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ASSISTANCE FOR VISIBILITY DATA ANALYSIS AND IMAGE DISPLAY TECHNIQUES

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1. Overview

The public visits national parks and wilderness areas to enjoy nature in an unimpaired state. Air pollutants can adversely affect that visitor experience by degrading the vistas, affecting the natural ecosystems of these areas, and in some extreme cases, adversely affecting visitor health. The NPS and CSU scientists are working together to better understand the scientific basis of these issues, providing that information to regulatory agencies at both the federal and state level, and interpreting it for the public.

The scattering and absorption of light by particles in the atmosphere affect the clarity of scenic views associated with national parks and wilderness areas. The Interagency Monitoring of Protected Visual Environments (IMPROVE) program routinely collects samples of particles that are analyzed for their chemical composition and optical properties in order to assess their visibility impacts and source origin. Results of these analyses will be shared with regulatory agencies, published in the scientific literature, presented at scientific meetings, and provided with the data through the web to collaborating scientists at other institutions.

Some of the most effective ways to present the impacts of pollutants on scenic vistas is by photographic imaging techniques that accurately depict how the scene will appear under various pollutant and meteorological conditions and through video productions that demonstrate pollutant effects on a scene over time. An image-based depiction of visibility reduction due to pollutants is dependent on a firm understanding of the optical characteristics of pollutants, on state-of-the-art measuring techniques, on the ability to simulate accumulated effects, and on professional quality image and video production techniques. The aforementioned analyses and techniques are the key elements to successfully carrying out this cooperative project.

In addition to unimpeded visibility, healthy ecosystems are critical to the long-term sustainability of our parks and the quality of the visitor experience. Ecosystem changes due to atmospheric deposition of nitrogen compounds have been documented at many locations in the Rocky Mountains. The origins, chemical composition, and temporal changes in the deposition are not well understood. Field measurements are critical to understanding these

changes and for charting a course for needed regulatory and policy actions to reduce nitrogen loadings. During the spring and summer of 2011, the NPS initiated a study with CIRA of nitrogen deposition at Grand Teton National Park. Additional analysis of the measurements continued under this agreement. Also, regional air quality modeling was performed to assess atmospheric nitrogen deposition at potentially affected parks.

Oil and gas development increasingly negatively impacts air quality and visibility in pristine environments across the western United States, but especially in the Bakken Shale region in the northern Great Plains, where development has significantly increased over the last several years. Trend analyses have shown that aerosol composition and visibility degradation has increased in these areas over the last decade. However, very little is known about the emissions and subsequent impacts on visibility, air quality, and deposition. Analysis of existing data, including aerosol composition, visibility, ozone, and deposition, was performed to understand baseline conditions and impacts of the rapid development occurring.

Investigating the causal mechanisms for elevated pollutant levels is a critical component of the activities described here. Eulerian, Lagrangian, and receptor models are used and integrated with measured data for source apportionment studies, and to evaluate the role of meteorology and other physical and chemical processes on measured and modeled concentrations. The results assist in the development of air quality policy positions within the NPS and to inform state and federal agencies in the development of strategies to mitigate air quality issues.

The specifics identified below describe a cooperative effort between the NPS and the CIRA at CSU to analyze, interpret, and make available air quality, deposition, and visibility data and analyses of these data. These data, interpretations, and analyses are available to the scientific community, regulatory agencies, and the public.

2. Major Activities Completed by CIRA/NPS

2.1 Aerosol Research

This activity supports basic scientific research into understanding the role of aerosols in visibility degradation, as well as the reporting of the status, trends, and causes of visibility in the parks. This information is necessary to meet the goals of returning visibility in class I areas to natural conditions.

Visibility, often characterized by light extinction coefficients (b_{ext}), depends strongly on aerosol composition (among other properties). Therefore, understanding the spatial and temporal trends of major aerosol species is critical to characterizing visibility in the parks. Spatial and seasonal analyses of IMPROVE data aid in identifying regions, seasons, and the species associated with significant visibility degradation. Integrating EPA's urban Chemical Speciation Network (CSN) and IMPROVE data extends the spatial analysis and provides for an examination of urban impacts on remote and rural regions across the country, thereby informing as to sources of haze in the parks.

Trend analyses quantify changes in major aerosol species and haze over time and support

studies designed to examine the impacts of emission mitigation strategies. Trend analyses have revealed significant widespread improvements in air quality at many national parks, especially in the East, but they also have revealed that visibility is worsening at specific parks during certain seasons (e.g., Bakken Shale region in winter). The use of visual perception software to simulate images corresponding to measured visibility conditions in national parks provides a view of early and current conditions and is a powerful method for communicating improvements in visibility to the public.

The impacts of meteorology and climate change on air quality in the parks can be significant. Understanding these connections requires additional tools, such as back trajectory analyses and regional and global modeling. Many publications have resulted from the incorporation of IMPROVE data in model evaluations and aerosol transport studies, with several that specifically focused on issues related to natural background concentrations and the impacts of intercontinental transport to remote and rural areas in the United States, in the context of the Regional Haze Rule. In addition, providing IMPROVE nephelometry data for remote aerosol trend studies across the globe increases our understanding of changes in the optical properties of remote aerosols as well as expands the usefulness of IMPROVE data to the wider scientific community. Peer-reviewed publications, conference presentations, and IMPROVE and ARD websites are the main avenues for disseminating the data and results of this work to the wider scientific and public communities.

Accomplishments for this task period include the following:

1. Continued research into aerosol source apportionment techniques, which include trajectory mass balance, source contribution functions, conditional probabilities, and empirical orthogonal functions, to assess the appropriateness of using these techniques for pollutants such as ozone and smoke. Continued to develop and use receptor models to determine transport pathways and estimate the proportion of a measured pollutant that can be attributed to each of several sources [Schichtel et al., 2012; Malm et al., 2013].
2. Continued to work on quantifying urban excess in aerosol concentrations using data from IMPROVE and EPA's CSN. Analyses were updated for the 2007–2010 time period.
3. Continued the investigation of speciated aerosol trends and gaseous pollutant emission trends using IMPROVE, CSN, and National Emissions Inventory (NEI) data [Hand et al., 2012a,b; 2013].
4. Continued work in understanding the spatial and seasonal variability in urban and rural aerosols using data from IMPROVE and CSN [Hand et al., 2012c; Hand et al., 2013].
5. Continued investigating California's impact on the visibility at Grand Canyon since 1980.
6. Continued work to understand contributions to haze from volcanic emissions at Hawaii and Haleakala national parks.
7. Continued to investigate new visibility metrics.
8. Continued development of a hybrid-receptor model for estimating source contributions to carbonaceous aerosols in class I areas [Schichtel et al., 2012].

9. Contributed to a review of literature and data relating fine particulate matter concentrations from biomass burning to visibility impairment. The primary goal was to better understand the errors and limitation of using human visual range measurements to estimate fine particulate matter concentrations and potential violation of health standards. This work was part of a larger review for the Forest Service and funded through the JFSP.
10. Research results from many of these tasks were presented at national conferences and meetings (see Deliverables).

2.2 Investigations into Nitrogen Deposition

Atmospheric nitrogen and sulfur species can cause a number of deleterious effects in the environment, including visibility impairment and changes in ecosystem function. Increased nitrogen deposition in high alpine regions of the Rocky Mountains of the western United States is adversely influencing ecosystems in those areas. Input of nitrogen to these sensitive ecosystems perhaps has already reached critical levels beyond which the damage is irreversible.

To investigate the sources of nitrogen in the atmosphere, measurements of nitrogen composition and deposition have been performed during two field campaigns: RoMANS II in Rocky Mountain National Park (2009) and GrandTrends in Grand Tetons National Park (2011). During both studies several monitoring sites were operated to measure reduced and oxidized nitrogen concentrations and their contributions to the nitrogen deposition budget (both wet and dry). From these data the spatio-temporal patterns of nitrogen deposition were inferred across the regions. In addition, these studies evaluated the suitability of routine monitoring networks for assessing total nitrogen deposition. Results indicate that up to half of the nitrogen deposition was not being measured, specifically, contributions from dry ammonia and organic nitrogen. These studies have led to the development of methods for measuring these compounds in a routine monitoring program.

While monitoring studies are necessary for understanding the nitrogen deposition budget, observational data alone are unable to directly inform as to the contribution of a source or source region due to the complexities of the physicochemical processes and the meteorological patterns that govern the fate of nitrogen species. Air quality models are capable of simulating the atmospheric physicochemical processes and are used to understand source contributions. Performing regional air quality modeling requires meteorological fields, emission inventories, and boundary conditions. In addition to modeling, statistical inference techniques based on physical principles are used. Both are used as a part of this activity to identify the likely source regions that contribute significantly to deposition at national parks in the Rocky Mountains. The tasks defined as a part of this activity aid the NPS in understanding nitrogen sources and their relative impacts on air quality and assist in identifying needed regulatory and policy actions specifically related to deposition.

RoMANS

1. Completed an analysis to understand the spatial and temporal variability in ammonia and other inorganic aerosol species around the Front Range in Colorado [Day et al., 2012].

2. Performed source apportionment studies to understand sources of ammonia to Rocky Mountain National Park (RMNP) using modeled conservative tracer releases [Malm et al., 2013].

3. Continued work to understand the spatial and temporal sensitivities in results of back-trajectory-based receptor models during RoMANS II.

4. Continued to apply process analysis to areas within and outside of RMNP using both tools built into the Comprehensive Air Quality Model with extensions (CAMx) model and post-processing tools. These tools are being used to calculate the relative contributions of individual model processes (e.g., advection, chemistry, deposition) in order to investigate the discrepancy between measured and modeled ambient concentrations of ammonia.

5. Analyzed future nitrogen deposition (2018) at RMNP for the 2012 Interim Milestone Report of the RMNP Nitrogen Deposition Reduction Plan. Future nitrogen deposition estimates were based on CAMx simulations and an updated emission inventory that reflected a 41% reduction in NO_x emissions within Colorado.

6. Research results from many of these tasks were presented at national conferences and meetings (see Deliverables).

GrandTrends

1. Analyzed measurements of reactive nitrogen in Grand Tetons.

2.3 Impacts of Oil and Gas Development in the Bakken Shale Region

The significant oil and gas development in the western United States, such as the Bakken Shale region in the northern Great Plains, is a significant new source of air pollutants that has negatively impacted air quality and visibility at parks in the region. In order to fully understand the scope of the problem, intensive monitoring of air quality needs to be performed. In addition, analysis of existing data, including aerosol composition, visibility, ozone, and deposition will be performed to understand baseline conditions and impacts of the rapid development occurring. Results from this work can help inform the development of meaningful policy and regulations to minimize the negative impacts of the oil and gas development.

1. Participated in the organization and execution of the Bakken Pilot Field Study

that was led by Jeff Collet and Sonia Kreidenweis from the CSU department of Atmospheric Science. The study took place from February through April 2013 at five sites in the region (Theodore Roosevelt National Park, north and south units, Knife River, Fort Union Trading Post, and Medicine Lake). Measurements at the main sampling site (THRO-N) included real-time gases, nephelometer, aethalometer, spot-sampler, IMPROVE channel A, URG sampler, passive samplers (NO_2, NH_3, O_3, VOC), meteorological parameters, and wet deposition. Measurements at THRO-S included primary air quality monitoring for the park, such as IMPROVE, Clean Air Status and Trends Network (CASTnet), National Atmospheric Deposition Program (NADP), and additional passive samplers. At Knife River nephelometer, ozone, URG, passive, and wet deposition measurements were made. Measurements at Fort Union included a URG sampler, ozone, meteorological parameters, passive samplers, and wet deposition. Medicine Lake sampling included a URG sampler, ozone, passive samplers, and wet deposition. We continued to analyze data from the study.

2. Continued to analyze all available gaseous, particulate, and deposition data from routine monitors at the above and nearby sites since 2000 to better understand seasonal and spatial baseline concentrations in the region.

2.4 Data, Dissemination, and Analysis Tools

This activity includes the development and maintenance of the infrastructure needed to perform regional air quality simulations and analyze, display, and disseminate large data sets and analyses.

1. Continued implementation and development of the IMPROVE website, including developing an interactive database allowing users to download data and selected analyses of these data. This includes appropriate quality assurance information, a display of current IMPROVE graphics, up to date information about the visibility regulations, and a growing bibliographic reference site for visibility and IMPROVE scientific information (http://vista.cira.colostate.edu/improve).

2. Continued to provide graphics support, graphs, posters, etc., to NPS researchers in the NPS Air Resources Division and CIRA.

3. Completed multimedia outreach materials for understanding and communicating climate change in national parks to the general public, including an interactive interpretative display for the Edwin B. Forsythe National Wildlife Refuge Visitor Center.

4. Continued work in Interactive Air Quality Exhibits, including “Air quality effects in Acadia National Park” at the Sieur de Monts complex.

3.0 Project Deliverables

Deliverables for this project include conference presentations and publications (see reference list).

PUBLICATIONS

Aerosol Research

1. Buchholz, B. A., S. J. Fallon, P. Zermeno, G. Bench and **B. A. Schichtel**, Anomalous elevated radiocarbon measurements of PM2.5, Nuclear Instruments & Methods in Physics Research Section B-Beam Interactions with Materials and Atoms, 294, 631-635, 2013.
2. Chand, D., R. Wood, S. J. Ghan, M. H. Wang, M. Ovchinnikov, P. J. Rasch, S. Miller, **B. A. Schichtel** and T. Moore, Aerosol optical depth increase in partly cloudy conditions, Journal of Geophysical Research-Atmospheres, doi:11710.1029/2012JD017894, 2012.
3. Chen, L. W. A., J. C. Chow, J. G. Watson, **B. A. Schichtel**, Consistency of long-term elemental carbon trends from thermal and optical measurements in the IMPROVE network, Atmospheric Measurement Techniques, 5(10), 2329-2338, 2012.
4. Collaud Coen, M., E. Andrews, A. Asmi, U. Baltensperger, N. Bukowiecki, **D. E. Day**, M. Fiebig, A. M. Fjaeraa, H. Flentje, A. Hyvärinen, A. Jefferson, S. G. Jennings, G. Kouvarakis, H. Lihavainen, C. Lund Myhre, **W. C. Malm**, N. Mihapopoulos, J. V. Molenar, C. O'Dowd, J. A. Ogren, **B. A. Schichtel**, P. Sheridan, A. Virkkula, E. Weingartner, R. Weller and P. Laj, Aerosol decadal trends - Part 1: In-situ optical measurements at GAW and IMPROVE stations, Atmospheric Chemistry and Physics, 13, 869-894, 2013.
5. **Hand, J. L., K. A. Gebhart, B. A. Schichtel and W. C. Malm**, Increasing trends in wintertime particulate sulfate and nitrate ion concentrations in the Great Plains of the United States (2000-2010), Atmospheric Environment, 55, 107-110, 2012a.
6. **Hand, J. L., B. A. Schichtel, W. C. Malm** and M. L. Pitchford, Particulate sulfate ion concentration and SO2 emission trends in the United States through 2010, Atmospheric Chemistry & Physics, 12, 10353-10365, doi:10.5194/acp-12-10353-2012, 2012b.
7. **Hand, J. L., B. A. Schichtel**, M. L. Pitchford, **W. C. Malm** and N. H. Frank, Seasonal composition of remote and urban fine particulate matter in the United States, Journal of Geophysical Research, 117D05209, doi:10.1029/2011JD017122, 2012c.
8. **Hand, J. L., B. A. Schichtel, W. C. Malm** and N. H. Frank, Spatial and temporal trends in PM2.5 organic and elemental carbon across the United States, Advances in Meteorology, Special Issue on Carbonaceous Particles in the Atmosphere: Experimental and Modeling Issues, accepted 2013.
9. **Schichtel, B. A., M. A. Rodriguez, M. G. Barna, K. A. Gebhart**, M. L. Pitchford and **W. C. Malm**, A semi-empirical, receptor-oriented Lagrangian model for simulating fine particulate carbon at rural sites, Atmospheric

Environment, 61, 361-370, 2012.

10. White, W. H., R. J. Farber, **W. C. Malm**, M. Nuttal, M. L. Pitchford and **B. A. Schichtel**, Comments on "Effect of coal-fired power generation on visibility at a nearby national park" by J. Terhorst and M. Berkman, Atmospheric Environment, 55, 173-178, doi:10.1016/j.atmosenv.2012.02.076, 2012.
11. Zhao, C., L. R. Leung, R. C. Easter, **J. L. Hand** and J. Avise, Characterization of speciated aerosol direct radiative forcing over California, Journal of Geophysical Research, 118, 2372-2388, doi:10.1029/2012JD018364, 2013.

Investigations into Nitrogen Deposition

RoMANS

1. Benedict, K. B., C. M. Carrico, S. M. Kreidenweis, **B. A. Schichtel, W. C. Malm** and J. L. Collett, Jr., A seasonal nitrogen deposition budget for Rocky Mountain National Park, Ecological Applications, 23(5), 1156-1169, 2013.
2. Benedict, K. B., **D. E. Day**, F. M. Schwandner, S. M. Kreidenweis, **B. A. Schichtel**, **W. C. Malm** and J. L. Collett, Jr., Observations of atmospheric reactive nitrogen species in Rocky Mountain National Park and across northern Colorado, Atmospheric Environment, 64, 66-76, 2013.
3. **Day, D. E**., X. Chen, **K. A. Gebhart**, C. M. Carrico, F. M. Schwandner, K. B. Benedict**, B. A. Schichtel** and J. L. Collett, Jr., Spatial and temporal variability of ammonia and other inorganic aerosol species, Atmospheric Environment, 61, 490-498, 2012.
4. Ellis, R. A., D. J. Jacob, M. Payer, L. Zhang, C. D. Holmes, **B. A. Schichtel**, T. Blett, E. Porter, L. H. Pardo, and J. A. Lynch, Present and future nitrogen deposition to national parks in the United States: critical load exceedances, Atmospheric Chemistry and Physics Discussion, 13, 9151-9178, doi:10.5194/acpd-13-9151-2013, 2013.
5. **Malm, W. C., B. A. Schichtel, M. G. Barna, K. A. Gebhart, M. A. Rodriguez**, J. L. Collett, Jr., C. M. Carrico, K. B. Benedict, A. J. Prenni and S. M. Kreidenweis, Aerosol species concentrations and source apportionment of ammonia at Rocky Mountain National Park, Journal of the Air & Waste Management Association, doi:10.1080/10962247.2013.804466, 2013.

PRESENTATIONS

Aerosol Research

1. Brewer, P., J. D. Ray and **K. A. Gebhart**, Volcanic contributions to haze at Hawaii Volcanoes and Haleakala National Parks, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
2. Brewer, P., T. Moore, **J. Hand**, and **S. Copeland**, Regional haze regulatory policy and progress assessment 2000-2010, Proceedings of the Air & Waste

Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.

3. Collett, J. L., Jr., Y. Desyaterik, A. P. Sullivan, C. J. Hennigan, A. L. Robinson, A. S. Holden, S. M. Kreidenweis and **B. A. Schichtel**, Aging of biomass burning aerosols: comparison of smog chamber experiments with ambient aerosols, presented at the American Association for Aerosol Research 31st Annual Conference, Minneapolis, October, 2012.
4. **Copeland, S. A**. and C. T. Moore, Jr., Comparative analysis of 2005-2009 "1st Progress Period" and 2000-2004 "Baseline" Regional Haze Rule metrics, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
5. Farber, R. J., **K. A. Gebhart, J. L. Hand**, J. Monroe and B. M. Kim, California's impact on Grand Canyon visibility since 1980, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
6. **Hand, J. L., B. A. Schichtel**, W. H. White and **W. C. Malm**, PM2.5 light absorbing carbon concentrations and filter-based light absorption measurements from major monitoring networks in the United States, presented at the 11th AeroCom workshop, Seattle, September 10-13, 2012.
7. **Hand, J. L., B. A. Schichtel, W. C. Malm**, M. L. Pitchford and N. Frank, Estimates of urban excess in $PM_{2.5}$ speciated aerosol concentrations using the CSN and IMPROVE networks, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
8. **Hand, J. L., B. A. Schichtel, W. C. Malm** and M. L. Pitchford, Temporal trends in urban and rural particulate sulfate ion concentrations across the United States, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
9. **Hand, J. L., B. A. Schichtel, W. C. Malm** and M. L. Pitchford, Visualization of visibility conditions associated with temporal trends in light extinction coefficients for remote and rural aerosols simulated using WinHaze, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
10. **Hand, J. L., B. A. Schichtel, W. C. Malm** and M. L. Pitchford, Twenty years of IMPROVE data: What we have learned and future issues, presented to the National Park Service- Air Resources Division, Lakewood, Colorado, October 17, 2012.
11. **Hand, J. L., B. A. Schichtel, W. C. Malm**, M. L. Pitchford and N. H. Frank, IMPROVE trends, presented at the IMPROVE (Interagency Monitoring of Protected Visual Environments) annual steering committee meeting, Lake Tahoe, California, October 23-24, 2012.

12. **Hand, J. L., B. A. Schichtel, W. C. Malm** and M. L. Pitchford, Widespread reductions in sulfate across the United States since the early 1900s, presented at the 19th International Conference on Nucleation and Atmospheric Aerosols, Fort Collins, Colorado, June 24-28, 2013.
13. **Hand, J. L., B. A. Schichtel, W. C. Malm**, M. L. Pitchford and N. H. Frank, Urban excess estimates in $PM_{2.5}$ speciated aerosol concentrations using the CSN and IMPROVE networks, presented at the 106th Air & Waste Management Annual Conference, June 25-28, 2013.
14. Liu, Y., L. Shenshen, J. Szykman and **B. A. Schichtel**, Satellite-observed trend in particle sulfate concentrations in the continental U.S. and its surrounding regions, presented at American Geophysical Union, San Francisco December 9-13, 2012.
15. **Malm, W. C**. and M. L. Pitchford, A review of old visibility metrics and a proposal of a new metric, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
16. Ogren, J. A., P. Sheridan, M. Collaud Coen, A. Asmi, P. Aalto, M. Kulmala, A. Virkkula, E. Andrews, A. Jefferson, E. Asmi, A. Hyvärinen, N. Kiveäs, H. Lihavainen, U. Baltensperger, N. Bukowiecki, E. Weingartner, W. Birmili, A. H. Wiedensohler, A. Hamed, **D. E. Day**, M. Fiebig, A. M. Fjaeraa, C. Lund Myhre, H. Flentje, A. G. Hallar, S. G. Jennings, C. O'Dowd, G. Kouvarakis, N. Mihapopoulos, J. Molenar, **B. A. Schichtel** and R. Weller, Aerosol decadal trends: In-situ measurements of number concentration and optical properties, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
17. **Schichtel, B. A., J. L. Hand, W. C. Malm**, M. L. Pitchford, W. H. White, C. E. McDade, **S. A. Copeland**, J. Vimont, N. H. Frank and J. Rice, PM2.5 composition in the United States and some interesting patterns, presented at the Abdulaziz City for Science and Technology conference, Riyadh, Saudi Arabia, May 13-14, 2012.
18. **Schichtel, B. A., M. A. Rodriguez, M. G. Barna, K. A. Gebhart**, L. A. Patterson, J. L. Collett, Jr. and **W. C. Malm**, Contributions of biomass burning and other sources to fine particulate carbon at rural locations throughout the United States, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
19. **Schichtel, B. A**. and J. Vimont, Panel Discussion: Routine speciated particulate monitoring in 2025: promise and problems of advanced particulate monitoring and analysis methods, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
20. **Schichtel, B. A., J. L. Hand, W. C. Malm**, M. Pitchford, W. White, C. McDade, **S. A. Copeland**, J. Vimont, N. Frank, and J. Rice, PM2.5 composition in the Unites States and some interesting patterns, presented to

Department of Physics and Atmospheric Science, Dalhousie University, Halifax, Nova Scotia, October, 2012.

21. **Schichtel, B. A., J. L. Hand**, W. C. Malm, M. Pitchford, Spatial and temporal speciated aerosol patterns to challenge global/regional chemical transport models, presented at the 6th International GEOS-Chem Meeting, Harvard University, Cambridge, May 6-9, 2013.
22. Sturtz, T. M., T. V. Larson and **B. A. Schichtel**, Source apportionment of primary and secondary fine particles: A hybrid model, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
23. Zhao, C., L. R. Leung, R. Easter, **J.L. Hand**, and J. Avise, Characterization of speciated aerosol radiative forcing over California, 13th Annual WRF Users' Workshop, Boulder, June 26-29, 2012.

Investigations into Nitrogen Deposition

RoMANS

1. **Barna, M. G., M. A. Rodriguez, K. A. Gebhart, B. A. Schichtel, W. C. Malm**, Modeled ammonia nitrogen deposition source apportionment at Rocky Mountain National Park for RoMANS2, CMAS annual meeting, UNC-Chapel Hill, October 15-17, 2012.
2. Benedict, K. B**., D. E. Day**, F. M. Schwandner, S. M. Kreidenweis, **B. A. Schichtel**, **W. C. Malm** and J. L. Collett, Jr., Transport and deposition of reactive nitrogen in Rocky Mountain National Park, presented at the Rocky Mountain National Park Research Conference, Estes Park, Colorado, March 28-29, 2012.
3. Benedict, K. B., **D. E. Day**, F. M. Schwandner, S. M. Kreidenweis, **B. A. Schichtel**, **W. C. Malm** and J. L. Collett, Jr., Transport and deposition of reactive nitrogen in Rocky Mountain National Park, presented at the American Meteorological Society First Conference on Atmospheric Biogeosciences, Boston, May 29 to June 1, 2012.
4. Benedict, K. B., Y. Desyaterik, S. M. Kreidenweis, **B. A. Schichtel** and J. L. Collett, Jr., Organic nitrogen concentrations and species in aerosol and precipitation samples from the Rocky Mountains, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
5. **Gebhart, K. A., M. G. Barna and M. A. Rodriguez**, A WRF application to support nitrogen deposition modeling for Rocky Mountain National Park, presented at the 11th Ad-Hoc Meteorological Modeling Group Meeting, Boulder, June 28-29, 2012.
6. **Gebhart, K. A., B. A. Schichtel, W. C. Malm, M. A. Rodriguez, M. G. Barna**, K. B. Benedict and J. L. Collett, Jr., Spatial and temporal sensitivities in results of back-trajectory-based receptor models as applies to the Rocky Mountain Atmospheric Nitrogen and Sulfur Study Part II (RoMANS II),

Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.

7. **Malm, W. C., B. A. Schichtel, M. G. Barna, K. A. Gebhart, M. A. Rodriguez**, J. L. Collett, Jr., C. M. Carrico, K. B. Benedict and A. J. Prenni, Source apportionment of ammonia at Rocky Mountain National Park using modeled conservative tracer releases, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
8. **Rodriguez, M. A., M. G. Barna, K. A. Gebhart, J. L. Hand, D. E. Day, B. A. Schichtel**, K. B. Benedict, J. L. Collett, Jr. and **W. C. Malm**, Modeling the fate of atmospheric reduced nitrogen in the western U.S. during the Rocky Mountain Atmospheric Nitrogen and Sulfur study (RoMANS II), Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
9. **Schichtel, B. A**., et al., Rocky Mountain Atmospheric Nitrogen and Sulfur Study (ROMANS), presented at the 2012 Agriculture Air Quality Symposium, Fort Morgan and Lamar, Colorado, February 16 -17, 2012.
10. **Schichtel, B. A**., K. B. Benedict, A. J. Prenni, **M. G. Barna, K. A. Gebhart, M. A. Rodriguez, D. E. Day**, E. J. T. Levin, C. M. Carrico, **W. C. Malm**, J. L. Collett, Jr. and S. M. Kreidenweis, Reactive nitrogen composition and origin in the United States Rocky Mountains, presented at the American Chemical Society National Meeting, Philadelphia, August 19-23, 2012.
11. **Schichtel, B. A**., et al., Reactive nitrogen composition and origin in the Rocky Mountains, presented to the Committee on Environment Natural Resources and Sustainability (CENRS) -- Air Quality Research Subcommittee Meeting, Washington D.C., June 21, 2013.

GrandTReNDS

1. Collett, J. L., Jr., K. B. Benedict, T. Prenni, Y. Li, E. J. T. Levin, **D. E. Day**, T. Lee, Y. Desyaterik, M. Schurman, X. Chen, S. M. Kreidenweis, **W. C. Malm** and **B. A. Schichtel**, Initial findings from Grand TReNDS: The Grand Teton reactive nitrogen deposition study, presented at the National Atmospheric Deposition Program Annual Meeting, Portland, Maine, October 3-4, 2012.
2. Collett, J. L., K. B. Benedict, A. J. Penni, **D. E. Day**, Y. Li, E. J. T. Levin, A. P. Sullivan, M. I. Schurman, T. Lee, Y. Desyaterik, S. M. Kreidenweis, **B. A. Schichtel**, GrandTReNDS: the Grand Teton reactive nitrogen deposition study, presented at American Geophysical Union, San Francisco, December 9-13, 2012.
3. **Day, D. E., B. A. Schichtel**, K. B. Benedict, A. J. Prenni, E. J. T. Levin, A. P. Sullivan, Y. Li, X. Chen, T. Lee, Y. Desyaterik, M. Schurman, **W. C. Malm**, S. M. Kreidenweis and J. L. Collett, Jr., Nitrogen deposition in the Grand Tetons: A spatial and historical perspective, Proceedings of the Air & Waste

Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.

4. Prenni, A. J., K. B. Benedict, E. J. T. Levin, A. P. Sullivan, Y. Li, X. Chen, T. Lee, Y. Desyaterik, M. Schurman, S. M. Kreidenweis, J. L. Collett, Jr., **D. E. Day**, **B. A. Schichtel and W. C. Malm**, Measurements of reactive nitrogen in Grand Teton National Park, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
5. **Schichtel, B. A.**, K. B. Benedict, E. J. T. Levin, **D. Day**, A. P. Sullivan, Y. Li, X. Chen, T. Lee, Y. Desyaterik, M. Schurman, S. M. Kreidenweis, J. L. Collett Jr. , **T. Thomson, M. Barna, K. Gebhart, W. C. Malm**, E. Porter, T. Blett, and S. O'Ney, Grand Tetons reactive nitrogen deposition study (GrandTReNDS), presentation to Wyoming Department of Environmental Quality on nitrogen deposition issues in the greater Yellowstone area April 30, 2013.

Other

1. **Barna, M. G**., Chemical transport modeling of nitrogen deposition and ozone in the western U.S.: A national park perspective, Distinguished Speakers Series seminar, presented at Washington State University, April 6, 2012.
2. **Barna, M. G**., Modeling the response of western regional ozone to changes in NOx and VOC emissions using CAMx's "direct decoupled method", presented to the Federal Land Managers Air Quality Task Force, Lakewood, Colorado, September 18, 2012.
3. **Barna, M. G., M. A. Rodriguez, K. A. Gebhart, B. A. Schichtel, W. C. Malm**, Chemical transport modeling of nitrogen deposition in the western U.S.: A national park perspective, NADP annual meeting, Portland, Maine, October 2-5, 2012.
4. **Barna, M. G.,** Applying CAMx to simulate nitrogen deposition and ozone impacts from a western Colorado EGU, 2013 Western Air Quality Modeling Workshop, Boulder, July 8-11, 2013.
5. Blett, T. and **B. A. Schichtel**, Nitrogen research contributions to critical loads science and policy, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
6. Chen, X., D. E. Day, **B. A. Schichtel**, W. C. Malm, J. Mojica, C. E. McDade, E. Hardison, S. M. Kreidenweis and J. L. Collett, Jr., A pilot monitoring study of atmospheric NHx at selected IMPROVE sites, Proceedings of the Air & Waste Management Association specialty conference, Aerosol and Atmospheric Optics: Visibility and Air Pollution, Whitefish, Montana, September 24-28, 2012.
7. Desyaterik, Y., Y. Sun, K. B. Benedict, J. L. Collett, Jr. and **B. A. Schichtel**, Organic nitrogen speciation in aerosols, precipitation, and cloudwater, presented at the American Chemical Society National Meeting, Philadelphia, August 19-23, 2012.

8. Prenni, J., X. Chen, A. Hecobian, S. M. Kreidenweis, J. L. Collett, Jr., **and B. A. Schichtel**, Measurements of gas phase reactive nitrogen during two wildfires in Colorado, presented at American Geophysical Union, San Francisco, December 9-13, 2012.
9. **Schichtel, B. A.**, K. B. Benedict, C. M. Carrico, A. J. Prenni, E. J. T. Levin, **D. E. Day**, X. Chen, J. Ray, **W. C. Malm, K. A. Gebhart, M. G. Barna**, J. L. Collett, Jr. and S. M. Kreidenweis, Measuring total reactive N and its composition, presented at the National Atmospheric Deposition Program Annual Meeting, Portland, Oregon, April 23, 2012.

PRESS RELEASE

1. **Hand J. L., B. A. Schichtel, W. C. Malm**, Progress in reducing air pollution at national parks: scientists at Colorado State University demonstrate significant improvements in U.S. visibility, CIRA-Colorado State University press release, March 11, 2013.