

Jeffrey L. Collett, Jr.¹, Katherine B. Beem¹, Suresh Raja¹, Florian Schwandner¹, Christian Carrico¹, Taehyoung Lee¹, Amy Sullivan¹, Sonia Kreidenweis¹, Bret Schichtel², and William Malm²

¹ Department of Atmospheric Science Colorado State University Fort Collins, CO 80523 ² NPS/CIRA, Colorado State University Fort Collins, CO 80523

The Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) Study

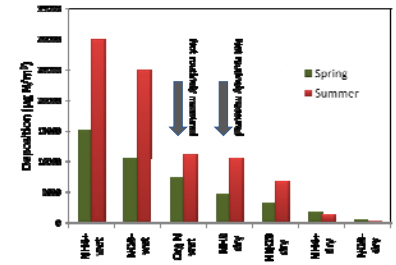
The Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study was designed to investigate both N and S wet and dry deposition and to determine the most important species and pathways contributing to N deposition. Gas and particle concentrations were measured and precipitation samples were collected to gain a better understanding of nitrogen and sulfur transport to and deposition in Rocky Mountain National Park (RMNP). Samples were collected at 12 sites across the state of Colorado in March and April 2006 and at 13 sites in north central Colorado in July and August 2006. Historical data suggest that these are the seasons when N deposition in RMNP is greatest. RMNP is experiencing a number of adverse effects due to atmospheric nitrogen and sulfur compounds. Airborne nitrate and sulfate particles contribute to visibility degradation in the park while nitrogen deposition is producing changes in ecosystem function and surface water chemistry.

The work presented here focuses on two important findings from the RoMANS study:

- Historical measurements of N deposition in the region have not included observations of dry deposition of gaseous ammonia (NH₃) nor wet or dry deposition of organic nitrogen. As shown below, the RoMANS study found dry deposition of NH₃ and wet deposition of organic nitrogen to be among the largest contributors to reactive nitrogen deposition in RMNP.
- The CASTNet program currently determines dry deposition fluxes as the product of a modeled dry deposition velocity (based on high time resolution meteorological measurements) and a weekly average concentration. Higher time resolution concentration measurements during the RoMANS study allow us to look at the influence of time averaging (at different timescales) on computed fluxes. For the RoMANS study location and time periods, the availability of high time resolution data (met or concentration) was not critical to the deposition fluxes determined.

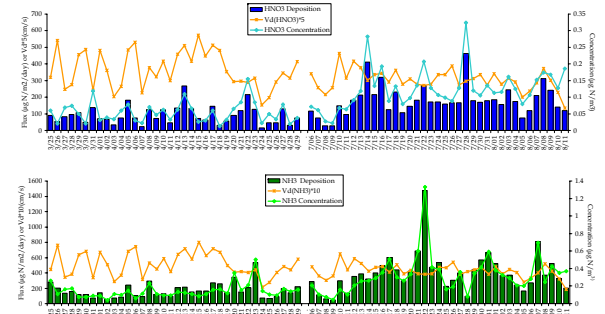
NH₃ and organic N are important contributors to N deposition

- Wet deposition is the major process by which reactive nitrogen is deposited in RMNP during both spring and summer.
- Dry deposition fluxes were dominated by gas phase species. Fine particle ammonium and nitrate fluxes were small, due to low deposition velocities.
- Wet deposition of organic nitrogen and dry deposition of gaseous ammonia were the 3rd and 4th most important pathways measured. Neither is included in routine monitoring efforts. Dry deposition of organic nitrogen, not measured in RoMANS, may also be important.



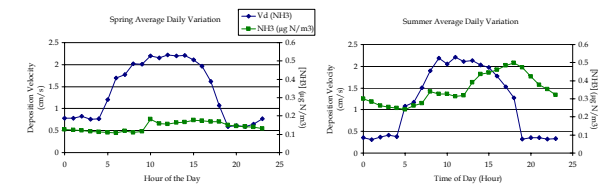
Do measurement timescales influence calculated dry deposition fluxes?

- Dry deposition is computed as the product of a measured concentration (C) and a modeled deposition velocity (V_d), which depends on measured meteorological inputs.

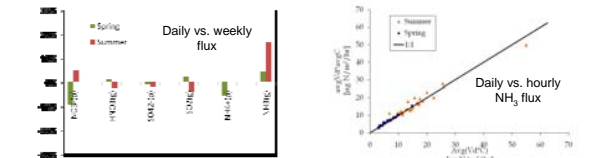


- While CASTNet computes weekly fluxes, the RoMANS study was able to examine fluxes at faster timescales due to higher time resolution concentration measurements. Daily fluxes of nitric acid and ammonia (right) in RoMANS are strongly affected by changing concentrations.

- If V_d and C are independent, the average of their products equals the product of their averages: $\langle V_d \cdot C \rangle = \langle V_d \rangle \cdot \langle C \rangle$. If V_d and C are correlated, then the average of their products will not equal the product of their averages and a bias results in the computed deposition flux. In this case the averaging timescale for measured concentration and modeled deposition velocity is important.



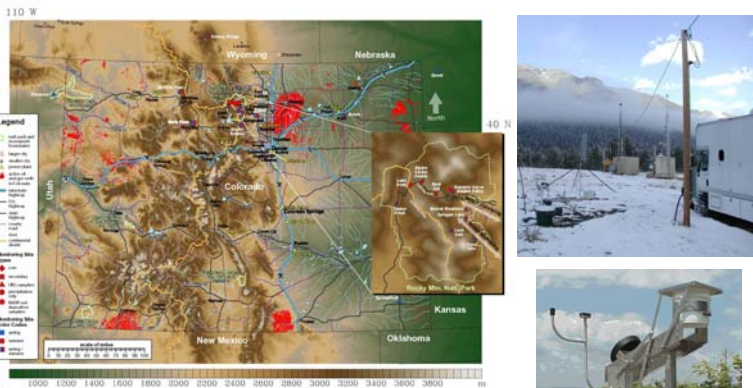
- Using the RoMANS dataset, we compared deposition fluxes computed by averaging deposition velocities and concentrations over timescales from hourly to monthly. The differences were mostly small, especially given the uncertainties in modeled dry deposition velocities.



Conclusions

- Dry deposition of ammonia and wet + dry deposition of organic N are important missing pieces of routinely characterized reactive N deposition fluxes.
- High time resolution determinations of deposition velocities and concentrations were not necessary for calculating unbiased deposition fluxes in Rocky Mountain National Park. High time resolution meteorological and concentration observations are important for source apportionment efforts, especially in regions of complex terrain at the urban-rural interface.

This work was funded by the National Park Service. We are grateful to officials in Rocky Mountain National Park for access to RoMANS study sites and to Air Resource Specialists for assistance with project conduct.



RoMANS measurements

Sites for the RoMANS study were located across much of northern Colorado (see map above). Results are presented here for the core study site in Rocky Mountain National Park (see map inset and photo above right). Measurements at the core site were made using the NPS/CSU Mobile Air Sampling Laboratory (photo above right) and included semi-continuous particle composition (PILS-IC), particle size distributions, and gases (NO_x, O₃, CO, SO₂, and NH₃). 24 hr measurements were made of PM_{2.5} inorganic ions, gaseous HNO₃, and gaseous NH₃ using a URG annular denuder/filter-pack system (see configuration below right). Precipitation was collected on an event basis using a Yankee Environmental Systems Total Precipitation Collector (see photo center right) and on a sub-event basis using a large polyethylene funnel. Meteorological measurements were taken from a 10 m CASTNet met tower co-located at the site. Dry deposition velocities were obtained from CASTNet at one hour time resolution. The NH₃ deposition velocity was assumed, based on a literature review, to equal 70% of the reported HNO₃ deposition velocity.

