Upslope Wind Events and Wet Deposition of Nitrogen in Rocky Mountain National Park

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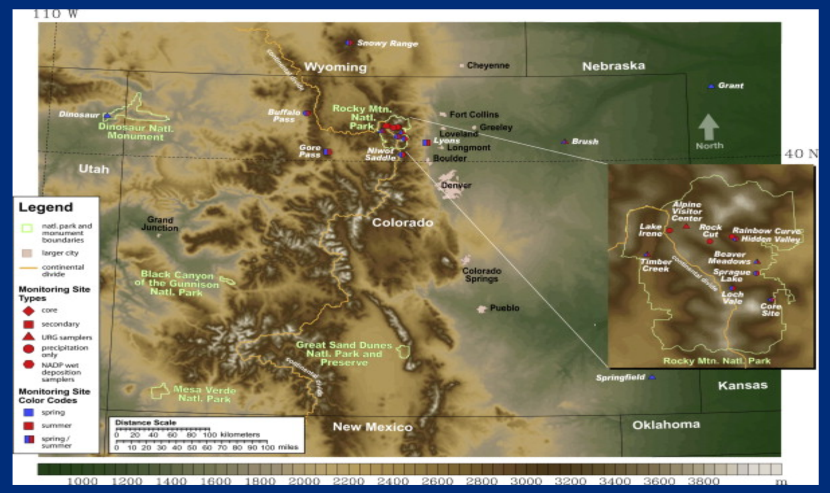
Introduction

- Rocky Mountain National Park (RMNP) is located at a high elevation with low nitrogen retention in plants and soil.
- Upslope wind events in the region are caused by synoptic scale storms as well as mountain valley wind patterns.
- Upslope wind events transport N species from Colorado plains and urban centers into RMNP.
- Upslope winds are common during the summer months.
- Wet deposition involves the scavenging of aerosol particles by water droplets, which can occur during precipitation events.
- NH_4^+ and NO_3^- are the largest wet nitrogen deposition pathways.



- Map of Colorado highlighting the location of Rocky Mountain National Park. Data from the Beaver Meadows site was used.

Sources of Nitrogen

- Burning fossil fuels
- Confined animal feeding
- Nitrogen fertilizers
- Wildfires

Effects of Nitrogen Deposition

- Soil mineralization
- Alters N cycle
- Stream acidification
- Decreases air quality

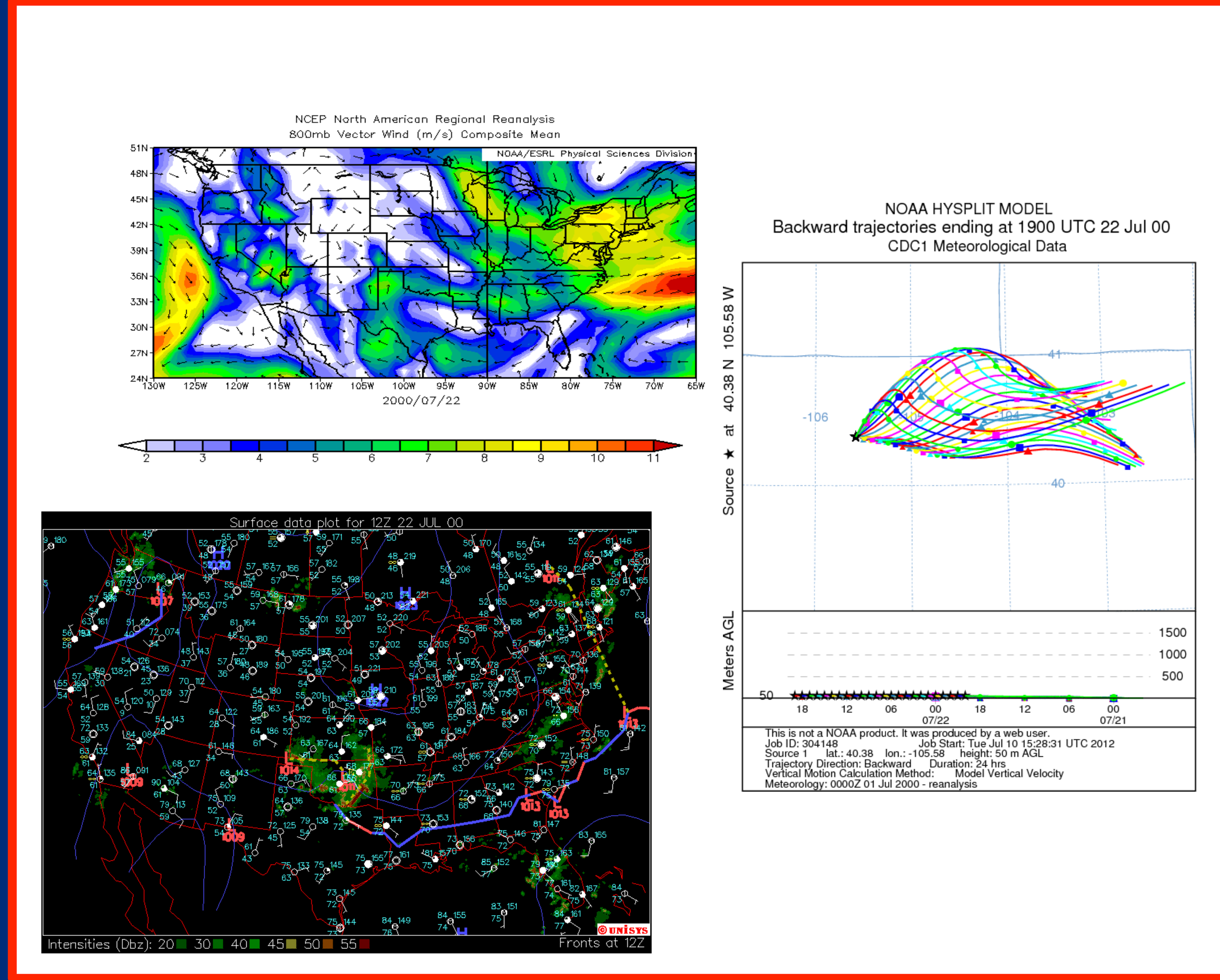
Objectives

- To determine when precipitation, deposition, and upslope wind events were most likely to occur together
- To understand how NH_4^+ and NO_3^- were transported into RMNP by using the HYSPLIT model
- Compare HYSPLIT model with vector wind maps and surface maps for consistency

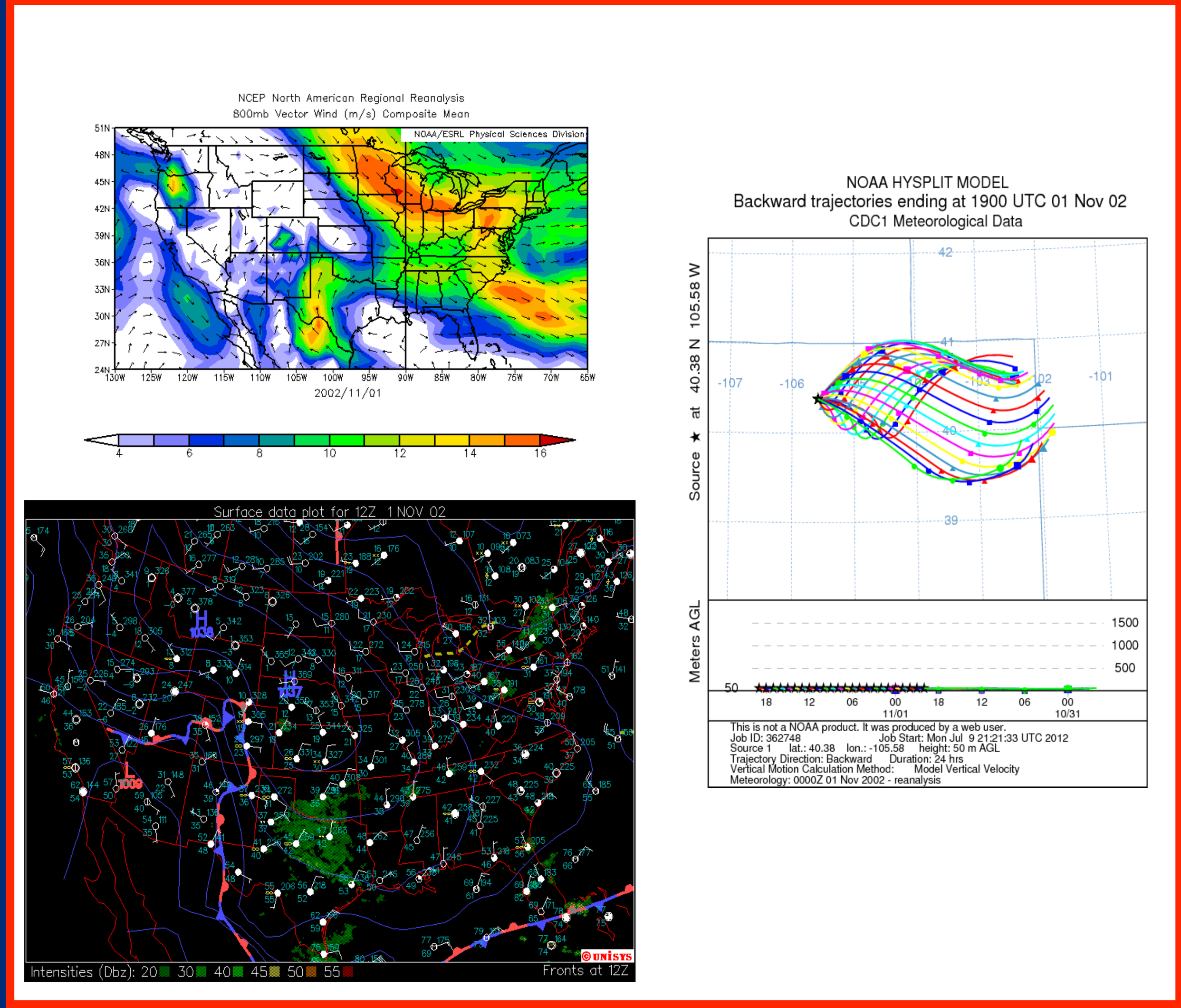
Methods

- National Atmospheric Deposition Program (NADP) monitors acidic precipitation in order to measure deposition.
  - NADP data from the Beaver Meadows site located in RMNP was analyzed from 2000-2010.
- The NOAA Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT) calculates backwards trajectories. Trajectories were calculated for the days when the NADP site recorded precipitation.
  - Air mass backward trajectories over 24-hour period
  - Winds from NE, E, or SE of RMNP were classified as upslope winds
- Vector maps
  - Speed and direction of winds
- Surface maps
  - Synoptic scale winds
  - Mountain-valley wind patterns

Data

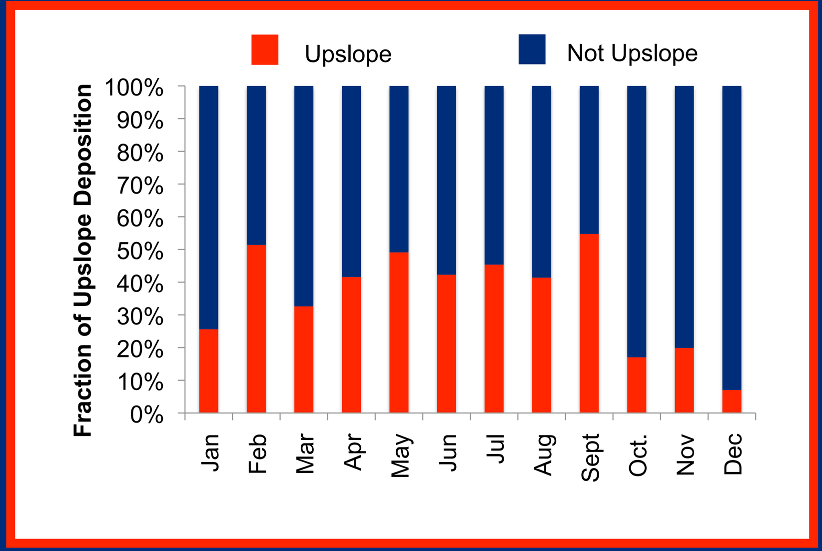


- **Vector map, surface map, and HYSPLIT backward trajectory of July 22, 2000**
  - The HYSPLIT backward trajectory shows that upslope winds occurred for 24 hours. Not all events occurred for the entire day as some were associated with summer-time mountain-valley circulations.
  - The vector map indicates that weak upslope winds occurred during the 24-hour period.
  - The surface map indicates that the upslope winds are possibly caused by synoptic scale forces because a low pressure system is present.

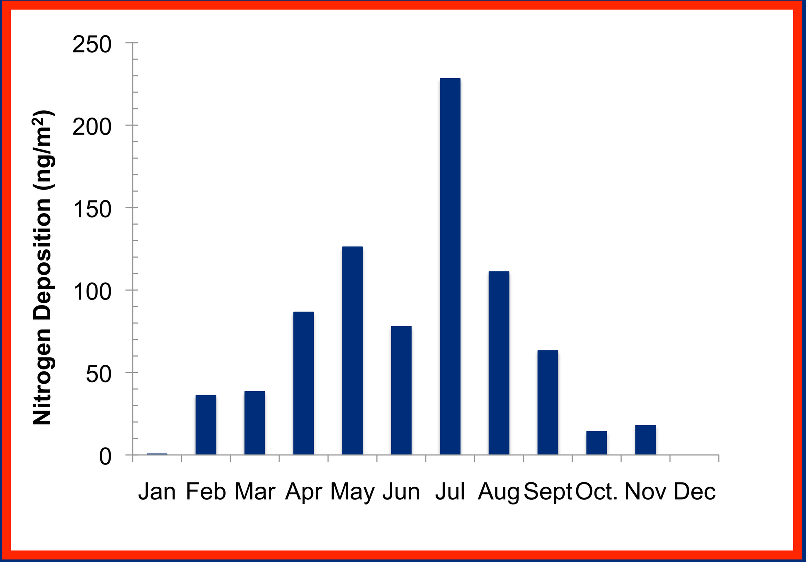


- **Vector map, surface map, and HYSPLIT backward trajectory of November 1, 2002**
  - The HYSPLIT backward trajectory shows that upslope winds occurred for 24 hours.
  - The vector map indicates that weak upslope winds occurred during the 24-hour period.
  - The surface map indicates that the upslope winds are caused by synoptic scale forces because a front is present.

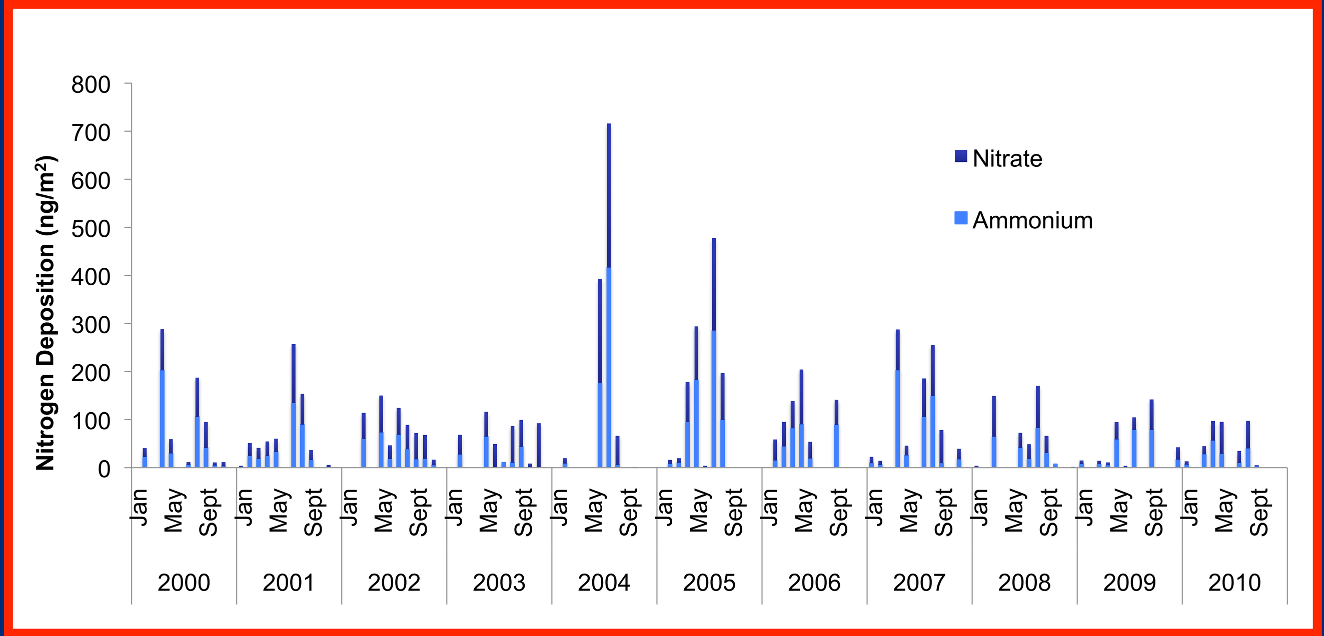
Results



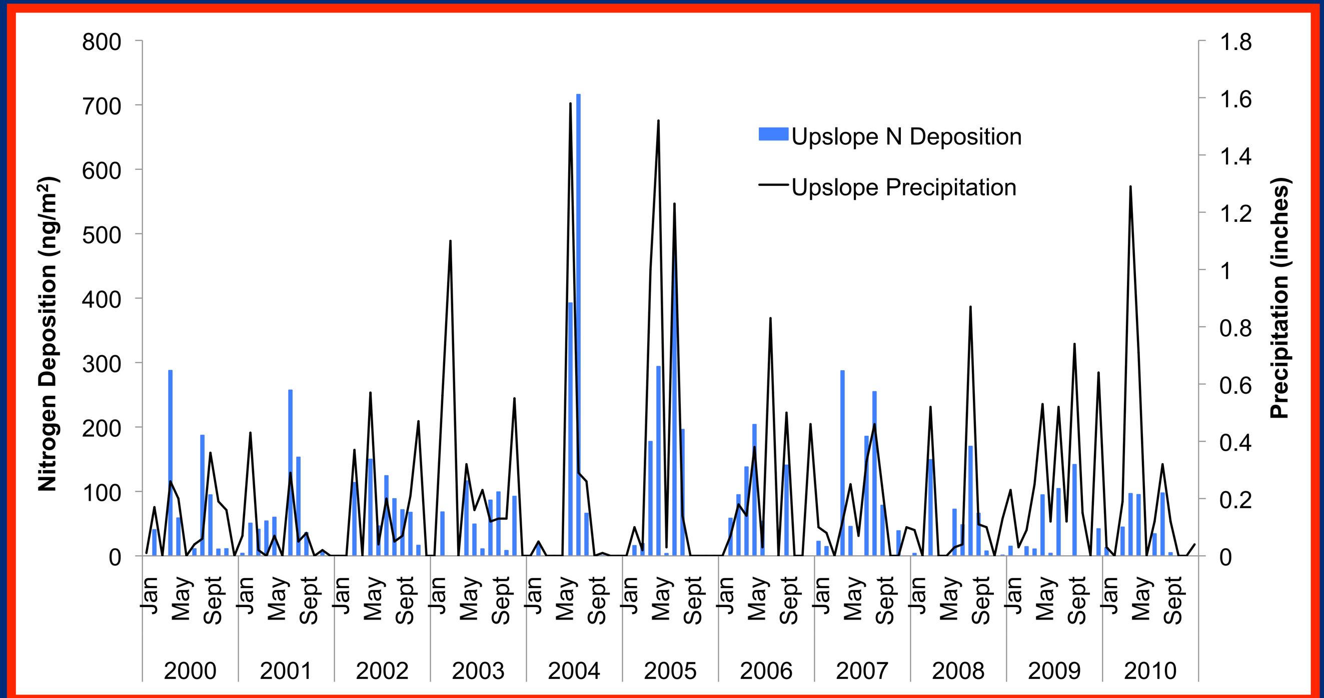
- **Average fraction of upslope deposition**
- The amount of upslope deposition varies month to month.
- The highest fraction of upslope deposition occurred during the summer months.



- **Average upslope nitrogen deposition**
- July was the month with the highest average amount of nitrogen deposition.
- The smallest amounts of deposition occurred in January and December.



- **Wet upslope deposition of nitrate and ammonium**
- Ammonium was the slightly larger deposition pathway.
- There was significantly high nitrogen deposition during 2004 and 2005.



- **The relationship between precipitation and deposition**
- Upslope precipitation and deposition often increase and decrease together.

Conclusions

- Upslope winds, precipitation, and nitrogen deposition are interrelated
  - Overall 44% of total wet deposition was upslope during 2000-2010.
  - Upslope deposition varies from month to month.
- The amount of NO_3^- and NH_4^+ deposited into RMNP was very similar.
  - 48% NO_3^-
  - 52% NH_4^+
- The amount of NO_3^- and NH_4^+ varied in individual upslope events.
- Both agricultural sources of nitrogen and urban sources of nitrogen contributed to deposition in RMNP, the reduced, agricultural nitrogen may be slightly more important.
- Often more precipitation results in greater deposition.
- The peak in the number of upslope events occurred in the summer.
  - 31% of events occurred in July and August combined
- Upslope events are less likely in winter.
- Upslope wind events are very important for the transport of nitrogen-containing pollutants from the Colorado plains and urban centers into RMNP.

Future Work

- Use more sophisticated modeling to better understand the timing of upslope winds and precipitation.
- Analyze NADP data from other sites in RMNP to compare the amounts of nitrogen deposition associated with upslope events.

References

Beem, K.B., Suresh R., Florian S.M., Courtney T., et al. "Deposition of reactive nitrogen during Rocky Mountain Airborne Nitrogen and Sulfur (RoMANS) study." *Environmental Pollution*. 158.33 (2010): 862-872.

Benedict, K.B., D. Day, F.M. Schwandner, S.M. Kreidenweis, et al. Observations of Atmospheric reactive Nitrogen Species in Rocky Mountain National Park and across Colorado. Submitted to *Atmospheric Environment*.

Benedict, K.B., S.M. Kreidenweis, B. Schichtel, W.C. Malm, et al. A Seasonal Nitrogen Deposition Budget for Rocky Mountain National Park. In preparation for submission to *Ecological Application*.

Draxler, R.R. and Rolph, G.D., 2012. HYSPLIT (HYsplit Single-Particle Lagrangian Integrated Trajectory) Model access via NOAA ARL READY Website (http://ready.arl.noaa.gov/HYSPLIT.php). NOAA Air Resources Laboratory, Silver Spring, MD.

Rolph, G.D., 2012. Real-time Environmental Applications and Display sYstem (READY) Website (http://ready.arl.noaa.gov). NOAA Air Resources Laboratory, Silver Spring, MD.

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