Nitrogen deposition in Rocky Mountain National Park

NPS, USDA-FS, EPA, NSF, Universities
Colorado DPHE & local partners
Nitrogen deposition in Rocky

- Overall nitrogen deposition is increasing.
- $\text{NO}_3$ (combustion sources) makes up >50%.
- $\text{NH}_4$ (agricultural sources) is increasing rapidly.
- Local and regional sources contribute to both.
- Local sources may contribute more during spring and summer.
## Nitrogen in atmospheric deposition

<table>
<thead>
<tr>
<th>Source</th>
<th>Emissions</th>
<th>Wet Deposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustion:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicles</td>
<td>$\text{NO}_x$</td>
<td>$\text{NO}_3^-$</td>
</tr>
<tr>
<td>Energy development</td>
<td>(Nitrogen oxides-gases)</td>
<td>(Nitrate-dissolved + particulate)</td>
</tr>
<tr>
<td>Energy production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>$\text{NH}_3$</td>
<td>$\text{NH}_4^+$</td>
</tr>
<tr>
<td>Livestock production</td>
<td>(Ammonia gas)</td>
<td>(Ammonium-dissolved + particulate)</td>
</tr>
<tr>
<td>Crop production</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
USA NO\textsubscript{x} Emissions
(million short tons/year)

- Natural emissions
- 1998 emissions
- 2010 target emissions

After Galloway et al., (2001)
Total NO\textsubscript{x} emissions

-- includes mobile and non-point sources

1999 County Emissions Density (Tons per sq.mi.) of Nitrogen Oxides

Source: US EPA Office of Air and Radiation, NEI Database

Monday, May 17, 2004
Nitrate Ion Concentrations
1985-2001

NATIONAL ATMOSPHERIC DEPOSITION PROGRAM
A Cooperative Research Support Program of the State Agricultural Experiment Stations (NRSP-3) Federal and State Agencies and Private Research Organizations

85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01

NO₃⁻ (mg/L)

USGS National Atmospheric Deposition Program / National Trends Network
Nitrate Ion Concentrations
1985-2001

Nitrate ion concentrations across the United States from 1985 to 2001, showing high concentrations in the northeastern United States.

NO₃⁻ (mg/L)

National Atmospheric Deposition Program / National Trends Network

USGS
Nitrate Ion Concentrations
1985-2001

NO$_3^-$ (mg/L)

National Atmospheric Deposition Program / National Trends Network
Nitrate Ion Concentrations
1985-2001

NO$_3^-$ (mg/L)

National Atmospheric Deposition Program / National Trends Network

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Nitrate Ion Concentrations
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Nitrate Ion Concentrations
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NO$_3^-$ (mg/L)

National Atmospheric Deposition Program / National Trends Network
Nitrate Ion Concentrations
1985-2001

National Atmospheric Deposition Program / National Trends Network

NO$_3^-$ (mg/L)
Nitrate Ion Concentrations
1985-2001

NO$_3^-$ (mg/L)

National Atmospheric Deposition Program / National Trends Network
Nitrate Ion Concentrations
1985-2001

NO₃⁻ (mg/L)

National Atmospheric Deposition Program / National Trends Network

USGS
Nitrate Ion Concentrations
1985-2001

National Atmospheric Deposition Program / National Trends Network
Percent change in NO$_3^-$ in wetfall

Lehmann et al., Environmental Pollution 2005
Trends in NO3 Concentrations in Precipitation, 1994-2003
FY2004 Annual Performance Report for NPS Government Performance and Results Act (GPRA)
Air Quality Goal Ia3

Improving Trend, \( p \leq 0.05 \)
Improving Trend, \( 0.05 < p \leq 0.15 \)
Degrading Trend, \( 0.05 < p \leq 0.15 \)
Degrading Trend, \( p \leq 0.05 \)
No Trend

02/03/2005

Downward pointing arrows denote trends toward decreasing nitrate (NO3) concentrations and improving air quality. Similarly, the up arrows correspond to trends toward higher nitrate concentrations and hence worsening air quality.
USA NH₃ Emissions
(million short tons/year)

Natural emissions
1998 emissions

After Galloway et al., (2001)
Total NH$_3$ emissions

-- includes mobile and non-point sources

1999 County Emissions Density (Tons per sq.mi.) of Ammonia

Source: US EPA Office of Air and Radiation, NEI Database
Ammonium Ion Concentrations
1985-2001
Ammonium Ion Concentrations
1985-2001

National Atmospheric Deposition Program / National Trends Network
Ammonium Ion Concentrations
1985-2001

National Atmospheric Deposition Program / National Trends Network
Ammonium Ion Concentrations
1985-2001

NH₄⁺ (mg/L)

National Atmospheric Deposition Program / National Trends Network
Ammonium Ion Concentrations
1985-2001

National Atmospheric Deposition Program / National Trends Network
Ammonium Ion Concentrations
1985-2001

NH$_4^+$ (mg/L)

National Atmospheric Deposition Program / National Trends Network

USGS
Percent change in NH4+ in wetfall

Lehmann et al., Environmental Pollution 2005
Trends in NH4 Concentrations in Precipitation, 1994-2003
FY2004 Annual Performance Report for NPS Government Performance and Results Act (GPRA)
Air Quality Goal Ia3
Snowpack chemistry

- Major ions
- Nutrients
- Trace metals
- $^{34}$S, $^{15}$N isotopes

Snowpack Sites Sampled Annually During 1993–2000 In the Rocky Mt. Region

- G.P. Ingersoll and others, USGS
Nitrate in Rocky Mountain snowpack (average, 1993-2000)

- G.P. Ingersoll and others, USGS
Annual VWM Inorganic N conc. in wetfall

- 10-year mean DIN concentration (NO3 + NH4)
- NADP sites in Colorado and Wyoming > 2400m elevation
Inorganic Nitrogen Concentration in Wetfall, Loch Vale NADP site.

- from NADP/NTN database
Composition of N deposition for 1999–2001

ROM406

- Wet NO3: 37.86%
- Wet NH4: 37.86%
- Dry HNO3: 19.68%
- Dry NH4: 3.62%
- Dry NO3: 0.97%

Source: CASTNET/NADP—NTN
Only complete years are shown
09/20/2002
Nitrogen concentrations in wetfall by season

RMNP Loch Vale NADP
1994-2003 mean concentrations

Inorganic N conc., M

Season

1. Fall
2. Winter
3. Spring
4. Summer

NO$_3^-$
NH$_4^+$
Airflow into Colorado

- Nolan Doesken, state climatologist
Bear Lake, Rocky Mt. Natl. Park
Bulk precipitation event samples

23 April 1999
5.7 cm precip

10.1 µmol/l DIN (NH4⁺ + NO3⁻)

29 April 1999
4.2 cm precip

32.5 µmol/l DIN (NH4⁺ + NO3⁻)

- Campbell and others, USGS
Sources of nitrogen emissions in Colorado

![Colorado Population, 1940 to 2025](chart)

*Source: U.S. Census Bureau, March 2001*

![Hog and Pig Inventory](chart)

*Colorado, December 1, 1982-97*

![Colorado Natural Gas Marketed Production](chart)

*USGS*
Source attribution using naturally occurring, stable isotopes of nitrogen compounds.

- Provide capability of distinguishing between major source categories of emissions.
- 3 isotopes in NO$_3$: $^{15}$N, $^{18}$O, $^{17}$O
- $^{15}$N in NH$_4^+$
- Recent advances in methodology expand possibilities.

**d$_{15}$N of Seasonal Snowpack 1994-2001**

Campbell and Kendall, unpub. data
Nitrogen deposition in Rocky

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- Local and regional sources contribute to both.
- Local sources may contribute more during spring and summer.
- Next steps?
  - Integrated modeling and monitoring studies of air quality + deposition, incorporating natural tracers to identify source categories.