot, R., Feddersen, D., Mao, H., and Lindberg, S. E., 2013. Do we understand what the mercury speciation instruments are actually measuring? Results of RAMIX. Environmental Science & Technology, dx.doi.org/10.1021/es3039104.

32. Gustin, M., Weiss-Penzias, P. S., & Peterson, C., 2012. Investigating sources of gaseous oxidized mercury in dry deposition at three sites across Florida, USA. Atmospheric Chemistry and Physics 12(19): 9201–9219 (not previously listed).

33. Hale, R. L., Hoover, J. H., Wollheim, W. M., & Vörösmarty, C. J., 2013. History of nutrient inputs to the Northeastern United States, 1930–2000. Global Biogeochemical Cycles, DOI: 10.1002/gbc.20049.

34. Heckel, P. F., Keener, T. C., & LeMasters, G. K., 2013. Background Soil Mercury: An Unrecognized Source of Blood Mercury in Infants? Open Journal of Soil Science 3: 23–29.

35. Houlton, B., Boyer, E., Finzi, A., Galloway, J., Leach, A., Liptzin, D., et al., 2013. Intentional versus unintentional nitrogen use in the United States: Trends, efficiency and implications. Biogeochemistry, DOI: 10.1002/gbc.20049.

36. Inglett, P. W., & Inglett, K. S., 2013. Biogeochemical changes during early development of restored calcareous wetland soils. Geoderma 192: 132–141.

37. Jicha, T. M., Johnson, L. B., Hill, B. H., Regal, R. R., Elonen, C. M., & Pearson, M. S., 2013. Spatial and temporal patterns of nitrification rates in forested floodplain wetland soils of upper Mississippi River Pool 8. River Research and Applications, DOI: 10.1002/rra.2663.

38. Jones, G. B., 2013. Nutrient Dynamics in Cool-Season Pastures (Doctoral dissertation, Virginia Polytechnic Institute and State University).

39. Keimowitz, A. R., Parisio, S., Adams, M. S., Interlichia, K., Halton, C., Kroenke, S., & Hubert, A., 2013. Identification of Ombrotrophic Bogs in the Catskill Mountains, NY by Geochemical and

Isotopic Methods. Wetlands 33: 355–364.

40. Kim, K. I., Kaiser, D. E., & Lamb, J., 2013. Corn response to starter fertilizer and broadcast sulfur evaluated using strip trials. Agronomy Journal 105(2): 401–411.

41. Kos, G., Ryzhkov, A., Dastoor, A., Narayan, J., Steffen, A., Ariya, P. A., & Zhang, L., 2013. Evaluation of discrepancy between measured and modelled oxidized mercury species. Atmos. Chem. Phys. 13: 4839-4863, DOI:10.5194/acp-13-4839-2013.

42. Kranabetter, J., Saunders, S., MacKinnon, J., Klassen, H., & Spittlehouse, D., 2013. An assessment of contemporary and historic nitrogen availability in contrasting coastal douglas-fir forests through δ15N of tree rings. Ecosystems, DOI: 10.1007/s10021-012-9598-z.

43. Lajtha, K., & Jones, J., 2013. Trends in cation, nitrogen, sulfate and hydrogen ion concentrations in precipitation in the United States and Europe from 1978 to 2010: A new look at an old problem. Biogeochemistry, DOI: 10.1007/s10533-013-9860-2.

44. Lamborg, C. H., Engstrom, D. R., Fitzgerald, W. F., & Balcom, P. H., 2013. Apportioning global and non-global components of mercury deposition through 210Pb indexing. Science of the Total Environment 448: 132–140.

45. Lei, H., Liang, X.-Z., Wuebbles, D. J., & Tao, Z., 2013. Model analyses of atmospheric mercury: present air quality and effects of transpacific transport on the United States, Atmos. Chem. Phys. Discuss. 13: 9849-9893, DOI:10.5194/acpd-13-9849-2013.

46. Lessard, C. R., Poulain, A. J., Ridal, J. J., & Blais, J. M., 2013. Steady-state mass balance model for mercury in the St. Lawrence River near Cornwall, Ontario, Canada. Environmental Pollution 174: 229–235.

47. Levengood, J. M., Soucek, D. J., Taylor, C. A., & Gay, D. A., 2013. Mercury in small Illinois fishes: Historical perspectives and current issues. Environmental monitoring and assessment, DOI: 10.1007/s10661-012-3040-z.

48. Liptzin, D., Daley, M. L., & McDowell, W. H., 2013. A comparison of wet deposition collectors at a coastal rural site. Water, Air, & Soil Pollution 224(5): 1–10.

49. Liu, B., Kang, S., Sun, J., Zhang, Y., Xu, R., Wang, Y., ... & Cong, Z., 2013. Wet precipitation chemistry at a high-altitude site (3,326 m asl) in the southeastern Tibetan Plateau. Environmental

Science and Pollution Research, DOI: 10.1007/s11356-012-1379-x.

50. Liu, X. H., & Zhang, Y., 2013. Understanding of the formation mechanisms of ozone and particulate matter at a fine scale over the southeastern U.S.: Process analyses and responses to future-year emissions. Atmospheric Environment 74: 259–276.

51. Lupo, C. D., & Stone, J. J., 2013. Bulk atmospheric mercury fluxes for the Northern Great Plains, USA. Water, Air, & Soil Pollution 224(2): 1–12.

52. Mast, M. A., 2013. Evaluation of stream chemistry trends in U.S. Geological Survey reference watersheds, 1970–2010. Environmental Monitoring and Assessment, DOI: 10.1007/s10661-013-3256-6.

53. Mast, M. A., & Ely, D., 2013. Effect of power plant emission reductions on a nearby wilderness area: A case study in northwestern Colorado. Environmental Monitoring and Assessment, DOI: 10.1007/s10661-013-3086-6.

54. Mattieu, C. A., Furl, C. V., Roberts, T. M., & Friese, M., 2013. Spatial trends and factors affecting mercury bioaccumulation in freshwater fishes of Washington State, USA. Archives of Environmental Contamination and Toxicology, DOI: 10.1007/s00244-013-9882-8.

55. McCrackin, M. L., Harrison, J. A., & Compton, J. E., 2013. A comparison of NEWS and SPARROW models to understand sources of nitrogen delivered to U.S. coastal areas. Biogeochemistry, DOI: 10.1007/s10533-012-9809-x.

56. McMurray, J. A., Roberts, D. W., Fenn, M. E., Geiser, L. H., & Jovan, S., 2013. Using Epiphytic Lichens to Monitor Nitrogen Deposition Near Natural Gas Drilling Operations in the Wind River Range, WY, USA. Water, Air, & Soil Pollution 224(3): 1–14.

57. Mitchell, M. J., Driscoll, C. T., McHale, P. J., Roy, K. M., & Dong, Z., 2013. Lake/watershed sulfur budgets and their response to decreases in atmospheric sulfur deposition: Watershed and climate controls. Hydrological Processes 27: 710–720, DOI: 10.1002/hyp.9670.

58. Mladenov, N., Williams, M. W., Schmidt, S. K., & Cawley, K., 2012. Atmospheric deposition as a source of carbon and nutrients to barren, alpine soils of the Colorado Rocky Mountains. Biogeosciences Discussions 9(3): 2375–2424 (not previously recorded).

59. Myers, T., Atkinson, R. D., Bullock Jr., O. R., & Bash, J. O., 2013. Investigation of effects of varying model inputs on mercury deposition estimates in the Southwest U.S. Atmos. Chem. Phys. 13: 997–

1009.

60. Nair, U. S., Wu, Y., Holmes, C. D., Ter Schure, A., Kallos, G., & Walters, J. T., 2013. Cloud-resolving simulations of mercury scavenging and deposition in thunderstorms. Atmospheric Chemistry & Physics Discussions 13: 3575–3611.

61. Nelson, J. A., Stallings, C. D., Landing, W. M., & Chanton, J., 2013. Biomass transfer subsidizes nitrogen to offshore food webs. Ecosystems, DOI: 10.1007/s10021-013-9672-1.

62. Nippert, J. B., Culbertson, T. S. F., Orozco, G. L. Ocheltree, T. W., & Helliker, B. R., 2013. Identifying the water sources consumed by bison: Implications for large mammalian grazers worldwide. Ecosphere 4(2) article 23, http://dx.doi.org/10.1890/ES12-00359.1.

63. Nimick, D. A., Caldwell, R. R., Skaar, D. R., & Selch, T. M., 2013. Fate of geothermal mercury from Yellowstone National Park in the Madison and Missouri Rivers, USA. Science of the Total Environment 443: 40–54.

64. Olson, J. R., & Hawkins, C. P., 2013. Developing site-specific nutrient criteria from empirical models. Freshwater Science 32(3): 719–740.

65. Park, J., Gall, H. E., Niyogi, D., & Rao, P. S. C., 2013. Temporal trajectories of wet deposition across hydro-climatic regimes: Role of urbanization and regulations at U.S. and East Asia sites. Atmospheric Environment 70: 280–288.

66. Paulot, F., Jacob, D. J., & Henze, D. K., 2013. Sources and processes contributing to nitrogen deposition: An adjoint model analysis applied to biodiversity hotspots worldwide. Environmental Science & Technology 47: 3226−3233.

67. Perakis, S. S., Sinkhorn, E. R., Catricala, C. E., Bullen, T. D., Fitzpatrick, J., Hynicka, J. D., & Cromack Jr., K., 2013. Forest calcium depletion and biotic retention along a soil nitrogen gradient. Ecological Applications, http://dx.doi.org/10.1890/12-2204.1.

68. Perrot, D., Perrot, D. O., Molotch, N. P., Williams, M. W., & Anderson, S. P., 2013. Nitrate export response to spatially distributed snowmelt in alpine catchments (Master's Thesis, University of Colorado).

69. Peters, E. B., Wythers, K. R., Bradford, J. B., & Reich, P. B., 2013. Influence of disturbance on temperate forest productivity. Ecosystems 16(1): 95–110.

70. Poor, N. D., Cross, L. M., & Dennis, R. L., 2013. Lessons learned from the Bay Region Atmospheric Chemistry Experiment (BRACE) and implications for nitrogen management of Tampa Bay. Atmospheric Environment 70: 75–83.

71. Poor, N. D., Pribble, J. R.,& Schwede, D. B., 2013. Application of watershed deposition tool to estimate from CMAQ simulations the atmospheric deposition of nitrogen to Tampa Bay and its watershed. Journal of the Air & Waste Management Association 63(1): 100–114.

72. Porter, E., Bowman, W., Clark, C., Compton, J., Pardo, L., & Soong, J. Interactive effects of anthropogenic nitrogen enrichment and climate change on terrestrial and aquatic biodiversity. Biogeochemistry, DOI: 10.1007/s10533-012-9803-3, 1-28.

73. Povak, N. A., Hessburg, P. F., Reynolds, K. M., Sullivan, T. J., McDonnell, T. C., & Salter, R. B., 2013. Machine learning and hurdle models improve regional predictions of stream water acid neutralizing capacity. Water Resources Research, DOI: 10.1002/wrcr.20308.

74. Price, J. R., Peresolak, K., Brice, R. L., & Tefend, K. S., 2013. Temporal Variability in the Chemical Weathering of Ca2+-Bearing Phases in the Loch Vale Watershed, Colorado, USA: A Mass-Balance Approach. Chemical Geology 342: 151–166.

75. Rao, P., Hutyra, L. R., Raciti, S. M., & Templer, P. H., 2013. Atmospheric nitrogen inputs and losses along an urbanization gradient from Boston to Harvard Forest, MA. Biogeochemistry, DOI: 10.1007/s10533-013-9861-1.

76. Rober, A. R., Wyatt, K. H., Turetsky, M. R., & Stevenson, R. J., 2013. Algal community response to experimental and interannual variation in hydrology in an Alaskan boreal fen. Freshwater Science, 32(1): 1–11.

77. Robichaud, P. R., Lewis, S. A., Wagenbrenner, J. W., Ashmun, L. E., & Brown, R. E., 2013. Post-fire mulching for runoff and erosion mitigation: Part I: Effectiveness at reducing hillslope erosion rates. Catena 105: 75–92.

78. Santhi, C., Kannan, N., White, M., Di Luzio, M., Arnold, J. G., Wang, X., & Williams, J. R., 2013. An integrated modeling approach for estimating the water quality benefits of conservation practices at the river basin scale. Journal of Environmental Quality, DOI:10.2134/jeq2011.0460.

79. Sather, M. E., Mukerjee, S., Smith, L., Mathew, J., Jackson, C., Callison, R., Scrapper, L., Hathcoat, A., Adam, J., Keese, D., Ketcher, P., Brunette, R., Karlstrom, J., & Van der Jagt, G., 2013. Gaseous oxidized mercury dry deposition measurements in the Four Corners area and Eastern Oklahoma,

U.S.A. Atmospheric Pollution Research 4: 168–180.

80. Seo, Y. S., Han, Y. J., Choi, H. D., Holsen, T. M., & Yi, S. M., 2012. Characteristics of total mercury (TM) wet deposition: Scavenging of atmospheric mercury species. Atmospheric Environment 49: 69–76 (not previously reported).

81. Sheu, G.-R., & Lin, N.-H., Characterizations of wet mercury deposition to a remote islet (Pengjiayu) in the subtropical Northwest Pacific Ocean. Atmospheric Environment, DOI: 10.1016/j.atmosenv.2013.05.038.

82. Shim, J. H., Powers H. H., Meyer C. W., & Dawson T. E., 2013. Hydrologic control of the oxygen isotope ratio of ecosystem respiration in a semi-arid woodland. Biogeosciences Discussions 10(108): 1–48.

83. Sorooshian, A., Shingler, T., Harpold, A., Feagles, C. W., Meixner, T., & Brooks, P. D., 2013. Aerosol and precipitation chemistry in the southwestern United States: Spatiotemporal trends and interrelationships. Atmospheric Chemistry and Physics Discussions 13(4): 8615–8662.

84. Skrzypek, G., Paul, D., & Wojtuń, B., 2013. The altitudinal climatic effect on the stable isotope compositions of Agave and Opuntia in arid environments–A case study at the Big Bend National Park, Texas, USA. Journal of Arid Environments 92: 102–112.

85. Sullivan, P. L., Price, R. M., Miralles-Wilhelm, F., Ross, M. S., Scinto, L. J., Dreschel, T. W., et al., 2013. The role of recharge and evapotranspiration as hydraulic drivers of ion concentrations in shallow groundwater on everglades tree islands, Florida (USA). Hydrological Processes, DOI: 10.1002/hyp.9575.

86. Sullivan, P. L., Engel, V., Ross, M. S., & Price, R. M., 2013. The influence of vegetation on the hydrodynamics and geomorphology of a tree island in Everglades National Park (Florida, USA). Ecohydrology, DOI: 10.1002/eco.1394.

87. Tang, R. W., Johnston, T. A., Gunn, J. M., & Bhavsar, S. P., 2013. Temporal changes in mercury concentrations of large-bodied fishes in the boreal shield ecoregion of northern Ontario, Canada. Science of the Total Environment 444: 409–416.

88. Wang, Y., Huang, J., Hopke, P. K., Rattigan, O. V., Chalupa, D. C., Utell, M. J., & Holsen, T. M., 2013. Effect of the shutdown of a large coal-fired power plant on ambient mercury species. Chemosphere 92: 360–367.

89. Wang, S., Holsen, T. M., Huang, J., & Han, Y. J., 2013. Evaluation of various methods to measure particulate bound mercury and associated artifacts. Atmospheric Chemistry and Physics Discussions 13(4): 8585–8614.

90. Wang, F., Mladenoff, D. J., Forrester, J. A., Keough, C., & Parton, W. J., 2013. Global sensitivity analysis of a modified CENTURY model for simulating impacts of harvesting fine woody biomass for bioenergy. Ecological Modelling 259: 16–23.

91. Willey, J. D., Mullaugh, K. M., Kieber, R. J., Avery, G. B., & Mead, R. N., 2013. Controls on the redox potential of rainwater. Environmental Science & Technology, dx.doi.org/10.1021/es302569.

92. Wollheim, W. M., Green, M. B., Pellerin, B. A., Morse, N. B., & Hopkinson, C. S., 2013. Causes and consequences of ecosystem service regionalization in a coastal suburban watershed. Estuaries and Coasts, DOI: 201310.1007/s12237-013-9646-8.

93. Yu, X., Driscoll, C. T., Huang, J., Holsen, T. M., & Blackwell, B. D., 2013. Modeling and Mapping of Atmospheric Mercury Deposition in Adirondack Park, New York. PloS one 8(3): 59322.

94. Zhang, Y., & Jaeglé, L., 2013. Decreases in Mercury Wet Deposition over the United States during 2004–2010: Roles of Domestic and Global Background Emission Reductions. Atmosphere 4(2): 113–131.

95. Zhang, Y., Xiu, G., Wu, X., Moore, C. W., Wang, J., Cai, J., ... & Zhang, R., 2013. Characterization of mercury concentrations in snow and potential sources, Shanghai, China. Science of the Total Environment 449: 434–442.

96. Zhu, L., Henze, D. K., Cady-Pereira, K. E., Shephard, M. W., Luo, M., Pinder, R. W., ... & Jeong, G. R., 2013. Constraining U.S. ammonia emissions using TES remote sensing observations and the GEOS-Chem adjoint model. Journal of Geophysical Research: Atmospheres. 118: 3355–3368, DOI:10.1002/jgrd.50166, 2013.