

Final Report for Task #J2350086188 (September 5, 2008, to February 28, 2010)

Assistance for Visibility Data Analysis and Image Display Technique

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1. Introduction and Overview

The public visits national parks and wilderness areas to enjoy nature in an unblemished setting. Air pollutants can adversely affect that visitor experience by degrading the vistas they come to see and by affecting the natural ecosystems of these areas. The National Park Service (NPS) and Colorado State University (CSU) scientists are working together to better understand the scientific basis of these issues and to make that information available to regulatory agencies and interpret it for the public.

Particles and gases in the atmosphere scatter and absorb light, affecting the view one has of a scene. This project analyzes particle data collected through the Interagency Monitoring of Protected Visual Environments (IMPROVE) program to determine its origins and electro-optical properties and better understand its chemical makeup. These analyses are published in the scientific literature, presented at scientific meetings, and made available with the data through the world-wide-web. The electro-optical properties of aerosols ultimately affect how the particles impair visibility. However, it is difficult for the public to visually interpret the meaning of changes in electro-optical variables used to quantify changes in scene appearance under different atmospheric particulate loading conditions. The most effective ways to present the effects of pollutants on scenic vistas are by photographic imaging techniques that accurately depict how the scene will appear under various illuminations and meteorological and pollutant conditions, through video productions that demonstrate pollutant effects on a scene over time and by regional air quality simulation modeling. An image-based depiction of visibility reduction due to pollutants is dependent on a firm understanding of the electro-optical characteristics of pollutants, on state-of-the-art measuring techniques, on a valid understanding of how chemicals are transformed as they travel through the atmosphere, 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 of successfully carrying out this cooperative project.

Healthy ecosystems are critical to having a natural, unblemished visitor experience. Ecosystem changes due to atmospheric deposition of nitrogen compounds have been documented at Rocky Mountain National Park. The origins, chemical makeup, and temporal scales of changes in the deposition are not well understood. Field measurements were made in the spring and summer of 2006 (RoMANS I) and for 2009 (RoMANS II) to provide data to enhance our understanding. This project analyzes some of these data and

utilizes four-dimensional chemical transport models to assess atmospheric nitrogen deposition at the park.

2. Major Activities Completed by CIRA/NPS

Aerosol Research

We continued work on the apportionment of light extinction among chemical species, using statistical and deterministic methods. We investigated the roles of particle composition, size distribution, and relative humidity on the optical effects of aerosols. When appropriate, we applied new models derived from special studies that reflect the latest state of the science in air pollution and visibility. We also continued to identify reasons for differences between reconstructed and measured fine particle mass and between reconstructed and measured and light extinction. Understanding these differences is necessary for the accurate prediction of visibility degradation. We also continued research on organic carbon aerosols, including their measurement, characterization, and source attribution.

We 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 organic and elemental carbon. We also continue 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.

We continued research into understanding biases in fine particle speciation measurements using statistical methods.

We collaborated in the calibration and development of visibility monitoring equipment (e.g., transmissometers and nephelometers) at the CSU optical monitor test facility.

IMPROVE Program

We continued the QA/QC and data management activities for the Interagency Monitoring of Protected Visual Environments (IMPROVE) program and its vast data resources continue to be a significant effort. Accomplishments this task period include the following:

- Data through December 2008 data were received and ingested into the VIEWS (Visibility Information Exchange Web System)/IMPROVE database. January through March 2009 data were made available as preliminary data via the IMPROVE and VIEWS query wizard.
- AQS and the Regional Haze Rule (RHR) datasets (1988-2008) were updated in the VIEWS database.
- A new version of the VIEWS website was launched.

- A data advisory regarding the under-prediction of chloride concentrations was posted on the IMPROVE website.
- Work is continuing on aspects of applying the new IMPROVE equation to the RHR.
- Presentations were made at the IMPROVE steering committee meeting in Wind Cave, South Dakota.
- Work was continued on the integration of IMPROVE and CSN (Chemical Speciation Network) network-wide data. These analysis are being prepared for inclusion in the next IMPROVE report.

Investigations of Smoke Aerosols

We continued analyses of data collected during special monitoring studies at the USDA Forest Service Missoula Fire Laboratory (FLAME I and II studies), designed to understand and improve the monitoring of smoke from forest wildfire, especially its physical and optical properties and particularly the hygroscopicity of smoke aerosols. Specifically, we are investigating $f(RH)$ measurements, chemical composition, and single particle morphology measurements from various forest fire fuels. Results from these analyses were submitted to Atmospheric Chemistry and Physics [Hand et al., 2010; Carrico et al., 2010].

We continued work to fingerprint smoke from forest wildfire and prescribed fire on aerosol filters, developing better emissions information about these types of fire. In addition, models will be used to investigate the impacts of smoke on regional haze levels.

Rocky Mountain Atmospheric Nitrogen and Sulfur Study (ROMANS)

The objective of the 2006 (RoMANS I) and 2009 (RoMANS II) study is to determine the fate and origin of nitrogen and sulfur species in Rocky Mountain National Park, specifically, to develop and refine emission estimates of ammonia, nitrogen oxides, and sulfur oxides and determine the relative contribution of long-range transport versus local emissions to ambient and deposited ammonium, nitrates, and sulfates levels in Rocky Mountain National Park. This is planned to be accomplished by apportioning the relative contribution of these species between mobile and stationary sources such as power plants, other industrial activity, feedlots, and fertilizer applications.

Continued data and model analyses from the 2006 and 2009 field campaign included

- Continued testing of filter-based method for sampling and monitoring of organic nitrogen containing aerosols.
- Continued testing of a modified, commercially available NO_x instrument.
- Continuation of laboratory analysis of filter, denuder, and precipitation samples from the 2009 field study.

- Continued analysis of real-time gas and particle data collected during RoMANS II study.
- Maintenance and operation of several measurement sites for the ROMANS II study.
- Continued analysis of data from NH₃ measurement study, comparing individual species to establish data consistency between samplers and between modified sampling system, and summarizing in a final report.
- Continued analyses of the model output from the CAMx regional air quality model used to simulate concentrations during the RoMANS field campaigns. Specifically, process analyses were performed to understand the model performance during RoMANS and results are being summarized in a manuscript in progress.
- Continued comparisons of model performance between the regional air quality models CAMx and CMAQ. CMAQ was run at the University of North Carolina as a part of a different project.
- Continued performing CAMx model runs for periods in 2009 to further understand nitrogen deposition in the Rocky Mountain National Park region.
- Began to transition the mesoscale meteorological modeling from the older MM5 model to the newer Weather Research and Forecasting (WRF) model and run the model for 2009 and possibly parts of 2006.
- Continued back trajectory analyses for 2009 (RoMANS II) that will be similar to those done for 2006.
- Continued to develop a new trajectory technique in which the trajectories are weighted by concentration or deposition. This new method was used to assess the representativeness of the RoMANS periods and was written up as a new chapter in the report.
- Continued to generate 5-day ATAD back trajectories (4 per day) for 181 IMPROVE and 274 CASTNET sites for 2008.
- In support of back trajectory analyses, and mesoscale meteorological modeling, continued to maintain and add to a collection of observational and analyzed meteorological datasets. Gridded datasets include GDAS, EDAS (NDAS), and NARR. NCAR's observational datasets DS464.0 and DS353.6 were discontinued after February 2007, requiring a move to MADIS and all new methods for handling that data. Software for dealing with MADIS is partially completed.
- Continued to generate hourly, 10-day Hysplit trajectories for 2000-2009 at four start heights for all NADP/NTN sites in Colorado and most in New Mexico,

Arizona, Wyoming, and Montana, and a few sites in other states. Also generated ATAD trajectories for all NADP/NTN sites for 1980-2008. This is in preparation for future analyses of nitrogen sources in order to better investigate trends.

- Continued to develop a new method for evaluating and exploring the sensitivity and range of source attribution results from the Trajectory Mass Balance (TrMB) model for two seasons and seven species.

Data and Display Dissemination

The program activities pertaining to the media center and web development included the following:

- Maintained and improved access to resources, including the CIRA/NPS/IMPROVE website and an FTP server for dissemination of data and summary reports, for the general public.
- Continued implementation and development of the IMPROVE website, including developing an interactive database, allowing users to download data and selected analyses of these data, including appropriate quality assurance information, directly from the web, 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>)
- Continued to develop and implement the interactive multimedia program “Introduction to Visibility”. Completed the “Impacts of Haze” section. This web document will introduce basic visibility science and monitoring concepts as well as the regional haze regulations to the regulatory community and the general public.
- Continued to provide graphics support, graphs, posters, etc., to the NPS researchers in the Air Resources Division and CIRA.
- Produced a web video cast for the Air Resources Division of the National Park Service. The 3.5 minute video gives an overview of the importance of air quality in national parks as it relates to visitor experience.
- Produced videos and CDs showing the impact of pollution on various parks. Generated park service training films. Duplicated and distributed videos and CDs as necessary. Developed custom graphic materials for presentation purposes.
- Produced the 2010 IMPROVE calendar.
- Completed the interactive tutorial describing the cycling of reactive nitrogen through the environment, showing basic concepts such the sources of reactive nitrogen, its effects in the atmosphere and the consequences of its deposition to our environment.

- Continued developing a multimedia program on climate change education and outreach.
- Conducted field visits to national park sites for inventory and quantification of night sky visibility. Provided other technical assistance as needed to agency on topics such as light pollution physics, outdoor lighting mitigation, ecological impacts of artificial light, and outreach strategies.

Project Deliverables

Deliverables for this project include conference papers, presentations, and publications.

Journal Articles

Beem, K. B., Raja, S., Schwandner, F., Taylor, C., Lee, T., Sullivan, A. P., Carrico, C. M., McMeeking, G. R., Day, D. E., Levin, E. J. T., Hand, J. L., Kreidenweis, S. M., Schichtel, B. A., Malm, W. C., and Collett, J. L., Jr. 2009. Deposition of reactive nitrogen during the Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study. *Environmental Pollution*, 158, 862-872.

Carrico, C. M., Petters, M. D., Kreidenweis, S. M., Sullivan, A. P., McMeeking, G. R., Levin, E. J. T., Malm, W. C., and Collett, J. L., Jr. 2010. Water uptake and chemical composition of fresh aerosols generated in open burning of biomass. *Atmospheric Chemistry and Physics Discussion*, 10, 3627-3658.

Christopher, S. A., Gupta, P., Nair, U. S., Jones, T. A., Kondragunta, S., Wu, Y. L., Hand, J. L., and Zhang, X. 2009. Satellite remote sensing and mesoscale modeling of the 2007 Georgia/Florida fires. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 2, 3, 163-175.

Hand, J. L., Day, D. E., McMeeking, G. R., Levin, E. J. T., Carrico, C. M., Kreidenweis, S. M., and Malm, W. C. 2010. Measured and modeled humidification factors of fresh smoke particles from biomass burning: Role of inorganic constituents. *Atmospheric Chemistry and Physics Discussion*, 10, 4225-4269.

Lewis, K., Arnott, P. W., Moosmüller, H. S., Chakrabarty, R. K., Carrico, C. M., Kreidenweis, S. M., Day, D. E., Malm, W. C., Laskin, A., Jimenez, J. L., Huffman, J. A., Ulbrich, I. M., Onasch, T. B., Trimborn, A., Liu, L., and Mishchenko, M. I. 2009. Reduction in biomass burning aerosol light absorption upon humidification: Roles of inorganically induced hygroscopicity, particle collapse, and photoacoustic heat and mass transfer. *Atmospheric Chemistry and Physics*, 9, 8949-8966.

Luginbuhl, C. B., Duriscoe, D. M., Moore, C. A., Richman, A. R., Lockwood, G. W., and Davis, D. R. 2009. From the ground up II: Sky glow and near-ground artificial light propagation in Flagstaff, Arizona. *Publications of the Astronomical Society of the Pacific*, 121, 204-212.

Mack, L. A., Levin, E. J. T., Kreidenweis, S. M., Obrist, D., Moosmüller, H. S., Lewis,

- K. A., Arnott, W. P., McMeeking, G. R., Sullivan, A. P., Wold, C. E., Hao, W. M., Collett, J. L., Jr., and Malm, W. C. 2010. Optical closure experiments for biomass smoke aerosols. Submitted to Atmospheric Chemistry and Physics Discussion, special Biomass Burning issue.
- Malm, W. C., McMeeking, G. R., Kreidenweis, S. M., Levin, E., Carrico, C. M., Day, D. E., Collett, J. L., Lee, T., Sullivan, A. P., and Raja, S. 2009. Using high time resolution aerosol and number size distribution measurements to estimate atmospheric extinction. *Journal of the Air & Waste Management Association*, 59, 9, 1049-1060.
- McMeeking, G. R., Kreidenweis, S. M., Baker, S., Carrico, C. M., Chow, J. C., Collett, J. L., Hao, W. M., Holden, A. S., Kirchstetter, T. W., Malm, W. C., Moosmuller, H., Sullivan, A. P., and Wold, C. E. 2009. Emissions of trace gases and aerosols during the open combustion of biomass in the laboratory. *Journal of Geophysical Research-Atmospheres*, 114.
- Petters, M. D., Parsons, M. T., Prenni, A. J., DeMott, P. J., Kreidenweis, S. M., Carrico, C. M., Sullivan, A. P., McMeeking, G. R., Levin, E. J. T., Wold, C. E., Collett, J. L., Jr., Moosmüller, H. S., Arnott, P. W., Malm, W. C., and Hao, W. M. 2009. Ice nuclei emissions from biomass burning. *Journal of Geophysical Research*, 114, D07209, doi:10.1029/20078D011532.
- Pitchford, M. L., Poirot, R. L., Schichtel, B. A., and Malm, W. C. 2009. Characterization of the Winter Midwestern Particulate Nitrate Bulge. *Journal of the Air & Waste Management Association*, 59, 9, 1061-1069.
- Reidmiller, D. R., Jaffe, D. A., Chand, D., Strode, S., Swartzendruber, P., Wolfe, G. M., and Thornton, T. A. 2009. Inter-annual variability of long-range transport as seen at the Mt. Bachelor observatory. *Atmospheric Chemistry and Physics*, 9, 557-572.
- Rivera-Rivera, N. I., Gill, T. E., Gebhart, K. A., Hand, J. L., Bleiweiss, M. P., and Fitzgerald, R. M. 2009. Wind modeling of the Chihuahuan Desert dust outbreaks. *Atmospheric Environment*, 43, doi:10.1016/j.atmosenv.208.09.069, 347-354.
- Rodriguez, M. A., Barna, M. G., and Moore, C. T. 2009. Regional impacts of oil and gas development on ozone formation in the western United States. *Journal of the Air & Waste Management Association*, 59, 1111-1118.
- Schichtel, B. A., Malm, W. C., Bench, G., Fallon, S., McDade, C. E., Chow, J. C., and Watson, J. G. 2008. Fossil and contemporary fine particulate carbon fractions at 12 rural and urban sites in the United States. *Journal of Geophysical Research*, 113, D02311, doi:10.1029/2007JD008605.
- Sullivan, A. P., Holden, A. S., Patterson, L. A., McMeeking, G. R., Kreidenweis, S. M., Malm, W. C., Hao, W. M., Wold, C. E., and Collett, J. L., Jr. 2008. A method for smoke marker measurements and its potential application for determining the contribution of biomass burning from wildfires and prescribed fires to ambient PM_{2.5} organic carbon. *Journal of Geophysical Research*, 113, D22302, doi:10.1029/2008JD010216.

Conference Papers

Barna, M. G., Rodriguez, M. A., and Moore, C. T. 2009. Simulating ozone impacts from oil and gas emissions in the western United States: Issues for future work. Presented at the Air & Waste Management Association Conference: Air Quality Impacts of Oil and Gas Production in the Rocky Mountains, Centennial, Colorado, September.

Beem, K., Collett, J. L., Jr., Raja, S., Schwandner, F., Carrico, C. M., Taylor, C., Lee, T., Sullivan, A. P., Day, D. E., McMeeking, G. R., Mack, L., Kreidenweis, S. M., Hand, J. L., Schichtel, B. A., and Malm, W. C. 2008. A spatial analysis of precipitation chemistry coupled with aerosol and gas concentrations during the Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study. Poster presented at the American Geophysical Union Fall Meeting, San Francisco, December.

Beem, K. B., Carrico, C. M., Schwandner, F., Mack, L., Lee, T., Sullivan, A. P., Raja, S., Kreidenweis, S. M., Malm, W. C., and Collett, J. L., Jr. 2009. The influence of averaging timescales on dry deposition calculations. Presented at the American Association for Aerosol Research 28th Annual Conference, Minneapolis, October 26-30.

Chand, D., McClure, S. E., Schichtel, B. A., Huddleston, J. M., Malm, W. C., and Moore, C. T. 2009. Inter-annual variation in NO₂ over the United States. Presented at the American Geophysical Union Fall Meeting, San Francisco, December.

Chand, D., McClure, S. E., Schichtel, B. A., Huddleston, J. M., Malm, W. C., Wood, R., and Moore, C. T. 2010. Transpacific transport of Eastern Asian aerosols based on the climatology of MODIS observations. Abstract Submitted to the Asia Oceania Geosciences Society.

Collett, J. L., Jr., Beem, K., Raja, S., Taylor, C., Carrico, C. M., Schwandner, F., Lee, T., Sullivan, A. P., Day, D. E., McMeeking, G. R., Mack, L., Kreidenweis, S. M., Hand, J. L., Schichtel, B. A., and Malm, W. C. 2008. Nitrogen deposition budgets for Rocky Mountain National Park. Presented at the American Geophysical Union Fall Meeting, San Francisco, December.

Cordova, A. M., Chand, D., Wood, R., Wallace, D., Hegg, D. A., Shaw, G. E., Krejci, R., Fochesatto, G. J., and Gallardo, L. 2009. Physical and chemical properties of aerosols at a coastal site, Paposo, Chile, during the VOCALS campaign. Presented at the American Geophysical Union Fall Meeting, San Francisco, December.

Duriscoe, D. M., Walker, C., and Moore, C. A. 2009. Astronomy in the national parks: Interpreting the scenery of the night. Presented at the American Astronomy Society annual meeting, Washington DC, January 3.

Duriscoe, D. M., Moore, C. A., and Jiles, T. G. 2009. National Park Service Night Sky Program update. Presented to the International Dark Sky Association Annual Meeting, Tucson, November 15.

Holden, A. S., Sullivan, A. P., Patterson, L. A., Schichtel, B. A., Malm, W. C.,

Kreidenweis, S. M., Bench, G., and Collett, J. L., Jr. 2008. Estimating contributions of primary biomass burning to fine particulates in ambient aerosol in the western United States. Presented at the American Association for Aerosol Research 27th Annual Conference, Orlando, October 20-24.

Holden, A. S., Desyaterik, Y., Collett, J. L., Jr., Kreidenweis, S. M., and Malm, W. C. 2009. Analysis of fresh and aged aerosols produced by biomass combustion. Presented at the American Association of Aerosol Research 28th Annual Conference, Minneapolis, October 26-30.

Kreidenweis, S. M., McMeeking, G. R., Arnott, W. P., Baker, S., Carrico, C. M., Chow, J. C., Collett, J. L., Jr., Hao, W. M., Holden, A. S., Kirchstetter, T. W., Levin, E. J. T., Lewis, K. A., Mack, L., Malm, W. C., Moosmüller, H., Sullivan, A. P., and Wold, C. E. 2009. The Fire Lab at Missoula Experiment (FLAME): Measurements of trace gases and aerosols during the open combustion of biomass in the laboratory. Presented at the 4th International Fire Ecology and Management Congress: Fire as a Global Process, Savannah, November 30-December 4.

Kreidenweis, S. M., DeMott, P. J., Petters, M. D., Prenni, A. J., Carrico, C. M., Wold, C. E., Collett, J. L., Jr., Moosmüller, H. S., Malm, W. C., and Hao, W. M. 2010. Ice nucleation behavior of particles generated in open burning of biomass. Presented at the 90th American Meteorological Society Annual Meeting, Atlanta, January 17-21.

Lee, T., Collett, J. L., Jr., Kreidenweis, S. M., Sullivan, A. P., Mack, L., Jimenez, J. L., Onasch, T. B., Malm, W. C., Wold, C. E., and Hao, W. M. 2009. Aerosol mass spectrometer measurement of the evolution of chemical smoke markers during laboratory open burning of wildland fuels. Presented at the American Association of Aerosol Research 28th Annual Conference, Minneapolis, October 26-30.

Levin, E. J. T., Carrico, C. M., Beem, K. B., Schurman, M., Day, D. E., Kreidenweis, S. M., Collett, J. L., Jr., Schichtel, B. A., and Malm, W. C. 2009. Aerosol number and volume concentrations during the second Rocky Mountain Atmospheric Nitrogen and Sulfur study (RoMANS 2). Presented at the American Association for Aerosol Research 28th Annual Conference, Minneapolis, October 26-30.

Levin, E. J. T., Mack, L., Carrico, C. M., McMeeking, G. R., Kreidenweis, S. M., Wold, C. E., Moosmüller, H. S., Arnott, W. P., Hao, W. M., Collett, J. L., Jr., and Malm, W. C. 2009. Optical properties of biomass burning smoke aerosols. Presented at the American Association for Aerosol Research 28th Annual Conference, Minneapolis, October 26-30.

Mack, L., Obrist, D., Moosmüller, H. S., Lewis, K., Arnott, P., McMeeking, G. R., Levin, E. J. T., Kreidenweis, S. M., Wold, C. E., Hao, W. M., Collett, J. L., Jr., and Malm, W. C. 2008. Optical closure experiments of biomass smoke aerosols. Presented at the American Association for Aerosol Research 27th Annual Conference, Orlando, October 20-24.

Mack, L., Lee, T., Jimenez, J. L., Kreidenweis, S. M., Collett, J. L., Jr., Moosmüller, H. S., Wold, C. E., Kimmel, J. R., Onasch, T. B., Hao, W. M., and Malm, W. C. 2009.

Elemental analysis of aerosol mass spectrometer measurements of laboratory open biomass burning aerosols. Presented at the American Association for Aerosol Research 28th Annual Conference, Minneapolis, October 26-30.

Malm, W. C., Schichtel, B. A., Barna, M. G., Gebhart, K. A., Collett, J. L., Jr., and Kreidenweis, S. M. 2008. Source apportionment of sulfur and nitrogen species at Rocky Mountain National Park using modeled conservative tracer releases and tracers of opportunity. Presented at the National Atmospheric Deposition Program Annual Meeting, Madison, October.

Malm, W. C., Collett, J. L., Jr., Kreidenweis, S. M., Schichtel, B. A., Moosmüller, H. S., Hao, W. M., and Carrico, C. M. 2009. Measurements needed to understand the role of biomass burning within the regulatory framework of the Environmental Protection Agency and the federal land managing community. Invited presentation at the American Association for Aerosol Research 28th Annual Conference, Minneapolis, October 26-30.

Moore, C. W. 2008. Outdoor lighting in parks. Presented at the Alaska and Pacific West Region Facility Managers Conference, San Diego, December 3.

Moore, C. A. 2009. Natural lightscapes. Presented at the Starlight 2009 Conference, Fuerteventura, Canary Islands, Spain, March 10.

Moore, C. W. and Richman, A. 2009. Finding inspiration in the face of endangered starry nights. Presented at the Sixth International Conference on the Inspiration of Astronomical Phenomena: Celebrating the 400th Anniversary of Galileo's First Astronomical Use of the Telescope, Venice, October.

Nordgren, T. E., Richman, A. R., and Moore, C. A. 2009. Fertile ground for astronomy in national parks. Presented at the Astronomical Society of the Pacific Annual Conference, Millbrae, California, September 14.

Patterson, L. A., Schichtel, B. A., Sullivan, A. P., Collett, J. L., Jr., Holden, A. S., Kreidenweis, S. M., and Malm, W. C. 2008. Development of a wildland fire smoke marker emissions map for the contiguous United States. Poster presented at the American Geophysical Union Fall Meeting, San Francisco, December.

Richman, A. R., Moore, C. A., and Hurst, A. 2009. Tangible astronomical experiences in national parks. Presented at the Astronomical Society of the Pacific Annual Conference, Millbrae, California, September 14.

Rivera-Rivera, N. I., Gebhart, K. A., Gill, T. E., Hand, J. L., Novlan, D. J., and Fitzgerald, R. M. 2009. Analysis of air transport patterns bringing dust storms to El Paso, Texas. Presented at the American Meteorological Society Annual Conference, January, Phoenix.

Rodriguez, M. A., Barna, M. G., Gebhart, K. A., Hand, J. L., Schichtel, B. A., and Malm, W. C. 2009. Regional air quality simulation of the Rocky Mountain Atmospheric Nitrogen and Sulfur study (RoMANS): Model diagnosis using integrated process

analysis. Presented at the International Aerosol Modeling Algorithms (IAMA) Conference, Davis, December.

Rodriguez, M. A. 2009. Regional air quality simulation of the Rocky Mountain Atmospheric Nitrogen and Sulfur study (RoMANS): Model diagnosis using integrated process analysis. Presented at the 25th Annual Clean Air Conference, Estes Park, September.

Schichtel, B. A., Malm, W. C., Barna, M. G., Gebhart, K. A., Collett, J. L., Jr., and Kreidenweis, S. M. 2008. Source apportionment of sulfur and nitrogen species at Rocky Mountain National Park using modeled conservative tracer releases and tracers of opportunity. Presented at the American Geophysical Union Fall Meeting, San Francisco, December.

Schichtel, B. A., Malm, W. C., Collett, J. L., Jr., Sullivan, A. P., Patterson, L. A., and Holden, A. S. 2009. Estimating the contribution of smoke and its source regions to fine particulate matter using a hybrid receptor model. Presented at the American Association of Aerosol Research 28th Annual Conference, Minneapolis, October 26-30.

Schurman, M., Collett, J. L., Jr., Hering, S. V., Day, D. E., Malm, W. C., and Lee, B. 2008. Developing and testing prototype compact denuders for ambient sampling applications. Presented at the American Association for Aerosol Research 27th Annual Conference, Orlando, October 20-24.

Schwandner, F., Beem, K., Raja, S., Desyaterik, Y., Kreidenweis, S. M., Malm, W. C., and Collett, J. L., Jr. 2008. Organic nitrogen in wet deposition in Rocky Mountain National Park. Poster presented at the National Atmospheric Deposition Program (NADP) Annual Meeting, Madison, October 14-16.

Shankar, U., Henderson, B., Arunachalam, S., Adelman, Z., Ran, L., Adams, E., Barna, M. G., and Rodriguez, M. A. 2009. Evaluation of CMAQ performance during the Rocky Mountain Atmospheric Nitrogen and Sulfur (RoMANS) study. Presented at the 8th Annual Community Modeling and Analysis (CMAS) Conference, Chapel Hill.

Other

Barna, M. G. and Rodriguez, M. A. 2009. Predicting dry deposition of total nitrogen at Rocky Mountain National Park. Presented at the 41st Annual Air Pollution Workshop and Symposium: Air Pollution in Remote and High Elevation Regions, Fort Collins, April.

Barna, M. G. 2009. Overview of chemical transport modeling. Presented at the Bureau of Land Management NEPA Technical Workshop, Denver, February 11-12.

Barna, M. G. 2009. Invited expert panel member at the Wyoming Department of Environmental Quality Winter Ozone Technical Forum, Cheyenne, December 8-9.

Carrico, C. M., Petters, M. D., Kreidenweis, S. M., Prenni, A. J., DeMott, P. J.,

McMeeking, G. R., Levin, E. J. T., Mack, L., Sullivan, A. P., Holden, A. S., Collett, J. L., Jr., Day, D. E., Hand, J. L., Malm, W. C., Wold, C. E., and Hao, W. M. 2008. Physicochemical properties of fresh biomass smoke aerosols. Invited talk presented at the NOAA Earth System Research Lab Chemical Sciences Division, October 29.

Collett, J. L., Jr., Raja, S., Beem, K., Schwandner, F., Lee, T., Sullivan, A. P., Taylor, C., Carrico, C. M., McMeeking, G. R., Kreidenweis, S. M., Day, D. E., Hand, J. L., and Malm, W. C. 2008. Transport and deposition of airborne nitrogen in Rocky Mountain National Park. Presented at Sonoma Technology, Inc., December 18.

Duriscoe, D. M. and Moore, C. A. 2009. Dark sky parks and outdoor lighting. Presented to the Death Valley National Park Management Team and Xanterra Parks and Resorts Management Team, Death Valley National Park, November 12.

Jiles, T. G. 2009. Night sky stories. Presented at the Poudre School District Eco Week, Pingree Park, Colorado, September 17.

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