

Nitrogen deposition in Rocky Mountain National Park





NPS, USDA-FS, EPA, NSF, Universities
Colorado DPHE & local partners

Nitrogen deposition in Rocky

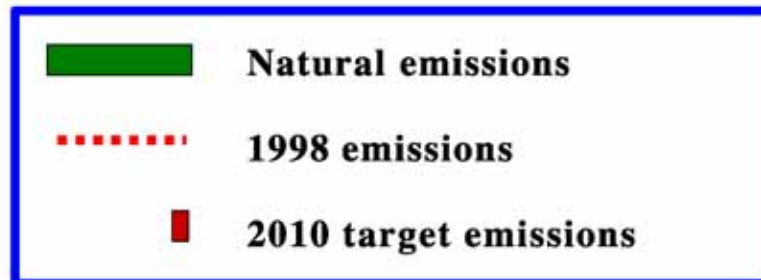
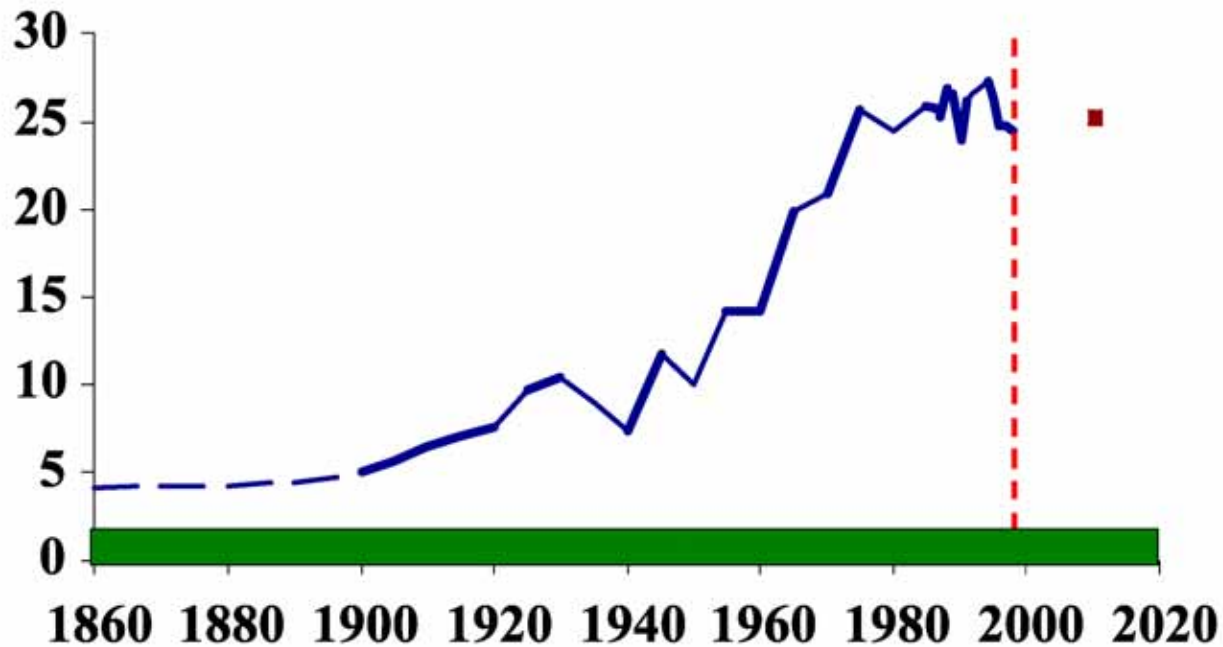
- Overall nitrogen deposition is increasing.
- NO_3 (combustion sources) makes up >50%.
- NH_4 (agricultural sources) is increasing rapidly.
- Local and regional sources contribute to both.
- Local sources may contribute more during spring and summer.

Nitrogen in atmospheric deposition

Source >>>	Emissions >>>	Wet Deposition
<p>Combustion:</p> <p>Vehicles</p> <p>Energy development</p> <p>Energy production</p> 	<p>NO_x</p> <p>(Nitrogen oxides-gases)</p>	<p>NO_3^-</p> <p>(Nitrate-dissolved + particulate)</p>
<p>Agriculture</p> <p>Livestock production</p> <p>Crop production</p> 	<p>NH_3</p> <p>(Ammonia gas)</p>	<p>NH_4^+</p> <p>(Ammonium-dissolved + particulate)</p>

USA NO_x Emissions

(million short tons/year)

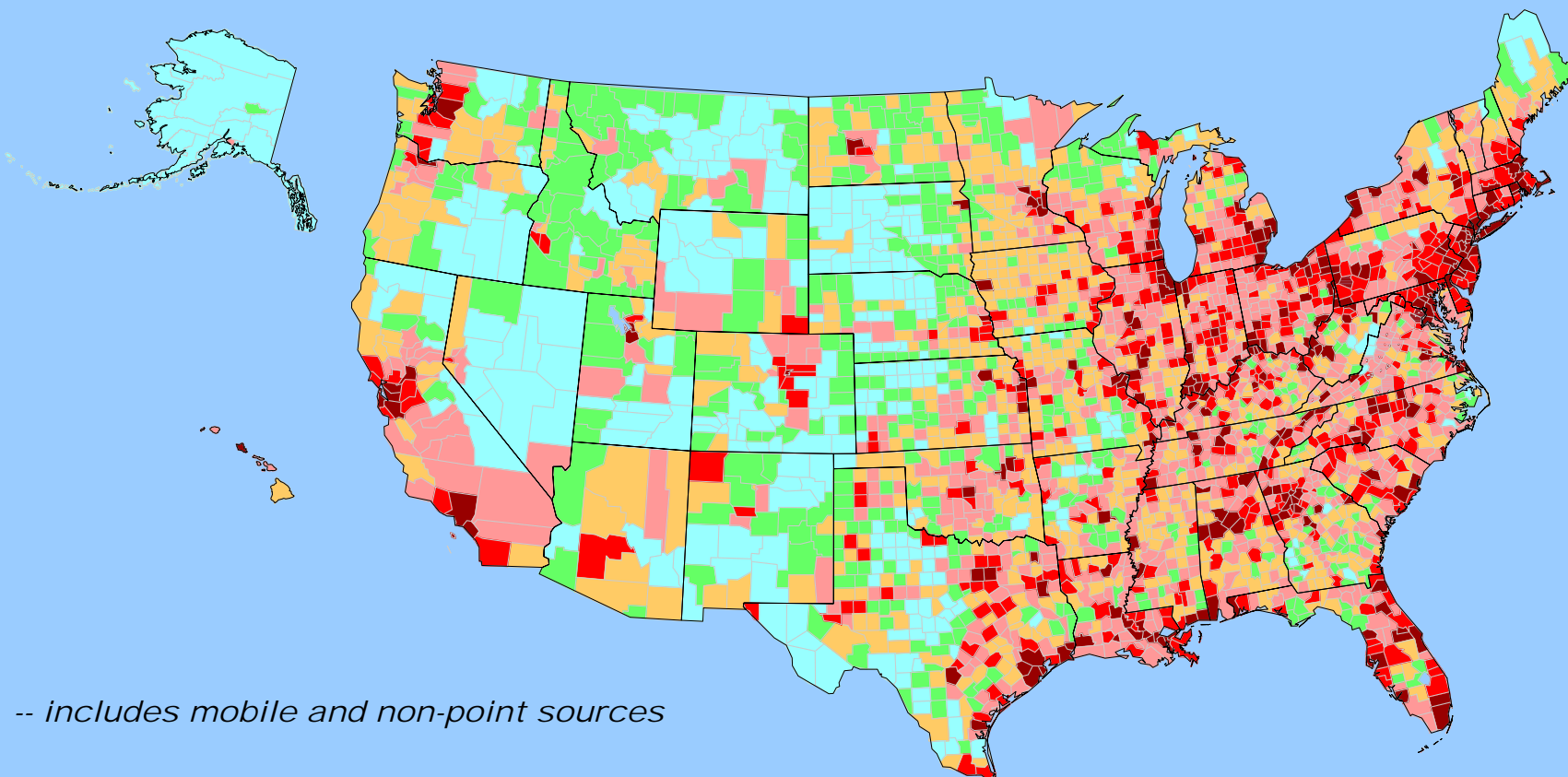


After Galloway et al., (2001)

Total NO_x emissions

Emissions Distribution Map – Criteria Air Pollutants
United States

AirData

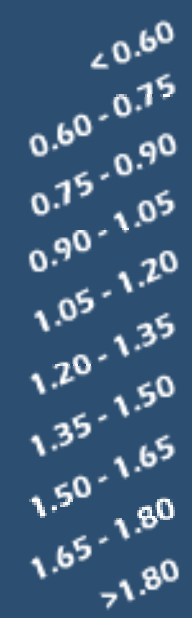


-- includes mobile and non-point sources

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



Nitrate Ion Concentrations 1985-2001

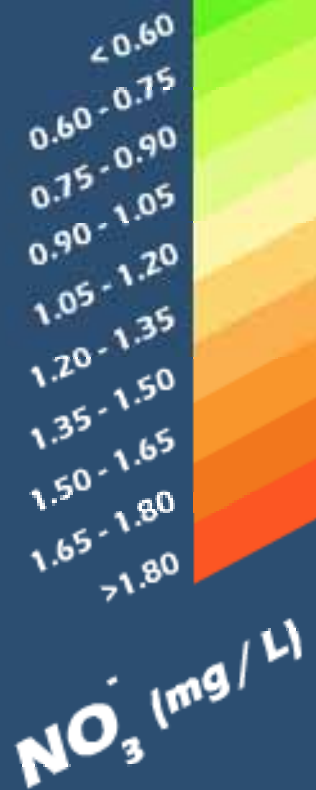
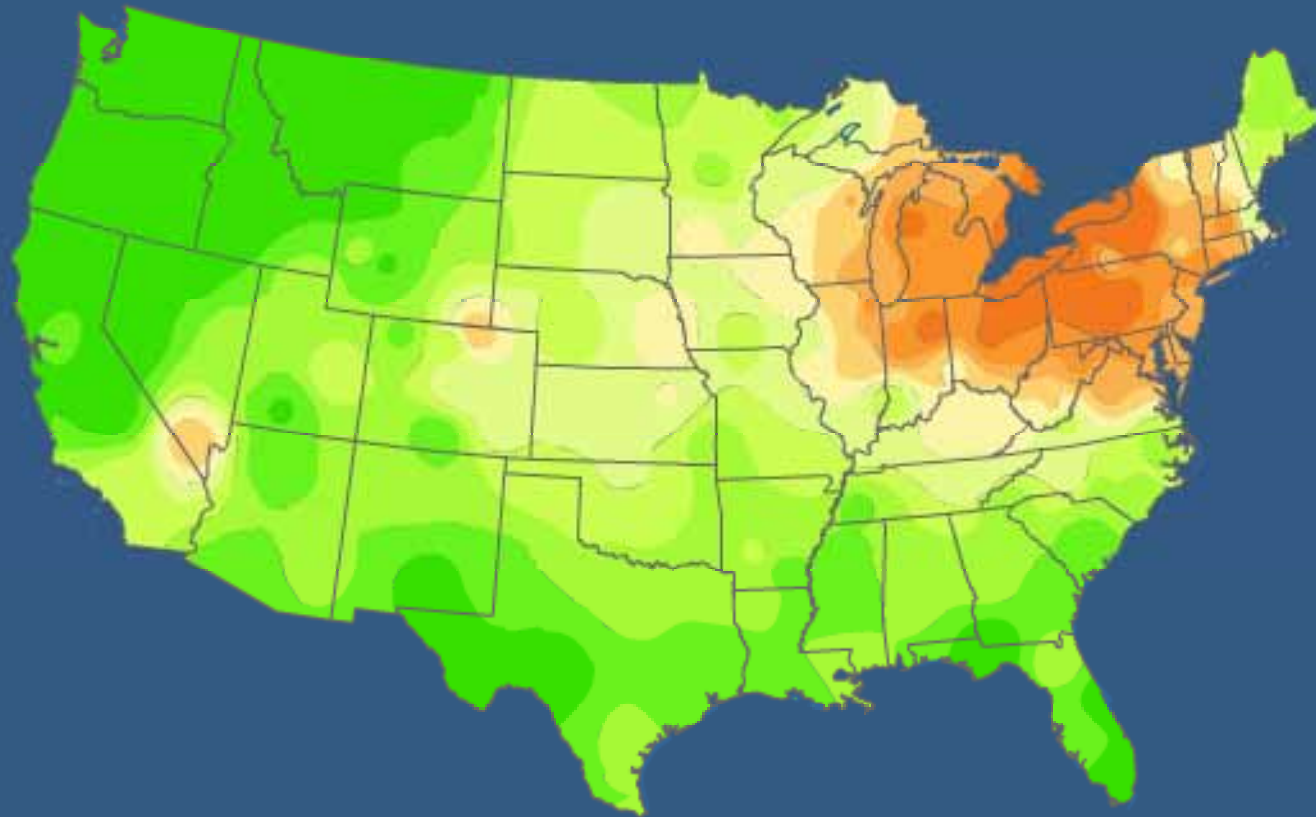


NO_3^- (mg / L)

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National Atmospheric Deposition Program / National Trends Network

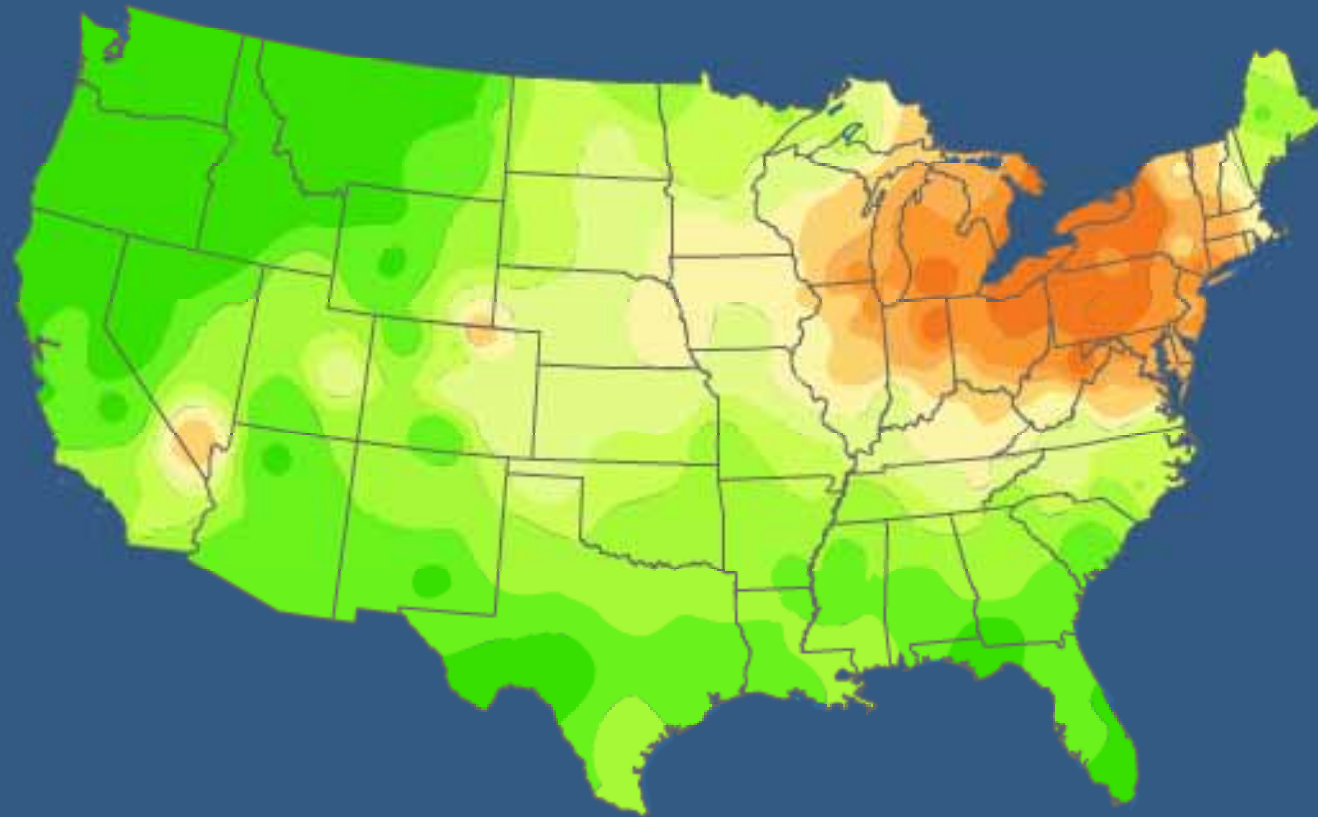
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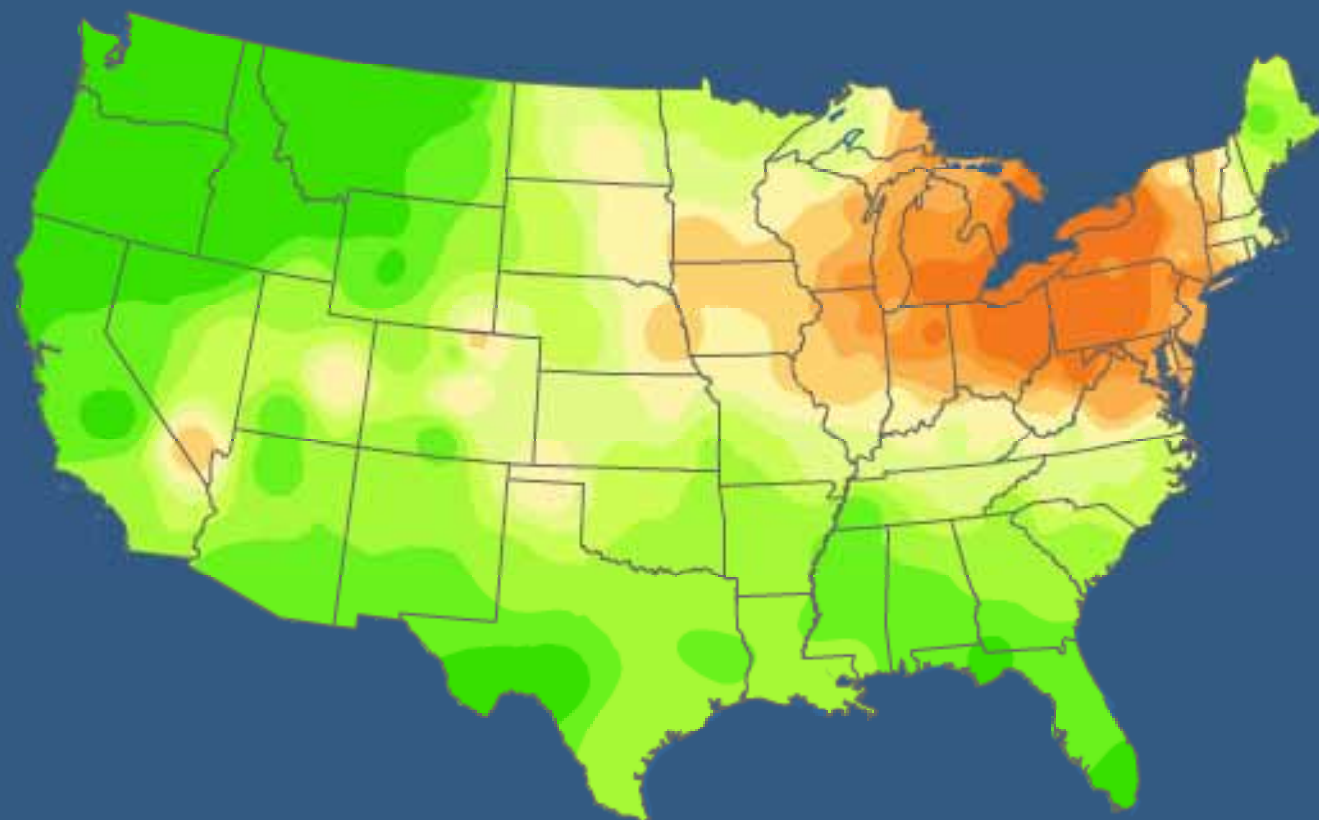
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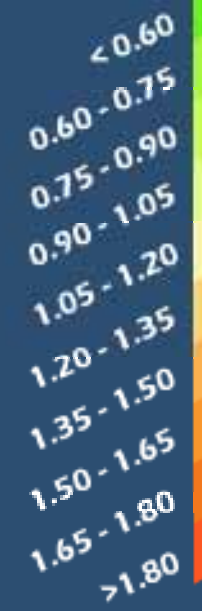
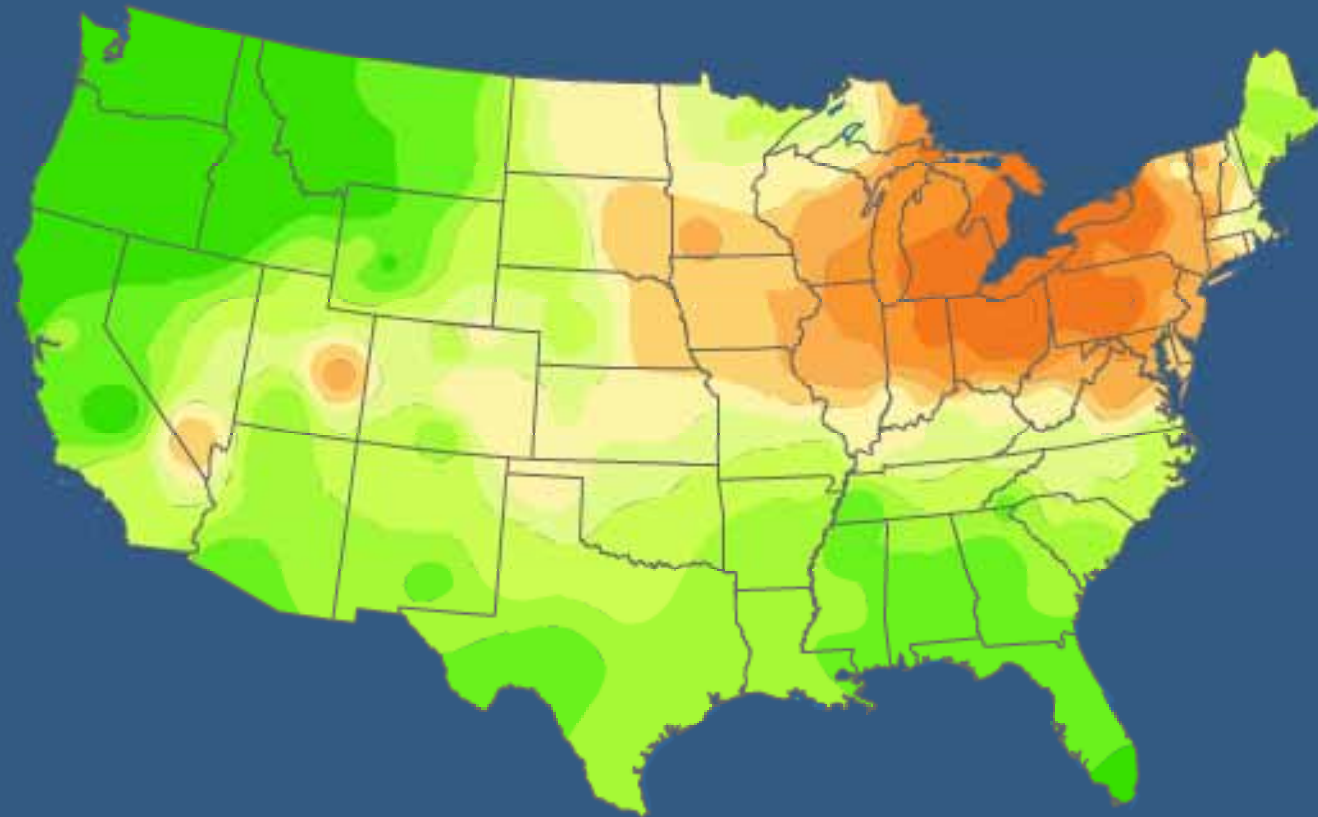
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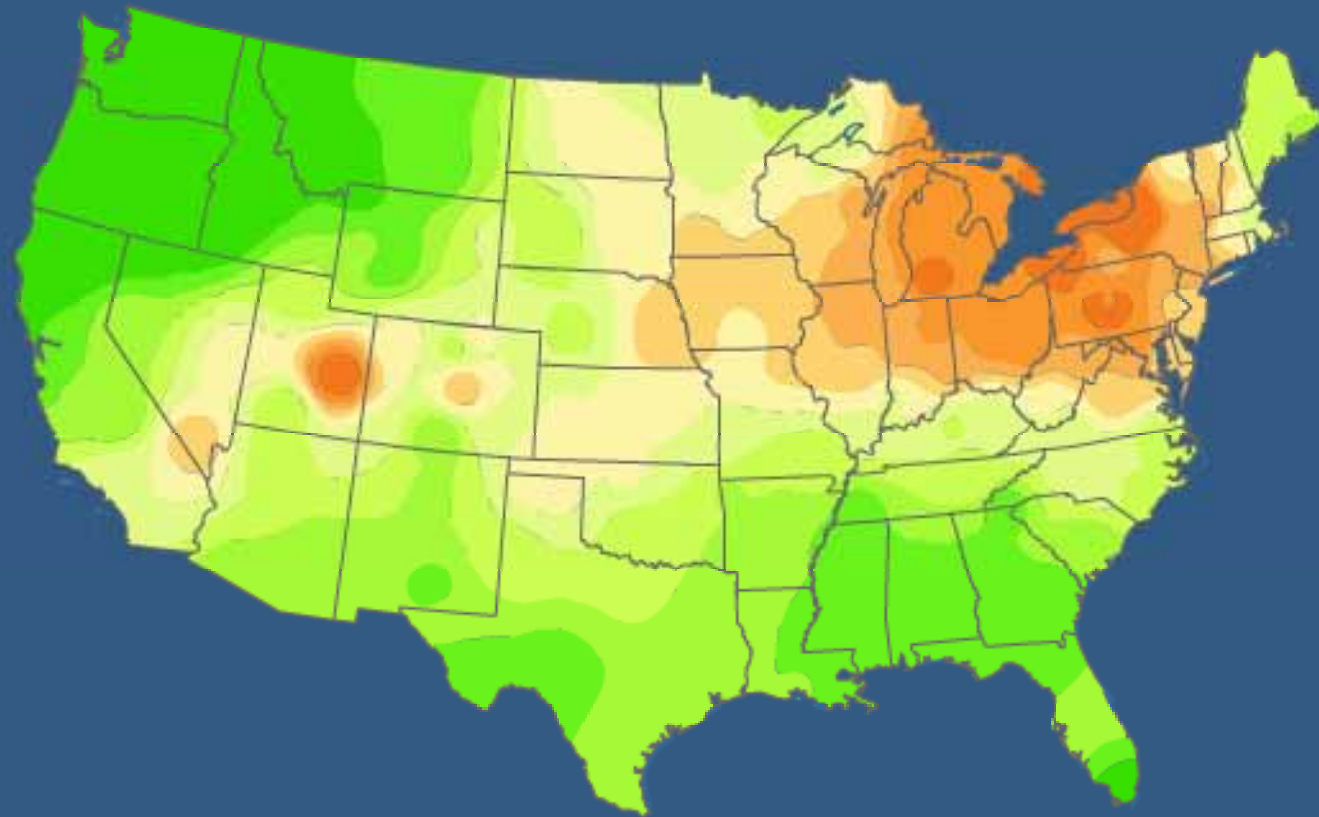


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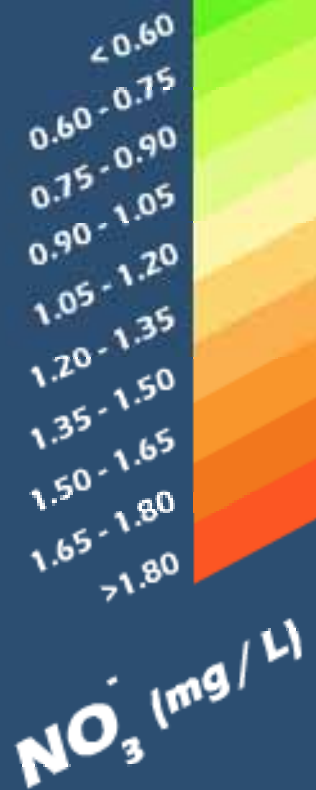
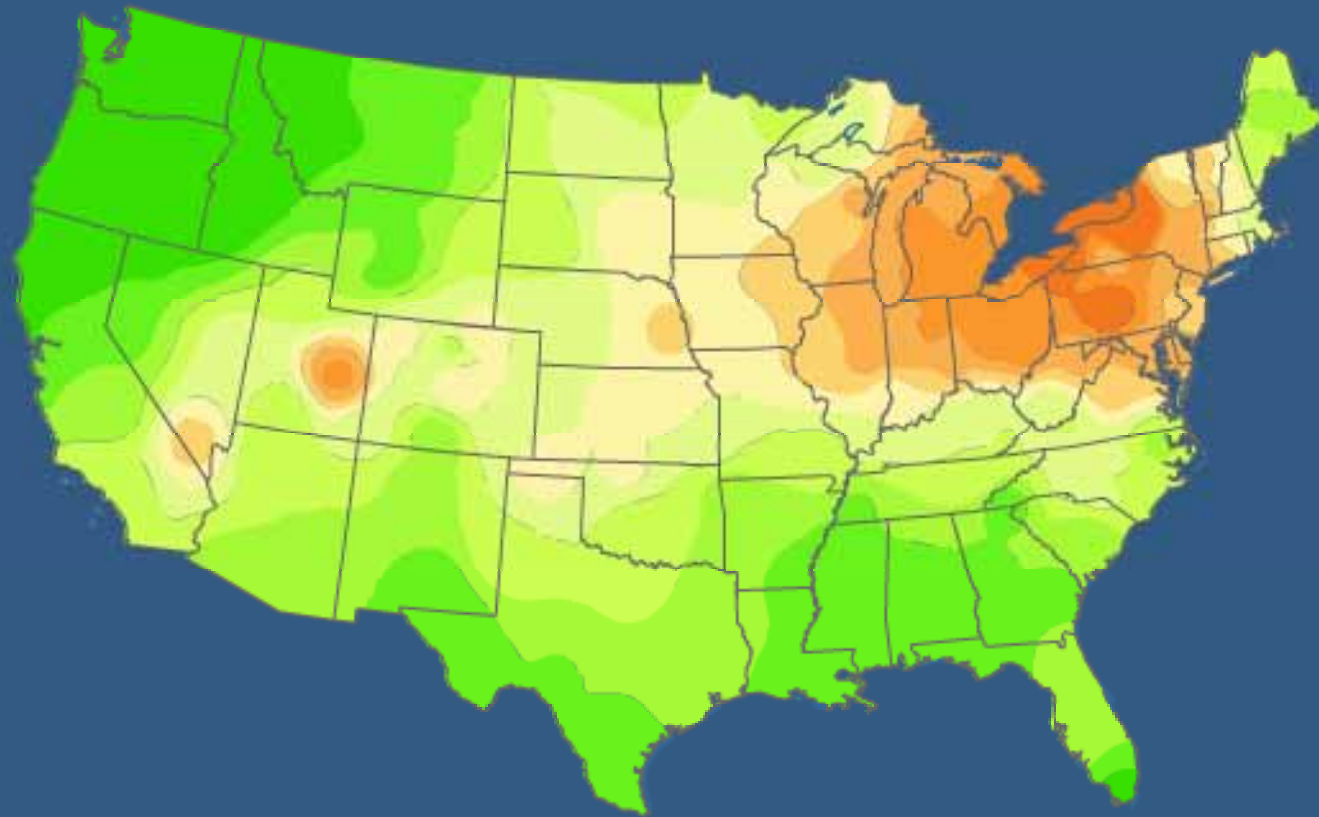
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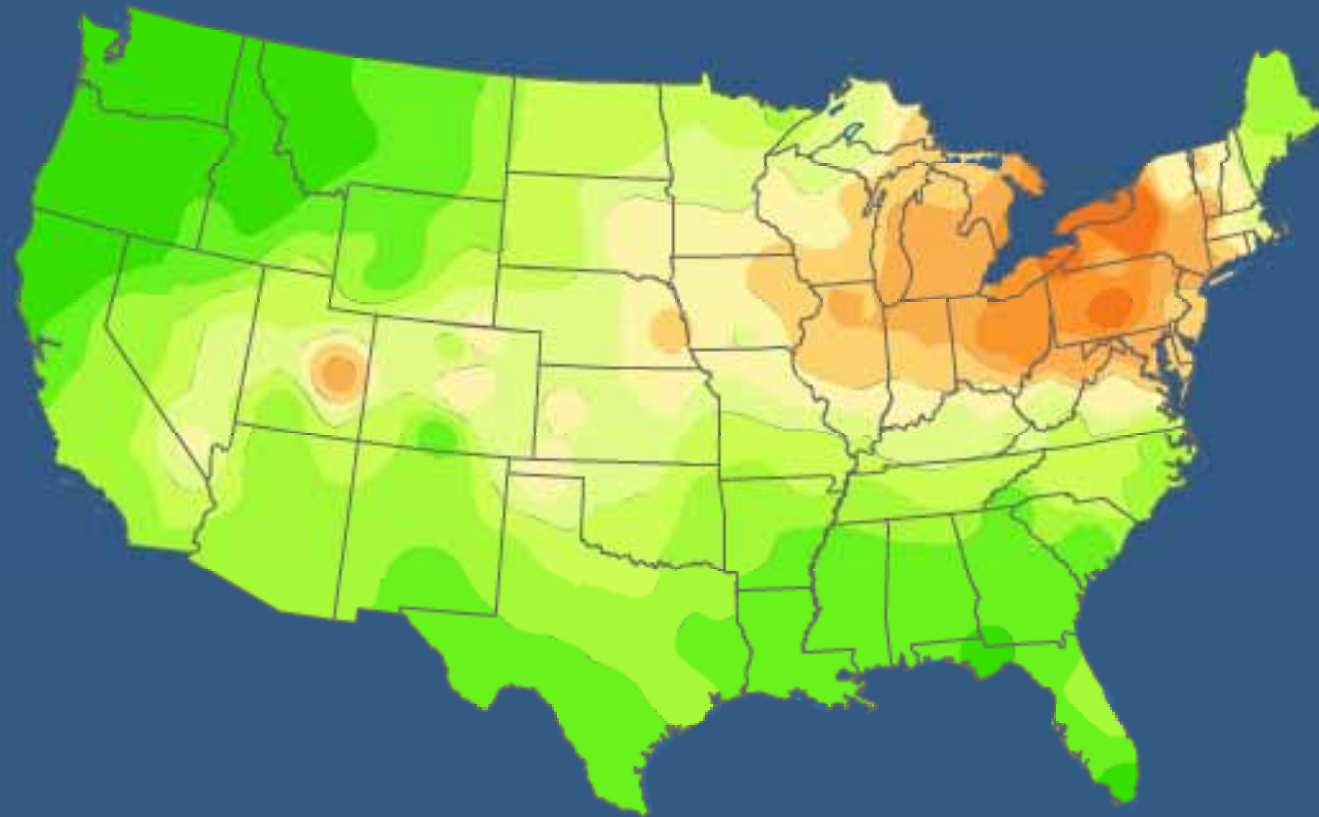
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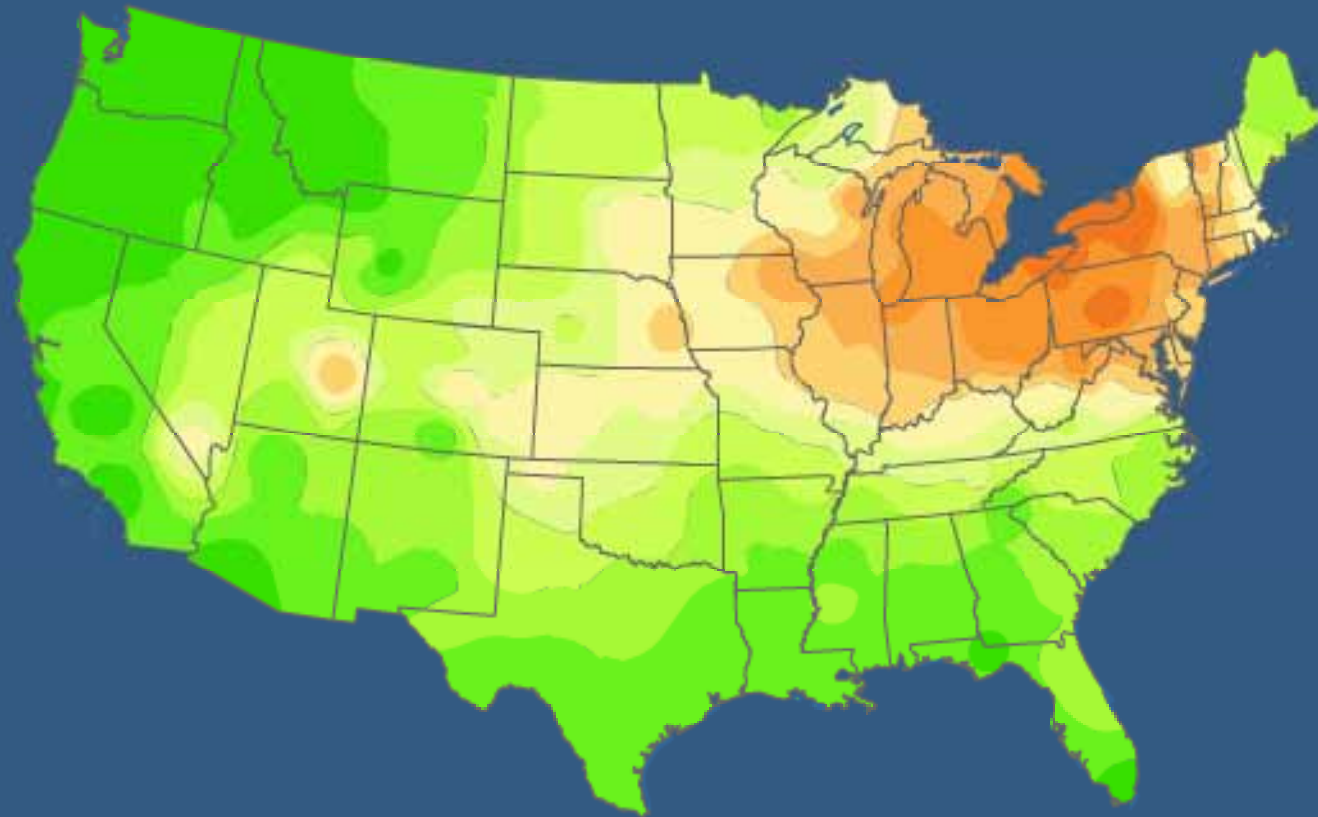
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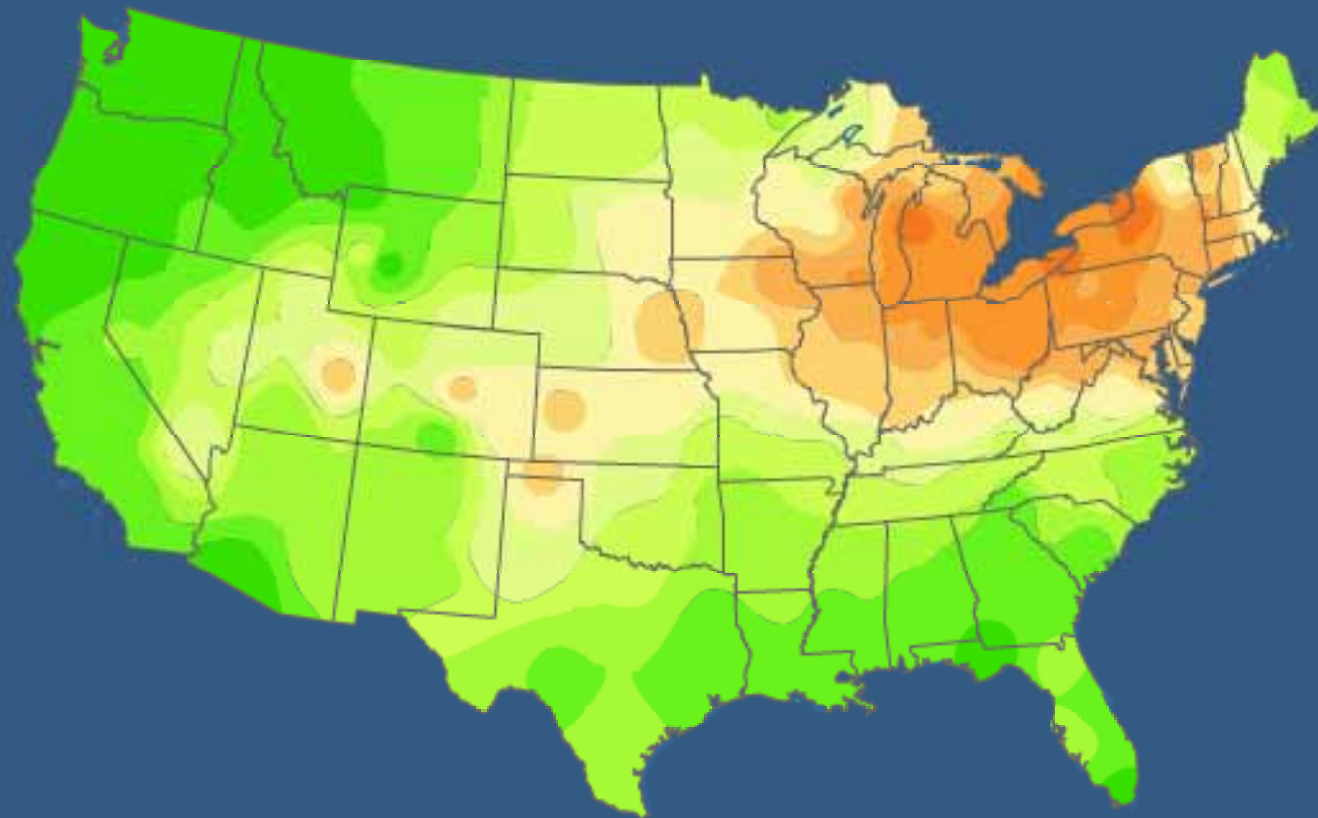
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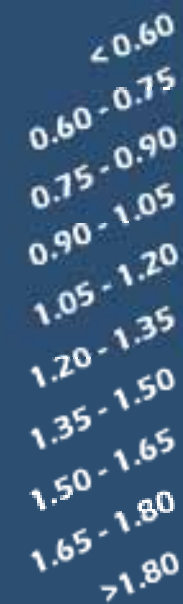
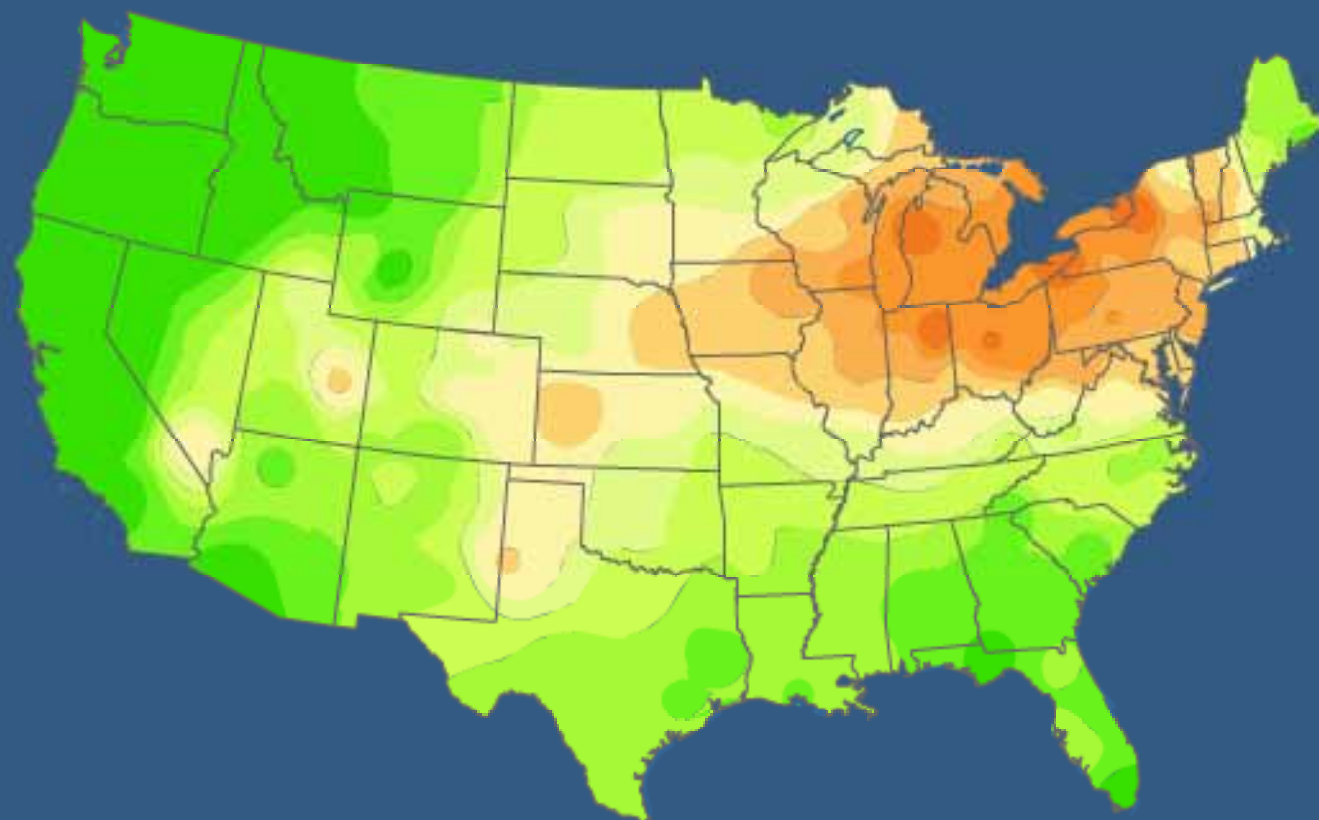
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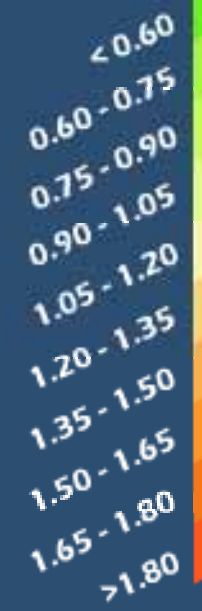
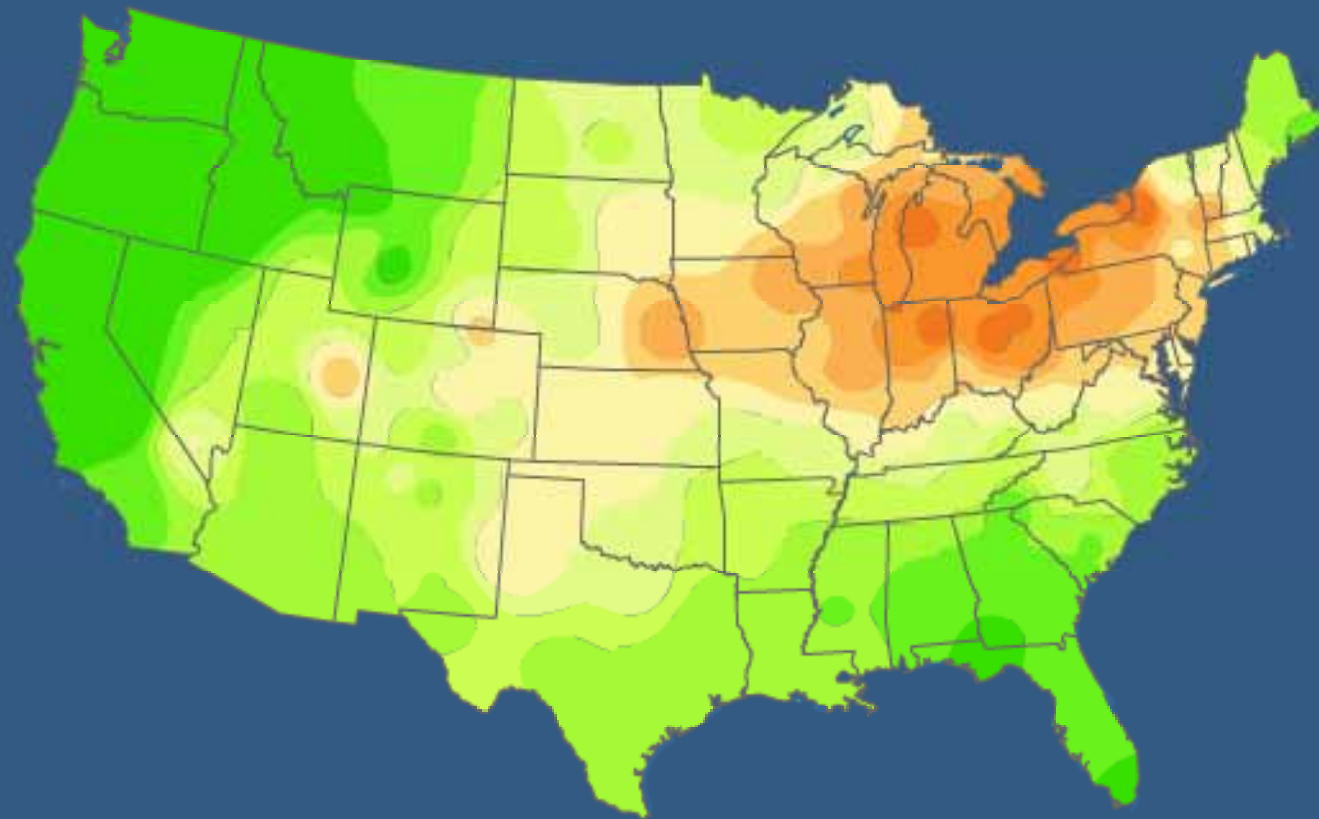


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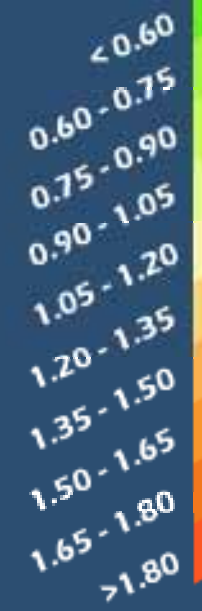
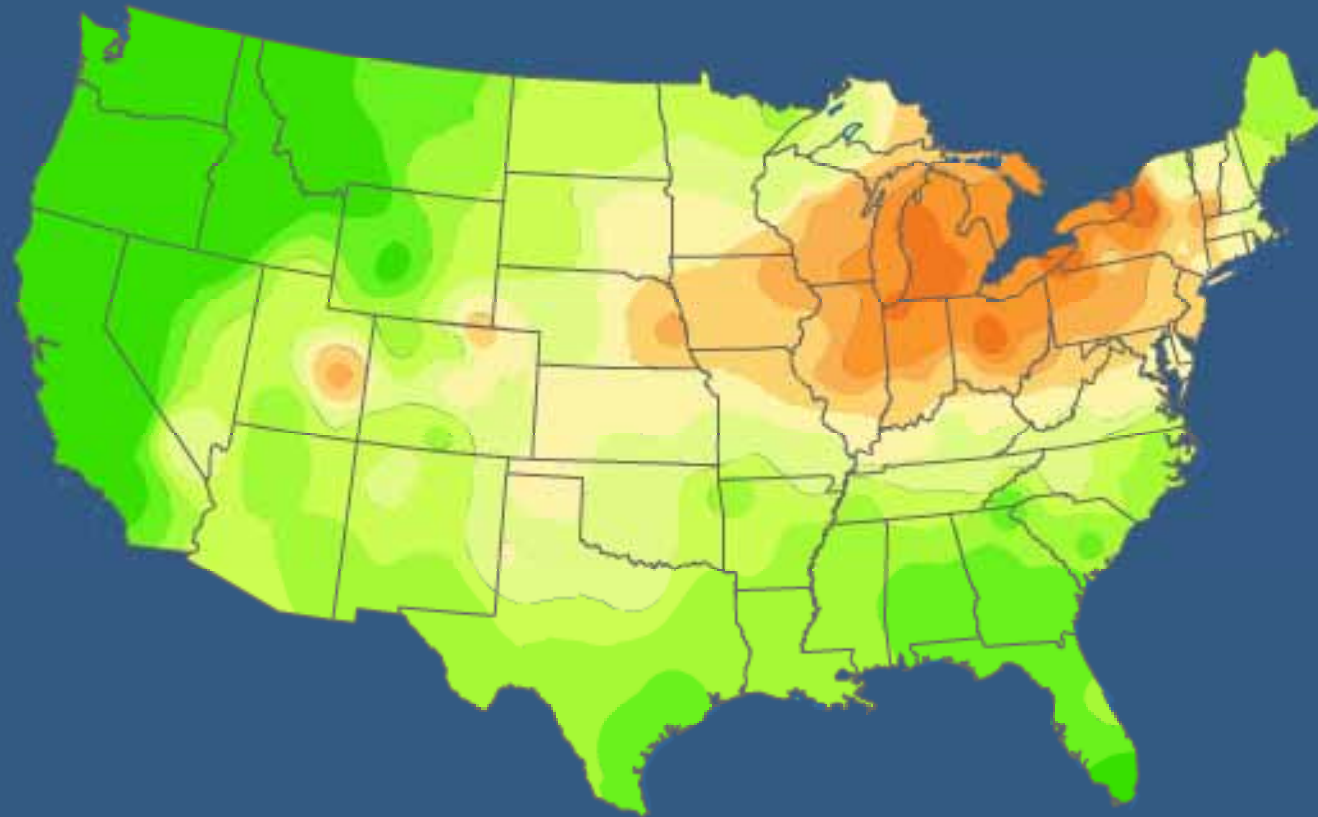


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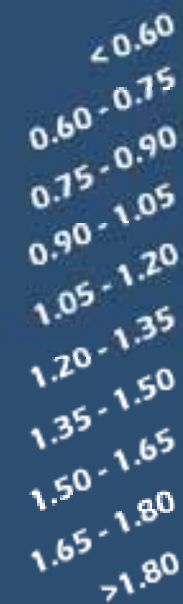
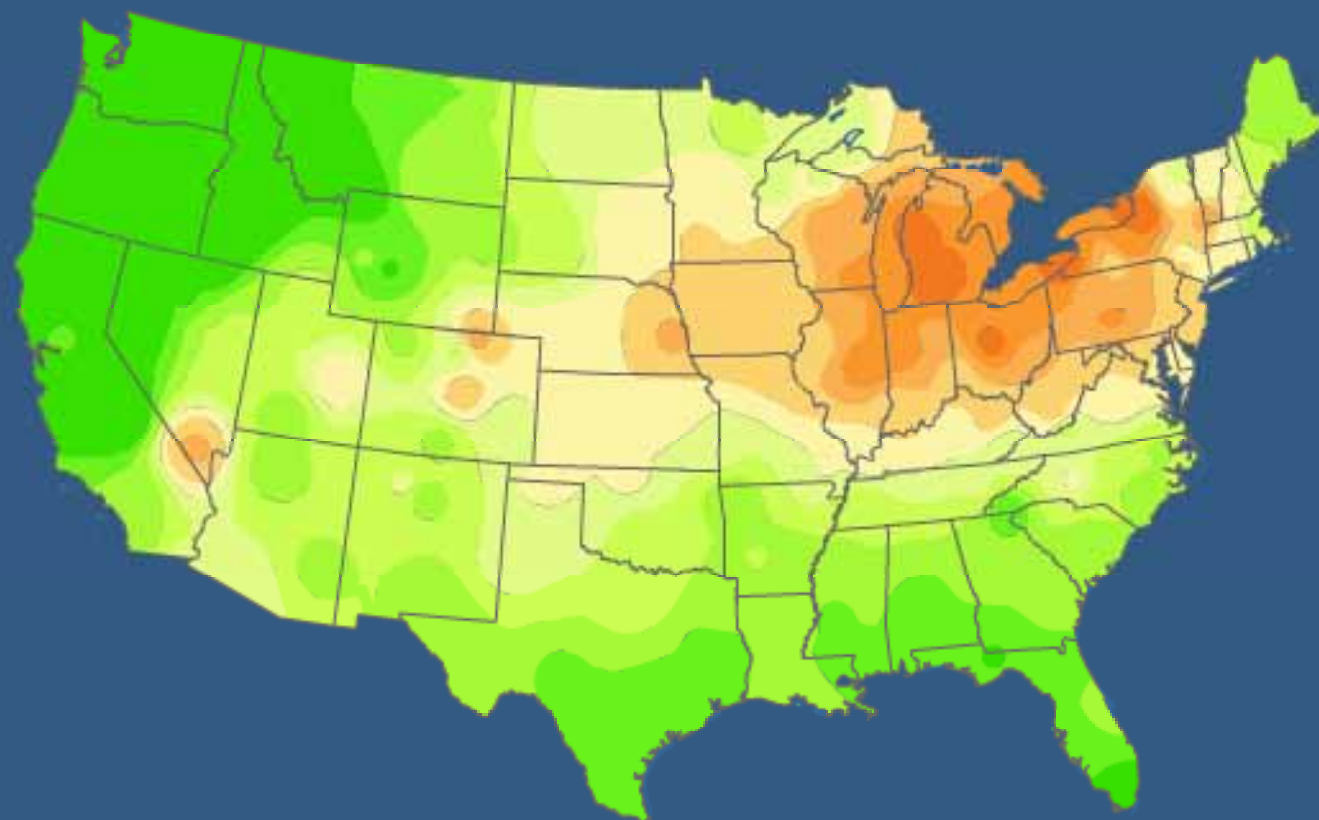


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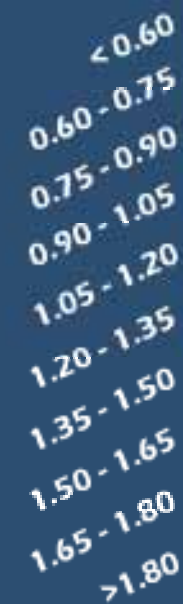
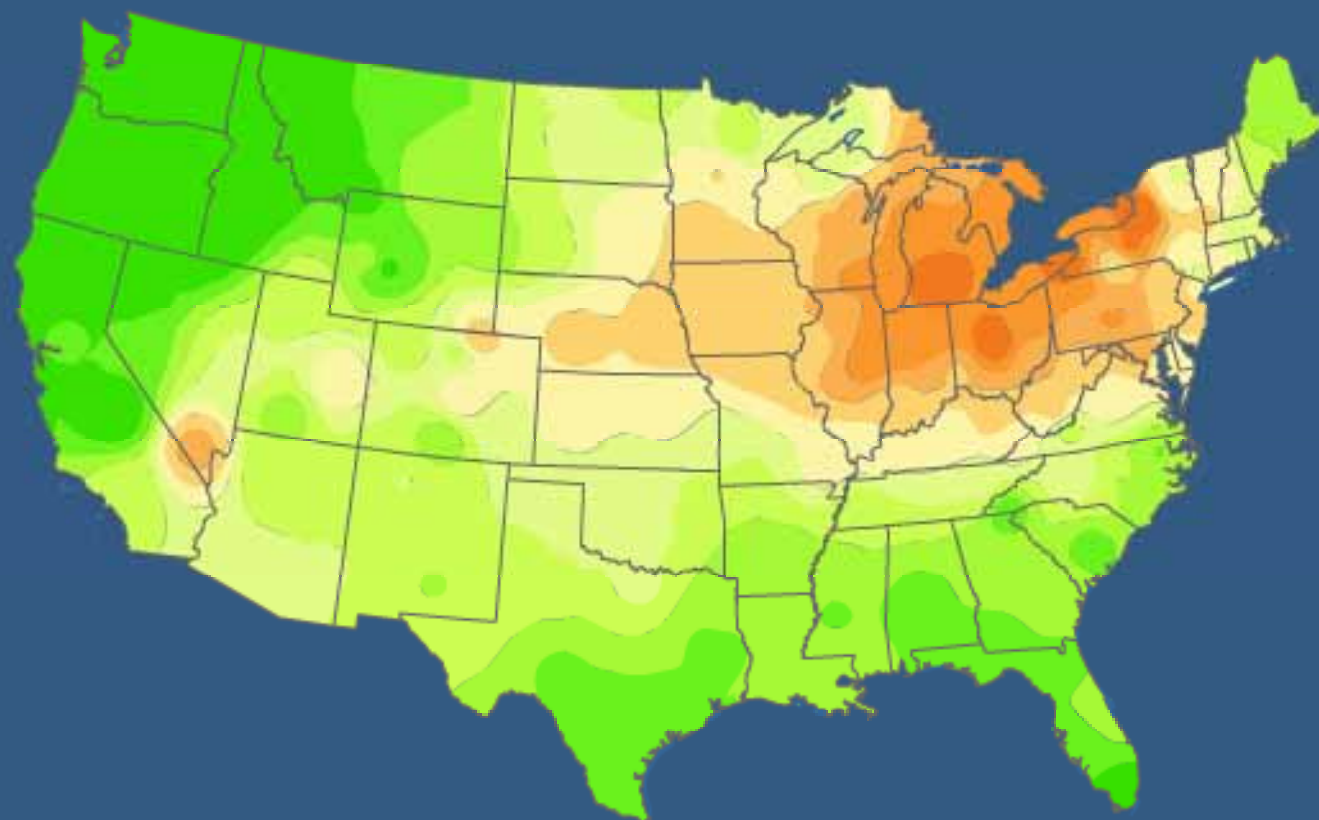


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National Atmospheric Deposition Program / National Trends Network

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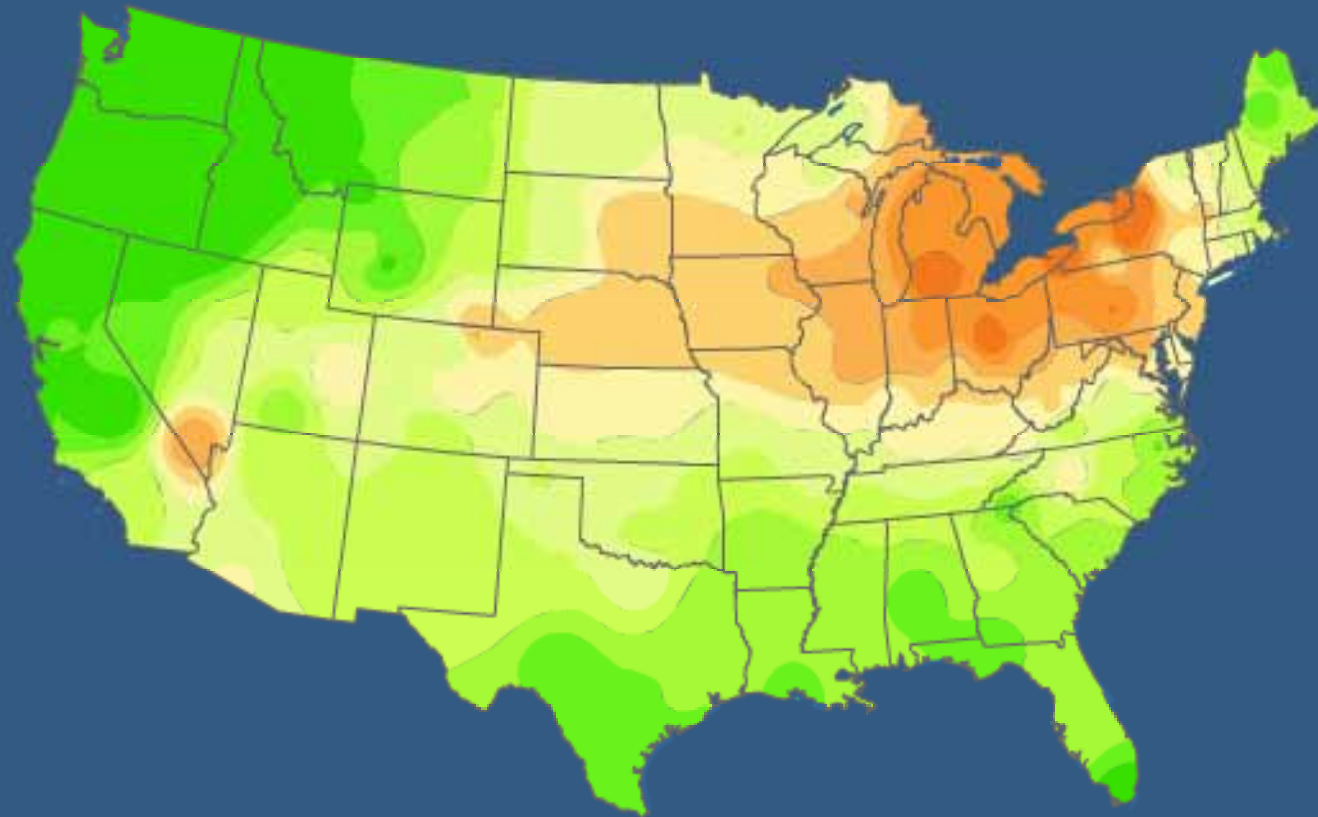


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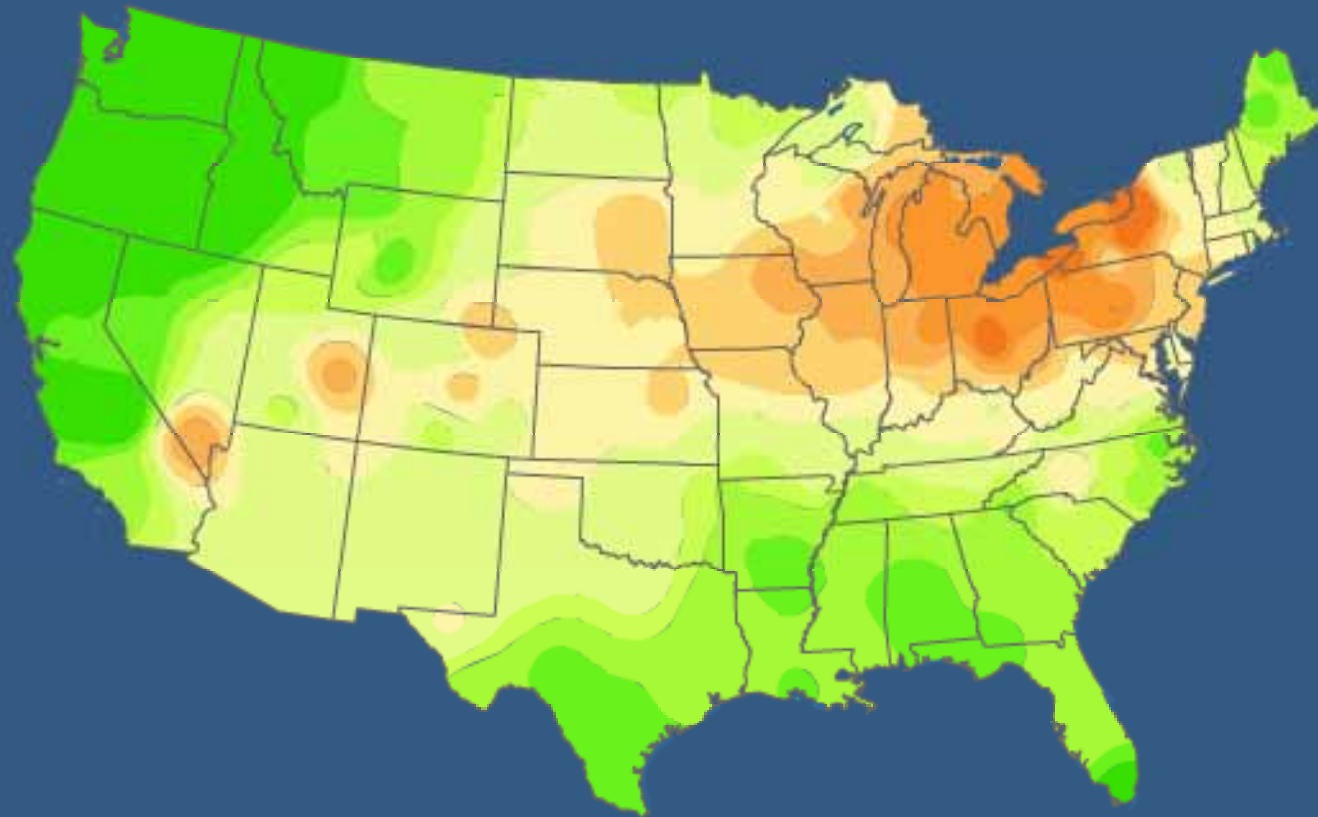
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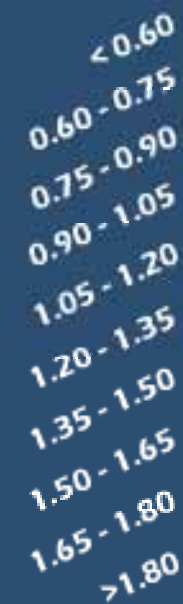
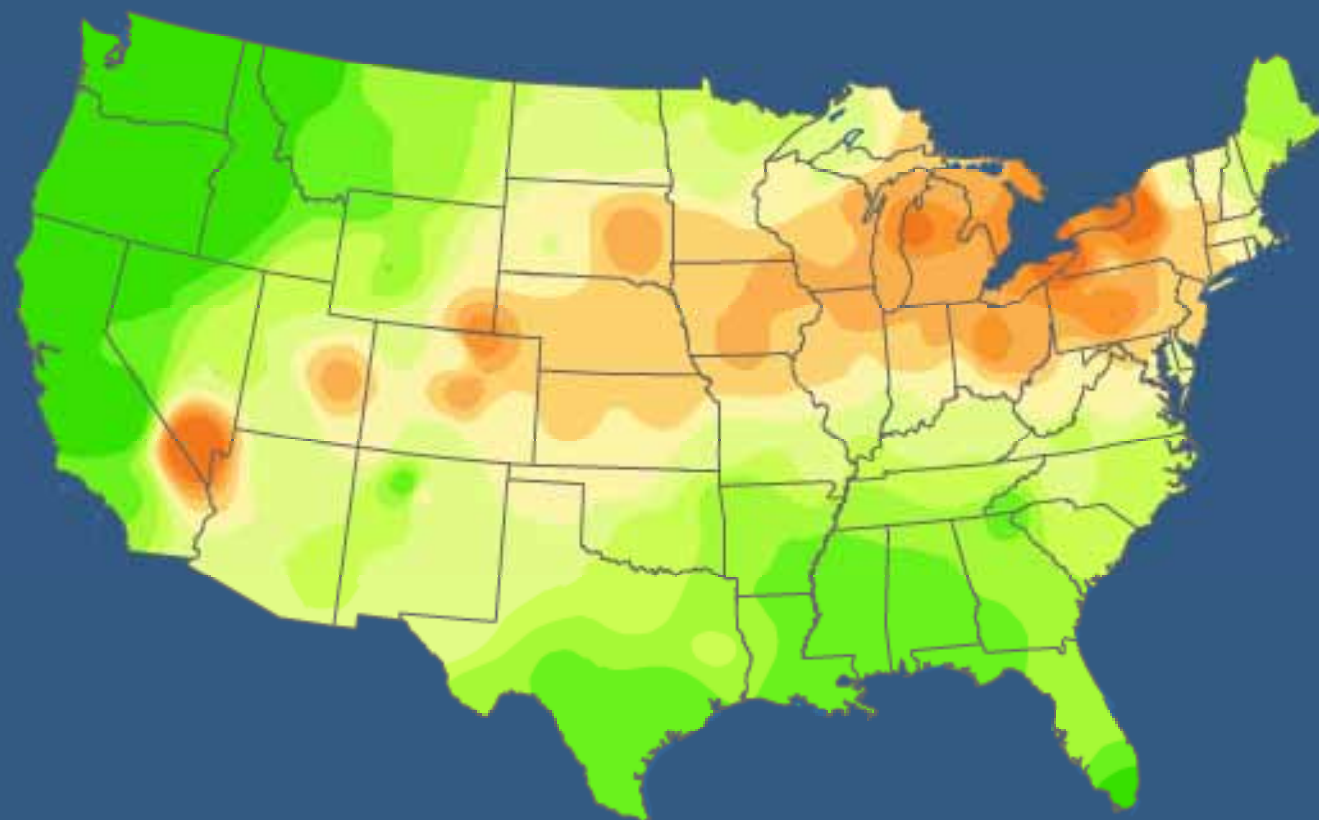
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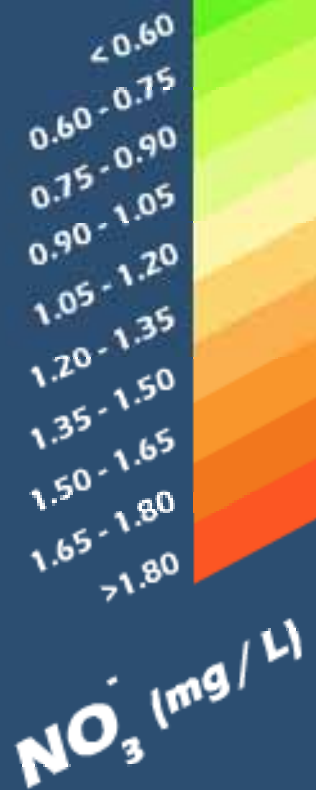
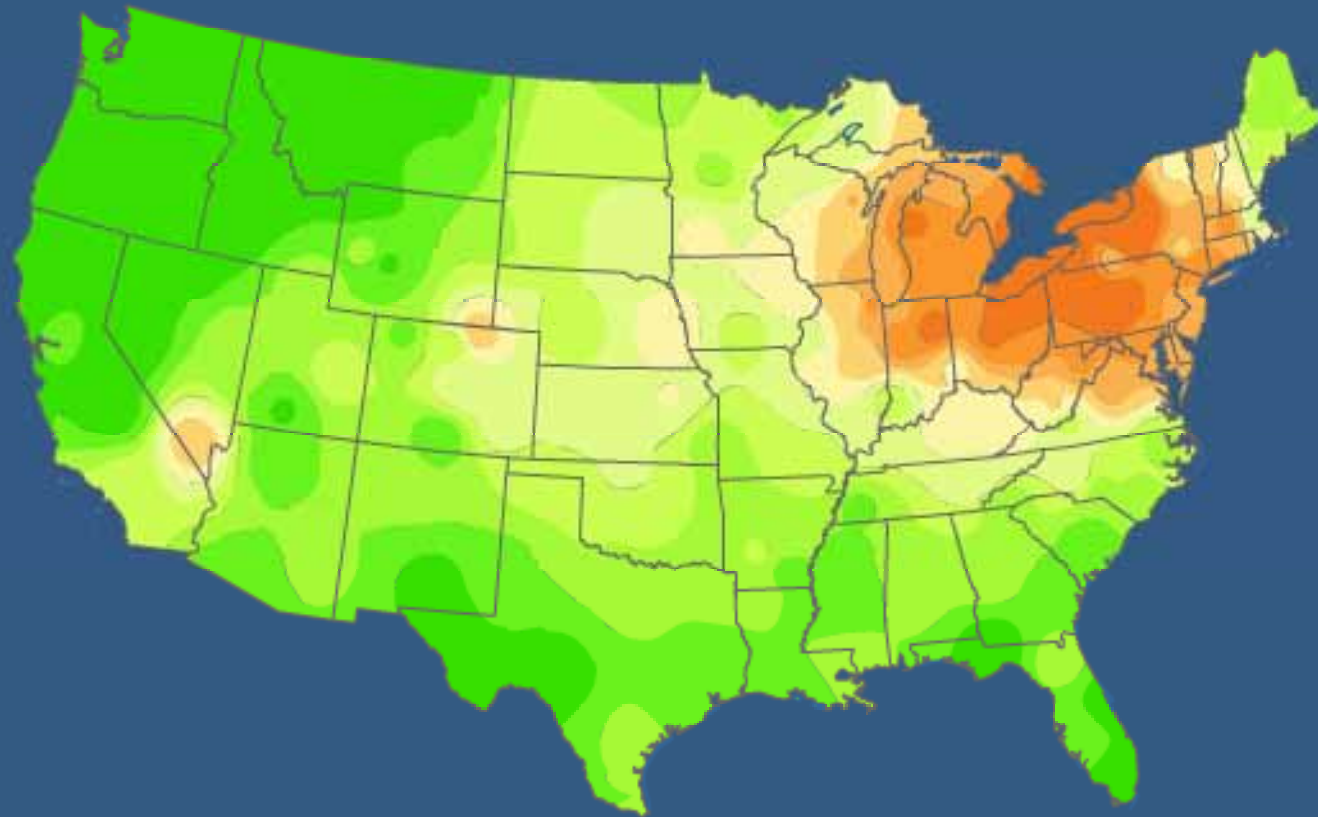


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National Atmospheric Deposition Program / National Trends Network

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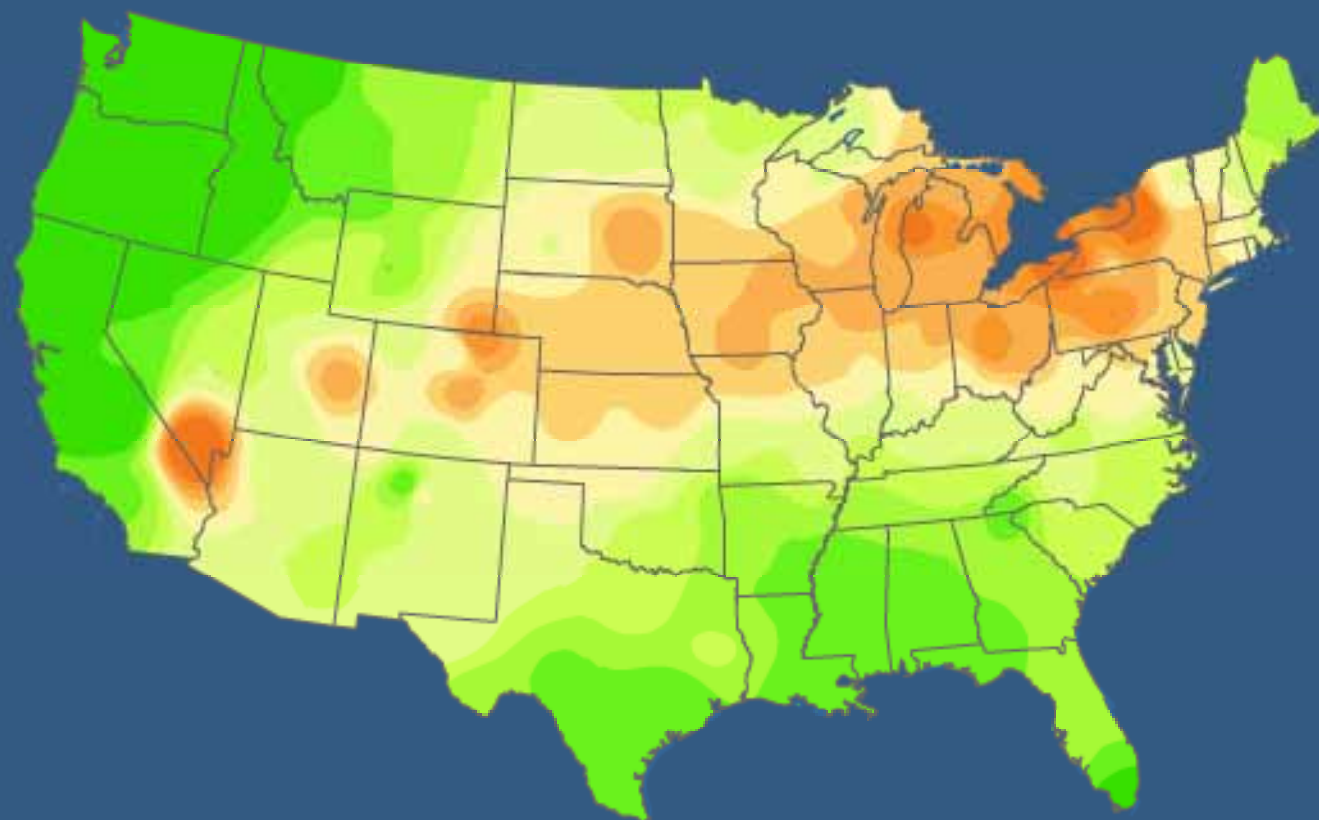
Nitrate Ion Concentrations 1985-2001



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National Atmospheric Deposition Program / National Trends Network

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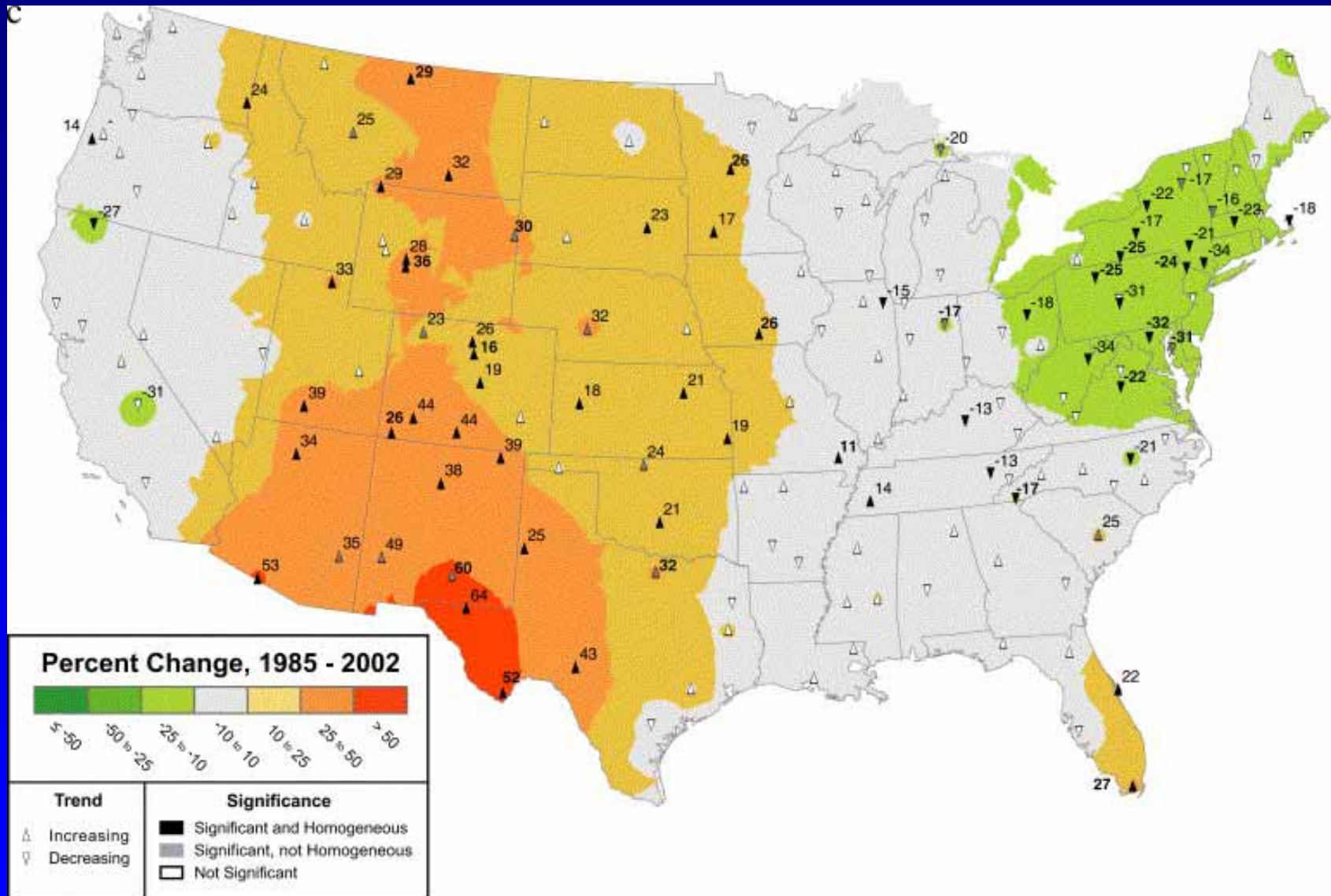
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National Atmospheric Deposition Program / National Trends Network

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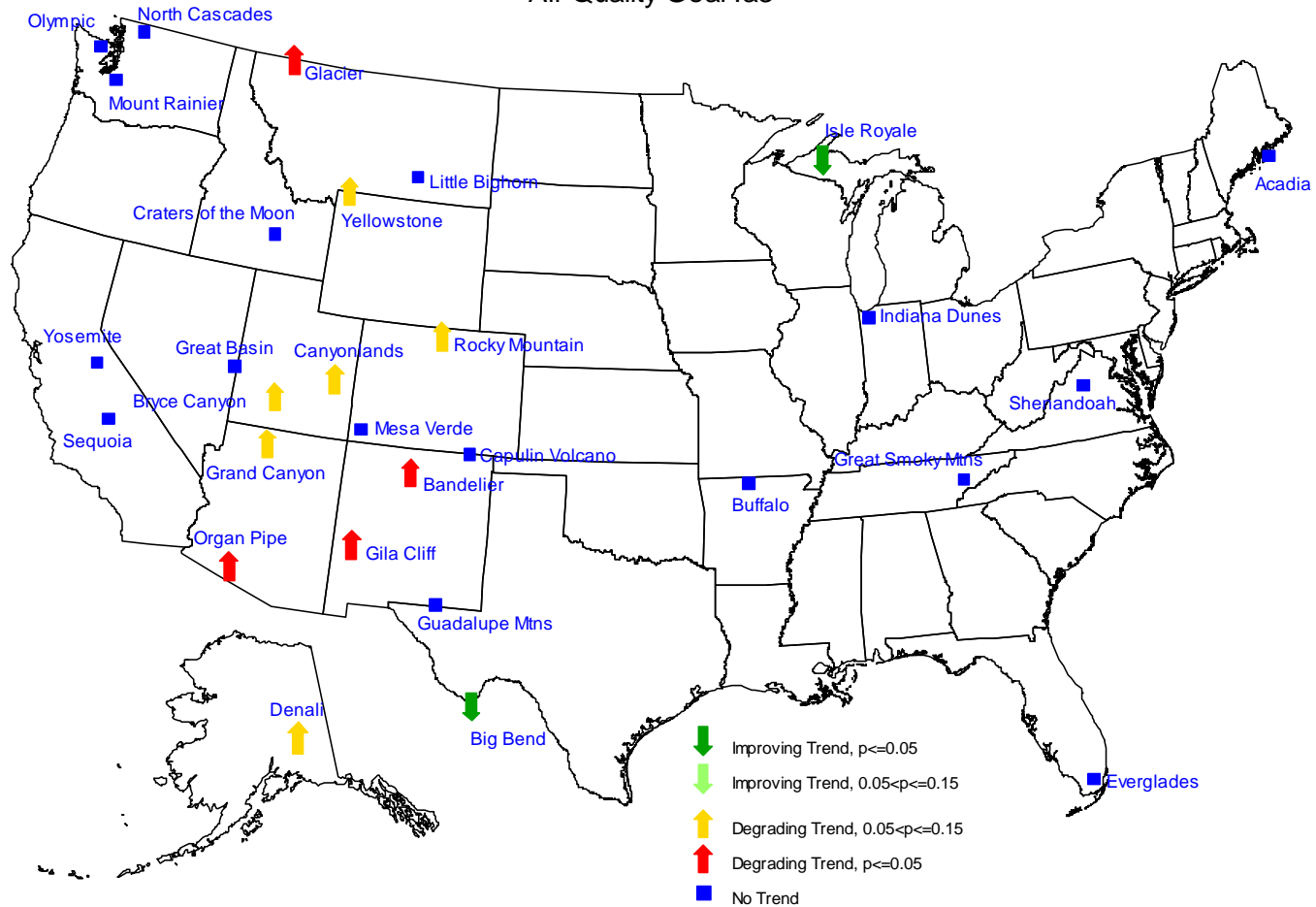
Percent change in NO_3^- in wetfall



Trends in NO3 Concentrations in Precipitation, 1994-2003

FY2004 Annual Performance Report for NPS Government Performance and Results Act (GPRA)

Air Quality Goal Ia3

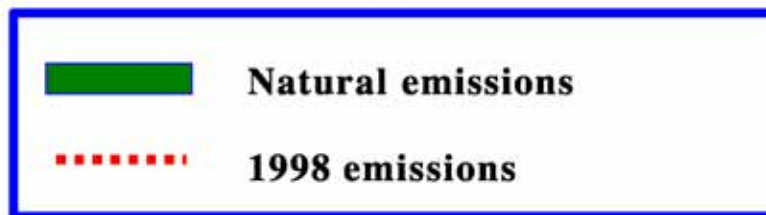
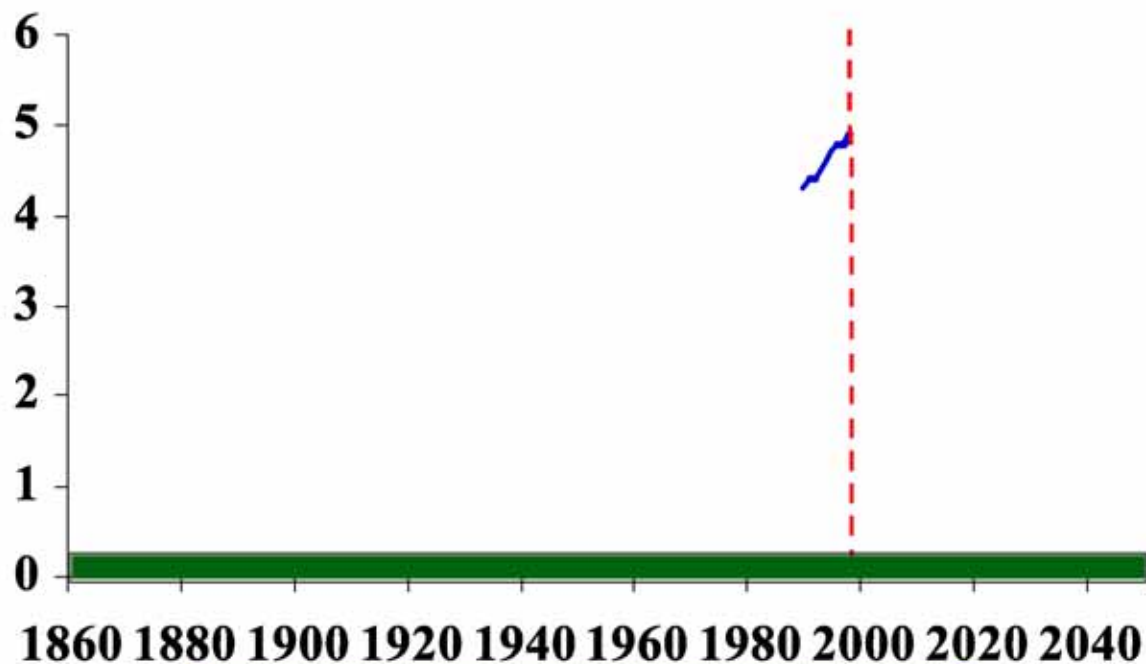


02/03/2005

up

USA NH₃ Emissions

(million short tons/year)

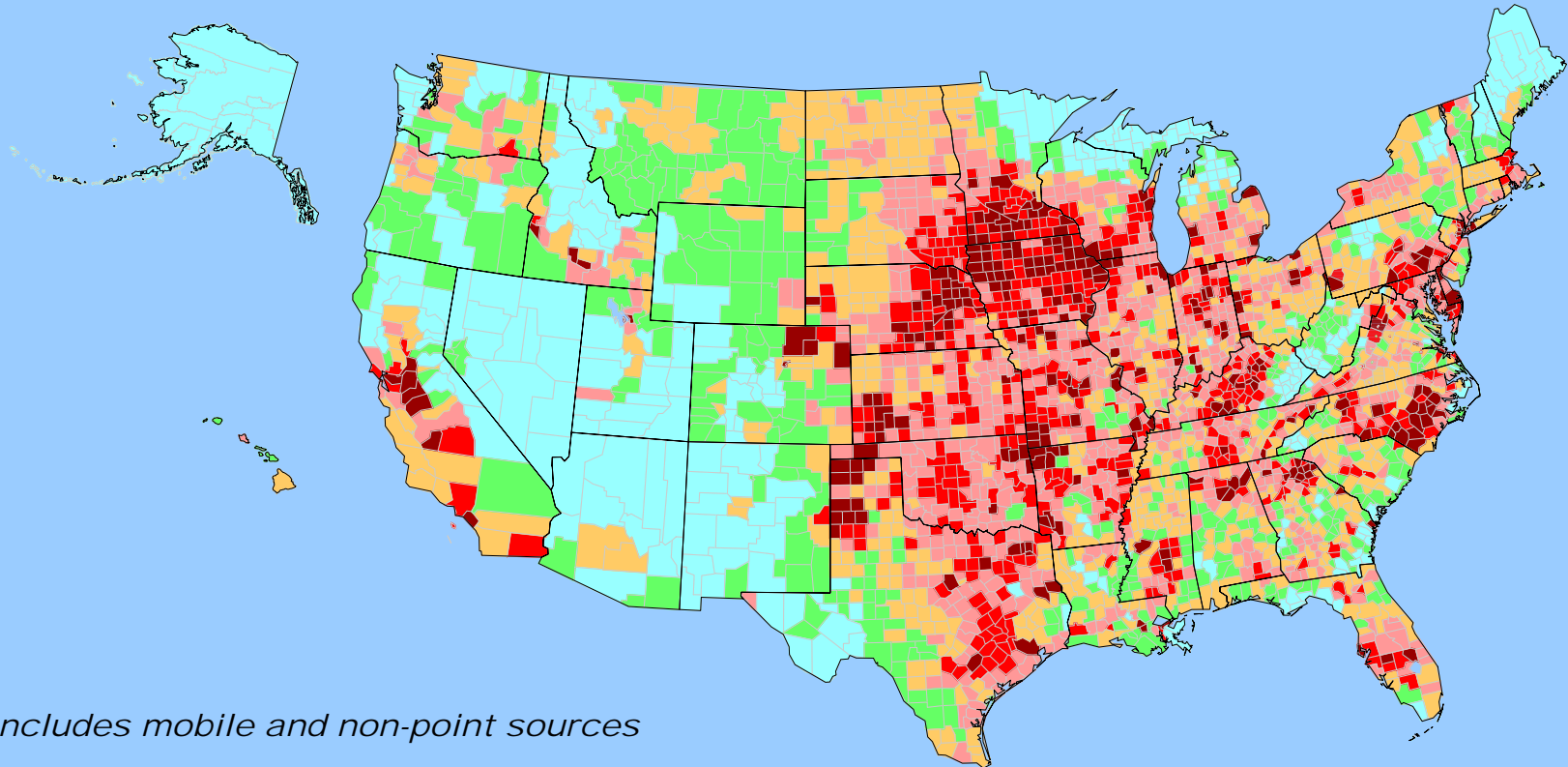


After Galloway et al., (2001)

Total NH₃ emissions

Emissions Distribution Map – Criteria Air Pollutants
United States

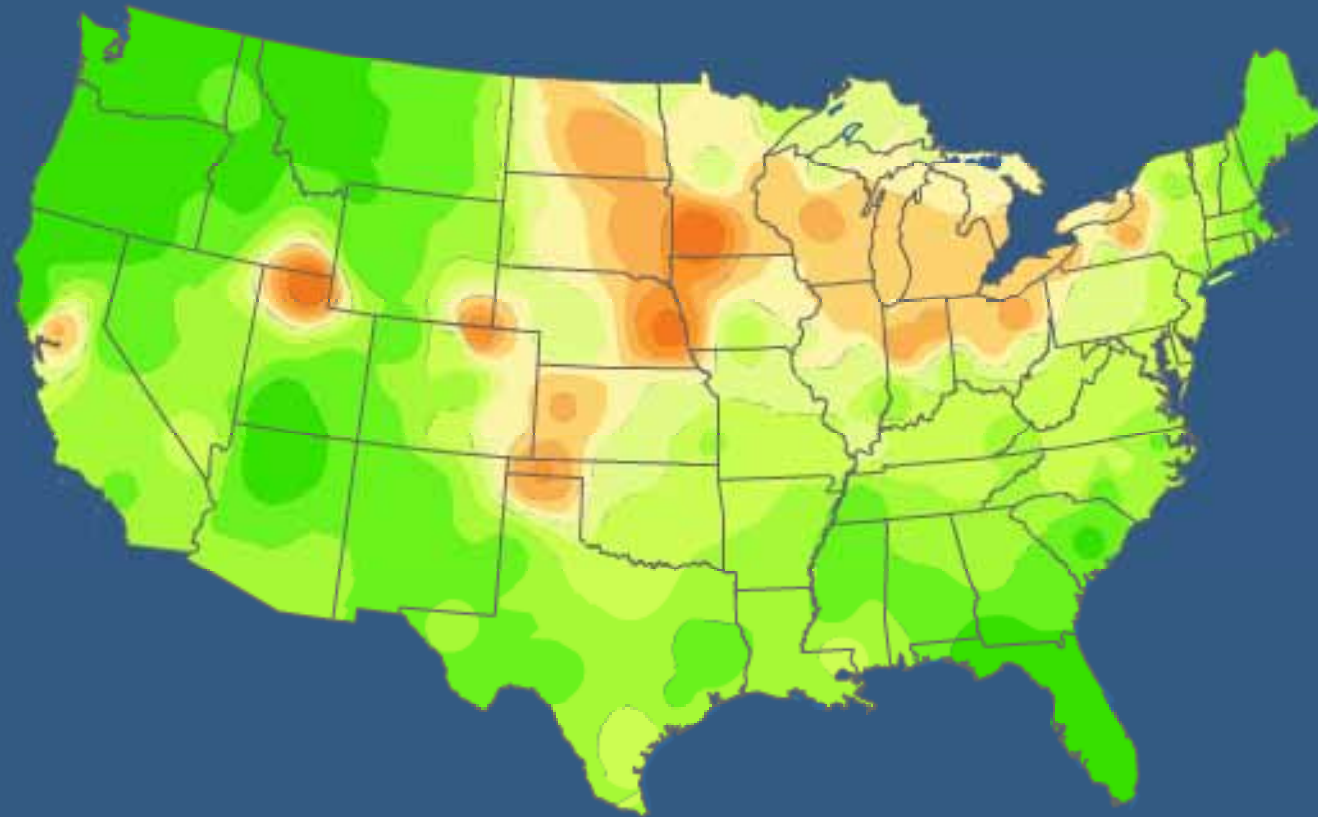
AirData



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



Ammonium Ion Concentrations 1985-2001

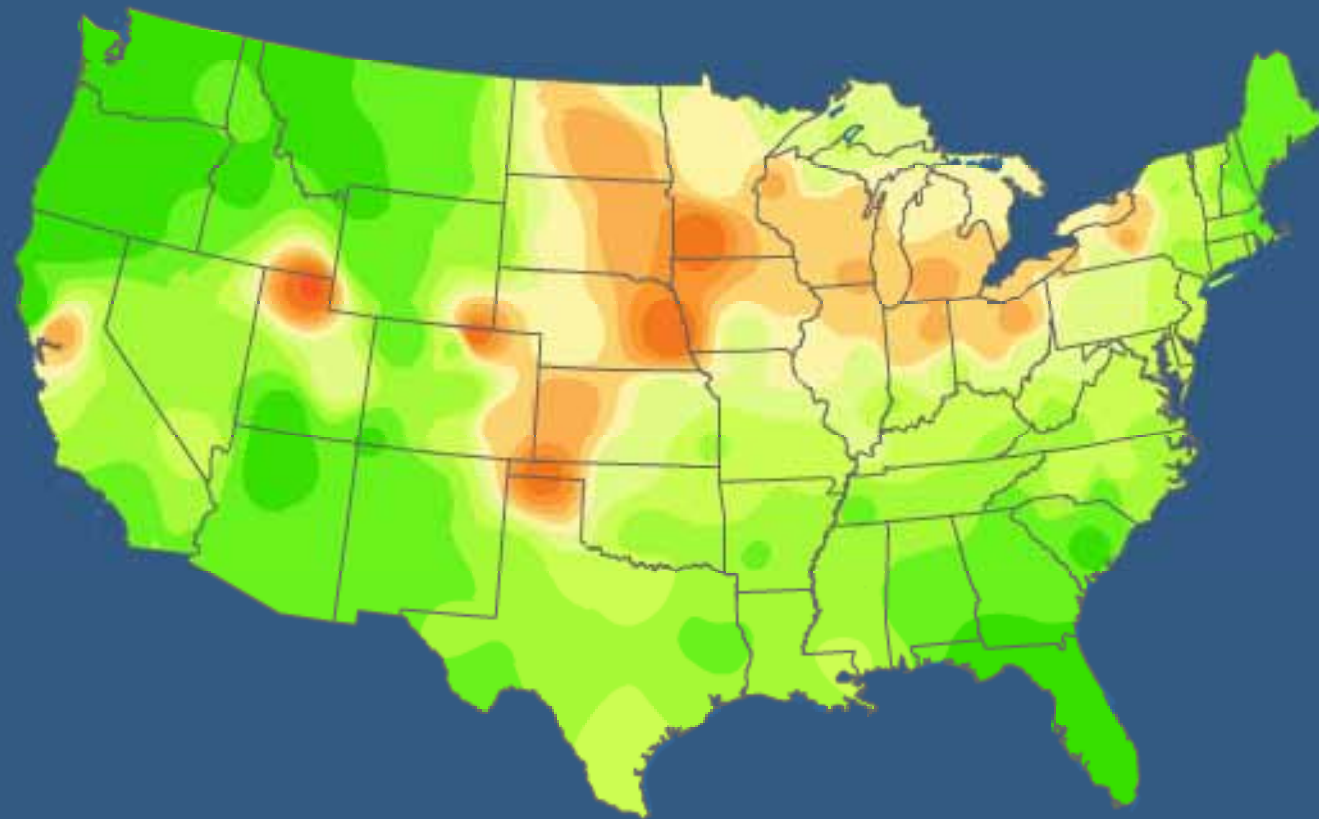


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NH_4^+ (mg/L)

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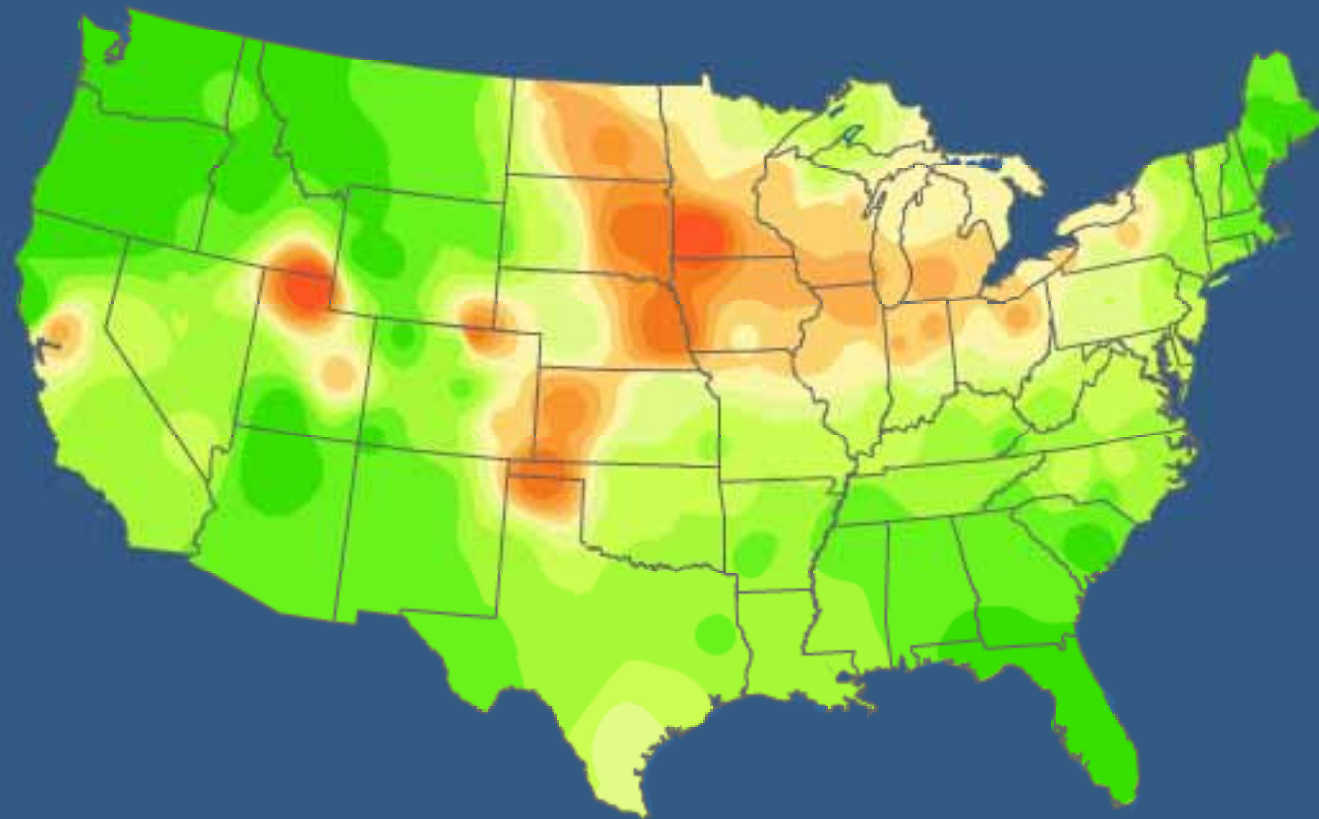


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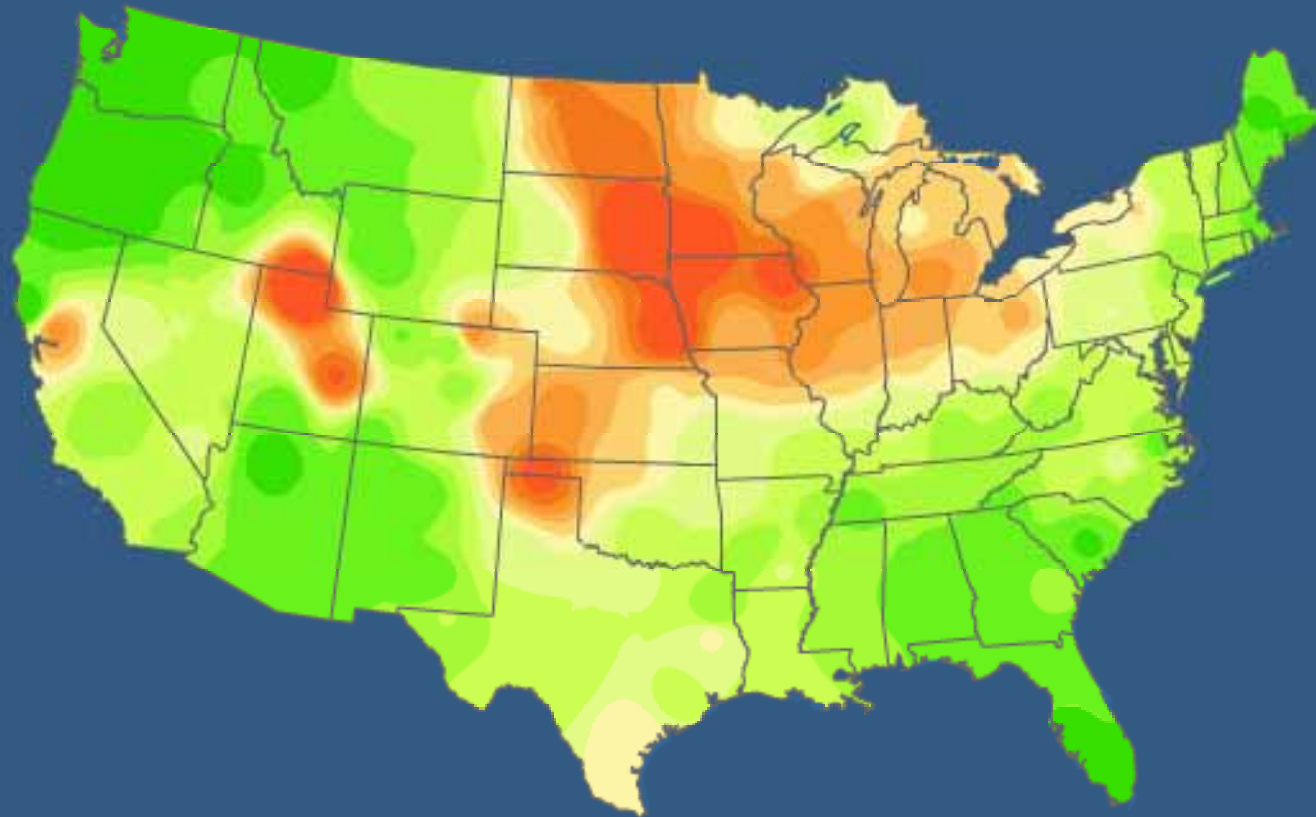


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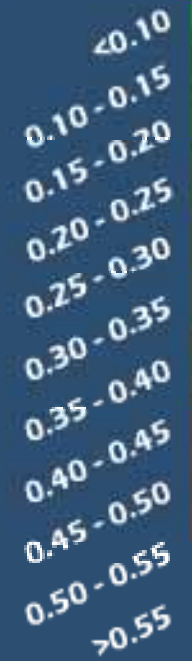
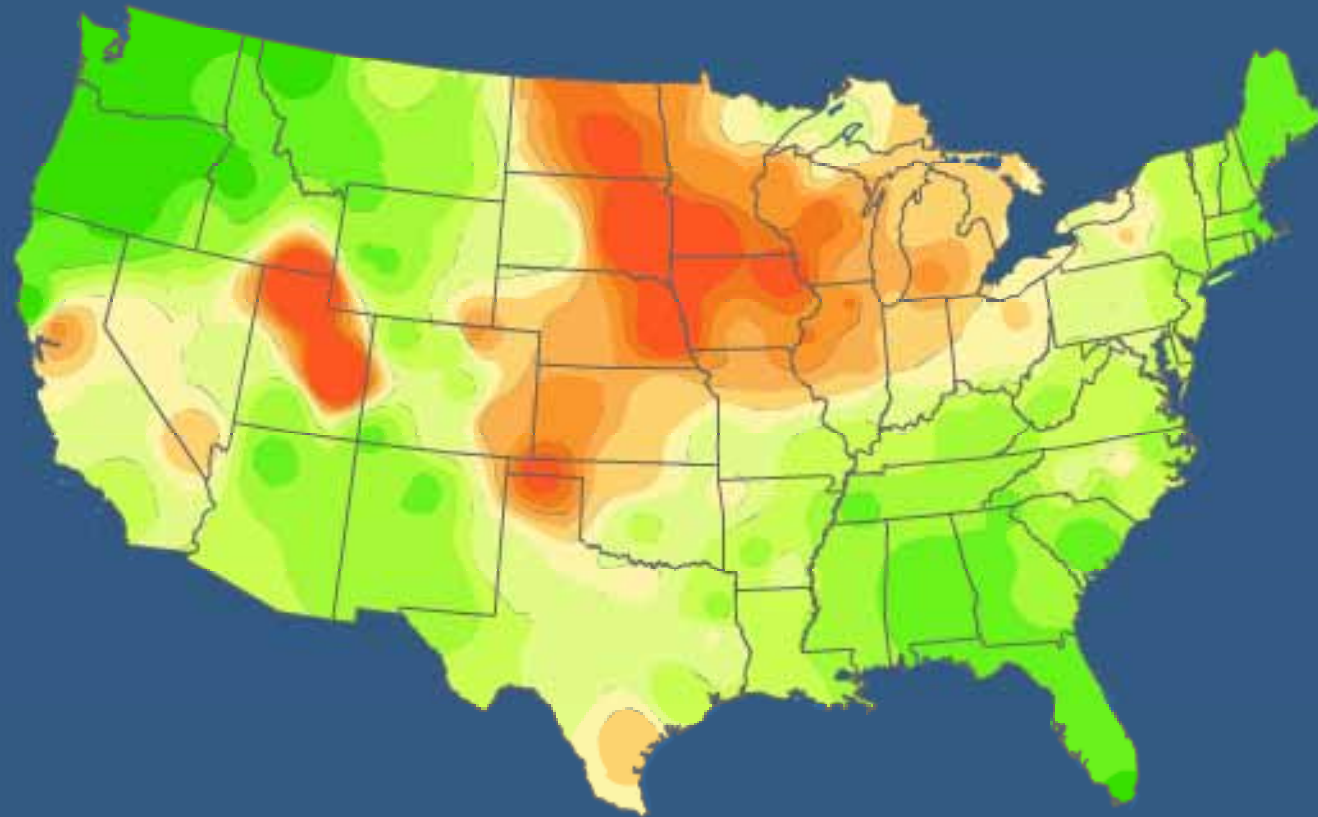


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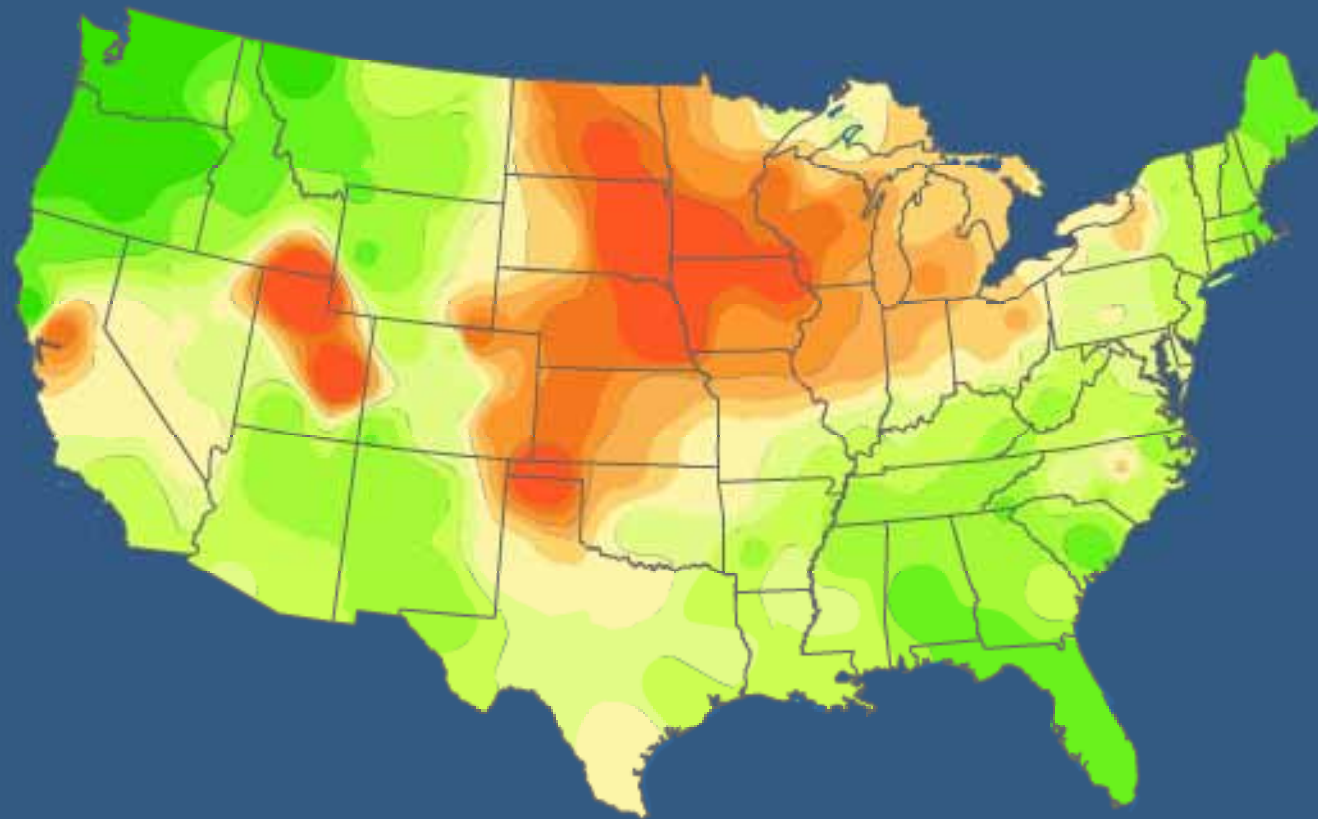
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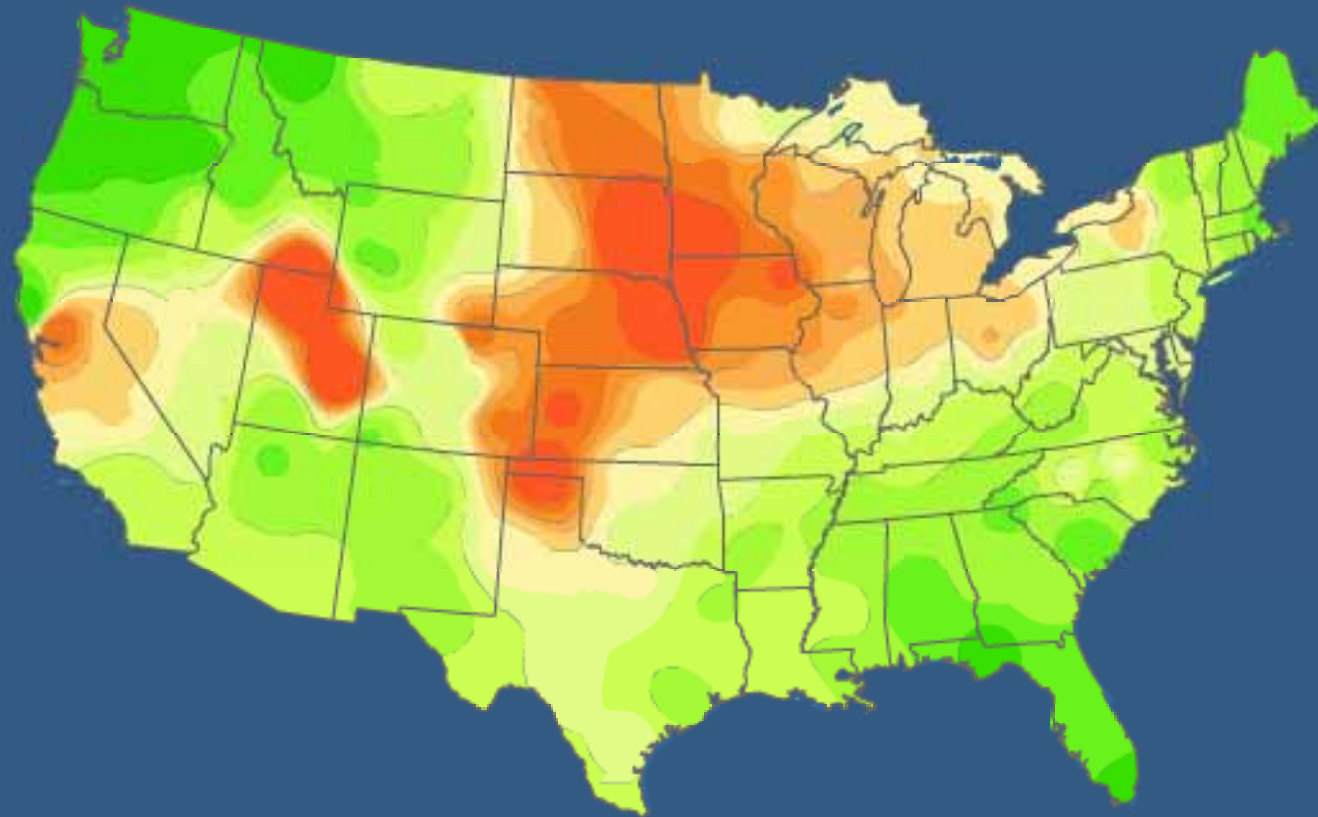


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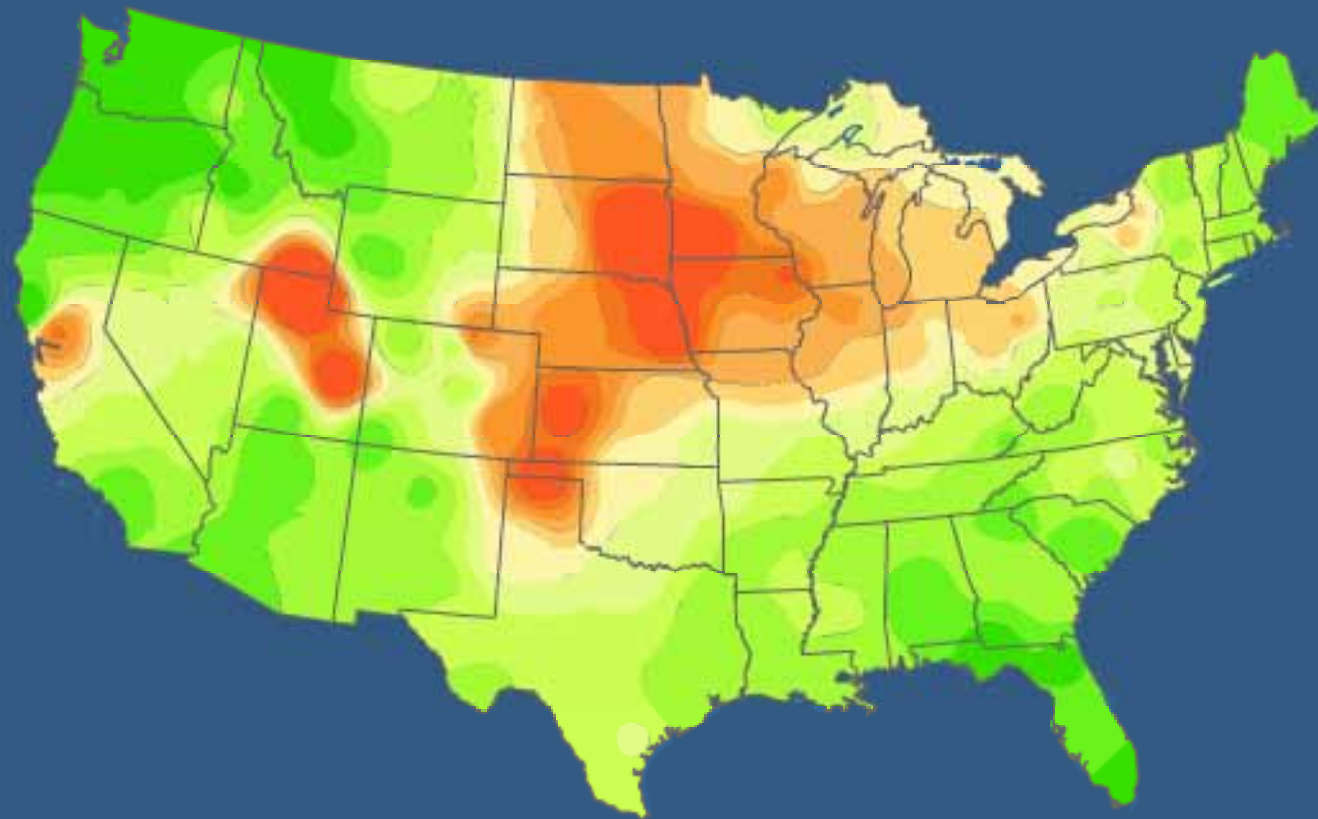


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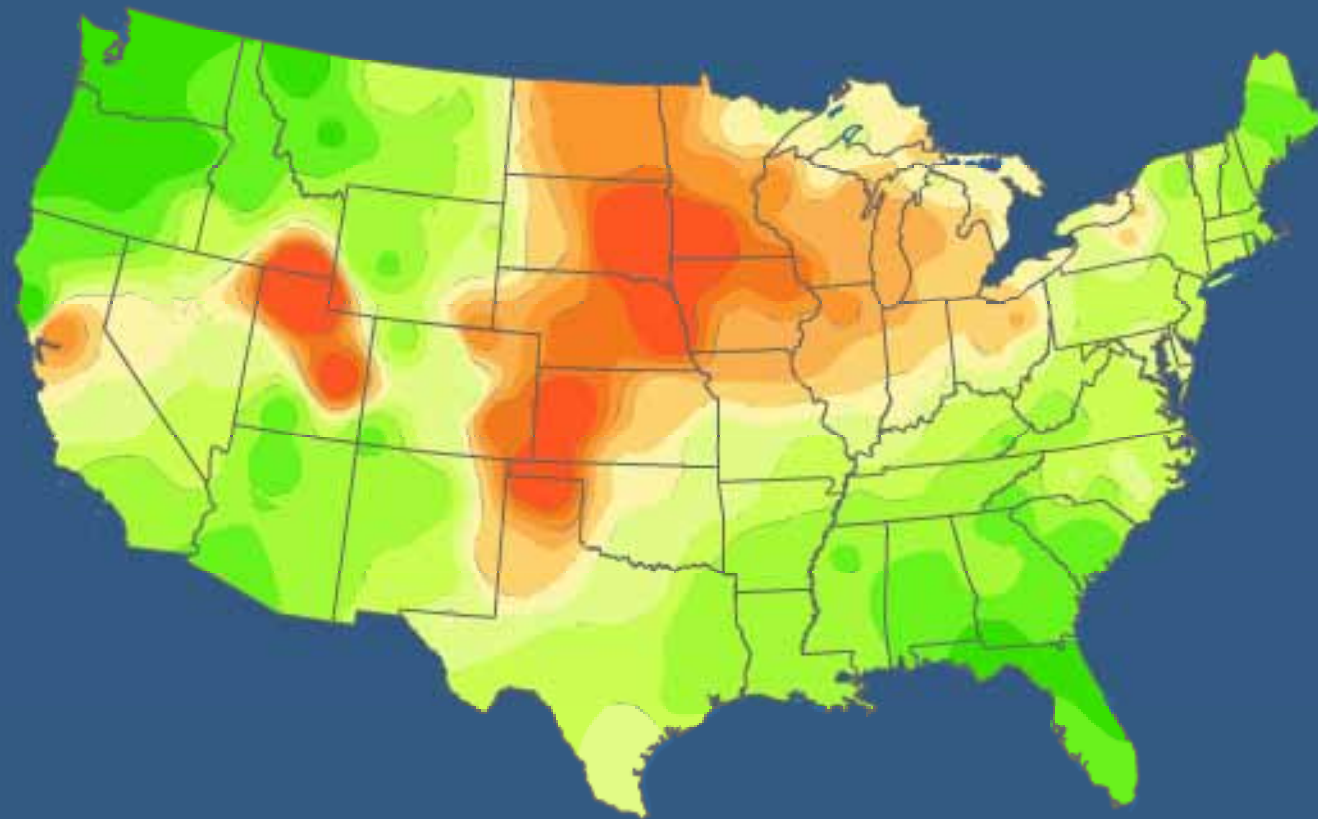


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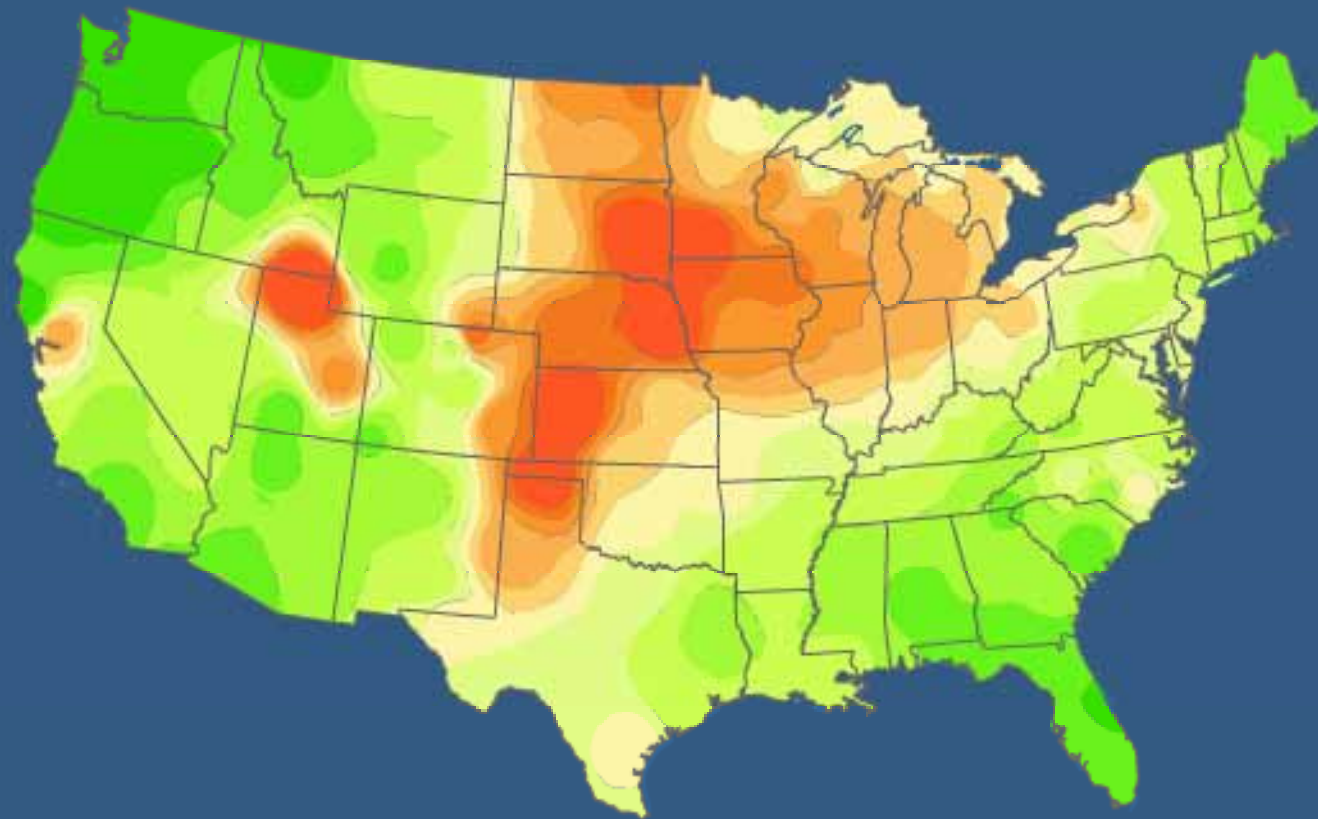
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National Atmospheric Deposition Program / National Trends Network

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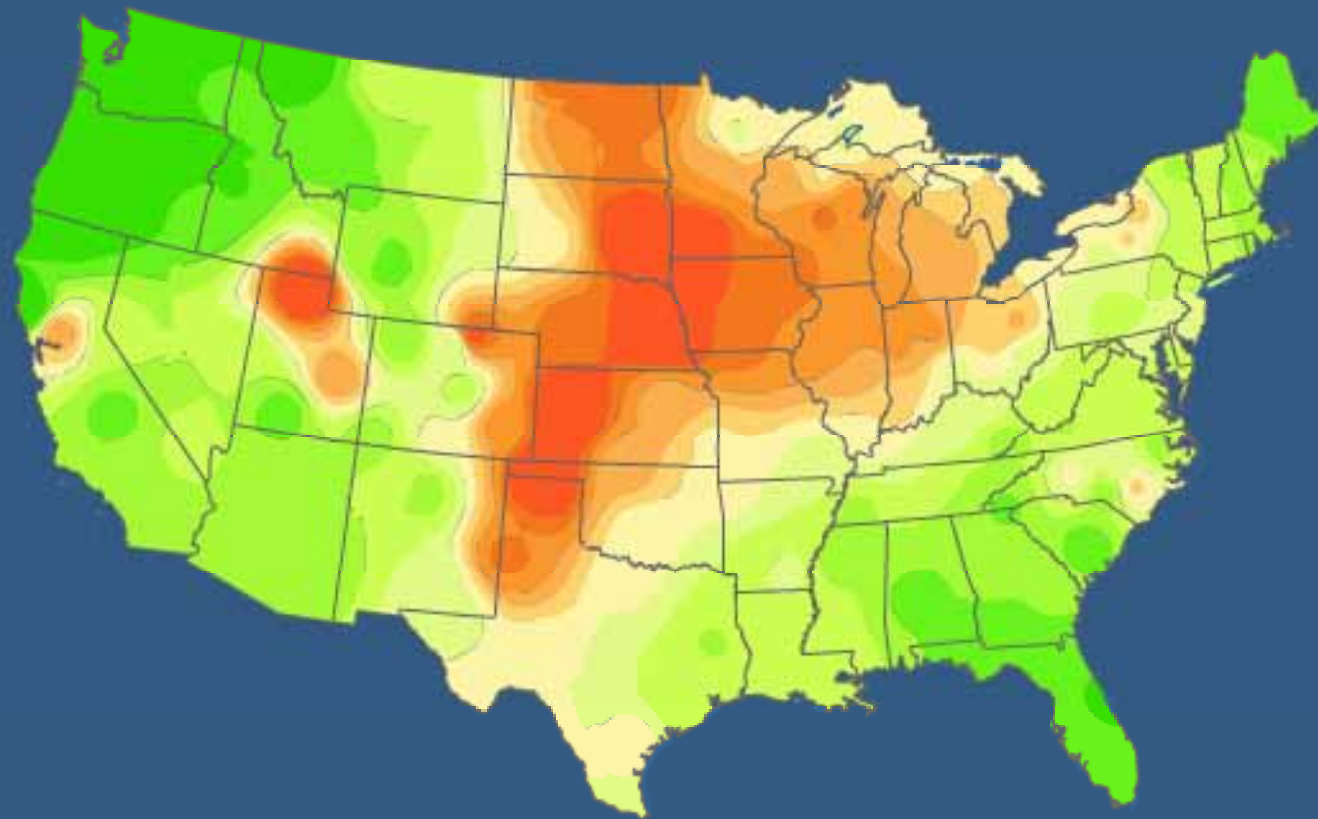


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Ammonium Ion Concentrations 1985-2001



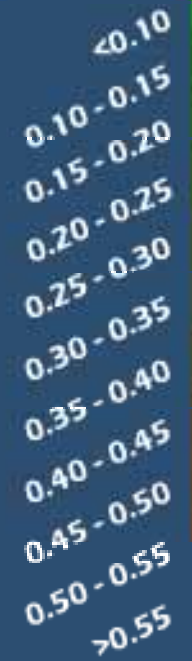
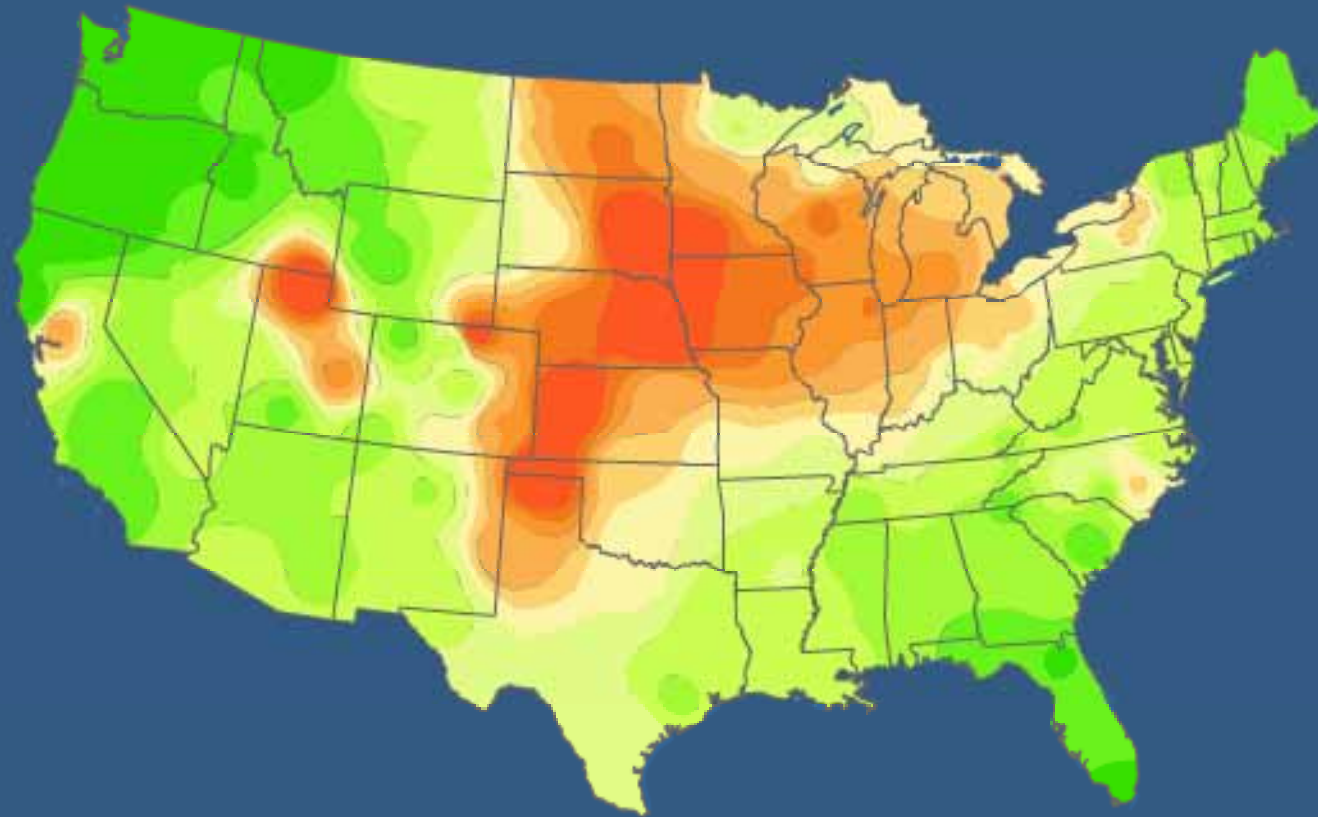
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0.45 - 0.50
0.50 - 0.55
>0.55

NH_4^+ (mg/L)

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

National Atmospheric Deposition Program / National Trends Network

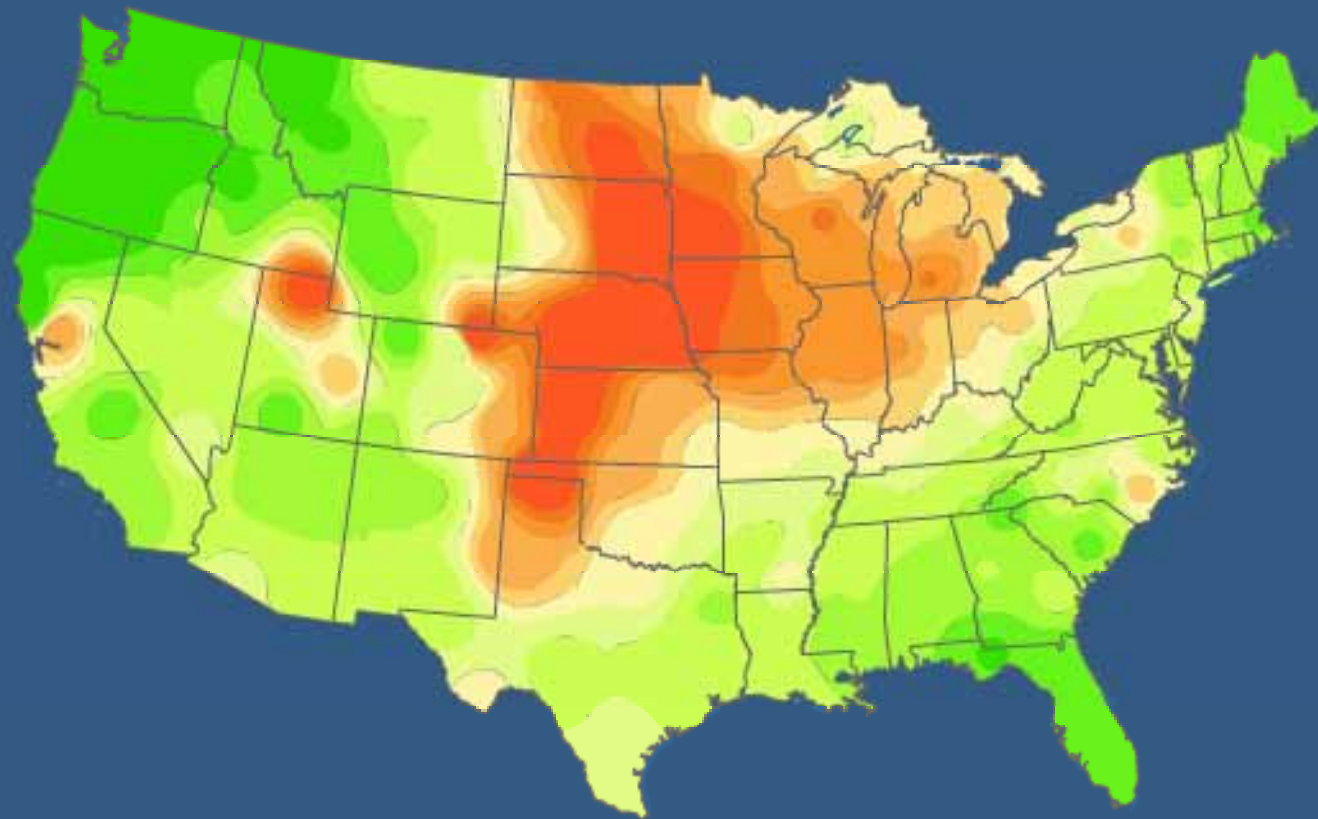
Ammonium Ion Concentrations 1985-2001



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NH_4^+ (mg/L)

Ammonium Ion Concentrations 1985-2001

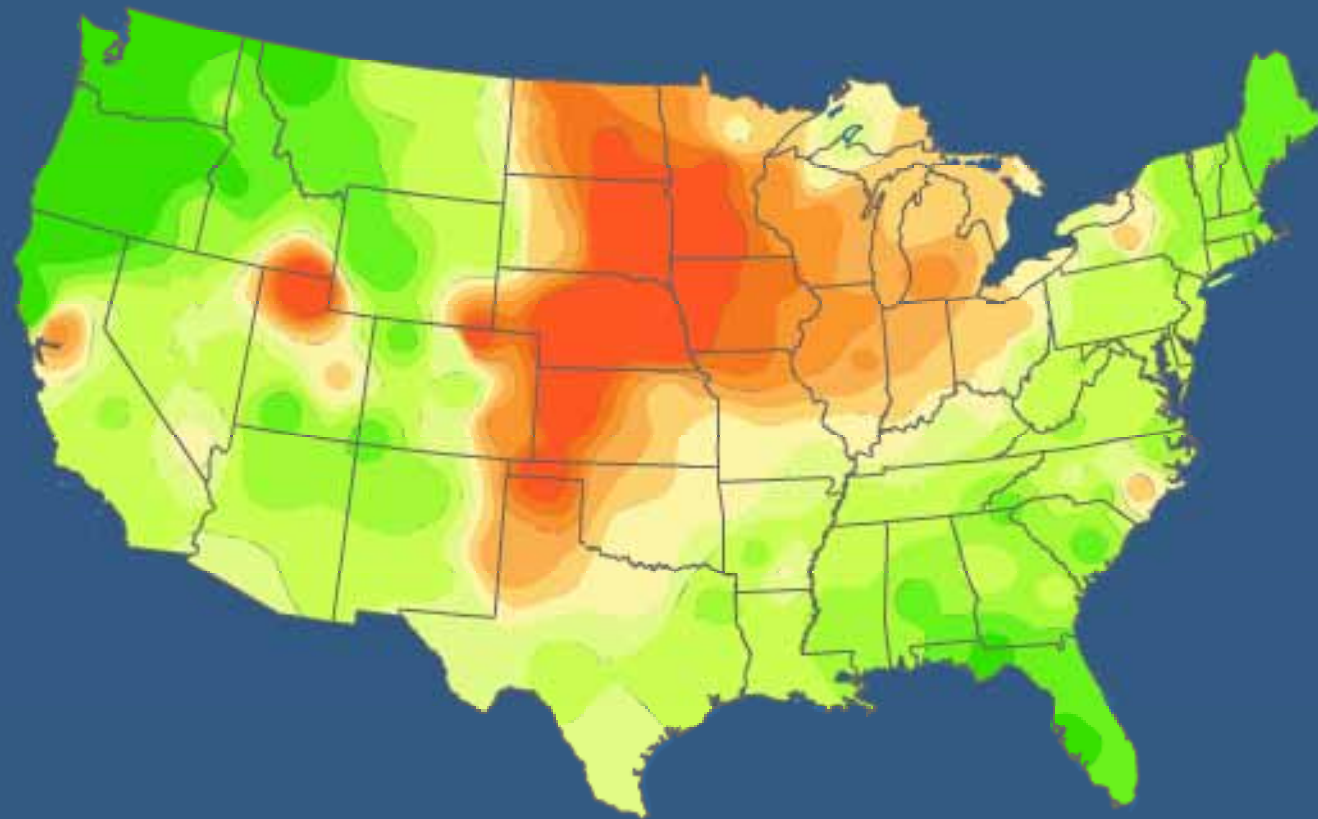


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NH_4^+ (mg/L)

Ammonium Ion Concentrations 1985-2001

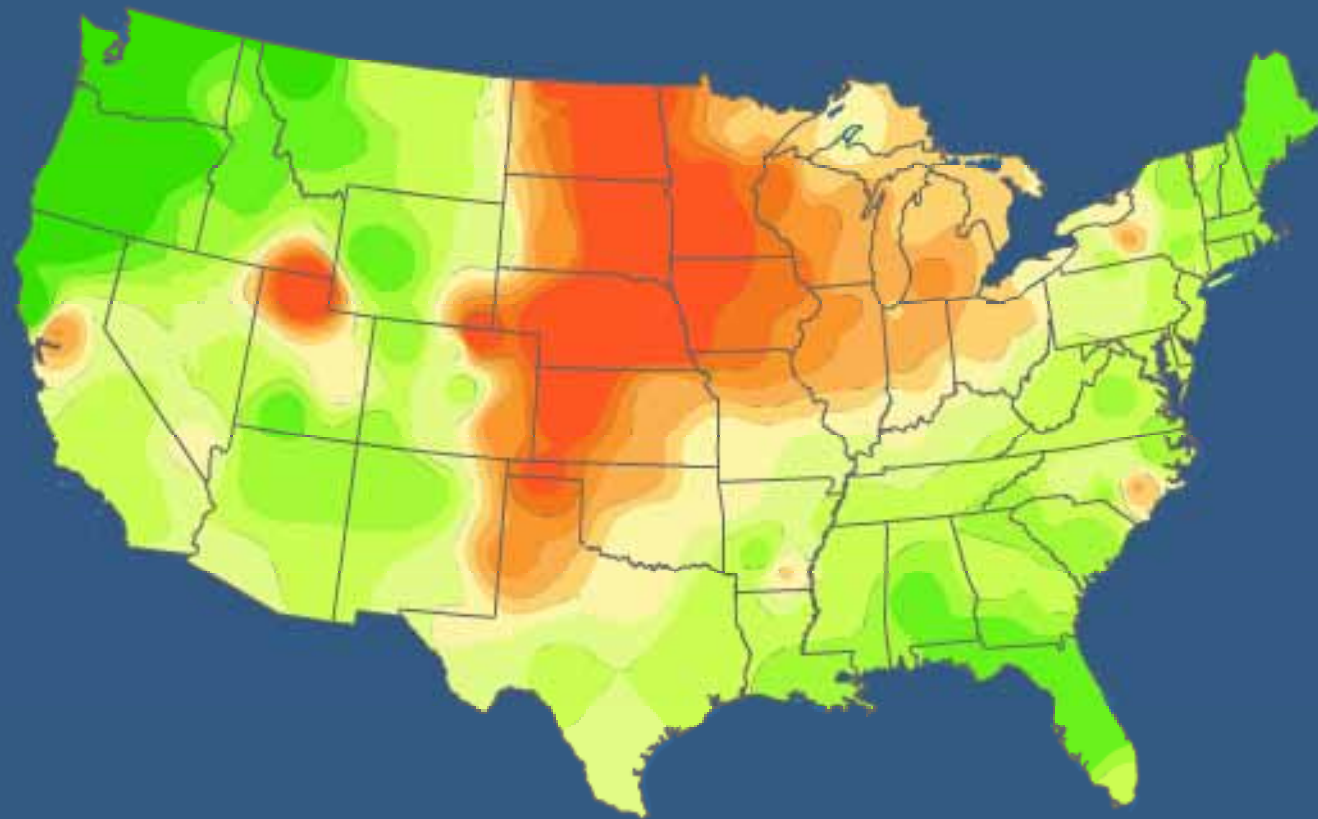


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NH_4^+ (mg/L)

Ammonium Ion Concentrations 1985-2001

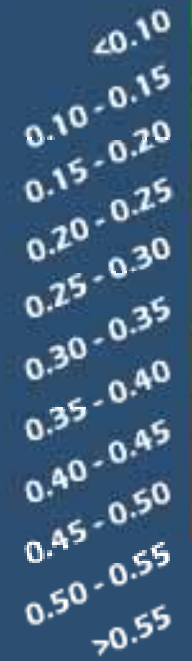
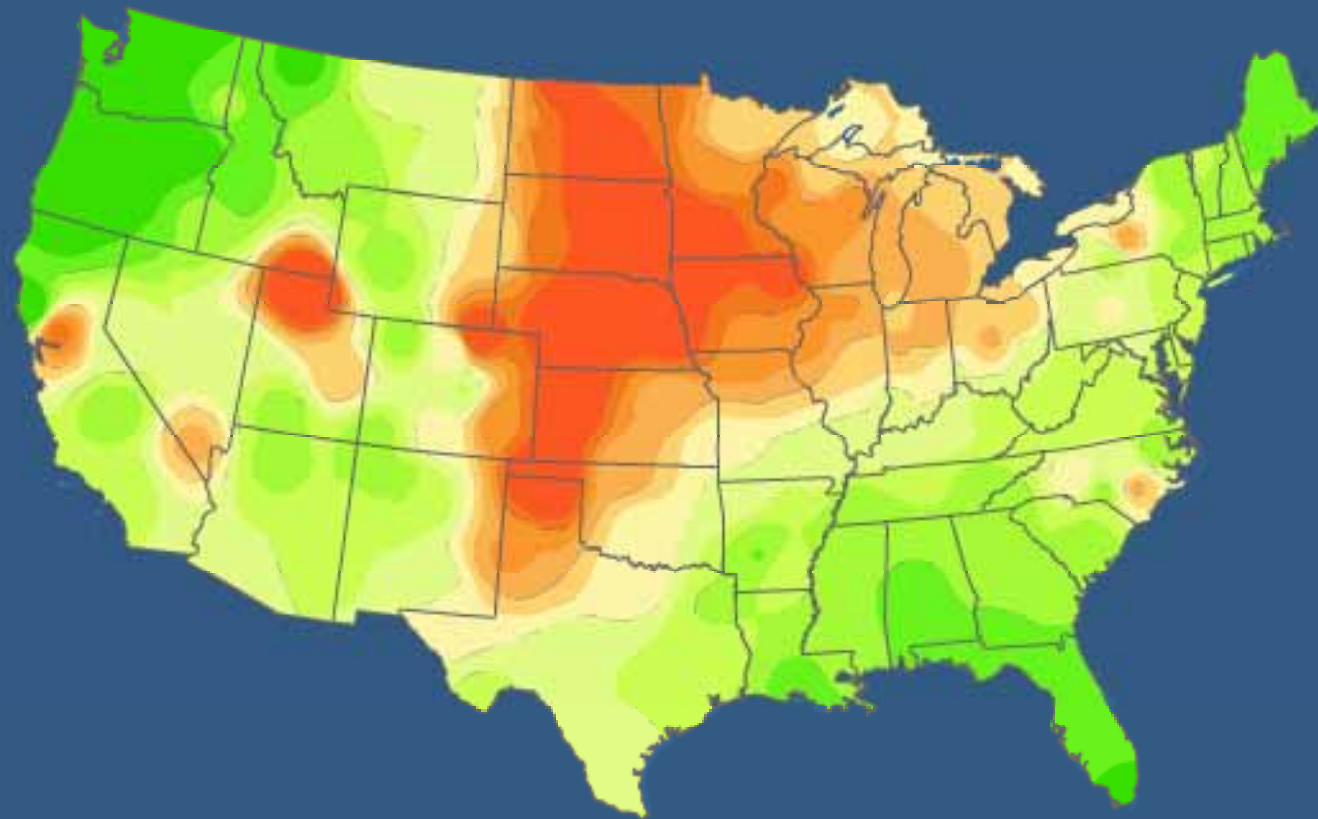


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NH_4^+ (mg/L)

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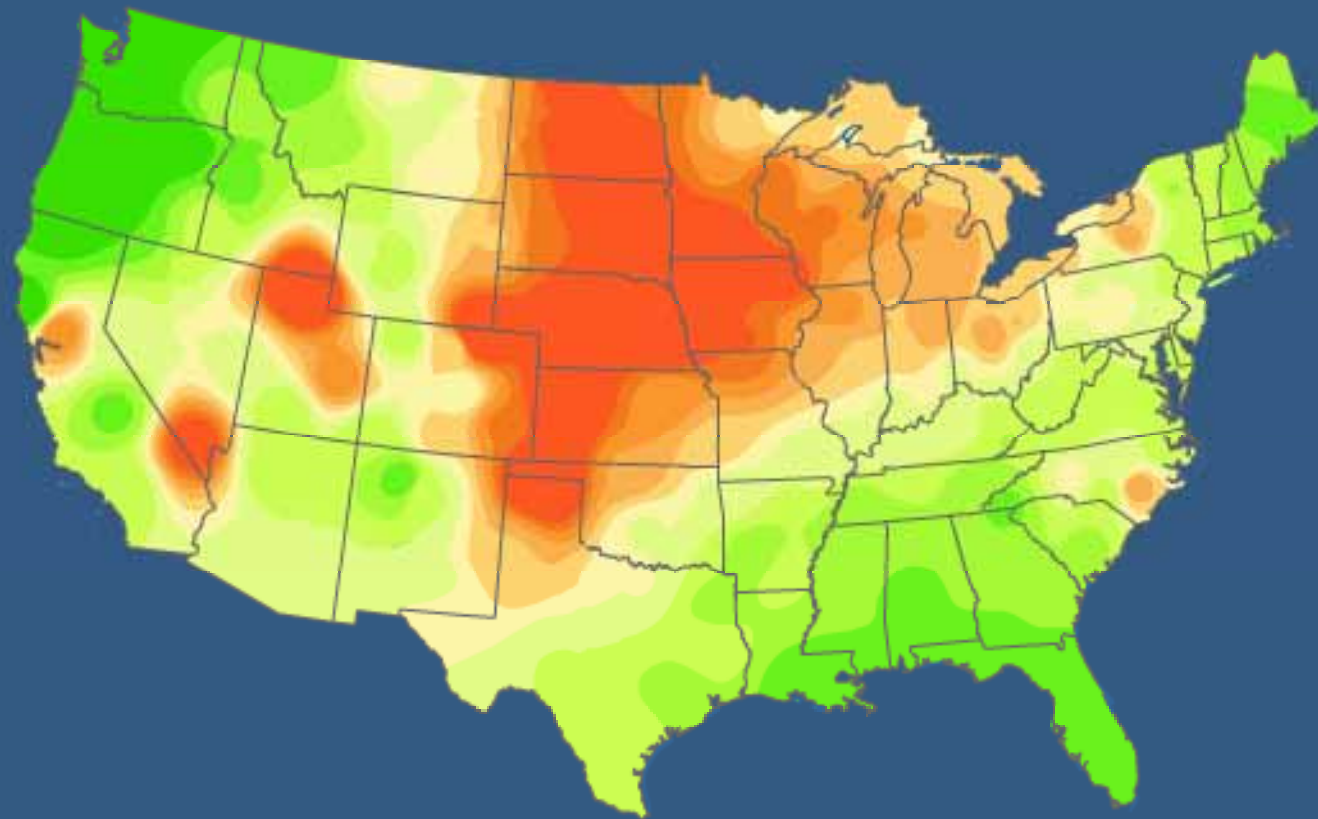
Ammonium Ion Concentrations 1985-2001



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NH_4^+ (mg/L)

Ammonium Ion Concentrations 1985-2001

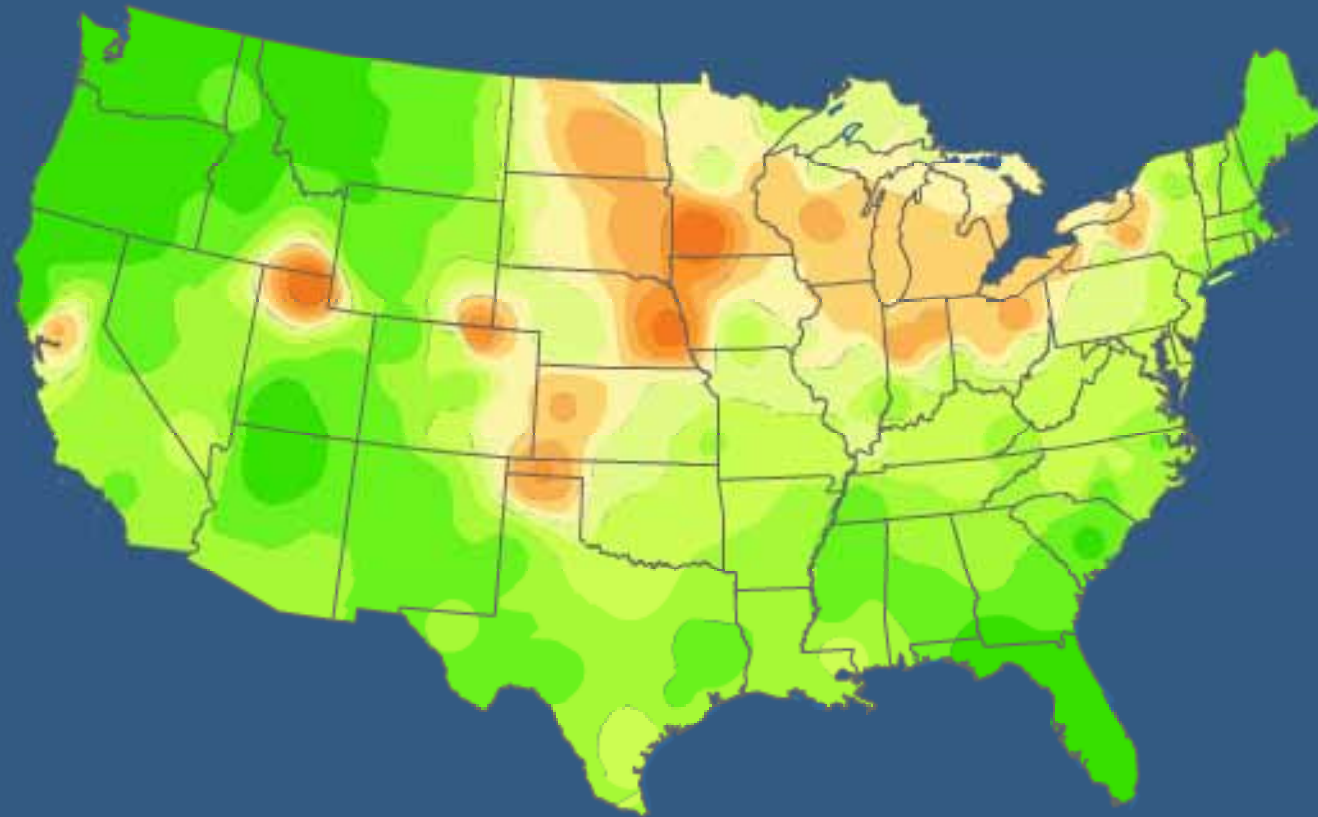


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NH_4^+ (mg/L)

Ammonium Ion Concentrations 1985-2001

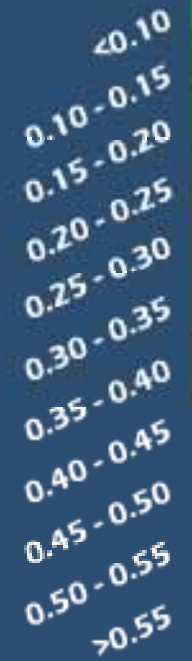
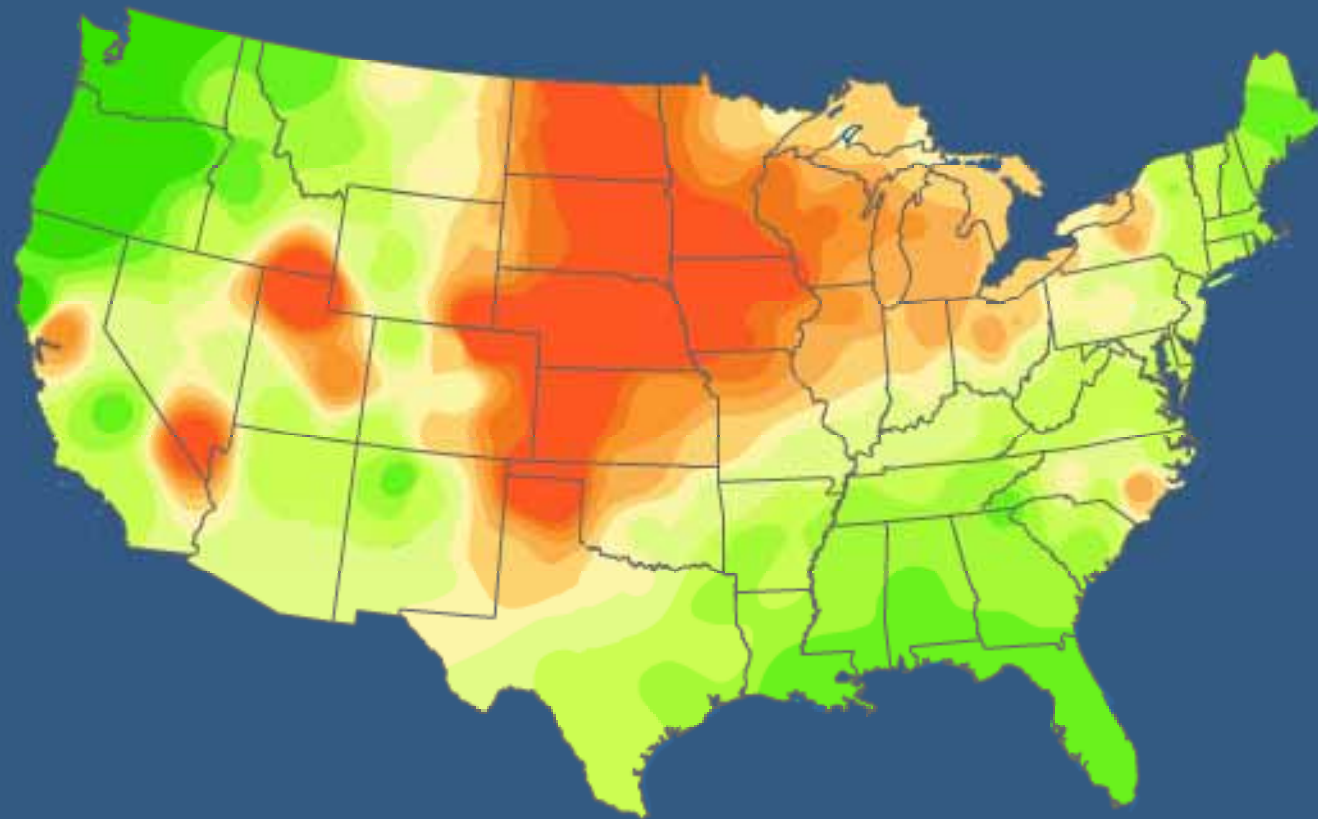


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$0.50 - 0.55$
>0.55

84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01

NH_4^+ (mg/L)

Ammonium Ion Concentrations 1985-2001

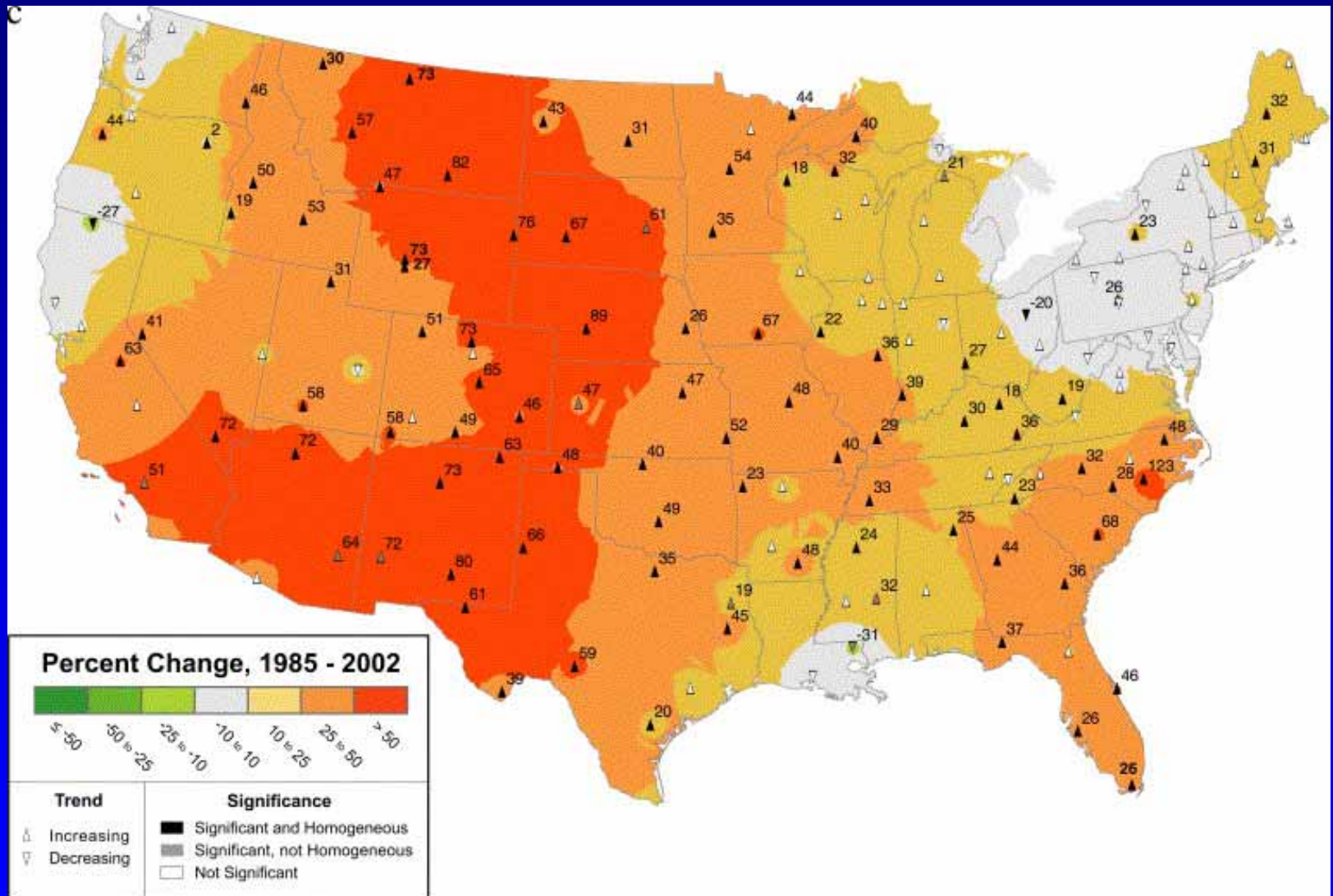


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NH_4^+ (mg/L)

National Atmospheric Deposition Program / National Trends Network

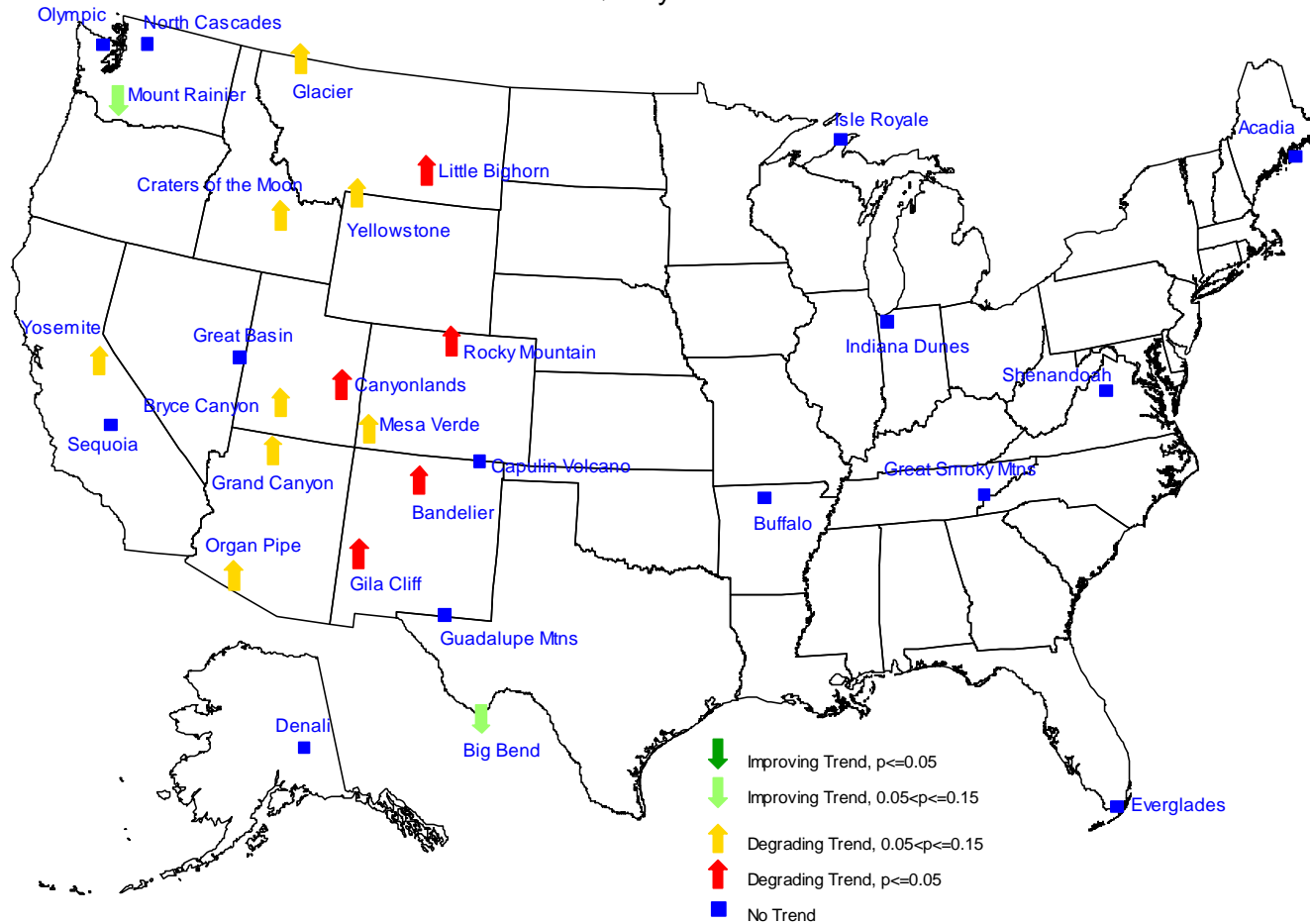
Percent change in NH₄⁺ in wetfall



Trends in NH4 Concentrations in Precipitation, 1994-2003

FY2004 Annual Performance Report for NPS Government Performance and Results Act (GPRA)

Air Quality Goal Ia3



02/03/2005

Snowpack chemistry

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



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

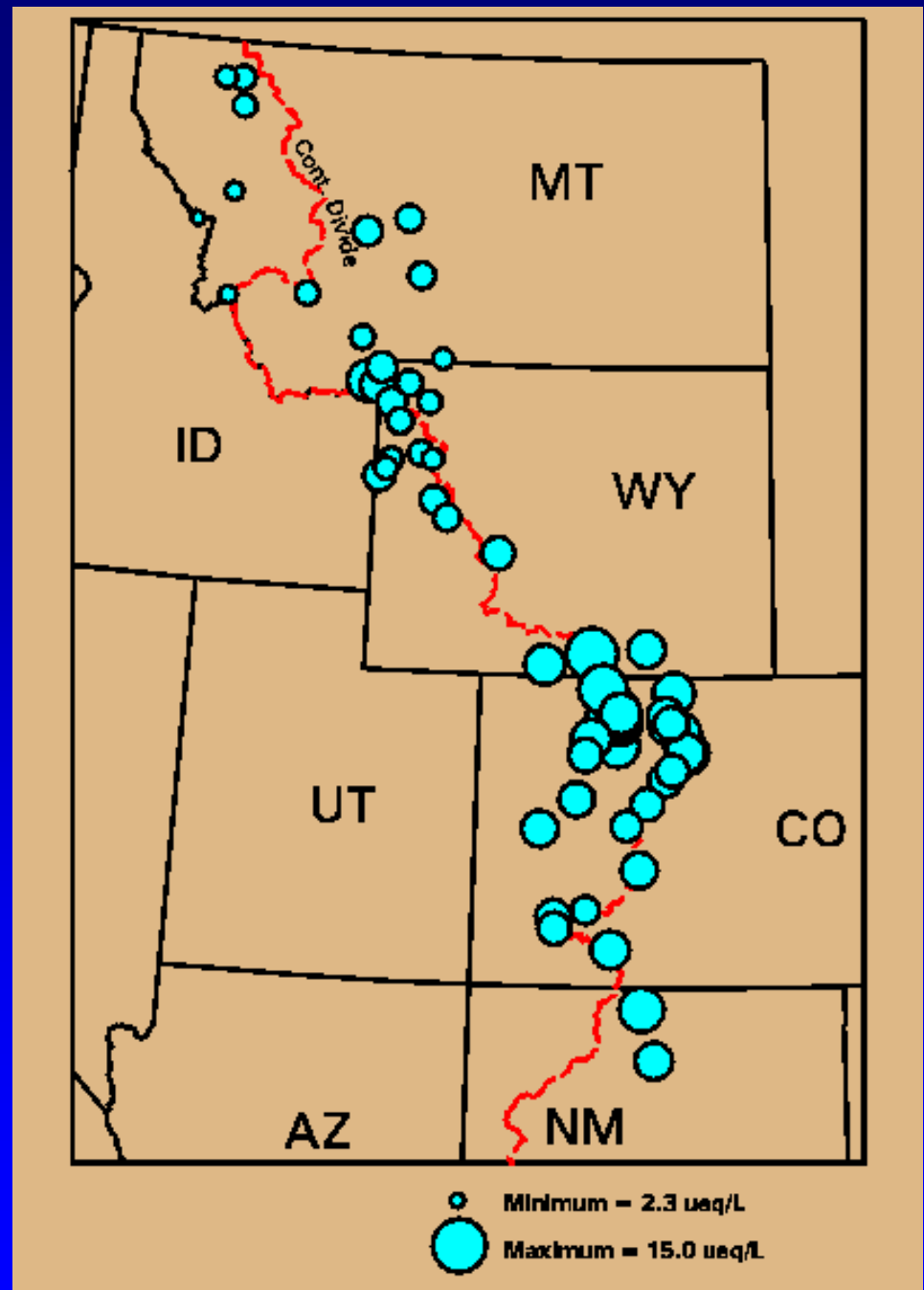


- G.P. Ingersoll and others, USGS

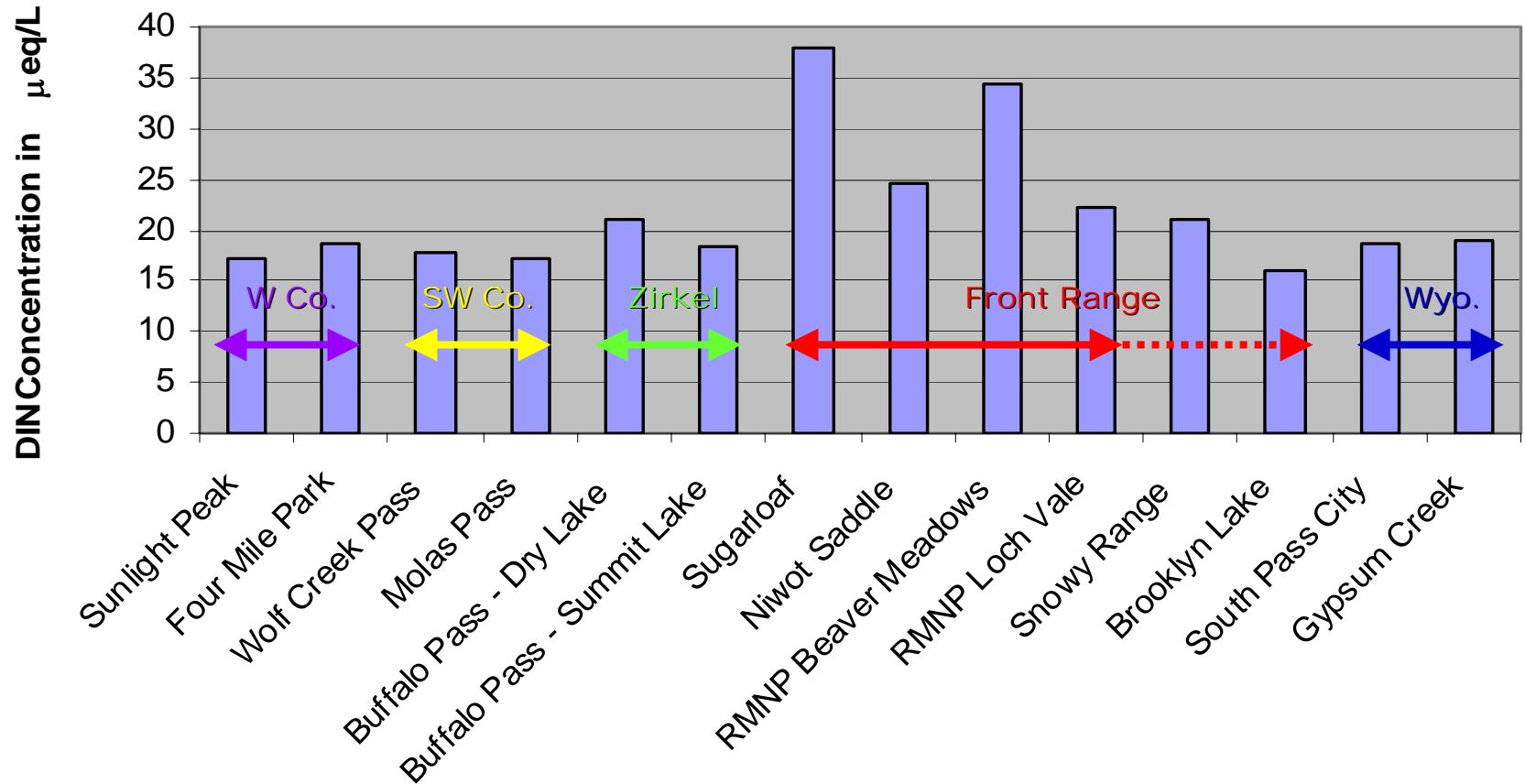
Nitrate in Rocky Mountain snowpack

(average, 1993-2000)

- G.P. Ingersoll and others, USGS

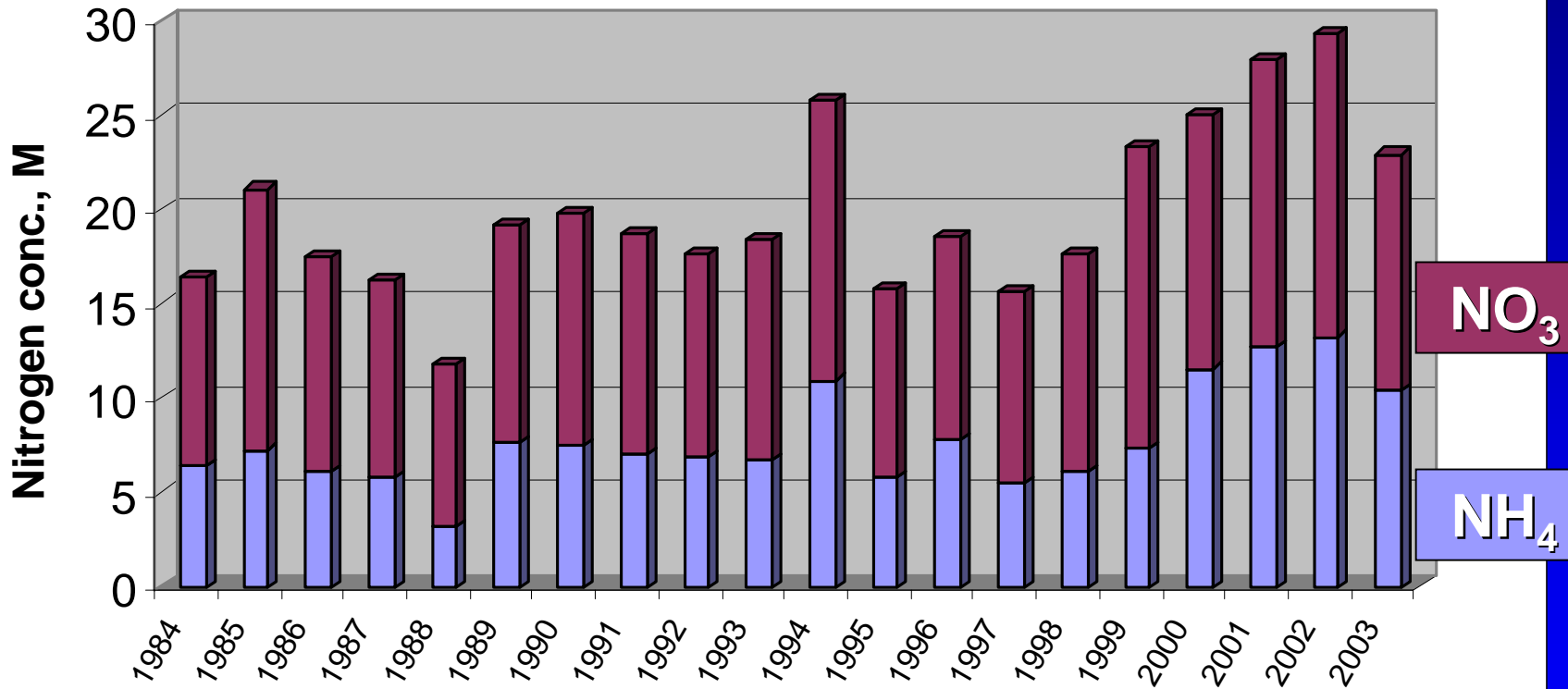


Annual VWM Inorganic N conc. in wetfall



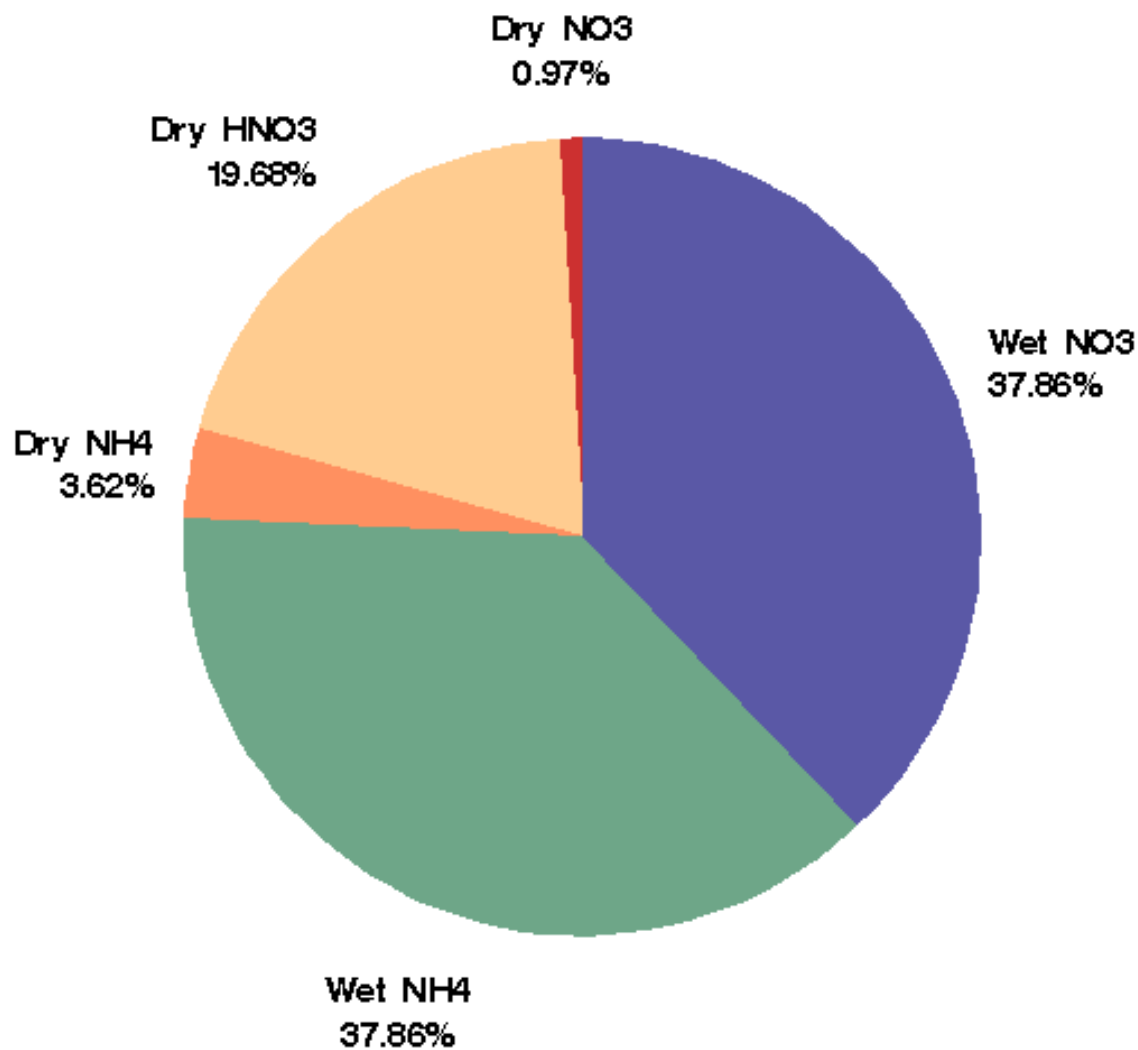
- 10-year mean DIN concentration ($\text{NO}_3 + \text{NH}_4$)
- NADP sites in Colorado and Wyoming > 2400m elevation

Inorganic Nitrogen Concentration in Wetfall, Loch Vale NADP site.



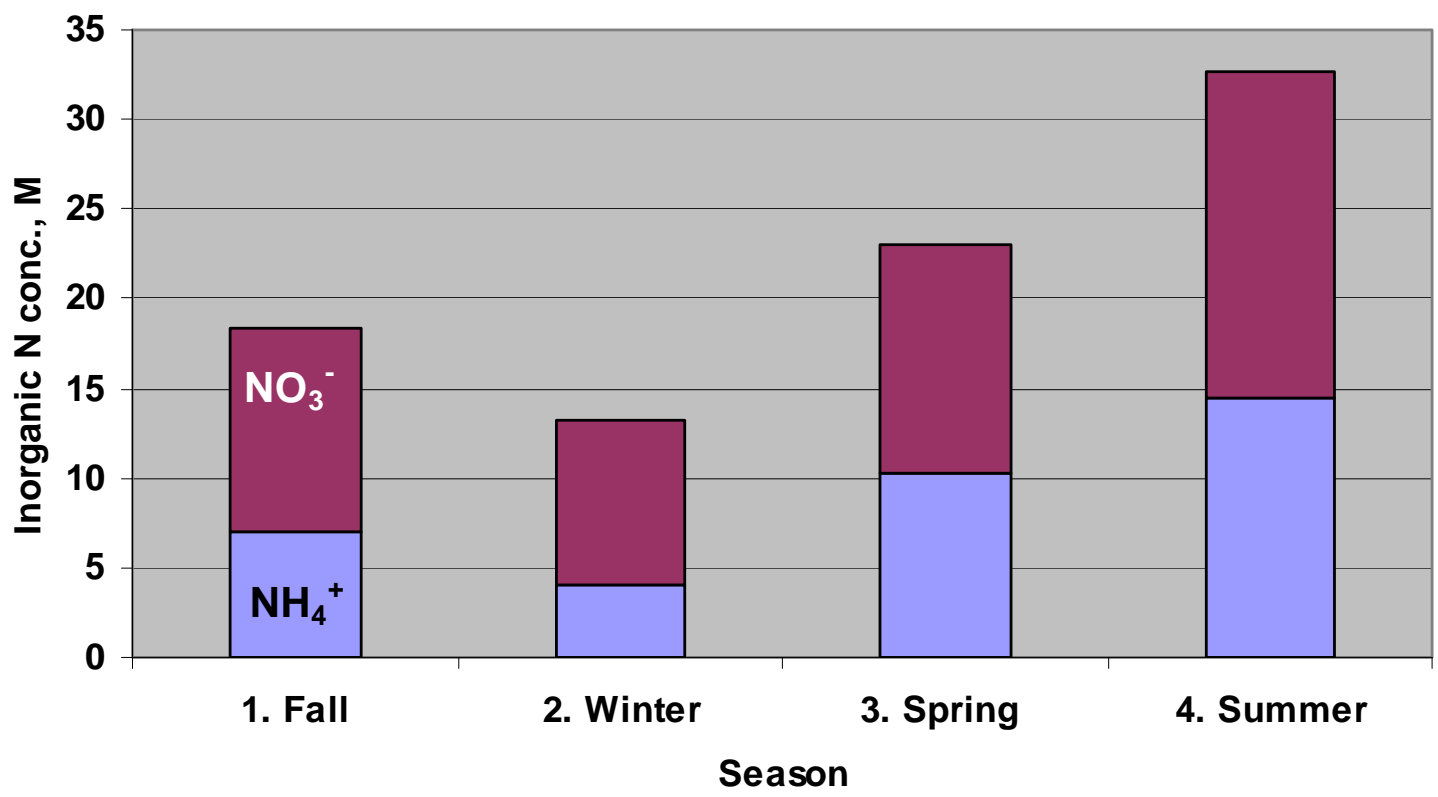
- from NADP/NTN database

Composition of N deposition for 1999–2001 ROM406

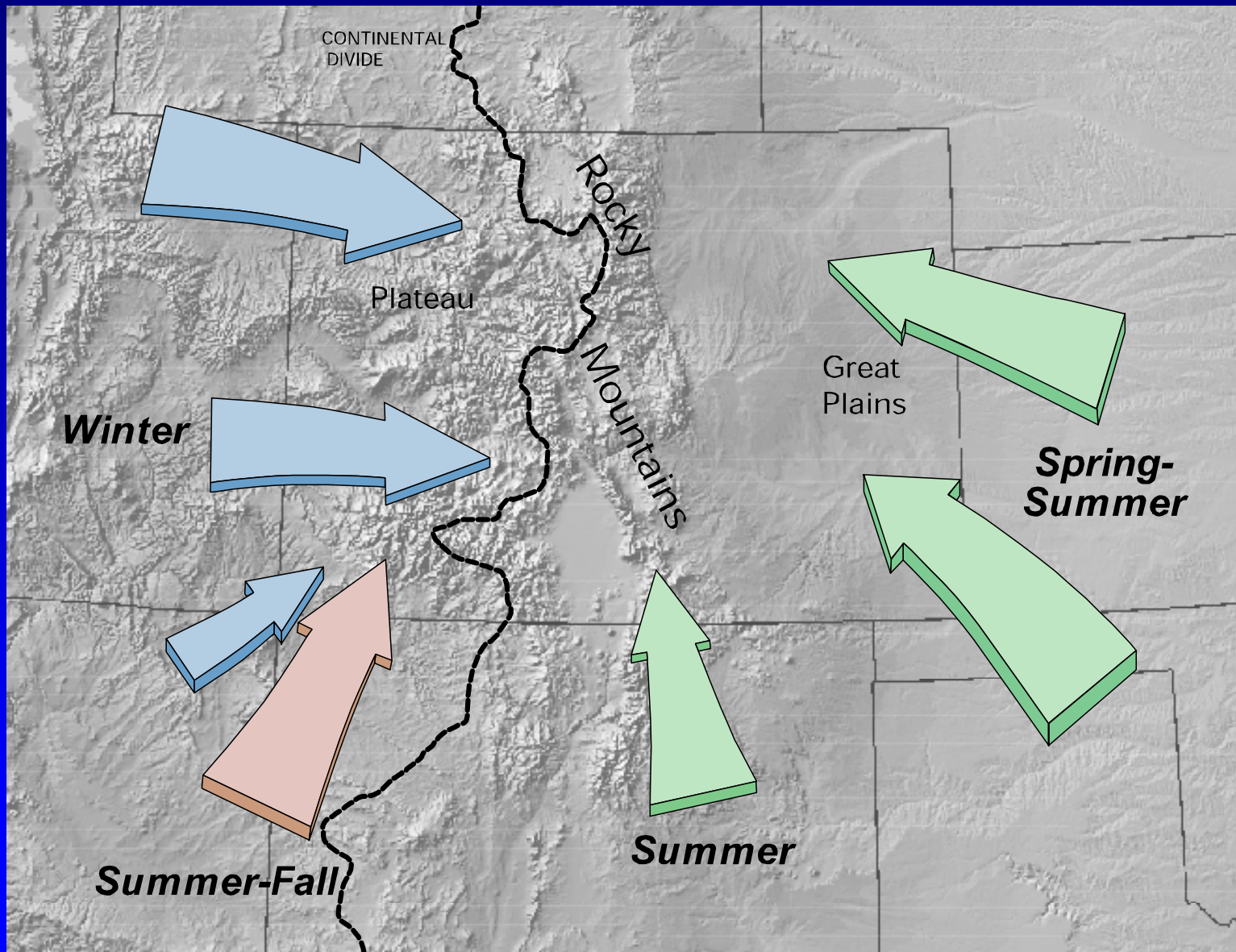


Nitrogen concentrations in wetfall by season

RMNP Loch Vale NADP
1994-2003 mean concentrations



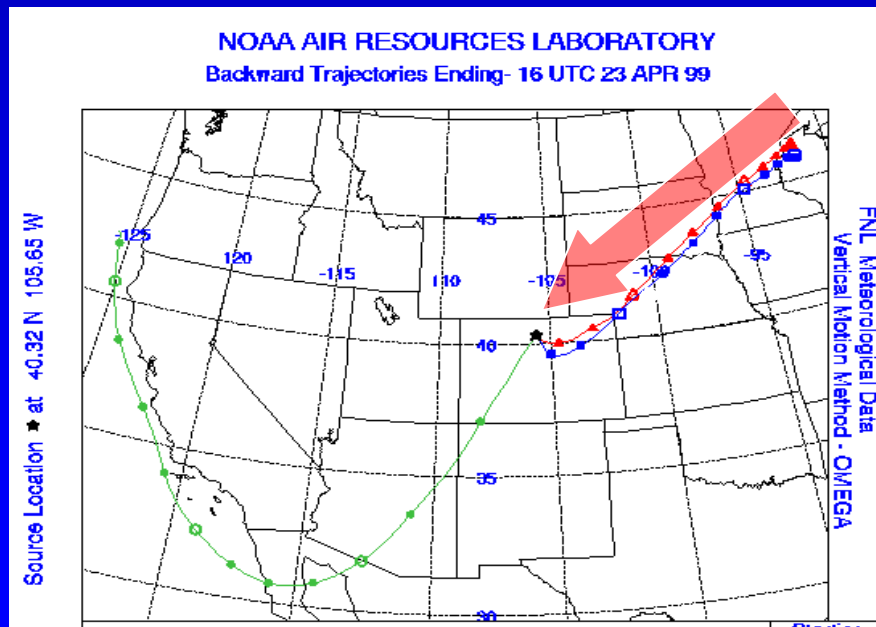
Airflow into Colorado



Bear Lake, Rocky Mt. Natl. Park Bulk precipitation event samples

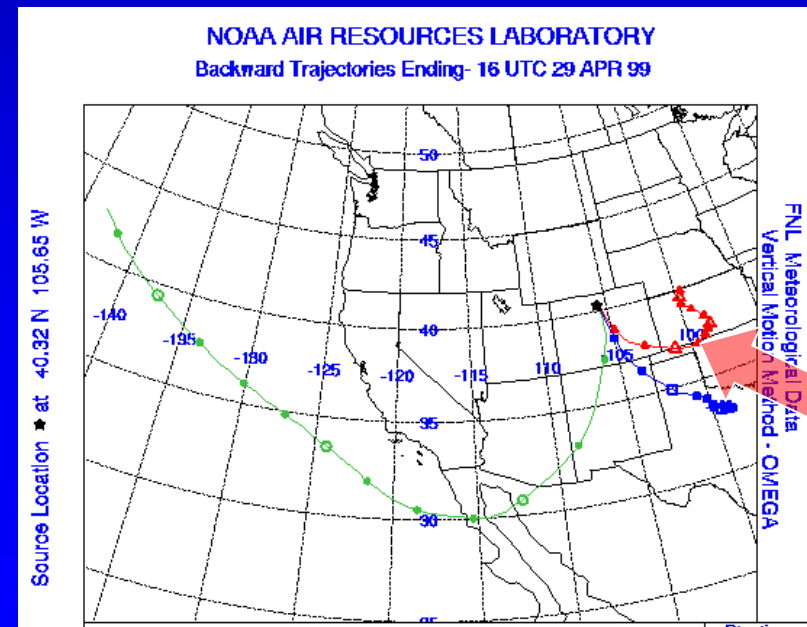
23 April 1999
5.7 cm precip

10.1 $\mu\text{mol/l}$ DIN (NH_4^+ + NO_3^-)



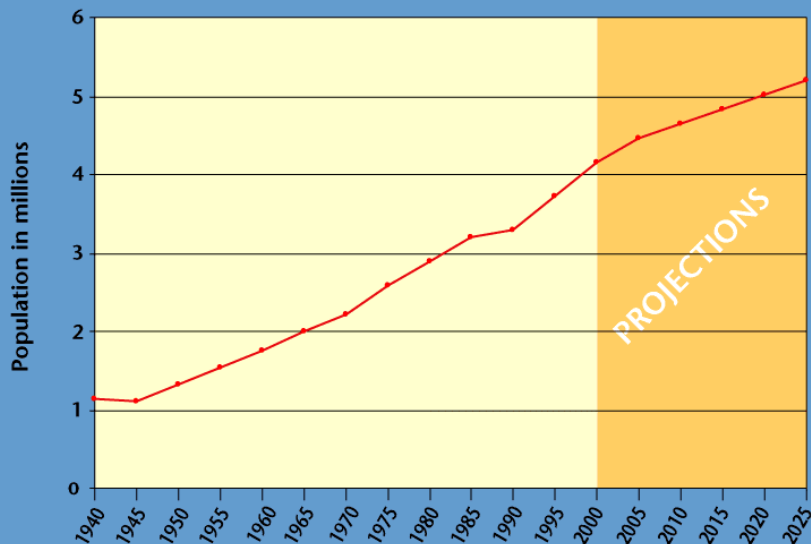
29 April 1999
4.2 cm precip

32.5 $\mu\text{mol/l}$ DIN (NH_4^+ + NO_3^-)



Sources of nitrogen emissions in Colorado

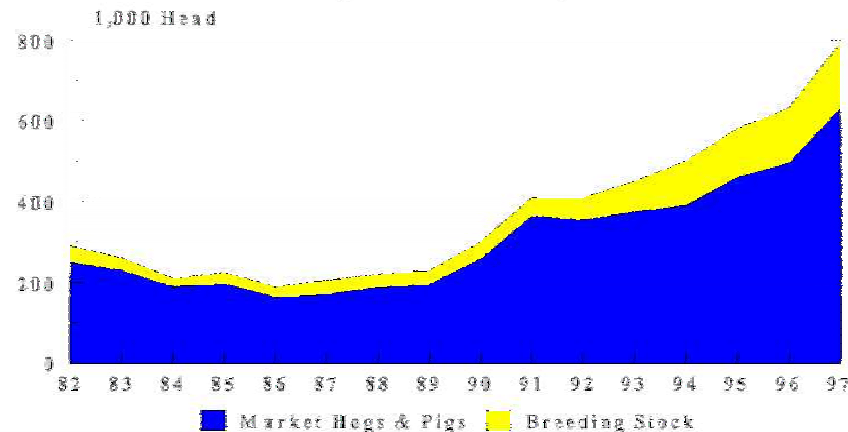
Colorado Population, 1940 to 2025



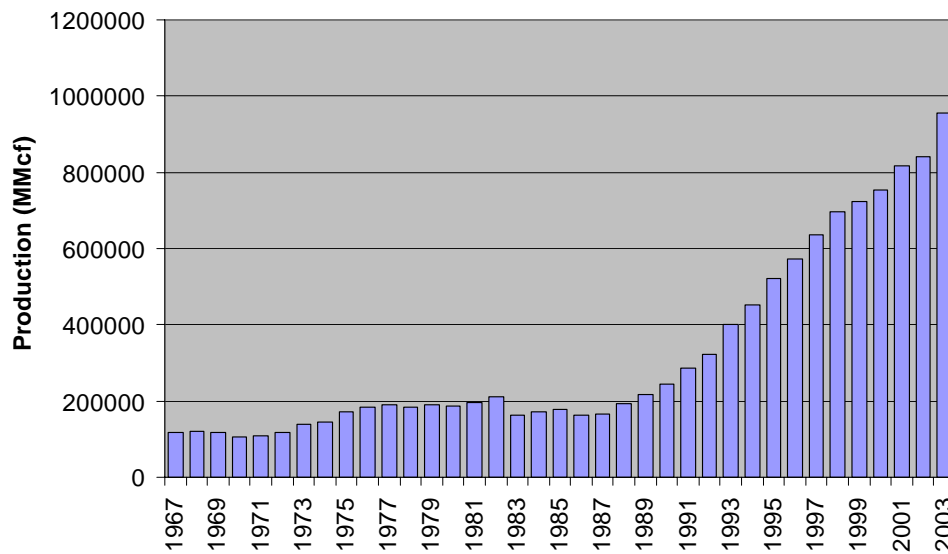
Source: U.S. Census Bureau, March 2001

HOG AND PIG INVENTORY

Colorado, December 1, 1982-97

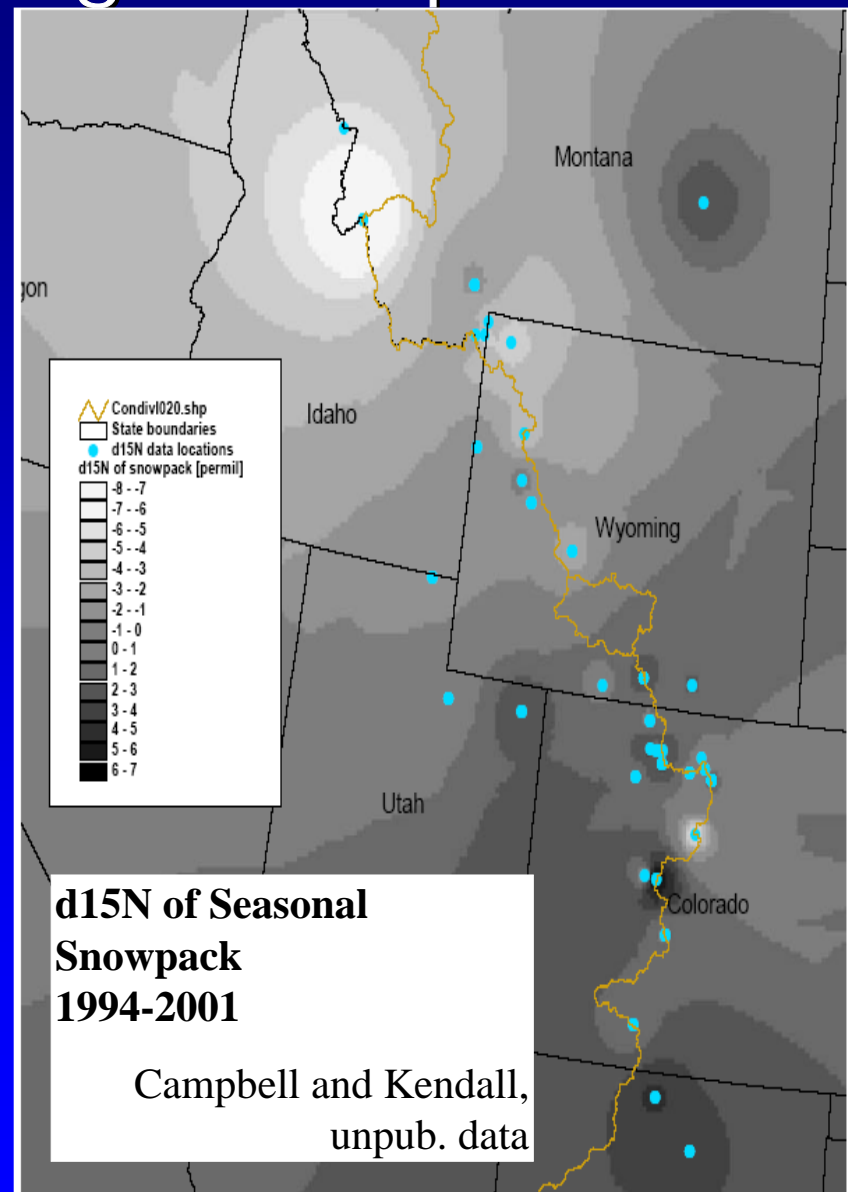


Colorado Natural Gas Marketed Production



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.



Nitrogen deposition in Rocky

- Overall nitrogen deposition is increasing.
- NO_3 (combustion sources) makes up >50%.
- NH_4 (agricultural sources) is increasing rapidly.
- 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.