Final report for Task # H2370094000/J2350107303

(September 1, 2010 – February 29, 2012)

Nitrogen Deposition in the Rocky Mountain region

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1. Overview of Project

The National Parks are immensely popular public resources. Protection of these national treasures requires understanding of various threats to park resources. Included are threats to visibility and to sensitive ecosystems. The research in this project relates directly to diagnosing and remedying air quality problems in our national parks. It provides the basis for informed decision-making about steps to protect park resources by improving and managing air quality.

The long-term goals of this project are to improve understanding of deposition of pollutant species to sensitive park ecosystems, to diagnose contributors to air quality problems in specific parks, and to generate fundamental new knowledge about specific pollutant species contributing to air quality and visibility problems in national parks. Attainment of these goals involves the planning, execution, and analysis of field measurements of air quality at select national parks.

The major goals of this task included continued efforts to characterize transport and deposition of reactive nitrogen species in Rocky Mountain NP, new efforts to examine atmospheric concentrations and deposition fluxes of reactive nitrogen species in Grand Teton NP, and implementation of a pilot-scale network for routine monitoring of atmospheric concentrations of ammonia plus $PM_{2.5}$ ammonium in the Rocky Mountain region.

2. Major National Park Service Research Activities Completed by CSU

Reactive nitrogen species concentrations and deposition in Rocky Mountain and Grand Teton National Parks

Measurements of atmospheric concentrations of reactive nitrogen species and deposition fluxes in Rocky Mountain National Park (RMNP) and Grand Teton National Park (GTNP) provide important new insights into the importance of various regional nitrogen deposition pathways and the sources of the deposited nitrogen. Extensive recent measurements in both parks by Colorado

State University (CSU) have documented the relative importance of various dry and wet reactive nitrogen deposition pathways.

During the 2006 Rocky Mountain Atmospheric Nitrogen and Sulfur (RoMANS) study, wet deposition of organic nitrogen and dry deposition of gaseous ammonia were found to be major contributors to reactive nitrogen deposition fluxes in the park. Prior to RoMANS, routine monitoring of gaseous ammonia and wet deposition of organic nitrogen were uncommon, especially in remote areas of the western U.S. CSU RMNP measurements from 2008-10 have confirmed the importance of these deposition pathways in subsequent years and extended information about the deposition budget across the full annual cycle. Figure 1 illustrates the seasonal contributions of multiple pathways to reactive nitrogen deposition in RMNP. Atmospheric reactive nitrogen species concentrations and deposition fluxes tend to be low during winter, when RMNP is fairly isolated from large emissions sources at lower elevations. Both concentrations and deposition fluxes increase during spring, summer, and fall, as the atmospheric boundary layer deepens and upslope flow from east of the Rockies transports emissions from large sources east of the park into RMNP. While spring upslope precipitation events were previously identified as important vectors for the transport and deposition of agricultural and urban emissions from eastern Colorado, the 2008-09 measurements also revealed the importance of similar events in autumn. These recent findings have been submitted for peer-publication in Atmospheric Environment (Benedict et al., 2012).

On an annual basis, the largest measured contributor to reactive nitrogen deposition in RMNP is wet deposition of ammonium, followed by wet deposition of nitrate, dry deposition of ammonia, and wet deposition of organic nitrogen (see Fig. 2). Smaller contributions are made by dry deposition of gaseous nitric acid and dry position of $PM_{2.5}$ ammonium, organic nitrogen, and nitrate. The total annual deposition by these pathways was approximately 3.5 kg N/ha. Dry deposition of gas phase organic nitrogen remains an unquantified, but potentially large, contributor to the RMNP reactive nitrogen deposition budget.

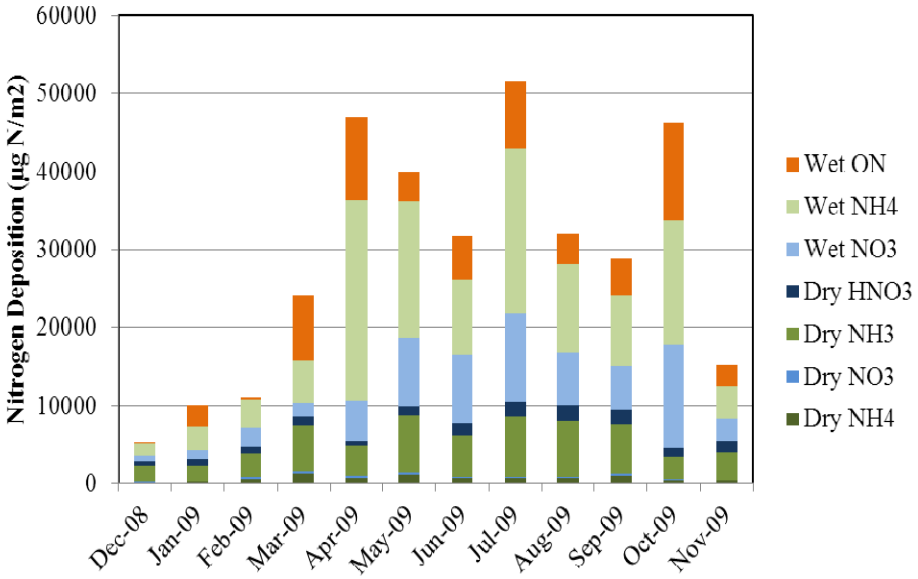

Figure 1. Monthly reactive nitrogen deposition budgets for RMNP, determined from the RoMANS II study in 2008-09.

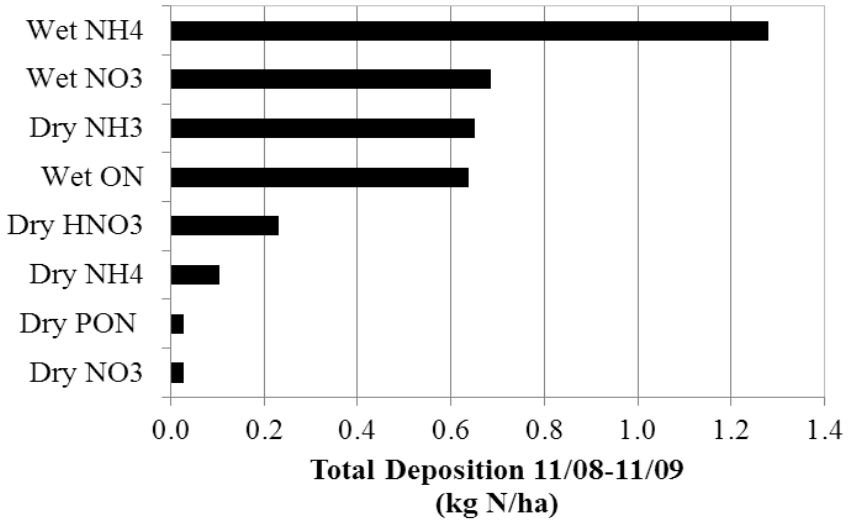

Figure 2. Total RMNP reactive nitrogen deposition by pathway for a year of measurements beginning November 2008. Measurements of $PM_{2.5}$ organic nitrogen (PON) began in April 2009 and continued through November 2009. The plotted PON deposition amount represents, therefore, only contributions from this 8-month period.

During spring and summer 2011, CSU and NPS shifted measurement efforts to Grand Teton NP to conduct the Grand Teton Reactive Nitrogen Deposition Study (GrandTReNDS). Grand Teton NP was of particular interest because of its sensitive alpine ecosystems, its proximity to large ammonia emissions from the Snake River Valley and emissions of nitrogen oxides from oil and gas activity in Wyoming and beyond, and the absence of previous air quality and deposition measurements in the park.

Twelve measurement sites were installed as part of the GrandTReNDS study. Table 1 summarizes the site locations and types of measurements made at each site. The most extensive set of measurements was made at the Grand Targhee ski resort, where the NPS Mobile Air Sampling Laboratory was deployed. Specific real-time measurements included a PILS-IC (Particle Into Liquid Sampler – Ion Chromatograph) system for $PM_{2.5}$ inorganic ion composition, several gas monitors for measurements of NO_x, NO_y, and NH_3, an aerosol mass spectrometer for measurement of PM_1 concentrations of inorganic and organic aerosol composition, aerosol size distributions, and a variety of meteorological parameters. These were complemented by 12 and 24 hr measurements of $PM_{2.5}$ aerosol composition and concentrations of key trace gases (HNO_3, NH_3, and SO_2) using a URG annular denuder/filter-pack system, 24-48 hr concentrations of organic (OC) and elemental carbon (EC) and organic nitrogen (ON) concentrations and smoke marker species concentrations using Hi-Vol filter sampling, daily wet deposition measurements (inorganic ion and ON concentrations), and passive sampler measurements of gaseous ammonia.

Longer term data records were collected at a site near Driggs, ID and from the NOAA Climate Monitoring site on the east side of GTNP, each equipped with 24 hr URG denuder/filter-pack sampling, wet deposition samplers, passive gas samplers, and meteorological stations. The lower elevations of these sites permitted much earlier access for measurement equipment. Several additional sites were equipped with passive sampling devices for measurement of gaseous

ammonia and nitric acid concentrations. A subset of these sites was equipped with automated wet deposition samplers.

Table 1. Site information for the 2011 Grand Tetons Reactive Nitrogen Deposition Study.

		Latitude	Longitude	Elevation (m)	Start of Sampling	Passive Site	24 Hr Gas and Particle	Precipitation
Driggs	(DR)	43.7404	-111.8703	1947	4/6/2011	X	X	X
Upper Grand Targhee	(GT)	43.7782	-110.9438	2722	4/28/2011	X	X[+]	X
Lower Grand Targhee	(TB)	43.7891	-110.9558	2454	4/21/2011		X	
NOAA Climate Station	(NC)	43.6614	-110.7120	1978	5/15/2011	X	X	X
Flagg Ranch	(FR)	44.0827	-110.6828	2086	7/5/2011	X		
Holly Lake	(HL)	43.7890	-110.7939	2826	7/24/2011	X		
Moran Junction	(MJ)	43.8276	-110.5156	2062	7/5/2011	X		
Rendezvous Peak	(RP)	43.5969	-110.8703	3176	7/21/2011	X		
South Badger	(SB)	43.8504	-110.9543	2166	7/21/2011	X		
Surprise Lake	(SL)	43.7291	-110.7768	2922	7/24/2011	X		
Death Canyon	(DC)	43.6566	-110.7818	2088	7/21/2011	X		
Tetons Science School	(TS)	43.6709	-110.5996	2131	7/21/2011	X		

[+]Precipitation and 24 hour gas and particle sampling began 7/24/2011.

Analysis of findings from the GrandTReNDS study are continuing under a separate task; preliminary results are presented here. Measurements at the core Grand Targhee measurement site (GT) indicate that this region is typical in some respects of remote continental locations, with a study average particle number concentrations of 1400 cm^{-3}. NO_x concentrations were also quite low, generally <1 ppb. Characterization of non-refractory submicron particulate matter via high resolution aerosol mass spectrometry also reveals low aerosol concentrations dominated by organics (Figure 3; organic avg = 1.6 $\mu g/m^3$). Inorganic species (Average: SO_4 = 0.3$\mu g/m^3$; NH_4 = 0.2$\mu g/m^3$; NO_3 = 0.08$\mu g/m^3$) are generally in constant proportion to each other and organics throughout the study, with some sulfate enhancement August 20-29. A peak in all concentrations is apparent August 15, when the site was impacted by biomass burning. The composition of the organic fraction is generally consistent with an aged aerosol. A pronounced $C_xH_yN^+$ fragment series (such as $C_4H_5N^+$ at *m/z* 67, Δ=-2) is indicative of the presence of amines. Work is ongoing to confirm this finding and determine possible sources for this reduced organic nitrogen aerosol type.

Ammonia was determined to be the most abundant atmospheric nitrogen species in the region. Ammonia concentrations are plotted in Figure 4 for each of the sites where daily URG denuder/filter-pack measurements were made. Also included in Figure 4 are weekly average concentrations from the NADP Ammonia Monitoring Network (AMoN) site located at Craters of the Moon (ID03), approximately 200

km west of Driggs. The westernmost GrandTReNDS site at Driggs, ID had the highest average ammonia concentrations, exceeded at times by Craters of the Moon, while measurements at the NOAA Climate Center were generally the lowest, indicating that the main sources impacting the region came from the west. Concentrations were slightly higher in the spring than in the summer at Driggs, and in September concentrations were decreasing at all sites.

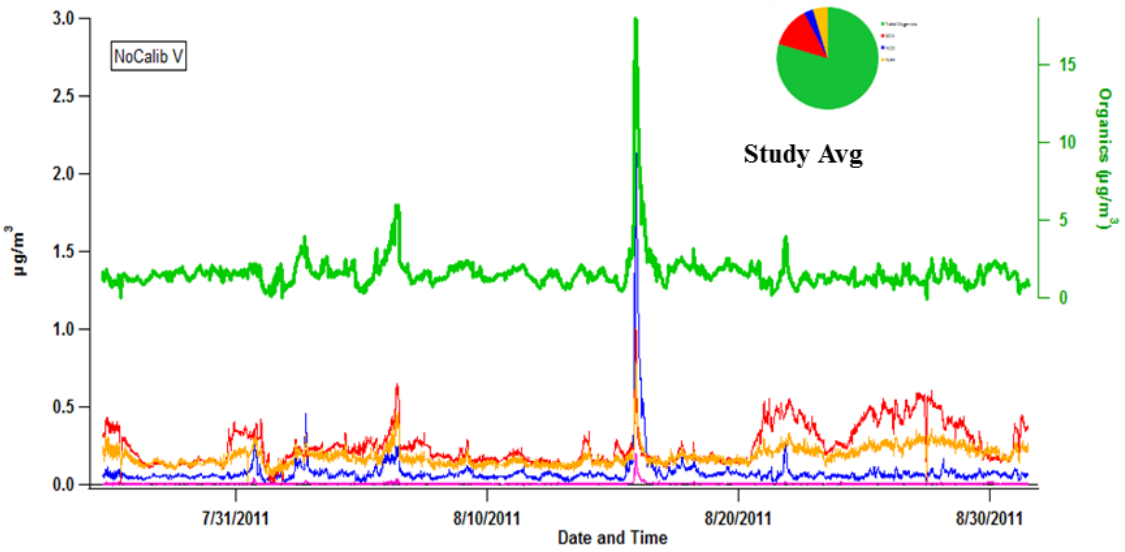

Figure 3. Time series of particulate organic, sulfate, nitrate, and ammonium concentrations during the intensive study period at the GrandTReNDS core study site.

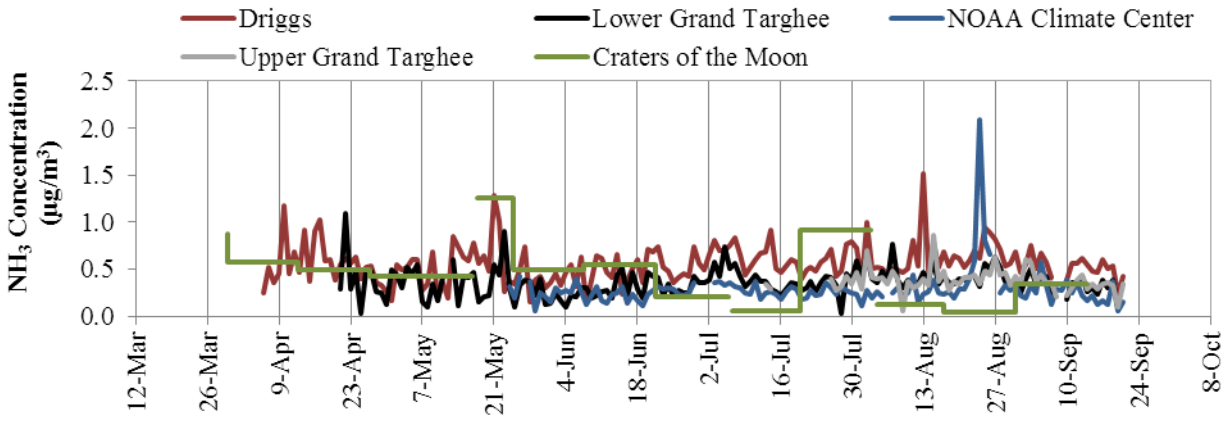

Figure 4. 24 hr altitude adjusted concentrations of gaseous ammonia (NH_3) from GrandTReNDS and NH_3 concentrations from the AMoN network site at Craters of the Moon.

Measurements from the passive ammonia samplers also indicate a west-to-east concentration gradient (see Figure 5). These samplers were deployed at 11 sites throughout the area, providing higher spatial

resolution than the more traditional measurement techniques. These measurements show a decrease in concentrations to the east, consistent with the location of large ammonia source regions west of the mountain range.

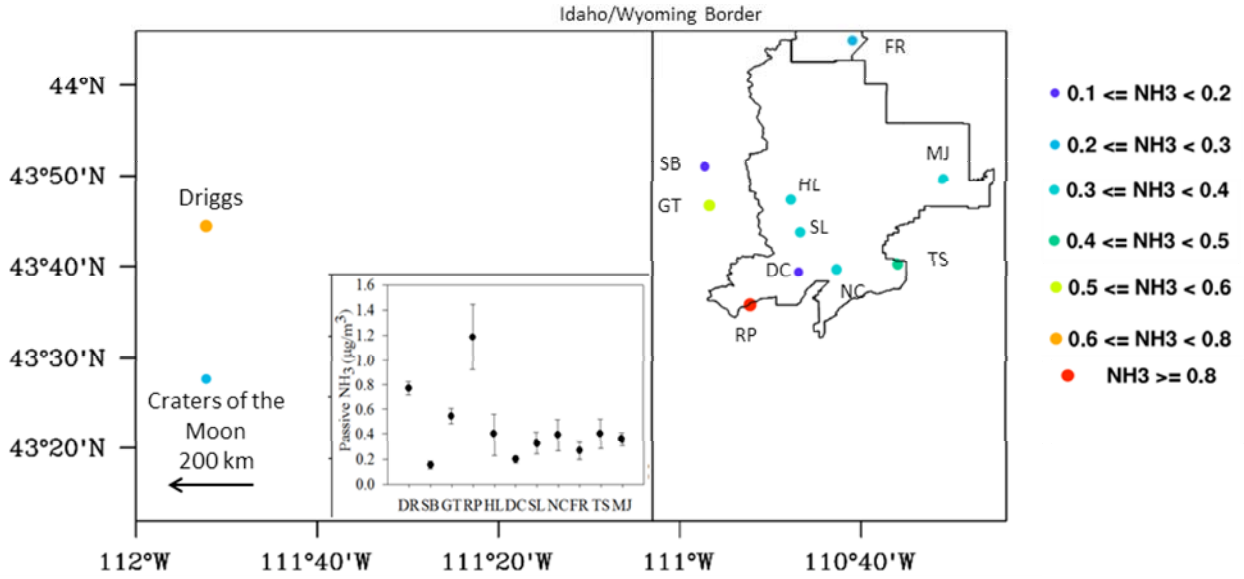

Figure 5. Spatial distribution of NH_3 from July to September 2011 from bi-weekly passive samplers deployed during GrandTReNDS. Data from Craters of the Moon are from NADP AMoN network weekly passive samplers. The color of each circle represents the average concentration at each sampling site. In the inset, sites are plotted according to longitude, west to east, and the error bars represent the standard deviation of concentrations during the study period at each site. The high concentrations at RP are believed to result from local emissions.

A diel cycle in ammonia concentrations was apparent in measurements at Grand Targhee (see Figure 6a). Data are shown from the Picarro cavity ring down and Air Sentry II ion mobility ammonia analyzers; bracketing the average values as dashed lines are values for ± 1 standard deviation. As can be been in the figure, both instruments show a clear increase in ammonia concentrations in the morning, peaking around noon, and then gradually decaying throughout the remainder of the day. This pattern is consistent with observed ammonia trends at Rocky Mountain National Park (RMNP) during the ROMANS campaign; however, the peak concentrations observed here were somewhat lower than those observed during ROMANS summer months. Despite the clear diel pattern in the GrandTReNDS data, results from ROMANS suggested that some of this variability may result from a sampling artifact, whereby ammonia adsorbs to surfaces in the inlet during the cold nighttime hours, and is then released when the sun rises and warms the inlet. To test this, for select periods we collected concurrent day-vs-night denuder samples, as denuders are not expected to suffer to the same extent from inlet artifacts. Results from these measurements are shown in Figure 4. The good agreement between the URG and the Picarro (6b) and Air Sentry (6c) suggest that the diel cycle observed with the continuous instruments is real and not a sampling artifact.

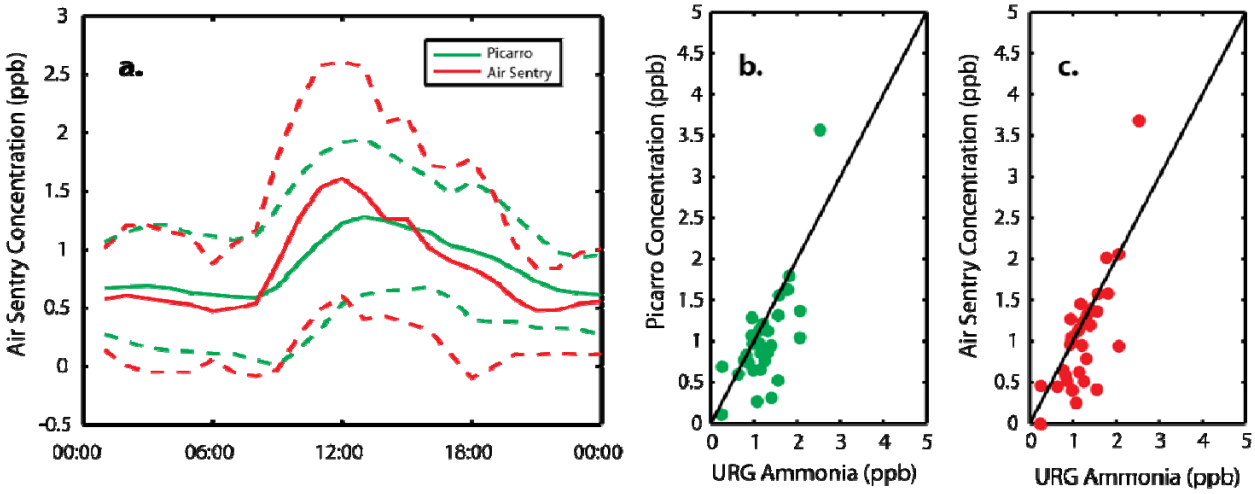

Figure 6. a.) Average daily ammonia concentrations throughout the study period from the Picarro and Air Sentry II instruments. Solid lines represent average values, while dashed lines designate ± 1 standard deviation. b.) Comparison of Picarro results with concurrent denuder measurements for sample periods aimed at capturing the diel cycle. c.) Comparison of Air Sentry II results with concurrent denuder measurements for sample periods aimed at capturing the diel cycle.

Efforts continue as part of a separately funded task to construct reactive nitrogen deposition budgets for GTNP and to analyze relationships between observed concentrations and deposition fluxes and local-to-regional scale transport patterns. Initial findings indicate that, relative to RMNP, dry deposition of ammonia is a bigger contributor to reactive nitrogen deposition at GTNP.

Improved characterization of atmospheric reactive nitrogen in IMPROVE

Since 2010 CSU and NPS have been working with the IMPROVE (Interagency Monitoring of Protected Visual Environments) network to improve characterization of atmospheric concentrations of reduced nitrogen species. Gaseous ammonia and $PM_{2.5}$ ammonium are measured together as NH_x; collection is made on an acid-impregnated filter. Sampling is done on IMPROVE's normal 1-in-3 day schedule using an additional installed IMPROVE sampler module.

Before deploying the additional IMPROVE samplers in the field to collect NH_x, comparisons were conducted in March-April 2010 at Fort Collins, CO to examine measurement precision; accuracy was also tested against a reference URG denuder/filter-pack sampler. Precision and accuracy findings were both good. The deployment of IMPROVE NH_x samplers in the field started in June 2010. Surprising amounts of methylamine were found on many samples. After extensive field and lab testing, it was determined that the methylamine resulted from a reaction between formaldehyde, produced by acid breakdown of the Delrin plastic used by IMPROVE for manufacture of filter cartridges and collected NH_x. NH_x sampling was suspended in October 2010 until new cartridges could be designed, tested for chemical inertness, and manufactured to

resume sampling. Polypropylene was proven to successfully meet all manufacture and sampling requirements and IMPROVE NH_x sampling resumed starting from late April 2011 in a pilot network including 9 IMPROVE sites: Bondville, Illinois plus 8 sites in the Rocky Mountain region of the country.

NH_x field blanks collected from April 2011 to January 2012 were similar across network sites with a low average airborne equivalent NH_x concentration of 0.030 $\mu g/m^3$. Co-located samplers installed at RMNP and Bondville demonstrated excellent field measurement precision. Monthly average concentrations for all IMPROVE NH_x sites from April 2011 to January 2012 are shown in Figure 7. Overall NH_x concentrations measured during the study period were lowest at Yellowstone NP; concentrations were highest at Cedar Bluffs and Bondville, both areas expected to be impacted by agricultural emissions. A seasonal cycle was observed at all sites, with NH_x concentrations climbing from spring into early summer; a second late autumn peak was observed at Bondville and Cedar Bluffs. One particularly surprising finding was the high summertime NH_x concentrations observed at Chiricahua. Concentrations here in June and July 2011 were comparable to those measured at Bondville and Cedar Bluffs. Some of the high concentration periods may be associated with wildfire emissions in the region, although an initial investigation of this hypothesis suggests that high NH_x concentrations were also observed on days where fire impacts were small. Further investigation of this topic, the possibility of cross-border transport of NH_x from northern Mexico, and spring/summer 2012 concentration measurements across the network are ongoing under a separately funded task.

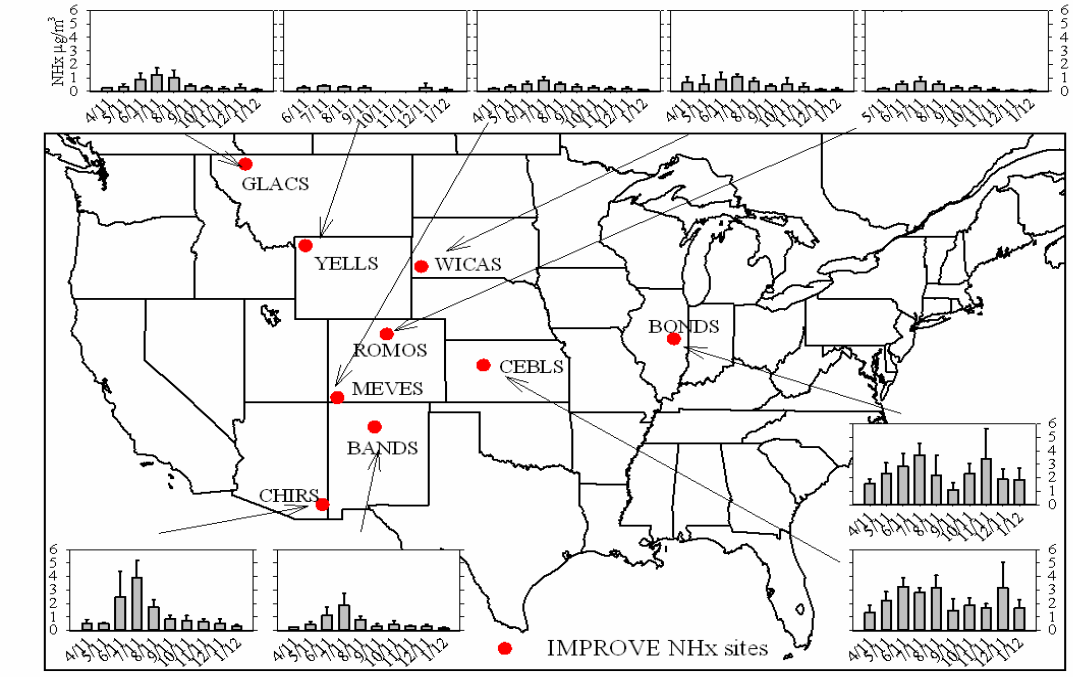

Figure 7. Monthly NH_x average concentrations measured from April 2011 to January 2012 at IMPROVE NH_x sites.

Chief Project Accomplishments

- Analysis of findings from 2008-2010 reactive nitrogen species concentration and deposition flux measurements in RMNP. Preparation and submission of a journal manuscript (Benedict et al., 2012) examining gradients in pollutant gradients in the RMNP region and across northern Colorado.
- Measurements of organic nitrogen content and speciation in RoMANS precipitation and aerosol samples.
- Collaboration with NPS/CIRA scientists on the analysis of the sources, transport, and deposition of reactive nitrogen in RMNP. Publication of two peer-reviewed journal articles on these subjects (Gebhardt et al., 2011; Rodriguez et al., 2011).
- Continued analysis of findings from earlier NPS-sponsored studies examining impacts of smoke from wild and prescribed fires on regional air quality. Publication of two peer-reviewed journal articles on this subject (Holden et al., 2011; Munchak et al., 2011).
- Conduct of the GrandTReNDS study in Grand Teton National Park and the surrounding region. Field operations were conducted from April – September 2011 and included measurements at 12 field sites.
- Collection and analysis of denuder and filter-pack samples in the GrandTReNDS study. Collection and analysis of wet deposition samples GrandTReNDS. Collection and analysis of Hi-Vol filter samples during GrandTReNDS for OC, EC, and smoke marker concentrations.
- Operation of continuous instruments for particle and gas phase composition during GrandTReNDS. Measurements included NOx, NOy, multiple methods for gaseous ammonia, and measurement of particle composition by PILS-IC and Aerosol Mass Spectrometer (AMS). Operation of continuous instruments for measurements of particle size distributions. Operation of meteorological stations for continuous meteorological data observations.
- Preparation of preliminary GrandTReNDS datasets for presentation, sharing with NPS personnel, and data analysis.
- Identification of sample artifact issues that impacted a pilot IMPROVE network to quantify atmospheric reduced nitrogen (NH_x = particulate ammonium + gaseous ammonia) concentrations. Tested and reconfigured sampling methodologies for the network to eliminate artifact formation of methylamine. Relaunched the network in April 2011.
- Initial analysis of NH_x concentrations measured in the Rocky Mountain region by the pilot IMPROVE network for summer/autumn 2011.
- Presentations of project findings at several national and international meetings, including the annual meetings of the American Association for Aerosol Research, the Air and

Waste Management Association, the American Geophysical Union, and the NADP annual meeting. See full presentation list below.

- ***Maintenance and operation of the NPS Mobile Air Sampling Laboratory***

During this project CSU researchers continued to maintain, improve, and operate the NPS Mobile Air Sampling Laboratory (MASL). The MASL was deployed during this time period in GTNP in support of the GrandTReNDS study.

Project Deliverables

Deliverables for this project include submission of peer-reviewed journal articles and submission of this final report. Several peer-reviewed journal articles were published (Rodriguez et al., 2011, Gebhart et al., 2011, Holden et al., 2011, Munchak et al., 2011) or submitted (Benedict et al., 2012) as part of this project.

Project peer-reviewed journal publications

1. Gebhart, K. A., Schichtel, B. A., Malm, W. C., Barna, M. G., Rodriguez, M. A., and Collett, Jr., J. L. (2011) Back-trajectory-based source apportionment of airborne sulfur and nitrogen concentrations at Rocky Mountain National Park, Colorado, USA. Atmos. Environ., 45, 621-633, doi:10.1016/j.atmosenv.2010.10.035.

2. Holden, A. S., Sullivan, A. P., Munchak, L. A., Kreidenweis, S. M., Schichtel, B. A., Malm, W. C., and Collett, Jr. J. L. (2011) Determining contributions of biomass burning and other sources to fine particle contemporary carbon in the western United States. Atmos. Environ., 45, 1986-1993, doi:10.1016/j.atmosenv.2011.01.021

3. Munchak, L. A., Schichtel, B. A., Sullivan, A. P., Holden, A. S., Kreidenweis, S. M., Malm, W. C., and Collett, Jr., J. L. (2011) Development of wildland fire particulate smoke marker to organic carbon emission ratios for the conterminous United States, Atmos. Environ., 45, 395-403,doi:10.1016/j.atmosenv.2010.10.006.

4. Rodriguez, M. A., Barna, M. G., Gebhart, K. A., Hand, J. L., Adelman, Z. E., Schichtel, B. A., Collett, Jr., J. L., and Malm, W. C. (2011) Modeling the fate of atmospheric reduced nitrogen during the Rocky Mountain Atmospheric Nitrogen and Sulfur Study (RoMANS): Performance evaluation and diagnosis using integrated processes rate analysis. Atmos. Environ., 45, 223-234, doi:10.1016/j.atmosenv.2010.09.011.

5. Benedict, K. B., Day, D., Schwandner, F. M., Kreidenweis, S. M., Chcichtel, B. Malm, W. C., and Collett, J. L. (2012) Observations of atmospheric reactive nitrogen species in Rocky Mountain National Park and across Colorado. *Atmos. Environ*., in review.

Project presentations

Beem, K.B., Y. Desyaterik, M.Z. Ozel, J.F. Hamilton, and J.L. Collett (2010) Identifying organic nitrogen compounds in Rocky Mountain National Park aerosols. Presented at the American Geophysical Union Fall Meeting, San Francisco, California, Dec. 13-17, 2010.

Benedict, K.B., J. L. Collett, Jr., C. M. Carrico, S. Raja, F. M. Schwandner, M. Schurman, E. Levin, D. Day, S. M. Kreidenweis, W. C. Malm, and B. A. Schichtel (2011) Transport and deposition of reactive nitrogen in the Rocky Mountain region. Presented at the American Chemical Society National Meeting, Denver, CO, August 2011.

Benedict, K., Y. Desyaterik, A. P. Sullivan, S. Kreidenweis, J. Collett et al. (2011) Speciation of organic nitrogen compounds in aerosol from Rocky Mountain National Park. Presented at the American Association for Aerosol Research 30th Annual Conference, Orlando, FL, Oct. 3-7 2011.

Carrico, C., J. Collett, Jr., S. Kreidenweis, E. Levin, A. Prenni, M. Schurman, D. Day, K. Benedict, J. Ray, B. Schichtel, and W. Malm (2011) Continuous measurements of reactive nitrogen species: observations from the laboratory and an alpine site. Presented at the Air and Waste Management Association Annual Meeting, Orlando, FL, June 2011.

Chen, X., D. Day, B. Schichtel, W. Malm, J. Mojica, C. McDade, S.M. Kreidenweis, and J. Collett, Jr. (2010) Atmospheric NHx monitoring: a pilot study at selected IMPROVE sites. Presented at the American Assn. for Aerosol Research 29th Annual Conference, Portland, Oregon, October 25-29, 2010.

Collett, Jr., J. L. (2011) Meteorological and chemical factors that influence background aerosol concentrations, Invited presentation at the Background Aerosol Workshop, Seoul, S. Korea, August 9, 2011.

Collett, Jr., J.L. Transport and deposition of airborne reactive nitrogen in the Rocky Mountain region. Presented to the National Park Service Air Resources Division, Fort Collins, CO, June, 2011.

Collett, Jr., J. L., Y. Desyaterik, A. Sullivan, C. Hennigan, A.L. Robinson, A.S. Holden, S.M. Kreidenweis and B. Schichtel (2010) Organic Nitrogen in Fresh and Aged Aerosols Produced by Biomass Burning. Presented at the American Assn. for Aerosol Research 29th Annual Conference, Portland, Oregon, October 25-29, 2010.

Collett, Jr., J.L., T. Lee, K.B. Beem, C.M. Carrico, S. Raja, F.M. Schwandner, Y. Li, S.M.

Kreidenweis, D. Chen, D. Day, W.C. Malm, B.A. Schichtel, J. Ray, M. Tigges, C. Archuleta, L. Sherman, J. Molenar, H.J. Sewell, J. Mojica, and C. McDade (2010) Temporal and spatial variability in atmospheric ammonia concentrations in the western United States. Presented at the 5th International Nitrogen Conference, New Delhi, India, Dec. 3-7, 2010.

Collett, Jr., J.L., K.B. Beem, C.M. Carrico, S. Raja, F.M. Schwandner, M. Schurman, E. Levin, S.M. Kreidenweis, W.C. Malm, and B.A. Schichtel (2010) Transport and deposition of reactive nitrogen species in Rocky Mountain National Park, USA. Presented at the 5th International Nitrogen Conference, New Delhi, India, Dec. 3-7, 2010.

Collett, Jr., J.L., Y. Li, T. Lee, D. Chen, K. Benedict, D. Day, S. Raja, F. M. Schwandner, C. M. Carrico, S. M. Kreidenweis, W. C. Malm, B. A. Schichtel, J. Ray, M. Tigges, S. Holcomb, C. Archuleta, L. Sherman, J. Molenar, H. J. Sewell, J. Mojica, and C. McDade (2011) Temporal and spatial variability in atmospheric ammonia concentrations in the western United States. Presented at the National Acid Deposition Program Annual Meeting, Providence, RI, Oct. 2011.

Day, D., W. Malm, B. Schichtel, X. Chen, F. Schwandner, and J. Collett, Jr. (2010) Observations of the Spatial and Temporal Variability of Ammonia at Several different sites in Colorado. Presented at the American Assn. for Aerosol Research 29th Annual Conference, Portland, Oregon, October 25-29, 2010.

Desyaterik, Y., L. Mack, T. Lee, S.M. Kreidenweis, J.L. Collett, J.L. Jimenez, and D.R. Worsnop (2010) Elemental Composition of Primary Aerosols Emitted from Burning of 21 Biomass Fuels Measured by Aerosol Mass Spectrometer. Presented at the American Geophysical Union Fall Meeting, San Francisco, California, Dec. 13-17, 2010.

Desyaterik, Y., Y. Sun, G. McMeeking, A. Sullivan, S. Kreidenweis,and J. Collett (2011) Speciation of "brown" carbon in biomass burning aerosols. Presented at the American Association for Aerosol Research 30th Annual Conference, Orlando, FL, Oct. 3-7 2011

Holden, A.S., Y. Desyaterik, A. Laskin, J. Laskin, B.A. Schichtel, W.C. Malm, S.M. Kreidenweis, and J.L. Collett (2010) Analysis of Fresh and Aged Aerosols Produced by Biomass Combustion. Presented at the American Geophysical Union Fall Meeting, San Francisco, California, Dec. 13-17, 2010.

Kreidenweis, S.M., J.L. Collett, H., Moosmuller, W.P. Arnott, W. Hao, and W.C. Malm (2010) Overview of the Fire Lab at Missoula Experiments (FLAME). Presented at the American Geophysical Union Fall Meeting, San Francisco, California, Dec. 13-17, 2010.

McCluskey, C.S., K.B. Beem, and J.L. Collett (2010) The Presence of Reactive Nitrogen in Fine and Coarse Aerosol. Presented at the American Geophysical Union Fall Meeting, San Francisco, California, Dec. 13-17, 2010.

Schichtel, B.A., Katherine Benedict, Christian M. Carrico, Ezra Levin, Derek Day, William C. Malm, Jeffrey L. Collett, Jr., and Sonia M. Kreidenweis (2011) Seasonal nitrogen deposition

budgets at Rocky Mountain National Park. Presented at the Air and Waste Management Association Annual Meeting, Orlando, FL, June 2011.

Schichtel, B., K. Beem, C. Carrico, E. Levin, D. Day, W. Malm, J. Collett, and S. Kreidenweis (2011) Seasonal nitrogen deposition budgets at Rocky Mountain National Park. Presented at the National Acid Deposition Program Annual Meeting, Providence, RI, Oct. 2011.

Schurman, M., T. Lee, Y. Sun, B. Schichtel, S. Kreidenweis, and J. Collett (2011) Investigating types and sources of organic aerosol in Rocky Mountain National Park using aerosol mass spectrometry, presented at the AGU Fall Meeting, San Francisco, CA, Dec. 2011.

Stratton, J.J, E.J. Levin, J.M. Ham, J.L. Collett, and T. Borch (2010) Quantifying Ammonia Emissions from High Elevation Grassland and Forest Soils. Presented at the American Geophysical Union Fall Meeting, San Francisco, California, Dec. 13-17, 2010.

Sullivan, A.P., S.M. Kreidenweis, and J.L. Collett (2010) Examination of Smoke Marker Ratios from Controlled Laboratory Burns vs. Wildfires and Prescribed Burns. Presented at the American Geophysical Union Fall Meeting, San Francisco, California, Dec. 13-17, 2010.