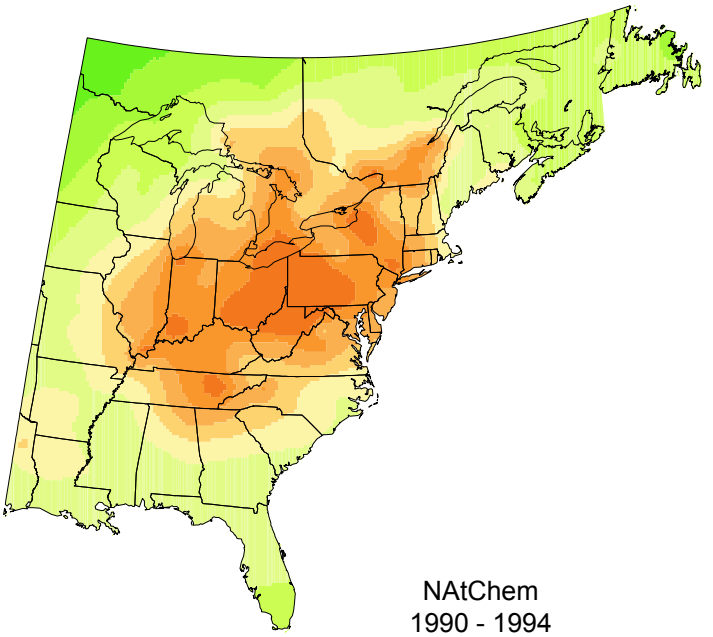
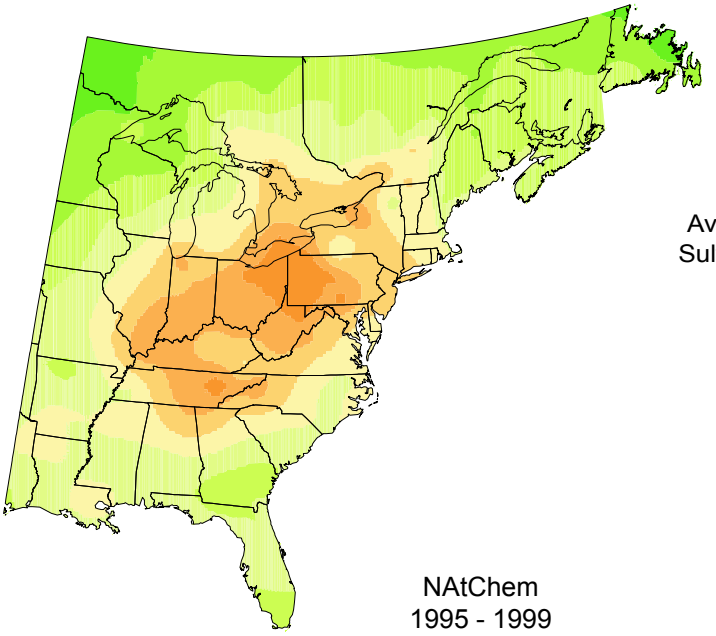
National Atmospheric Deposition Program

2003 Annual Summary



NAtChem
1990 - 1994



NAtChem
1995 - 1999

Average non-sea-salt
Sulfate Wet Deposition
(kg/ha)

- ≤ 3
- 3 - 6
- 6 - 9
- 9 - 12
- 12 - 15
- 15 - 18
- 18 - 21
- 21 - 24
- 24 - 27
- > 27

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

NADP and NAtChem

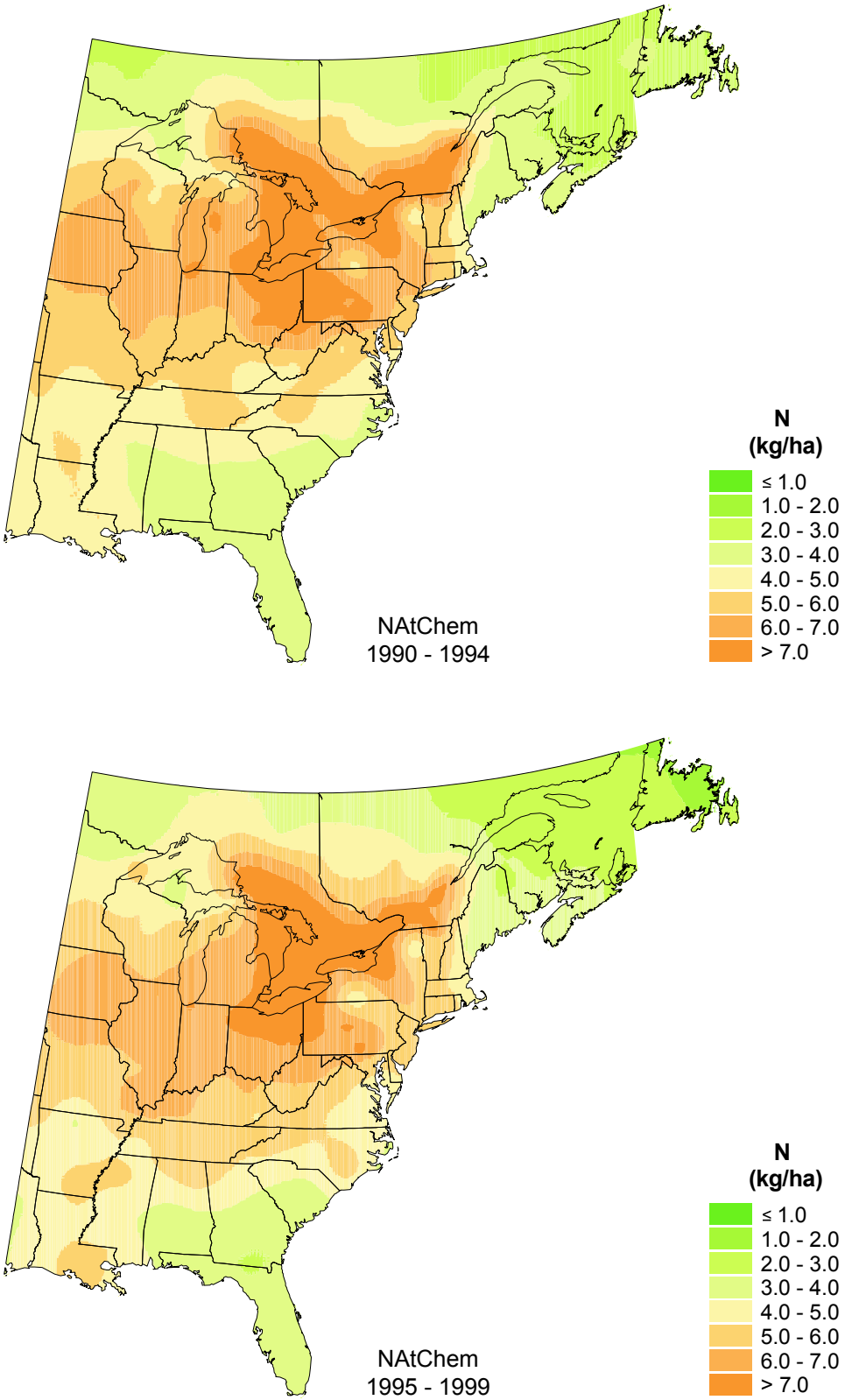
In 1992, the National Atmospheric Deposition Program (NADP) agreed to provide data and information to the National Atmospheric Chemistry (NAtChem) Database and Analysis System, now operated by the Meteorological Service of Canada. The NAtChem database archives North American air and precipitation chemistry data in support of research on atmospheric processes, spatial and temporal patterns of air pollutant concentrations and deposition, source-receptor relationships, and long-range transport of air pollutants. This system consists of databases for particulate matter, air toxics, and precipitation chemistry. Information about this system and data and products are accessible on-line (www.msc.ec.gc.ca/natchem).

The NAtChem precipitation chemistry database was initiated in 1987 and combines data from 23 precipitation chemistry networks, 12 Canadian federal and provincial networks and 11 U.S. networks. Networks included must have operated two or more years at rural and background locations representing a wide geographic area or region. The NAtChem system combines data from diverse networks with different sampling and analytical equipment and methods and nonuniform data handling procedures. Only data that meet NAtChem completeness and representativeness criteria are used for maps, time-series analyses, and other statistical summaries.

Data from three Canadian federal government networks are stored in the NAtChem database. The earliest is the Canadian Network for Sampling Precipitation, which began in 1977 and was replaced in 1983 by the Canadian Air and Precipitation Monitoring Network (CAPMoN). The CAPMoN continues to operate more than 20 sites and participates in ongoing data comparisons with the NADP at the Penn State (PA15) site in central Pennsylvania, where there are co-located NADP/National Trends Network (NTN) and NADP/Atmospheric Integrated Research Monitoring Network (AIRMoN) sites; and at a southern Quebec site near Frelighsburg, Canada. Data from Canadian provincial networks in Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario, and Quebec also are archived in the NAtChem database. These provincial networks generally began operations in the late 1970s or early 1980s, and some have been discontinued. Of the 11 U.S. networks that originally provided data to the NAtChem database, only the two NADP networks still remain (NTN, 1978 - present, and AIRMoN, 1992 - present).

The NAtChem database now archives more than 20 years of North American precipitation chemistry measurements. Products include: quality-assured data in a standard format; annual, seasonal, quarterly, and monthly statistical summary tables; annual and seasonal concentration and deposition maps; and charts showing wet deposition trends and average concentrations. Variables shown include concentrations of sulfate, non-sea-salt-sulfate, nitrate, chloride, ammonium, sodium, potassium, calcium, magnesium, and hydrogen ion (pH). Also available is precipitation depth, which is used to calculate deposition fluxes and precipitation-weighted concentrations. Data, products, and special data analyses can be requested through the NAtChem Web site.

[**About the cover and page 3:** Depicted are annual average deposition maps for two 5-year periods (1990-1994 and 1995-1999) produced by the NAtChem Database and Analysis System. Sulfate depositions have been reduced by the calculated sea-salt contribution to sulfate concentrations at sites within 100 kilometers (km) of the ocean. Sea-salt corrections were based on oceanic salinity following World Meteorological Organization guidelines (see Appendix H of www.wmo.ch/web/arep/reports/prec_chem_manual.pdf).]



Annual average inorganic nitrogen deposition from nitrate and ammonium for two five-year periods, 1990-1994 and 1995-1999.

NADP Background

In 1977, U.S. State Agricultural Experiment Stations (SAES) organized a regional project, later titled NADP, to measure atmospheric deposition and study its effects on the environment. Sites in the NADP precipitation chemistry network began operations in 1978 with the goal of providing data on the amounts, trends, and geographic distributions of acids, nutrients, and base cations in precipitation. The network grew rapidly in the early 1980s, and the regional project became national. Much of this expansion was funded by the National Acid Precipitation Assessment Program (NAPAP), established in 1981 to improve understanding of the causes and effects of acidic precipitation. Reflecting the federal NAPAP role in the NADP, the network name was changed to NADP/NTN. Today, the NADP is SAES National Research Support Project -3. The network has more than 250 sites and is designated NTN.

A second network (AIRMoN) joined the NADP in 1992. Although measuring the same chemicals as NTN, AIRMoN sampling is daily rather than weekly. These higher resolution samples enhance researchers' ability to evaluate how emissions affect precipitation chemistry using computer models that simulate atmospheric transport and removal of pollutants on a storm-by-storm basis. This network also evaluates alternative sampling and preservation methods. There were 9 AIRMoN sites at the end of 2003.

The Mercury Deposition Network (MDN) joined the NADP in 1996. All MDN samples are analyzed for total mercury, and some for the more toxic methyl mercury. Forty-four states have advisories warning people to limit consumption of fish and wildlife from certain water bodies because of mercury contamination (see http://www.epa.gov/ost/fish). Researchers use MDN data to evaluate the role of precipitation as a source of mercury in these water bodies. At the end of 2003, there were more than 80 MDN sites, including seven sites in Canada.

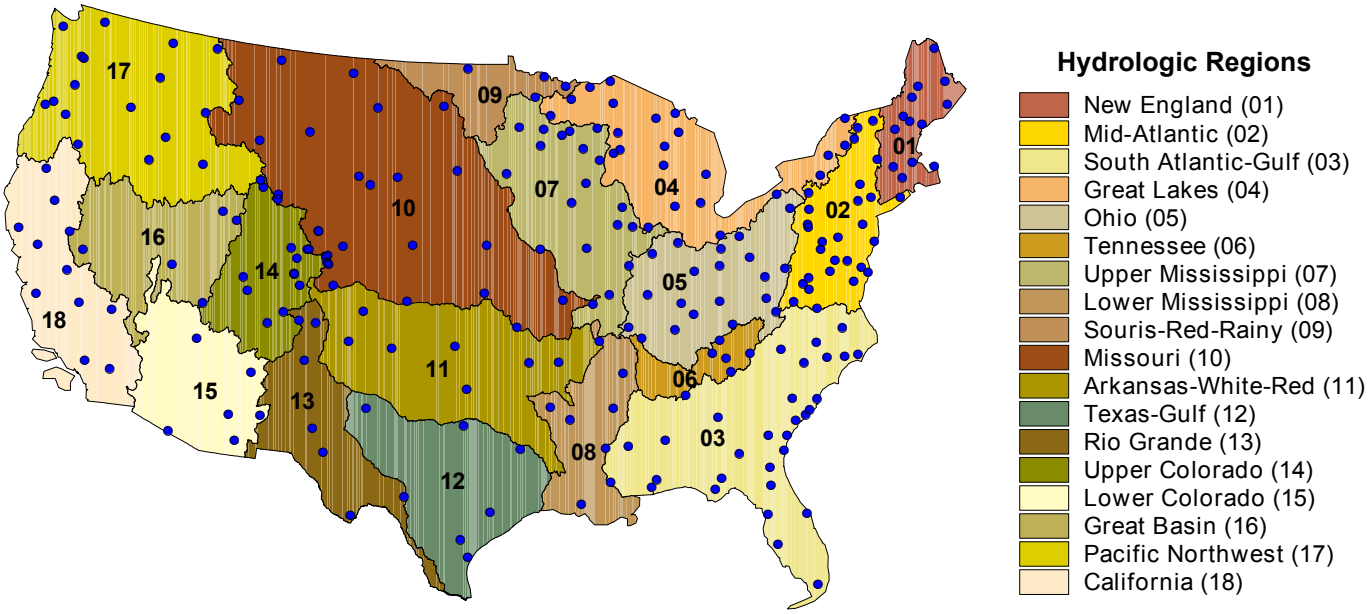
National Trends Network

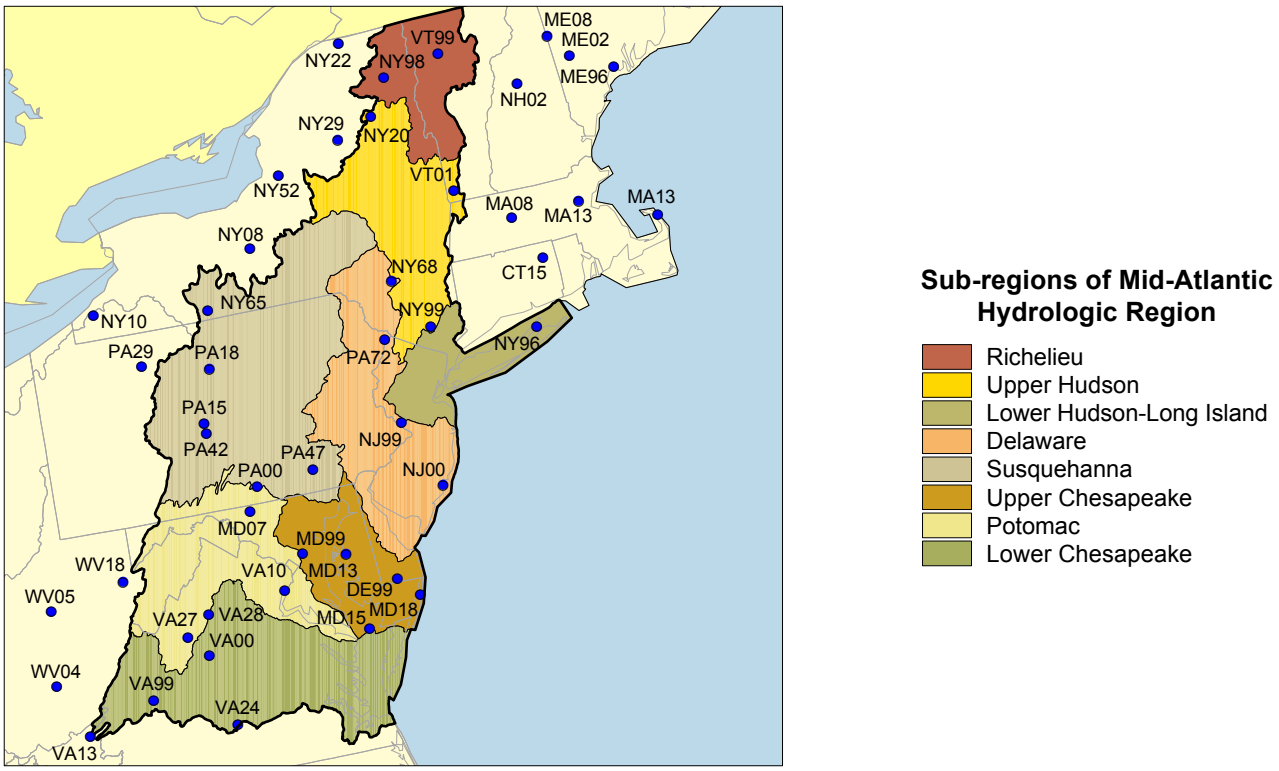
The NTN is the only network providing a long-term record of precipitation chemistry across the United States. Sites predominantly are located away from urban areas and point sources of pollution. Each site has a precipitation chemistry collector and gage. The automated collector ensures that the sample is exposed only during precipitation (wet-only sampling).

Site operators collect samples weekly on Tuesday morning. They transfer each sample from the collection bucket to a shipping bottle, and send it to the Central Analytical Laboratory (CAL) at the Illinois State Water Survey for analysis, and data entry, verification, and screening. All sample containers are cleaned at the CAL, the sole laboratory since the program began. The CAL measures sample volume, conductivity, and concentrations of calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), ammonium (NH_4^{+}), sulfate (SO_4^{2-}), nitrate (NO_3^{-}), chloride (Cl^{-}), and H^{+} as pH. The CAL also measures orthophosphate as an indicator of sample contamination.

The CAL reviews field and laboratory data for completeness and accuracy, and flags samples that have been mishandled, grossly contaminated, or compromised by precipitation collector failures. The CAL delivers all data and information to the NADP Program Office for a final set of checks and resolution of remaining discrepancies. These data then are made available on the NADP Web site (http://nadp.sws.uiuc.edu).

Web access to NTN data begins with a map that displays sites by state or, as shown in the top figure on page 5, by U.S. Geological Survey hydrologic region. (See http://water.usgs.gov/GIS/huc.html for a description.) Each region is either a major river system (e.g., region 10, Missouri) or the combined drainage of a series of rivers (e.g., region 2, Mid-Atlantic). The map at the bottom of the page displays NTN sites in the 8 sub-regions of the Mid-Atlantic Hydrologic Region.





Active NTN sites in hydrologic regions (top) and sub-regions of the Mid-Atlantic Hydrologic Region (bottom).

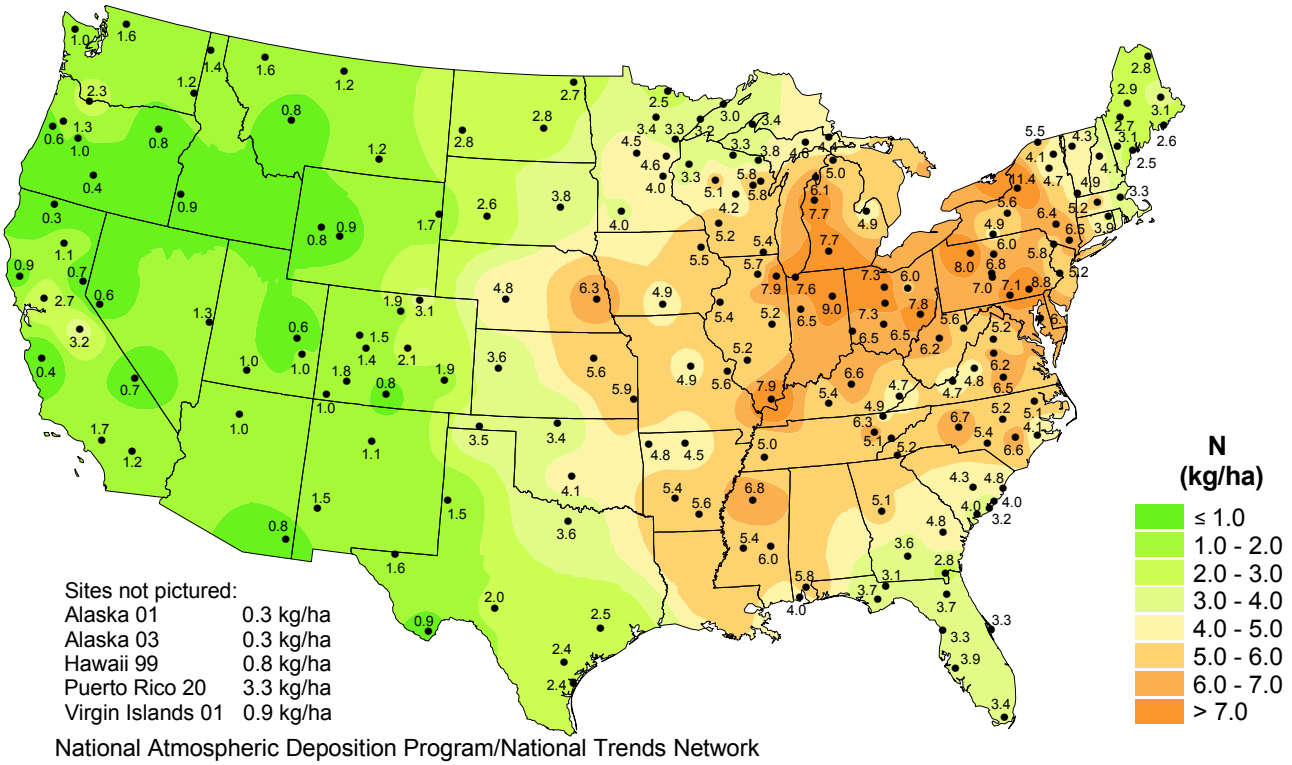
NTN Maps

The NTN maps show spatial variability in the annual concentration and wet deposition of selected acidic ions, nutrients, and base cations on regional and national scales. Only sites meeting prescribed data completeness criteria are included. In 2003, 193 sites met these criteria. Black dots mark site locations, and annual concentration or deposition values appear next to each site. Concentrations are precipitation-weighted averages. (See the NADP Web site for an explanation of the data completeness criteria or how the precipitation-weighted averages or deposition fluxes were calculated.)

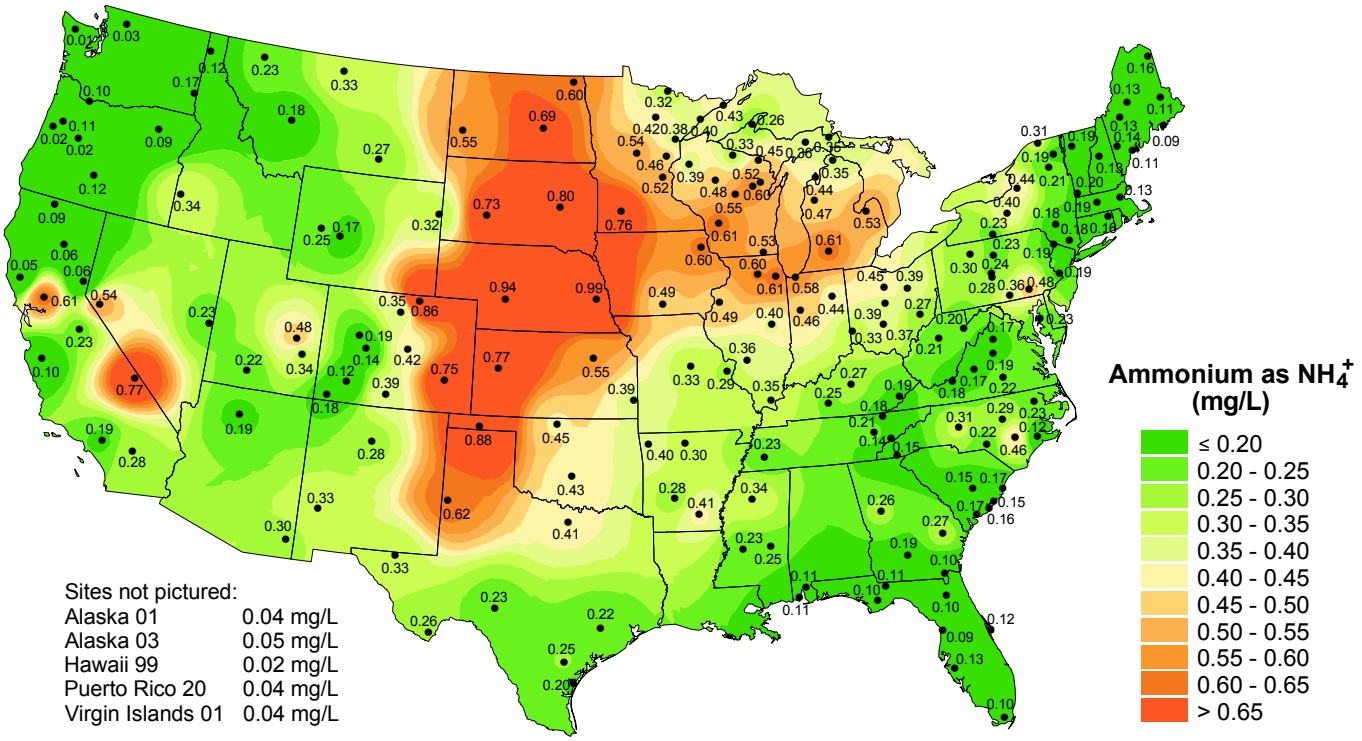
Color contours on the NTN maps were created by using site values to compute an array of regularly spaced grid-point values across the nation. Sites within 500 km of each grid point were used in computations. Color contours represent the classes of concentrations or depositions indicated in the legend. (See the NADP Web site for information about the algorithm used to compute grid-point values.)

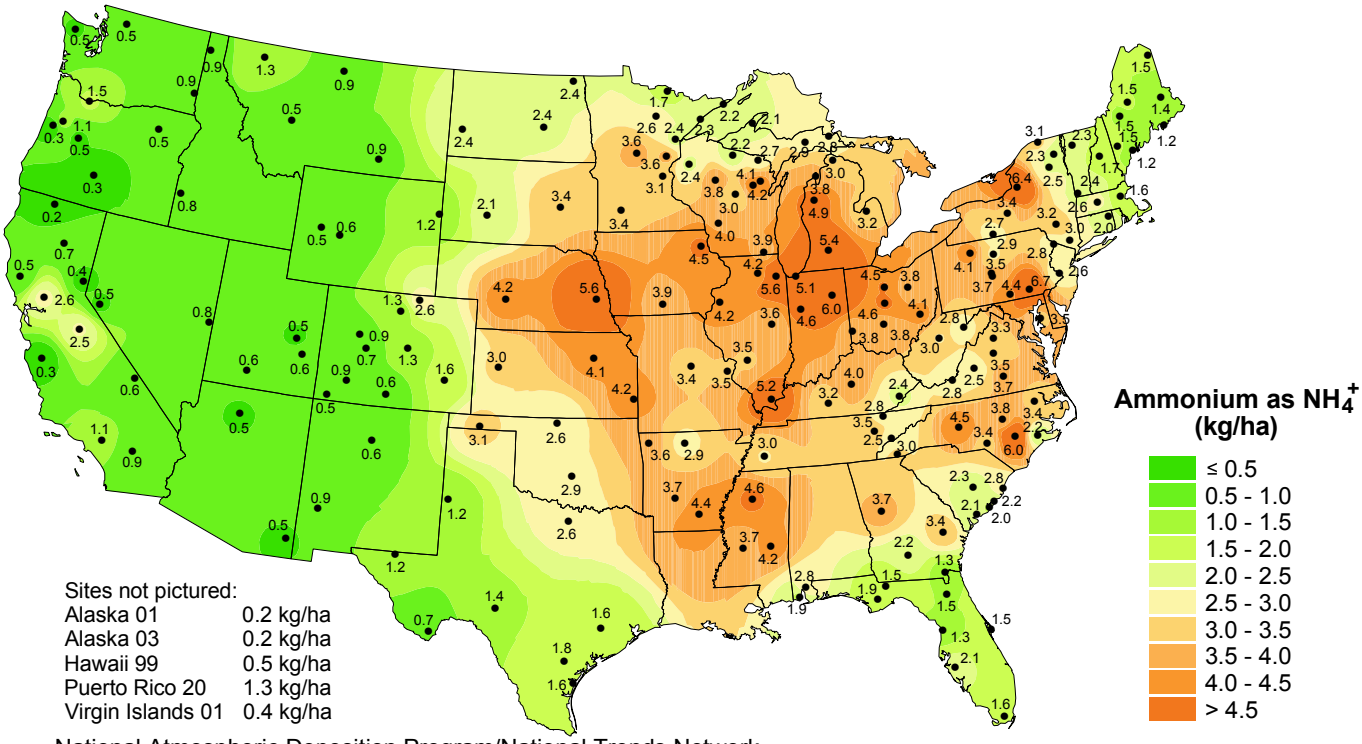
In addition to the map of inorganic nitrogen wet deposition, shown below, concentration and deposition maps show NH_4^+, NO_3^-, SO_4^{2-}, Ca^{2+}, and laboratory pH. Also shown is a map of total precipitation. Concentration and deposition maps of Mg^{2+}, Na^+, K^+, Cl^-, and field H^+, not shown, are available from the NADP Web site.

Explanation of NTN Color Contours: Refer to the figure below, which has eight inorganic nitrogen deposition classes or contours. For example, the lightest green color in the legend represents 3.0 - 4.0 kilograms per hectare (kg/ha). Nitrogen deposition values in the area covered by this contour are greater than 3.0 kg/ha and less than or equal to 4.0 kg/ha.

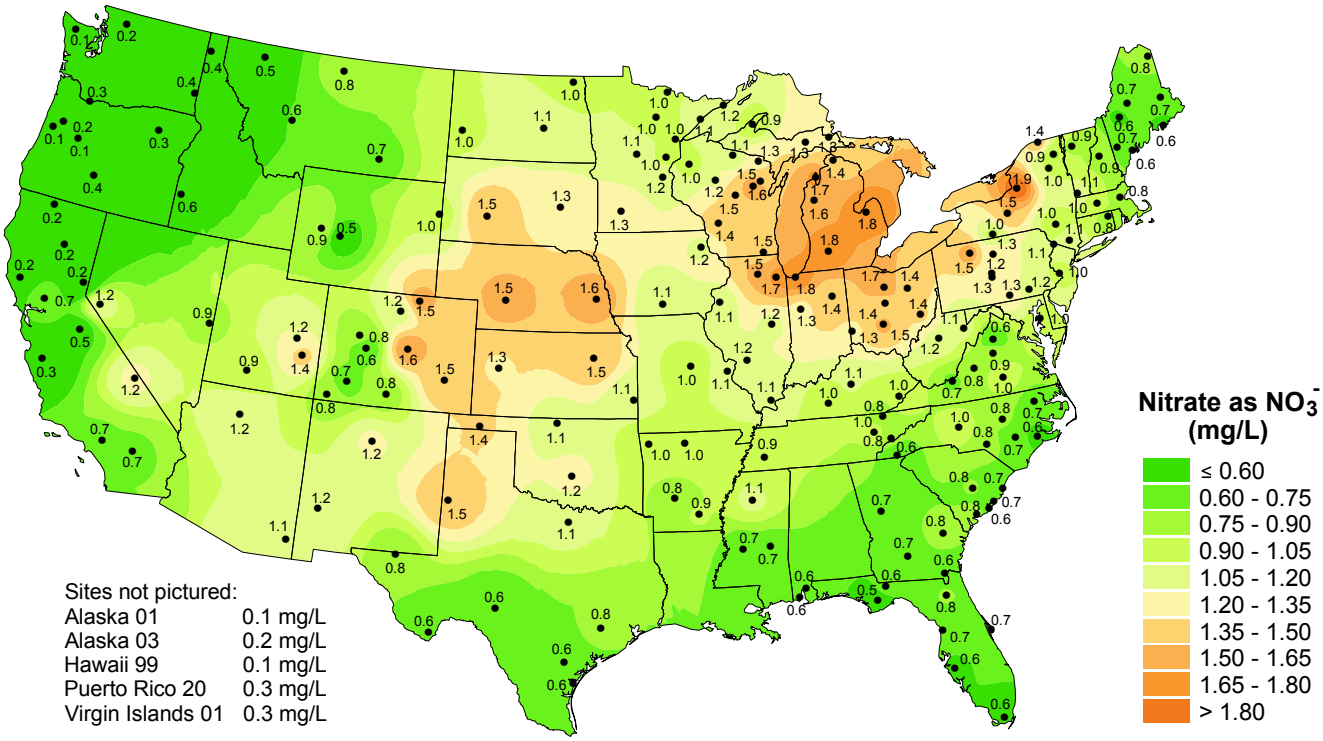


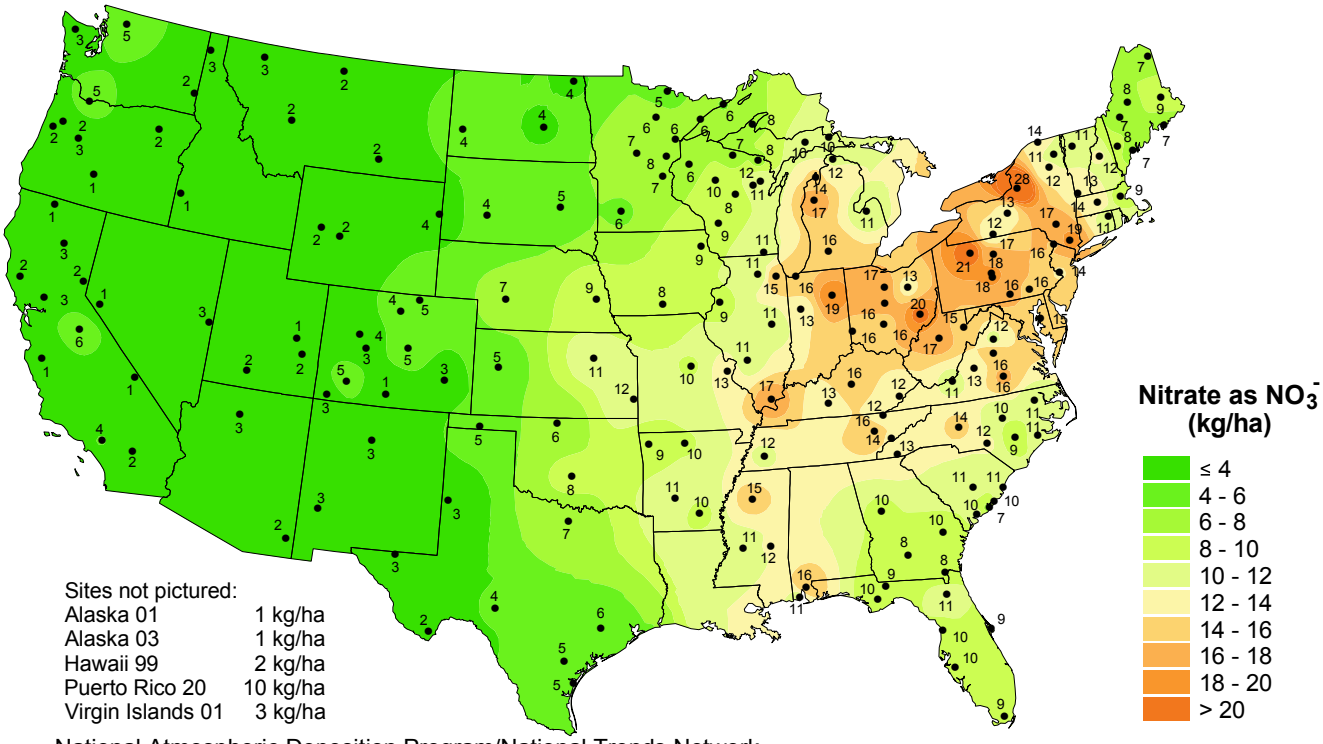
Inorganic nitrogen wet deposition from nitrate and ammonium, 2003.





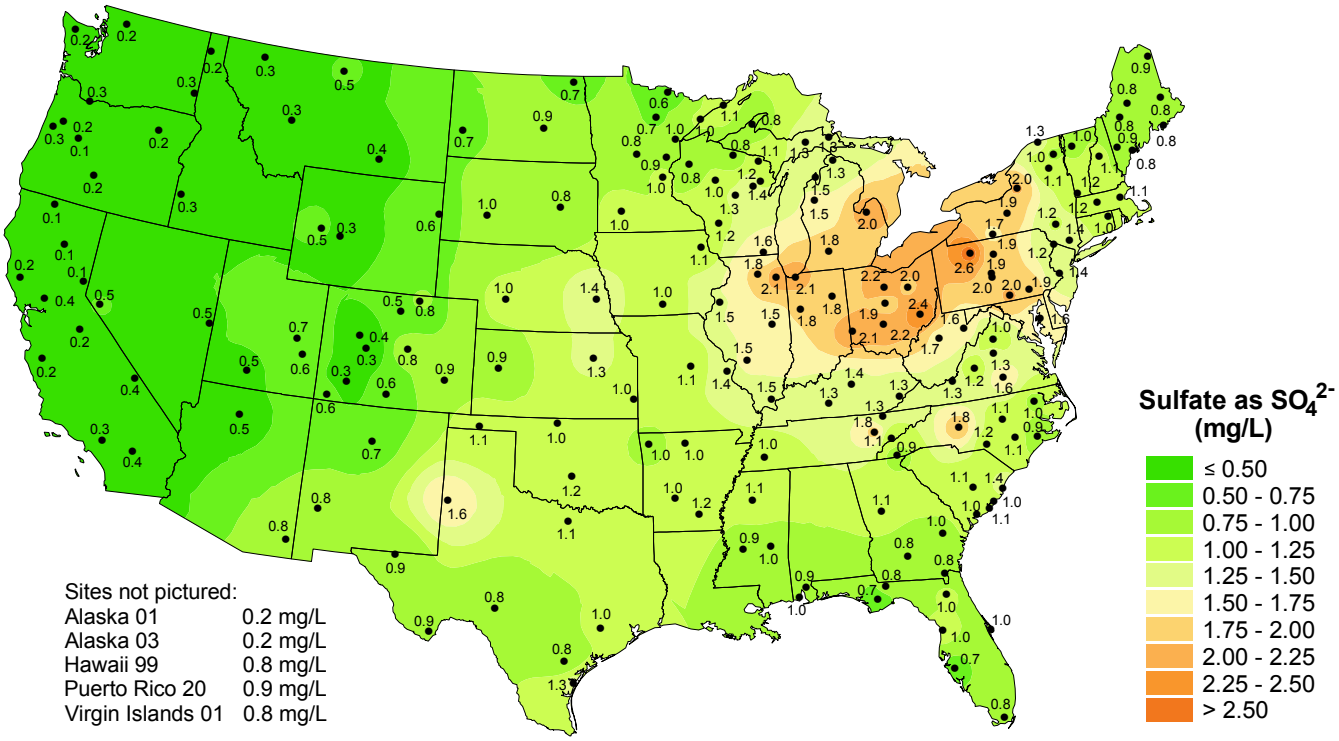
Ammonium ion concentration (top) and wet deposition (bottom), 2003.

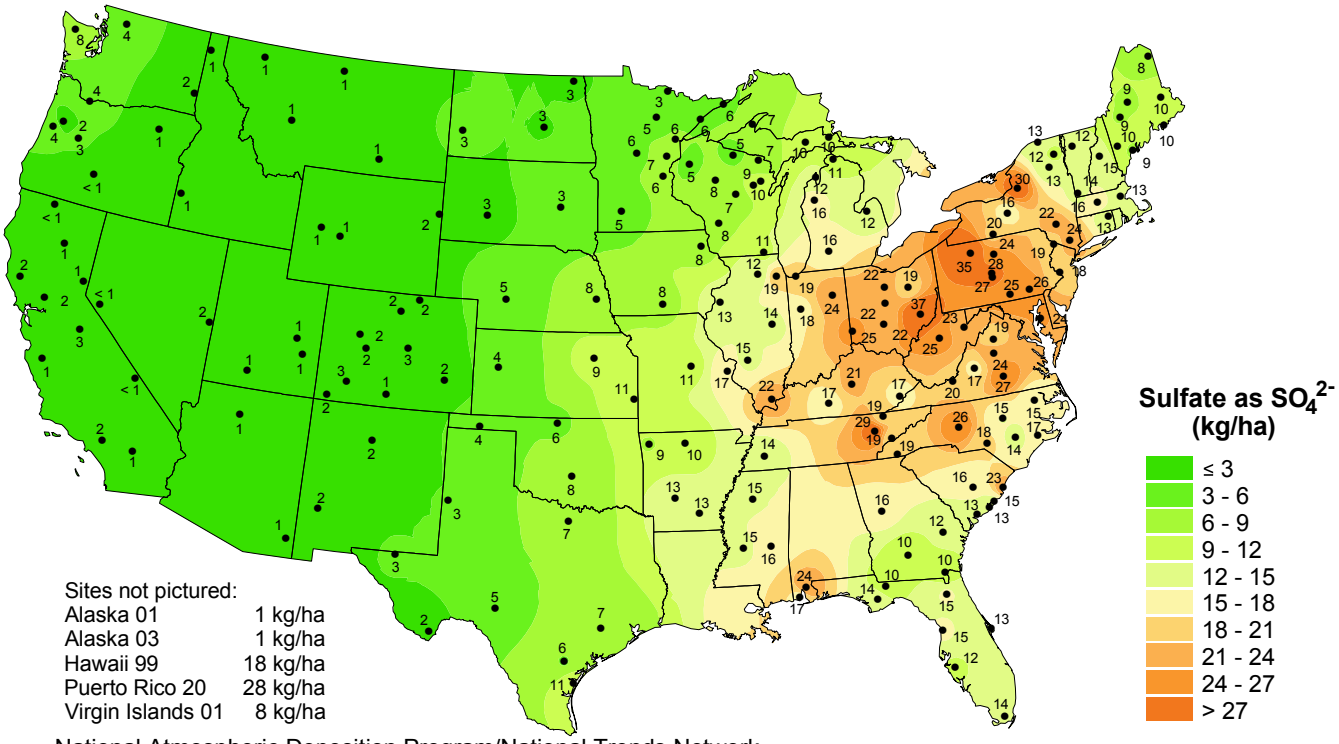




National Atmospheric Deposition Program/National Trends Network

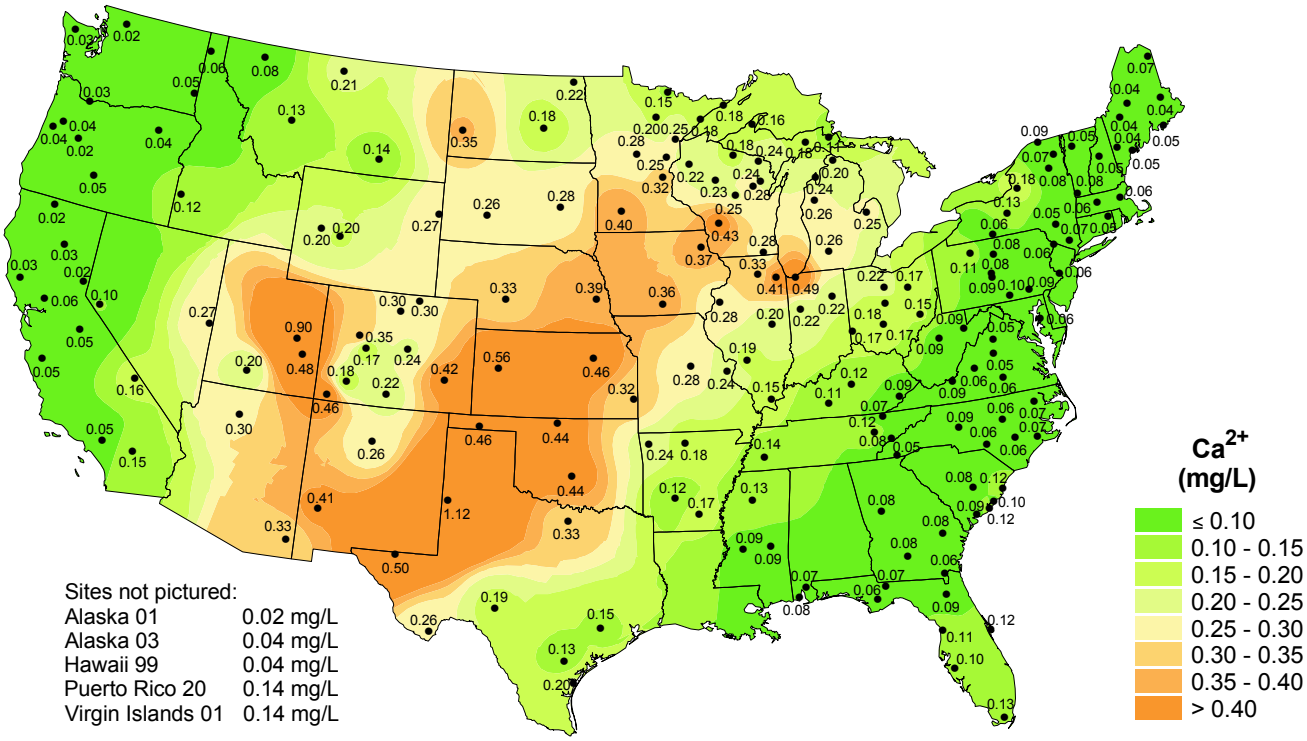
Nitrate ion concentration (top) and wet deposition (bottom), 2003.

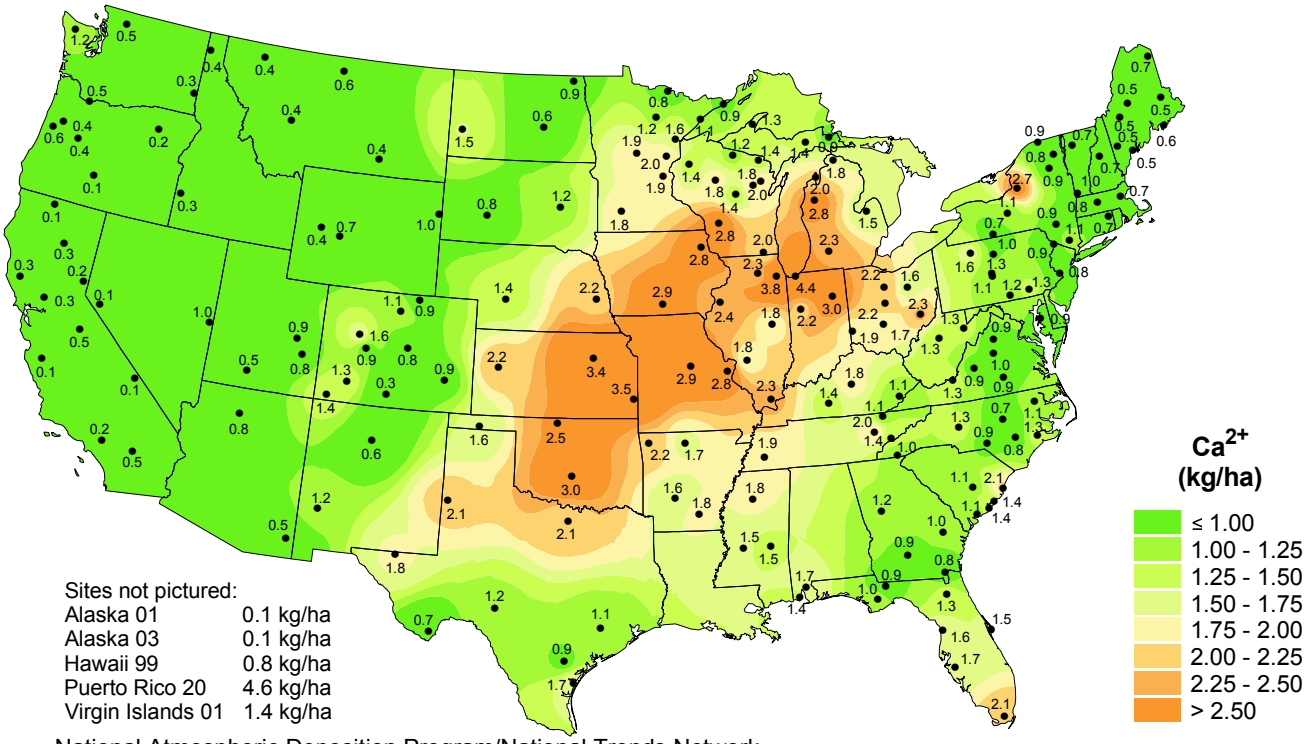




National Atmospheric Deposition Program/National Trends Network

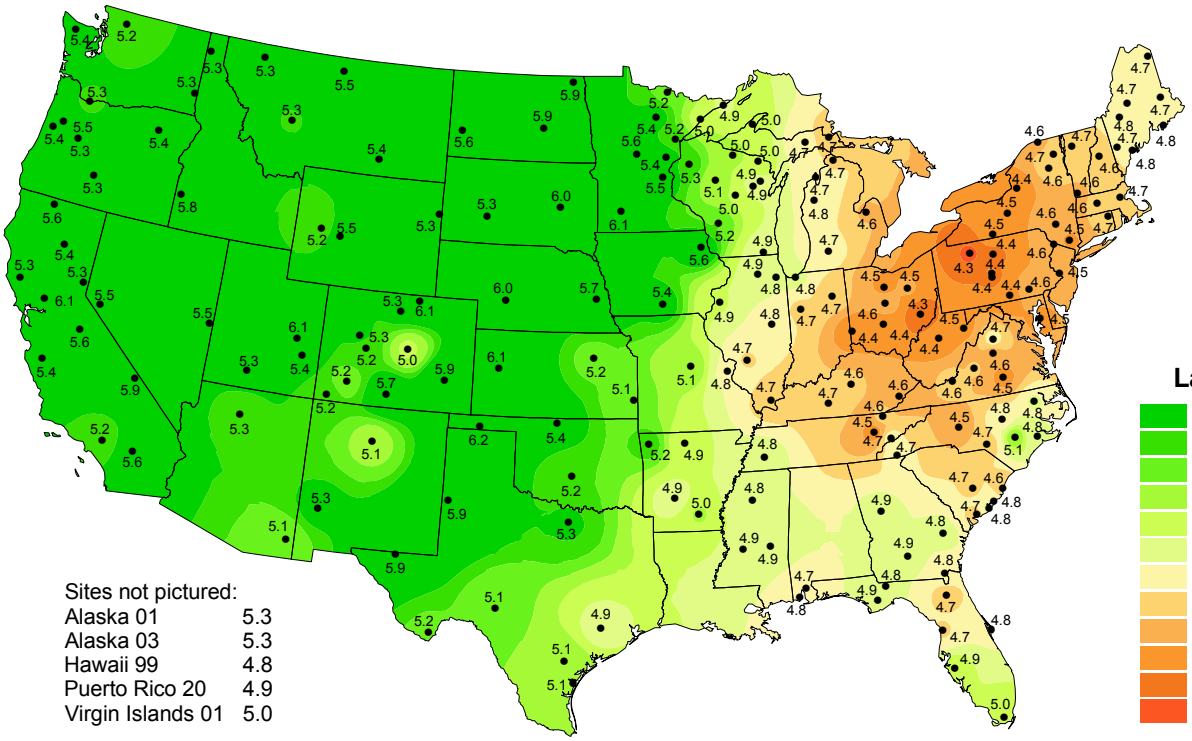
Sulfate ion concentration (top) and wet deposition (bottom), 2003.

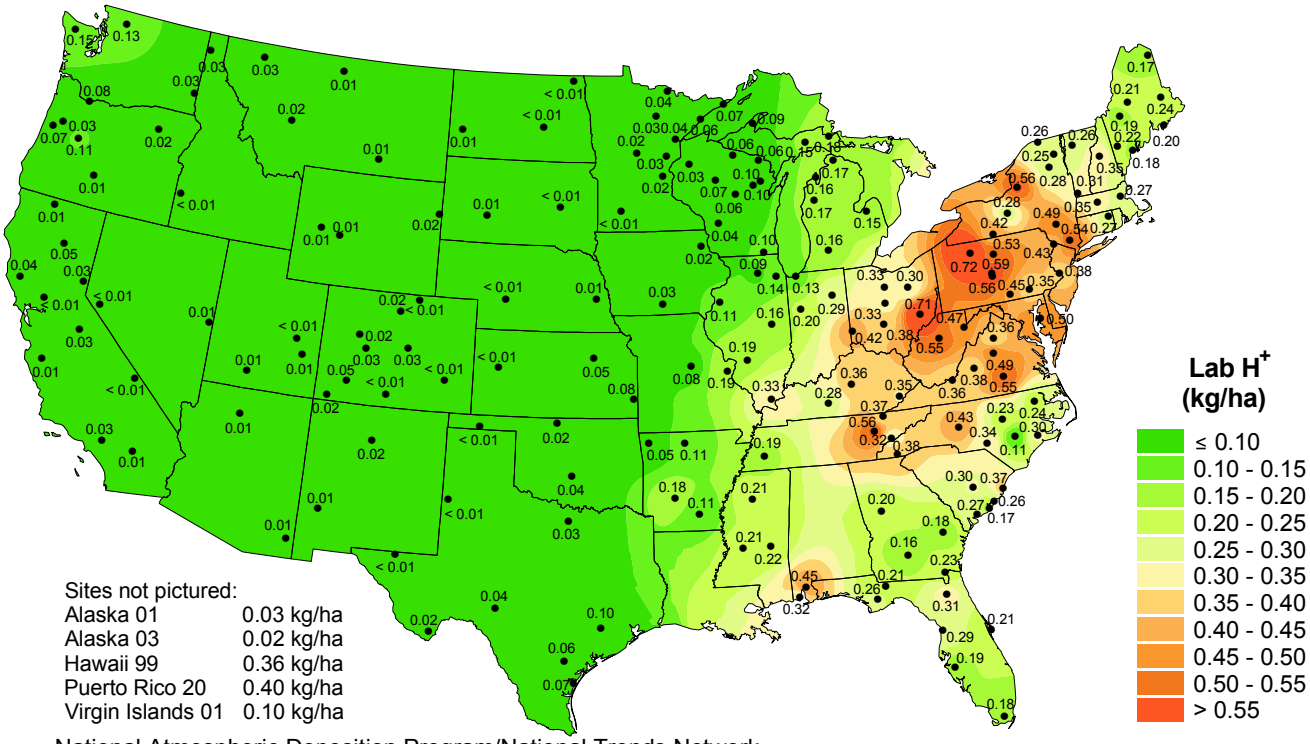




National Atmospheric Deposition Program/National Trends Network

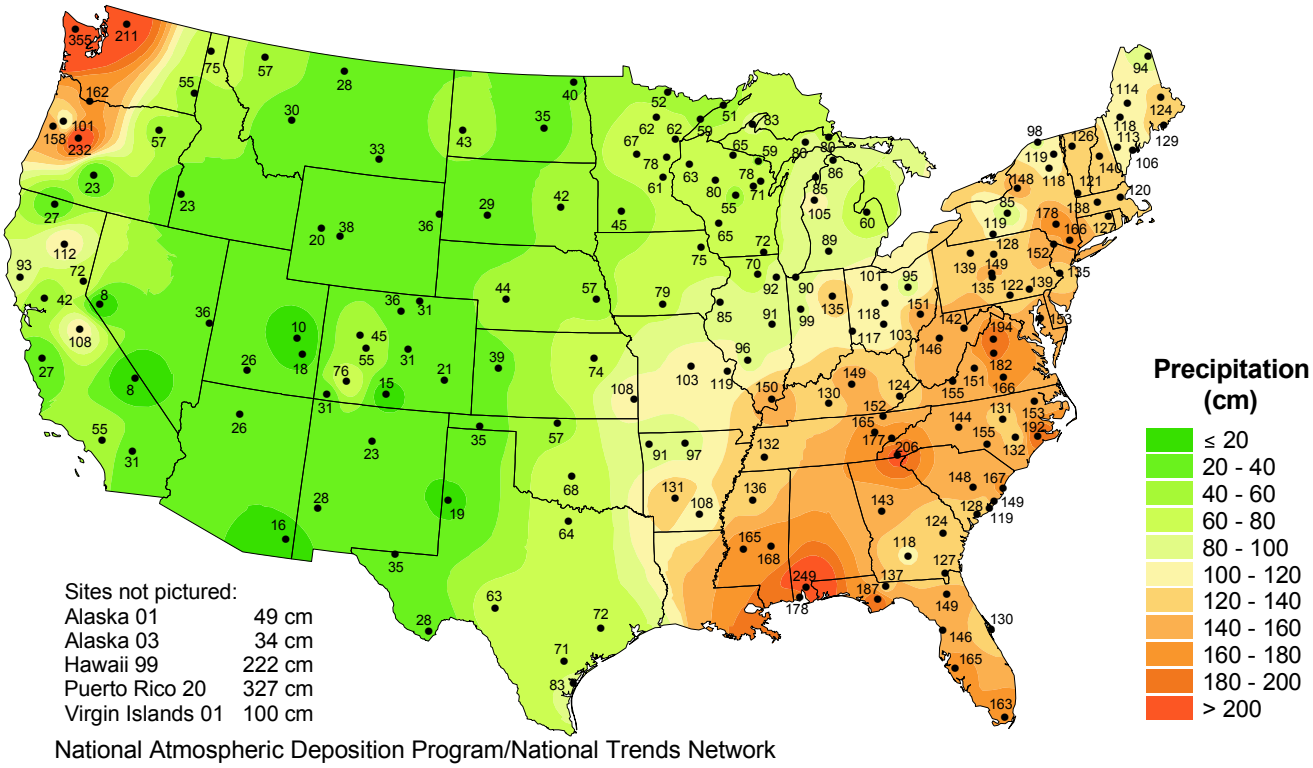
Calcium ion concentration (top) and wet deposition (bottom), 2003.





National Atmospheric Deposition Program/National Trends Network

Hydrogen ion concentration as pH (top) and wet deposition (bottom) from pH measurements made at the Central Analytical Laboratory, 2003.



Total precipitation, 2003.

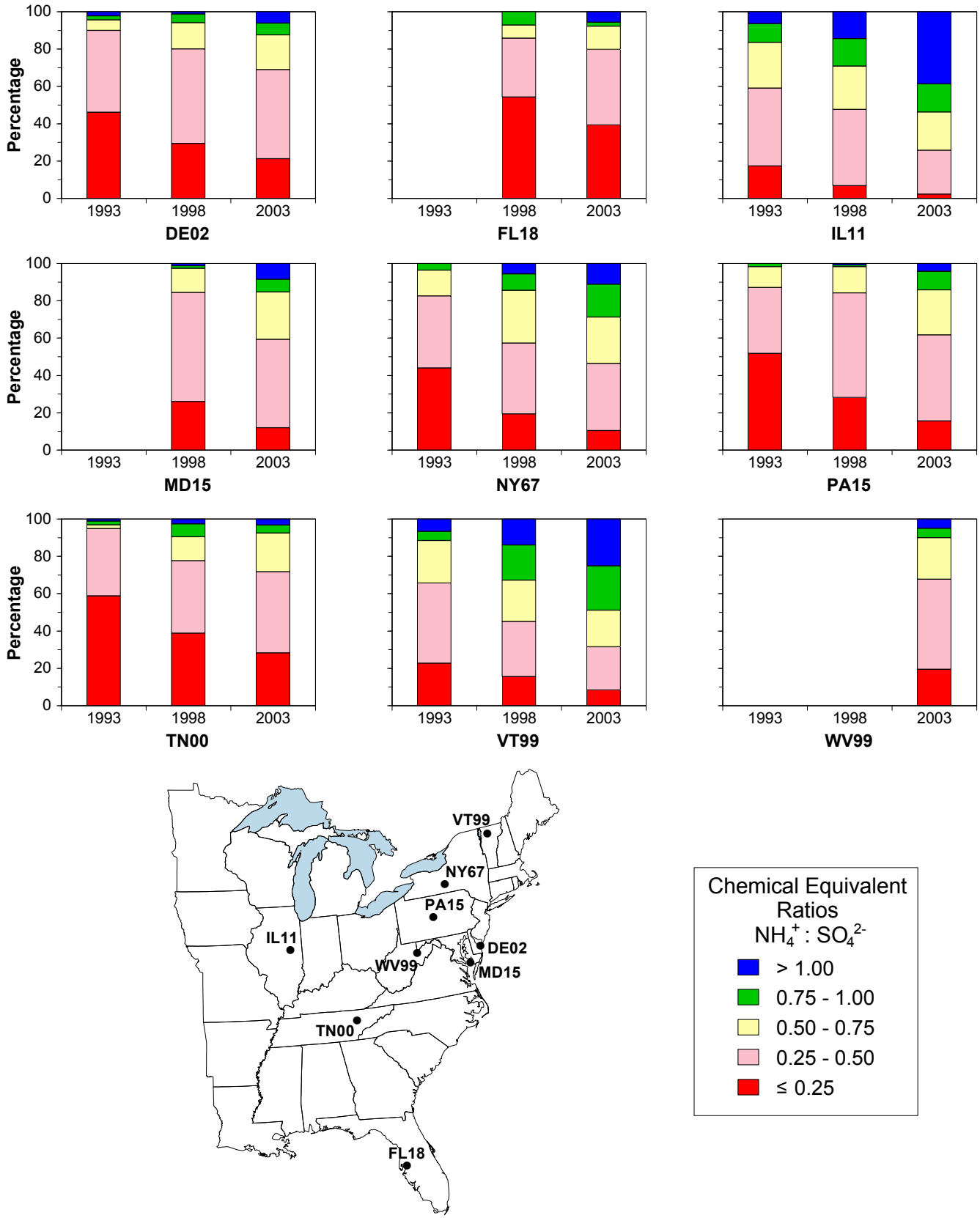
Atmospheric Integrated Research Monitoring Network

At AIRMoN sites, samples are collected daily within 24 hours of the start of precipitation to obtain higher resolution data than at NTN sites, at which samples are collected weekly. Weekly samples often contain precipitation from several storms, whereas daily samples are often from a single storm. Single-storm data facilitate studies of atmospheric processes and the development and testing of computer simulations of these processes. Making data available for these studies is a principal AIRMoN goal.

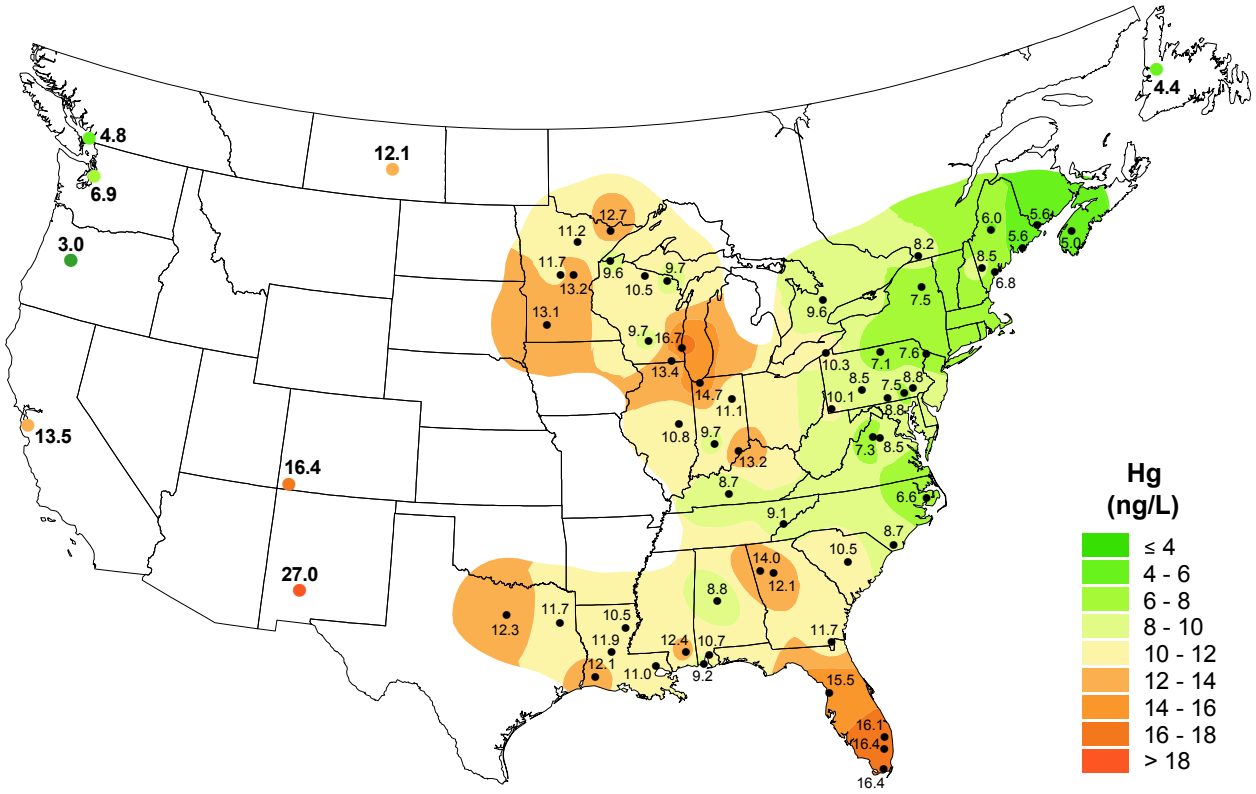
To retard chemical changes, AIRMoN samples are refrigerated from collection until CAL analysis. Chemical analyses and data screening procedures for AIRMoN and NTN are similar, although low-volume AIRMoN samples are not diluted to accommodate a complete analysis, as is standard NTN procedure. During the AIRMoN data review, the CAL also assigns an overall quality rating code before sending data to the NADP Program Office for final checks and posting on the NADP Web site.

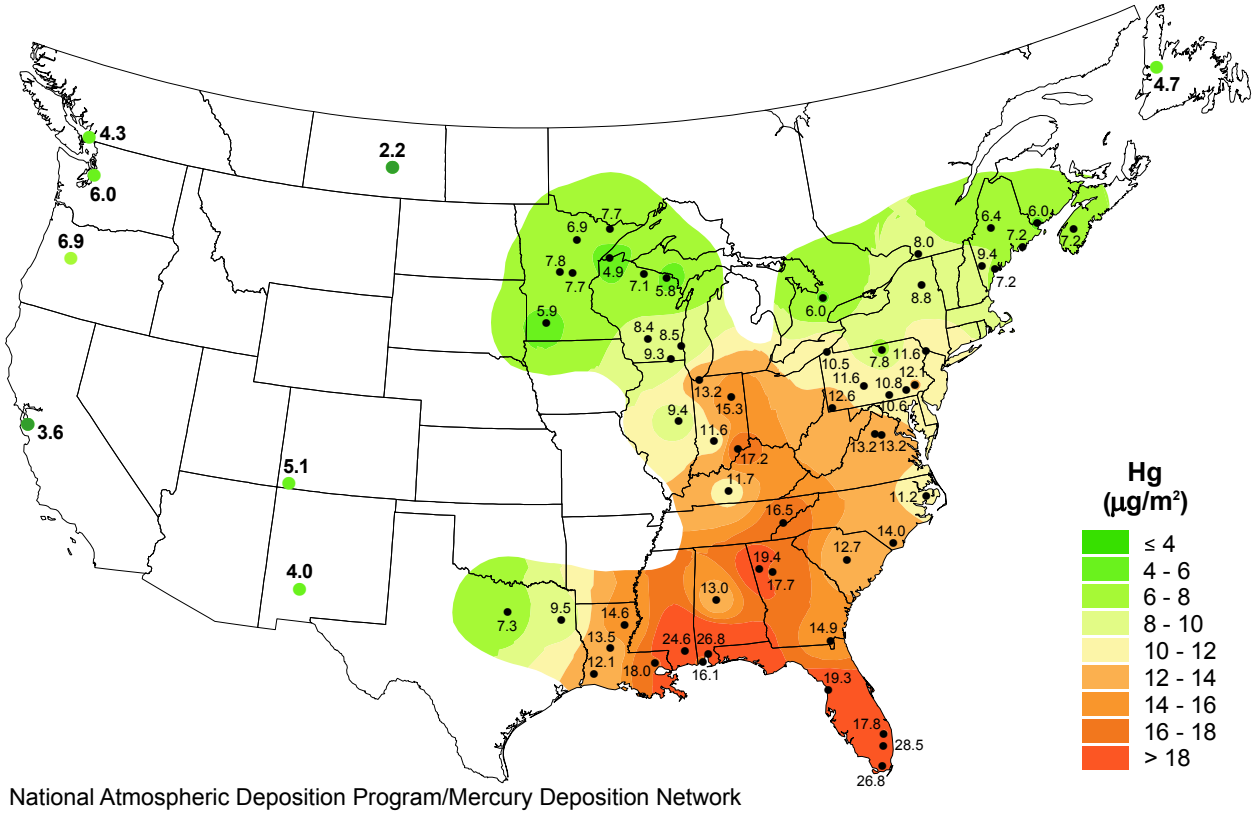
AIRMoN Data

Bar charts on page 13 show the fraction of samples with ammonium to sulfate ratios in five classes for the nine AIRMoN sites active at the end of 2003. Percentage frequency-of-occurrence bars are shown for 1993, 1998, and 2003. A missing bar indicates a site not yet operational. Chemical equivalent concentrations were used to compute the ratios. Ammonium hydrogen sulfate, an aerosol commonly observed in eastern states, has a ratio of 0.50 and is referred to as an acidic aerosol (ammonium equivalents balance only one of two sulfate equivalents). Ammonium sulfate, another common aerosol, has a ratio of 1.00 and is referred to as a neutral aerosol (ammonium and sulfate equivalents are equal). The percentage of high ratios generally increased from 1993 to 2003.



Percentage frequency of occurrence of ammonium (NH_4^+) to sulfate (SO_4^{2-}) chemical equivalent ratios for samples at AIRMoN sites active at the end of 2003.





National Atmospheric Deposition Program/Mercury Deposition Network

Total mercury concentration (top) and wet deposition (bottom), 2003.

Mercury Deposition Network

The MDN is the only network providing a long-term record of mercury (Hg) in precipitation across the United States. All MDN sites follow standard procedures and have uniform precipitation chemistry collectors and gages. The automated collector has the same basic design as the NTN collector, but was modified to preserve mercury. Modifications include a glass funnel, connecting tube, and bottle for collecting samples, and an insulated enclosure to house this sampling train. With each MDN sample, the entire sampling train is replaced with one that is cleaned by the Mercury Analytical Laboratory (HAL) at Frontier Geosciences, Inc., Seattle, Washington. Rigorous cleaning procedures ensure that each component is essentially mercury-free. By following those procedures and stringent sampling protocols, the MDN is able to report total mercury concentrations below 1 part per trillion (<1 nanogram/liter).

The HAL reviews field and laboratory data for completeness and accuracy, and flags samples that were mishandled, grossly contaminated, or compromised by precipitation collector failures. The HAL delivers all data and information to the NADP Program Office for final checks and resolution of remaining discrepancies. These data are made available on the NADP Web site.

MDN Maps

The MDN maps on page 14 show spatial variability in the annual concentration and wet deposition of total mercury. Only sites meeting prescribed data completeness criteria are included. In 2003, 65 sites met these criteria. Concentrations are precipitation-weighted averages. (See the NADP Web site for an explanation of the data completeness criteria or concentration or deposition calculations.)

In the eastern United States and southeastern Canada, color contours display the concentration and deposition distributions. Black dots mark site locations, and concentration or deposition values appear next to each site. These contours were created by using site values to compute an array of regularly spaced grid-point values. Sites within 500 km of each grid point were used in computations. In the area covered by color contours, it was necessary to have two or more data points occurring within 500 km of each grid point. The boundary of the color-contoured area was trimmed at the coastline and over land 250 km from outermost data points. The landward boundary was smoothed. The colors represent classes of concentrations or depositions indicated in the legend. (See the NADP Web site for information on the algorithm used to compute grid-point values.)

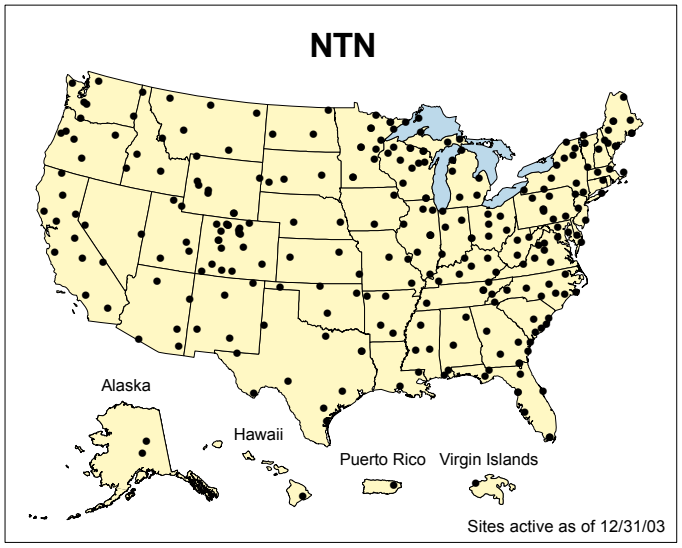
Outside of the color-contoured area where data are too sparse to draw contours, colored dots mark the locations of sites meeting data completeness criteria. Dot colors represent concentration or deposition classes in the legend. Actual values are printed next to the colored dots.

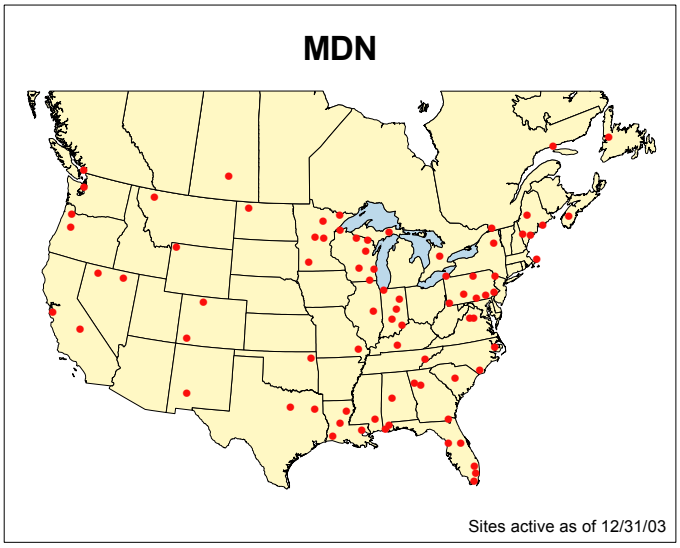
Recent Uses of NADP Data

- Scientists, students, educators, and others interested in the NADP logged nearly 160,000 sessions on the NADP Web site in 2003. This site had more than 53,000 unique visitors, and now receives more than 1.3 million hits annually. Records show that about 60 percent of users study atmospheric deposition or its effects on aquatic and terrestrial ecosystems and cultural resources, and 40 percent use NADP data for educational purposes.

- Two new college textbooks included NTN pH maps: *Environment, the Science Behind the Stories* and *Chemistry: A World of Choices*.

- Scientists published more than 80 journal articles using or citing NADP data in 2003. A bibliography of NADP publications is available (http://nadp.sws.uiuc.edu/lib/bibsearch.asp/).





Note:

When referencing maps or information in this report, please use the citation: National Atmospheric Deposition Program. 2004. *National Atmospheric Deposition Program 2003 Annual Summary*. NADP Data Report 2004-01. Illinois State Water Survey, Champaign, IL.

The NADP is National Research Support Project - 3: A Long-Term Monitoring Program in Support of Research on the Effects of Atmospheric Chemical Deposition. More than 250 sponsors support the NADP, including private companies and other nongovernmental organizations, universities, local and state government agencies, State Agricultural Experiment Stations, national laboratories, Native American organizations, Canadian government agencies, the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the Tennessee Valley Authority, the U.S. Geological Survey, the National Park Service, the U.S. Fish & Wildlife Service, the Bureau of Land Management, the U.S. Department of Agriculture - Forest Service, and the U.S. Department of Agriculture - Cooperative State Research, Education, and Extension Service (under agreement no. 2002-39138-11964). Any findings or conclusions in this publication do not necessarily reflect the views of the U.S. Department of Agriculture or other sponsors.

The NADP Program Office is located at the Illinois State Water Survey, an affiliated agency of the University of Illinois and a Division of the Illinois Department of Natural Resources. All NADP data and information, including color contour maps in this publication, are available from the NADP Web site:

http://nadp.sws.uiuc.edu

For further information, special data requests, or to obtain copies of this publication, contact the NADP Program Office, Illinois State Water Survey, 2204 Griffith Drive, Champaign, IL 61820.
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