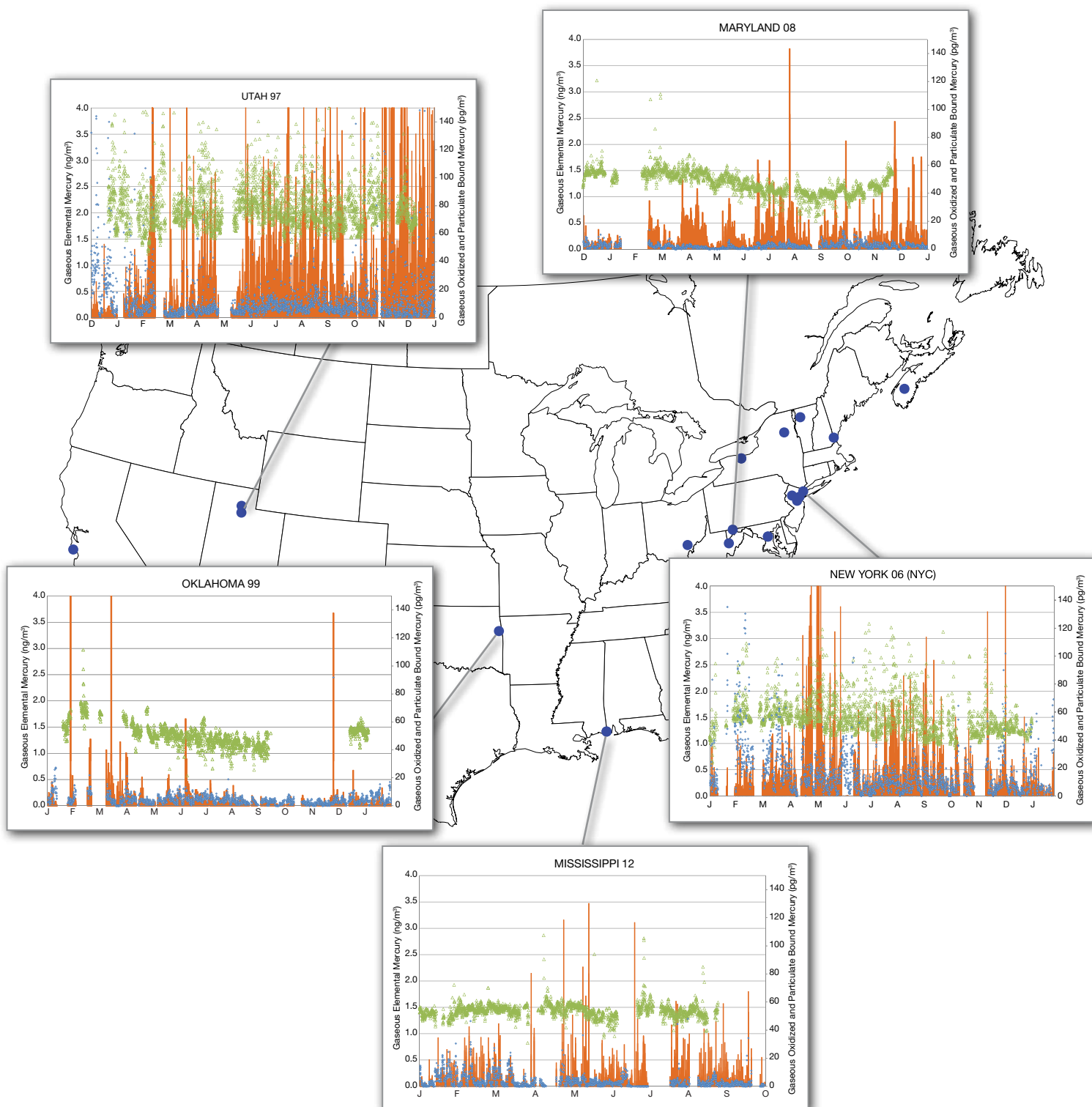
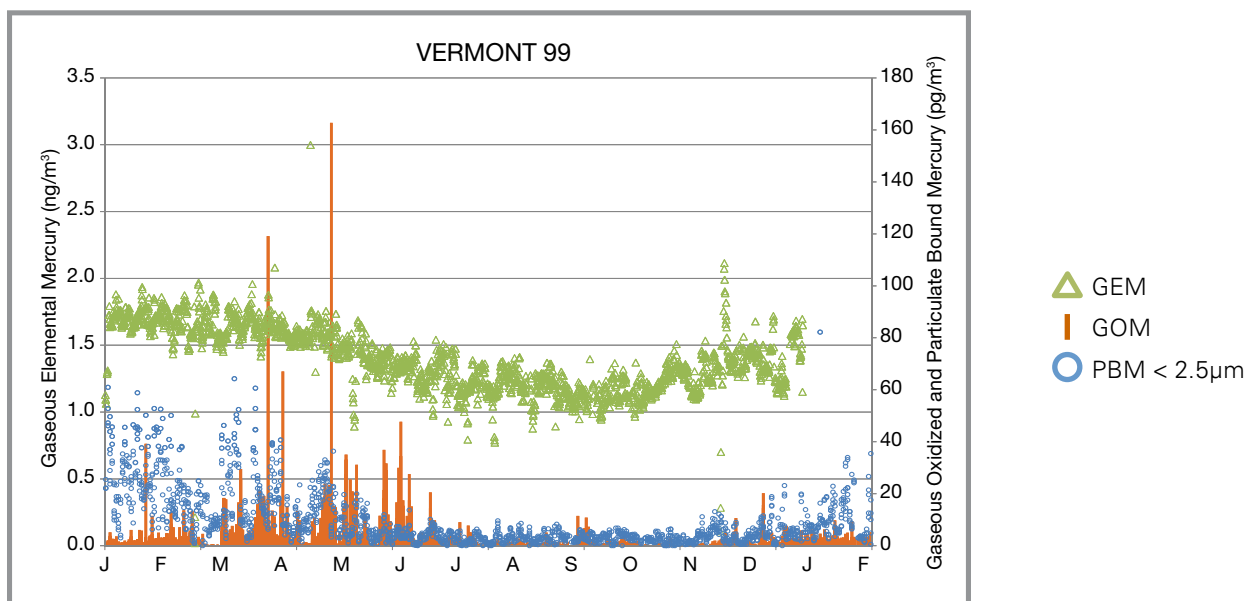




National Atmospheric Deposition Program

2009 Annual Summary





On the cover: The Atmospheric Mercury Network (AMNet), the newest network in NADP. The map shows active AMNet sites in 2009. The graph shows example timelines of valid two-hour average atmospheric mercury concentrations for Gaseous Elemental Mercury (GEM), Gaseous Oxidized Mercury (GOM), and Particulate-Bound Mercury (PBM).

2009 Highlights

The National Atmospheric Deposition Program (NADP) provides data that support informed decisions on environmental issues related to precipitation, deposition chemistry, and atmospheric mercury species. NADP data are relevant to scientists, educators, policy-makers, and the public. All data are available free of charge via the website (<http://nadp.isws.illinois.edu>). Products available on this site include seasonal and annual averages, time series trend plots, concentration and deposition maps, and reports.

In 2009, the NADP processed 13,214 samples from the 250-site National Trends Network (NTN), 1,297 samples from the 7-site Atmospheric Integrated Research Monitoring Network (AIRMoN), and 6,748 samples from the 115-site Mercury Deposition Network (MDN). The Atmospheric Mercury Network (AMNet) provided nearly 36,400 valid observations.

The NADP website is the primary tool for disseminating data from the four NADP networks. There are approximately 40,000 registered users on the site. In 2009, the site was accessed approximately 1.65 million times and had 90,000 unique visitors. Data were downloaded more than 26,000 times during the year. Users of the NADP website include federal and state agencies, universities, and primary and secondary (K-12) schools. Eighty-five percent of the data downloads relate to acid and nutrient species; the remaining 15 percent relate to mercury in wet deposition.

NADP'S NEW NETWORK

At the NADP Fall 2009 Meeting and Scientific Symposium, the technical sub-committees voted to approve the Atmospheric Mercury Network (AMNet) as an official NADP network. This network has operated as an NADP special study since 2008. The focus of AMNet is the measurement of atmospheric mercury concentrations across North America. These data are

used for understanding the distribution of mercury in the atmosphere and the environment. Currently, AMNet has 21 sites (see cover). On-site analyzers measure atmospheric mercury concentrations on a continuous basis. More information about AMNet can be found on page 18 and at <http://nadp.isws.illinois.edu/amn/>.

NEW INITIATIVES

The Ammonia Monitoring Network (AMoN) continued to operate throughout 2009 as an NADP special study. Two-week integrated measurements were made at 21 sites across North America. Data were used to quantify the spatial and temporal differences in ammonia concentrations. Passive measurement of atmospheric ammonia compares favorably with other systems for its measurement, and yields repeatable results over time. More information about AMoN can be found at <http://nadp.isws.illinois.edu/nh3net>.

Other Highlights of 2009:

- The NADP continues to modernize its network of precipitation gages to an all-digital network. This work originated with the NADP Technical Committee's directive in 2006. At the end of 2009, 143 sites had installed digital precipitation gages and were collecting data from those instruments.
- Approximately 150 journal articles and scientific reports used NADP data to further scientific research, policy decisions, education, and outreach.
- Collaboration continues with U.S. Department of Agriculture - Cereal Disease Laboratory (CDL) scientists at the University of Minnesota to measure soybean rust spores (SBR, *Phakopsora pachyrhizi*) in NTN sample filters. Soybean rust is a fungal parasite that can cause significant loss in soybean yield.

This research study started in 2005 with analysis of sample filters from mid-May through mid-September for select NTN sites. In 2009, the CDL found that 8 percent of the tested samples were positive for SBR. These results are similar to those from 2008. Weekly SBR counts varied widely. Temporal and seasonal SBR information is available.

- Scientists at the U.S. Environmental Protection Agency (USEPA) supported research at the NADP's Central Analytical Laboratory (CAL) to determine whether organic nitrogen deposition can be measured reliably and accurately in weekly NTN samples. The results from the study indicated that organic nitrogen can be measured reliably, and that an organic fraction can be differentiated from the inorganic fraction. This added information contributes to the understanding of nitrogen deposition patterns.
- NADP continues to assist authors and publishers to introduce NADP data and data products into new science textbooks. The latest is *Chemistry Matters* and its associated study guide (Allen and Allen, Kendall-Hunt Publishing Co.). This text-

book highlights the NTN acid deposition map in its discussion of the formation of acid precipitation and identifies the acidic impacts in North America.

- Chemists at the CAL measured the concentration of bromide ions in NTN and AIRMoN samples as part of a special study with the U.S. Geological Survey (USGS). Bromide is released into the environment via natural and anthropogenic processes, including agricultural fumigants and flame-retardants. Methyl bromide is classified as an ozone-depleting substance, and its use is strictly regulated and monitored by the U.S. EPA. Although there are regulations in place, there is a concern about the amount of bromide present in the atmosphere.
- The U.S. Environmental Protection Agency's Science Advisory Board has a draft document titled *Reactive Nitrogen in the United States: An Analysis of Inputs, Flows, Consequences, and Management Options* (<http://yosemite.epa.gov/sab/sabpeople.nsf>). This report uses NADP measurements to support many advisory conclusions about nitrogen addition to the environment.

NADP Background

The National Atmospheric Deposition Program was established in 1977 under State Agricultural Experiment Station (SAES) leadership to address the problem of atmospheric deposition and its effects on agricultural crops, forests, rangelands, surface waters, and other natural and cultural resources. In 1978, sites in the NADP precipitation chemistry network first began collecting one-week, wet-only deposition samples for analysis at the Illinois State Water Survey's Central Analytical Laboratory (CAL), located at the University of Illinois, Urbana-Champaign. The network was established to provide data on amounts, temporal trends, and geographic distributions of the atmospheric deposition of acids, nutrients, and base cations by precipitation.

Initially, the NADP was organized as SAES North Central Regional Project NC-141, which all four SAES regions further endorsed in 1982 as Interregional Project IR-7. A decade later, IR-7 was reclassified as National Research Support Project No. 3 (NRSP-3), which it remains. NRSP projects are multistate activities that support research on topics of concern to more than one state or region of the country. Multistate projects involve the SAES in partnership with the USDA National Institute of Food and Agriculture and other universities, institutions, and agencies. In October 1981, the federally supported National Acid Precipitation Assessment Program (NAPAP) was established to increase understanding of the causes and effects of acidic precipitation. This program sought to establish a long-term precipitation chemistry network of sampling sites distant from point source influences. Because of its experience in organizing and operating a national-scale network, the NADP agreed to coordinate operation of NAPAP's National Trends Network (NTN). To benefit from identical siting criteria and operating procedures and a shared analytical laboratory, NADP and NTN merged with the designation

NADP/NTN. This merger brought substantial new federal agency participation into the program. Many NADP/NTN sites were supported by the USGS, NAPAP's lead federal agency for deposition monitoring. NAPAP continues under Title IX of the federal Clean Air Act Amendments of 1990.

In October 1992, the AIRMoN joined the NADP. AIRMoN sites collect samples daily when precipitation occurs. In January 1996, the NADP established the MDN, the third network in the organization. The MDN was formed to provide data on the wet deposition of mercury to surface waters, forested watersheds, and other receptors. In October 2009, AMNet joined the NADP as the fourth network. AMNet measures the concentration of atmospheric mercury.

SAES project NRSP-3 was renewed in 2009, and it continues to offer a unique opportunity for cooperation among scientists from land-grant and other universities, government agencies, and non-governmental organizations. It provides a framework for leveraging the resources of nearly 100 different sponsoring agencies to address contemporary and emerging issues of national importance.



Typical AMNet equipment setup.

ABOUT THE MAPS

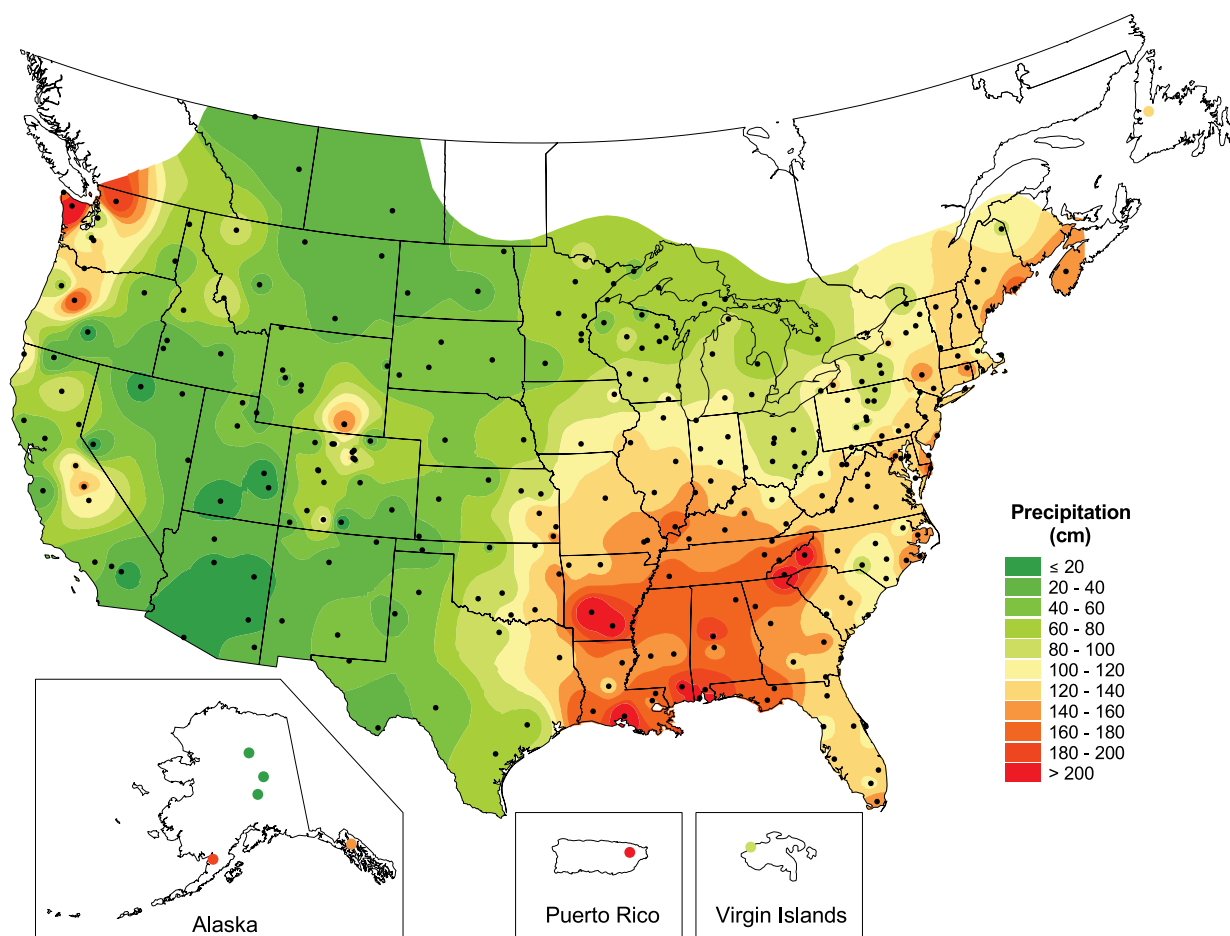
This annual report is a principal product of the NADP. It summarizes the results of network operation for the most recent calendar year in map form. Black dots mark site locations that meet NADP completeness criteria (see the NADP website for details). On the concentration and deposition maps, open circles designate urban sites, defined as having at least 400 people per square kilometer (km^2) within a 15-km radius of the site. Color contours are created by using site values to compute grid-point values across the nation. Sites within 500 km of each grid point are used in computations. Urban sites do not contribute to the contours. Color contours and color-filled urban sites represent classes of concentrations (as milligrams per liter, mg/L) or depositions (kilograms per hectare, kg/ha) in the legend, with measured values next to each site. MDN maps

use nanograms per liter (ng/L) for concentration and micrograms per meter squared ($\mu\text{g/m}^2$ year) for annual sums of deposition.

Beginning with this 2009 map series, the precipitation and deposition maps now use precipitation values from all NADP sites (see map below).

By way of example in interpreting the maps, the bottom figure on Page 13 has eight inorganic nitrogen deposition classes or contours. The lightest green color in the legend represents 3.0–4.0 kilograms per hectare (kg/ha) as summed over the year. 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 .

Maps are current based on data as of September 2010. NADP may update the maps at any time, posting the maps on its website (<http://nadp.isws.illinois.edu>).



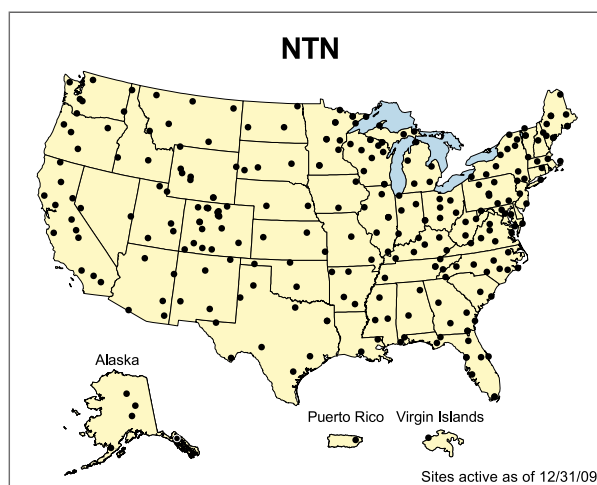
Total precipitation from all NADP wet deposition networks, 2009.

National Trends Network (NTN)

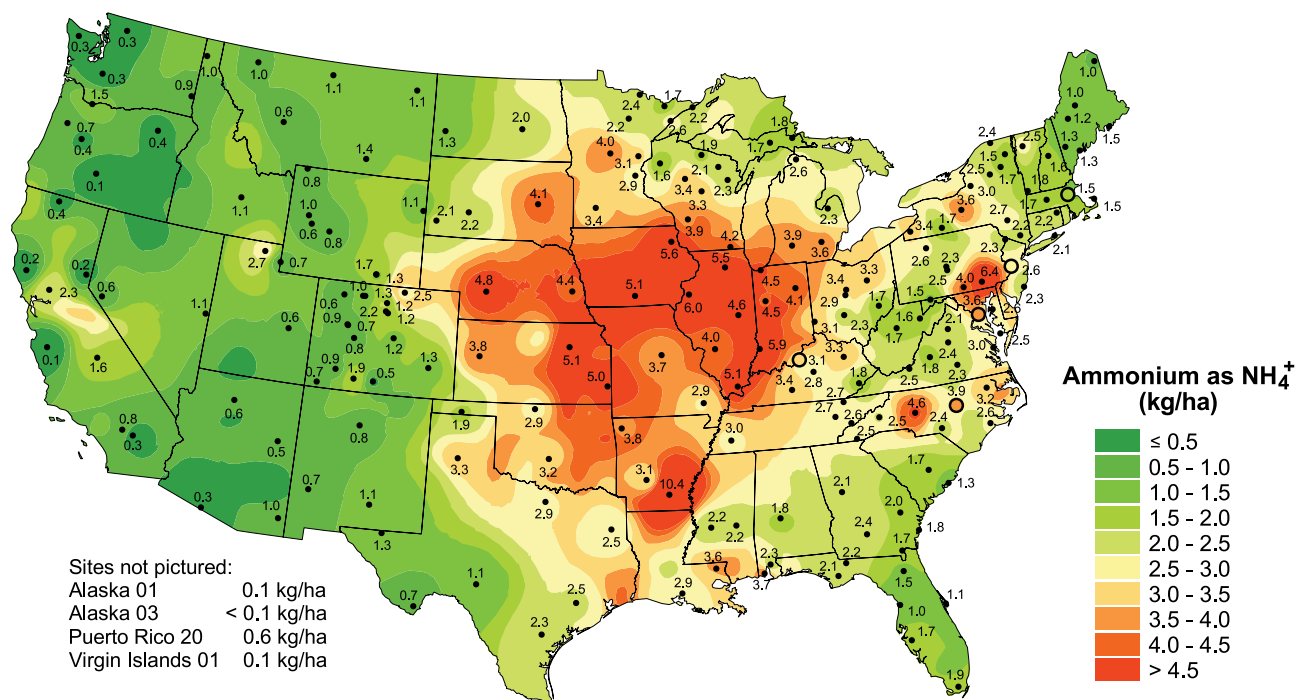
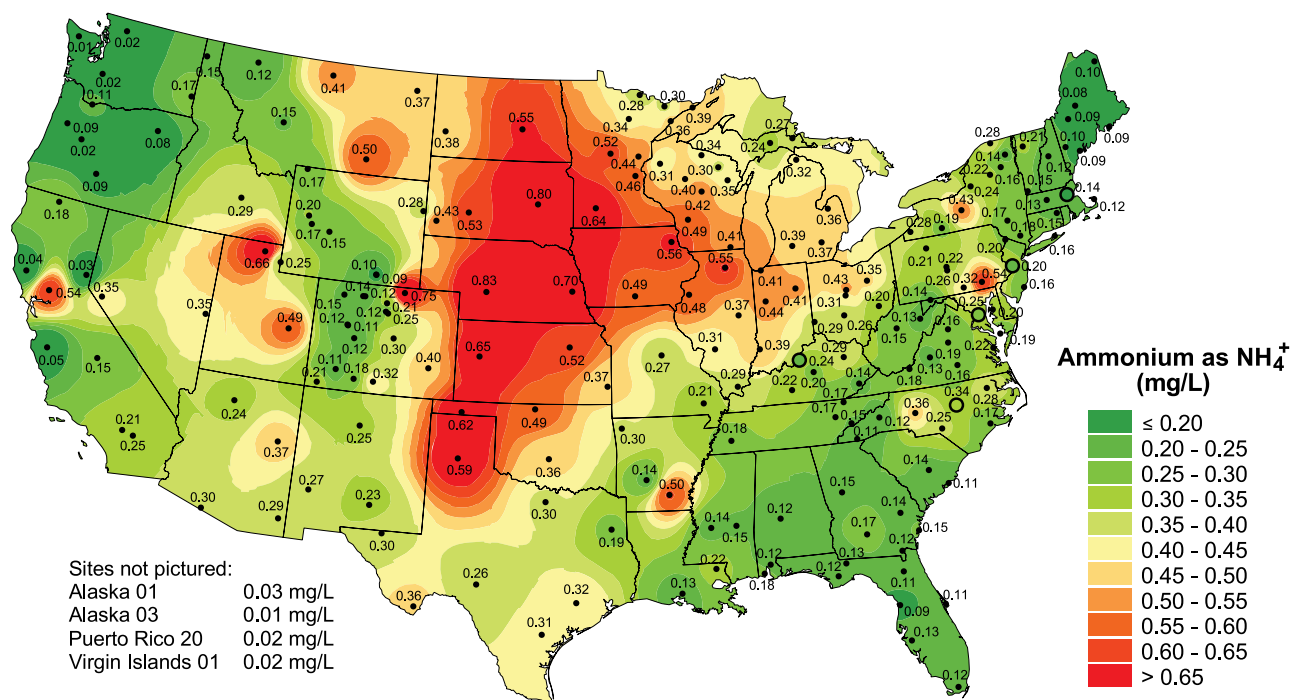
The NTN is the largest North American network that provides a long-term record of precipitation chemistry. Sites are located away from urban areas and point sources of pollution. Each site has a precipitation collector and raingage. The automated collector ensures sampling only during precipitation (wet-only sampling). Site operators follow standard operational procedures to help ensure NTN data comparability and representativeness across the network. Weekly samples are collected each Tuesday morning, using containers provided by the CAL. All samples are sent to the CAL for analysis of free acidity (H^+ as pH), specific conductance, and calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), sulfate (SO_4^{2-}), nitrate (NO_3^-), chloride (Cl^-), and ammonium (NH_4^+) ions. The CAL also measures orthophosphate ions (PO_4^{3-} , the inorganic form), but only for quality assurance as an indicator of sample contamination. The CAL reviews field and laboratory data for accuracy and completeness, and flags samples that were mishandled, compromised by precipitation collector failures, or grossly contaminated. Data from the NTN is freely accessible from the NADP website (<http://nadp.isws.illinois.edu/ntn/>).

NTN MAPS

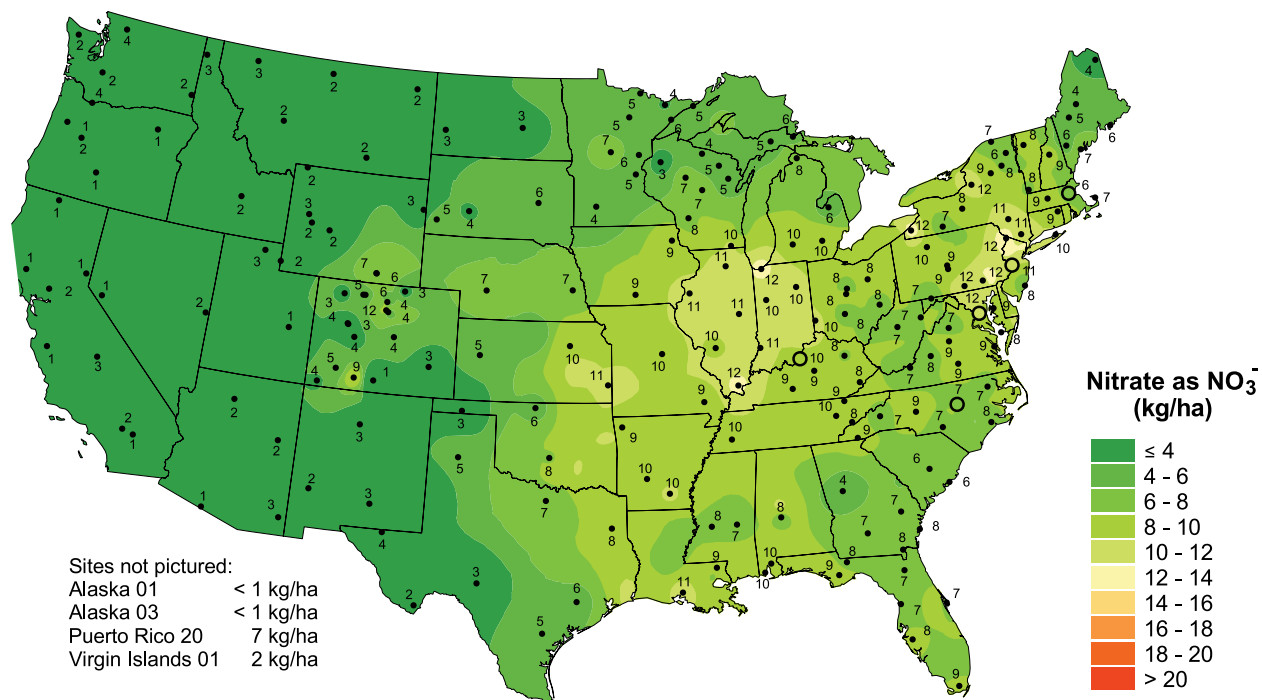
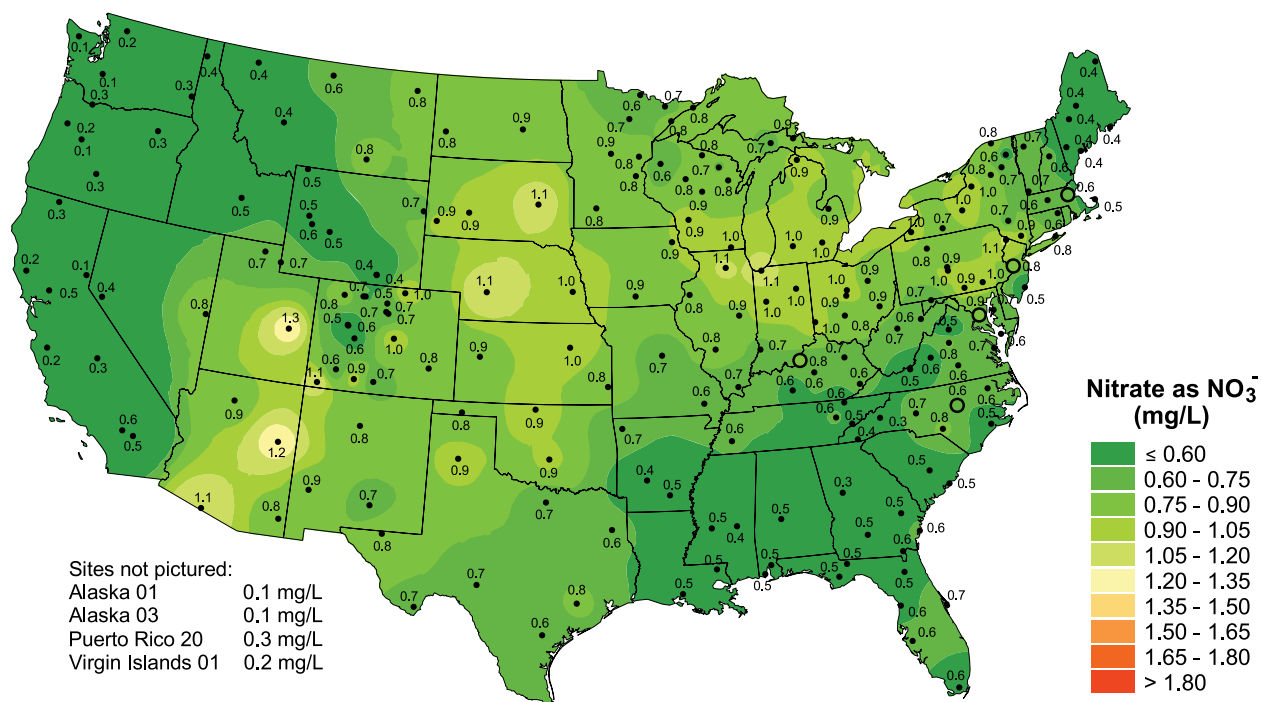
The maps on pages 8 through 13 show precipitation-weighted mean concentration and annual wet



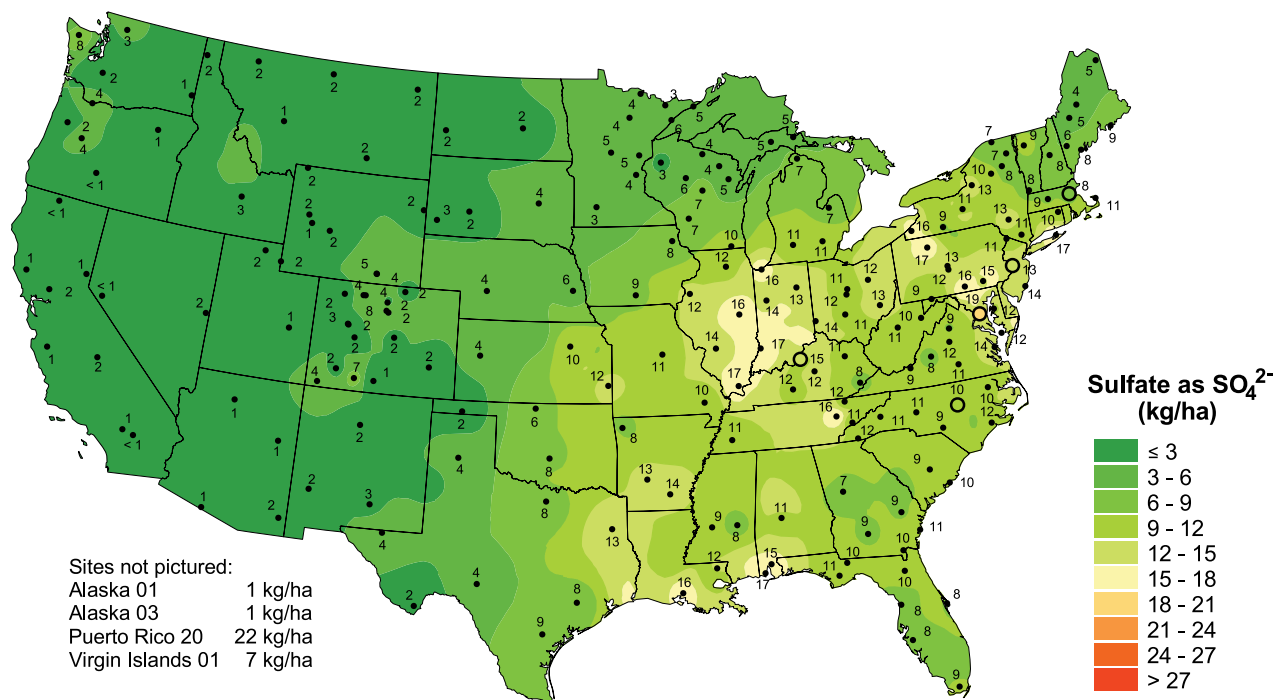
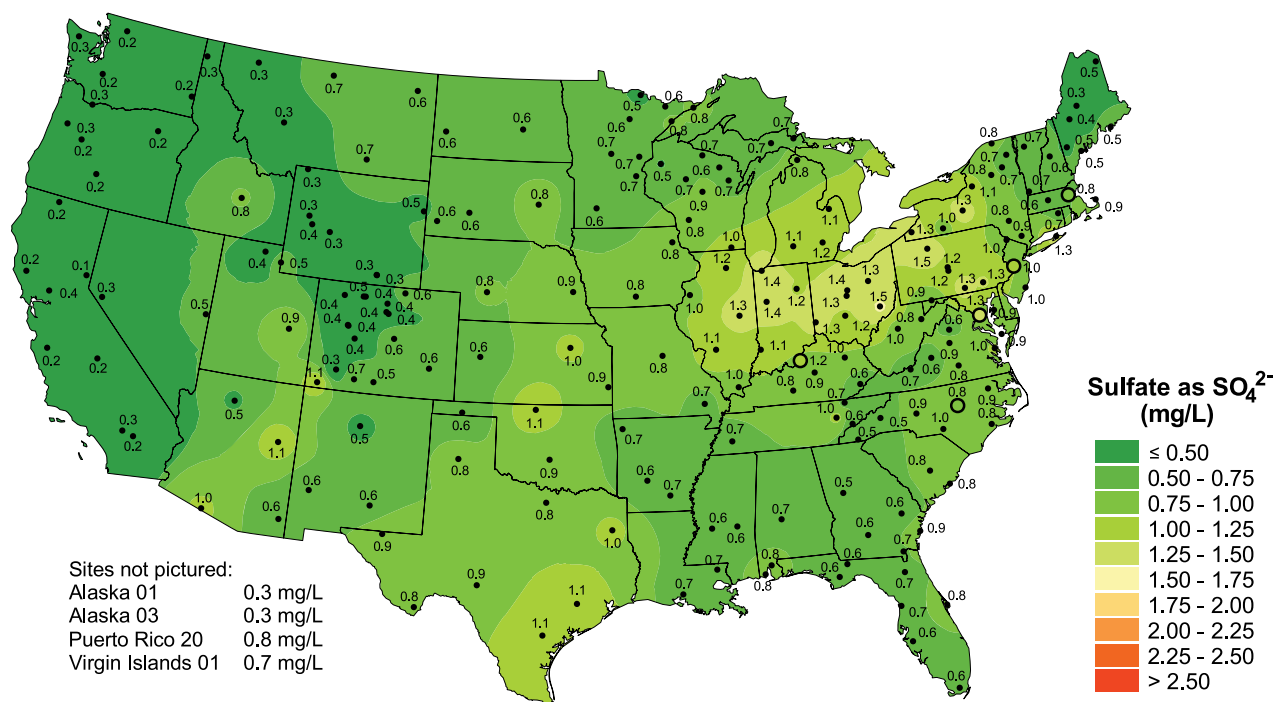
deposition for select acidic ions, nutrients, and base cations. Spatial variability in these species can be seen both on a regional and a national scale. Only sites meeting NADP data completeness criteria were used to generate the contours. In 2009, 211 of the 251 active sites met these criteria. Concentration and deposition maps are included for NH_4^+ , NO_3^- , SO_4^{2-} , Ca^{2+} , and pH. A map for wet deposition of inorganic nitrogen ("N", i.e., $\text{NH}_4^+ + \text{NO}_3^-$) is also included. Maps of Mg^{2+} , Na^+ , K^+ , and Cl^- are not included in this report, but are available from the NADP website.



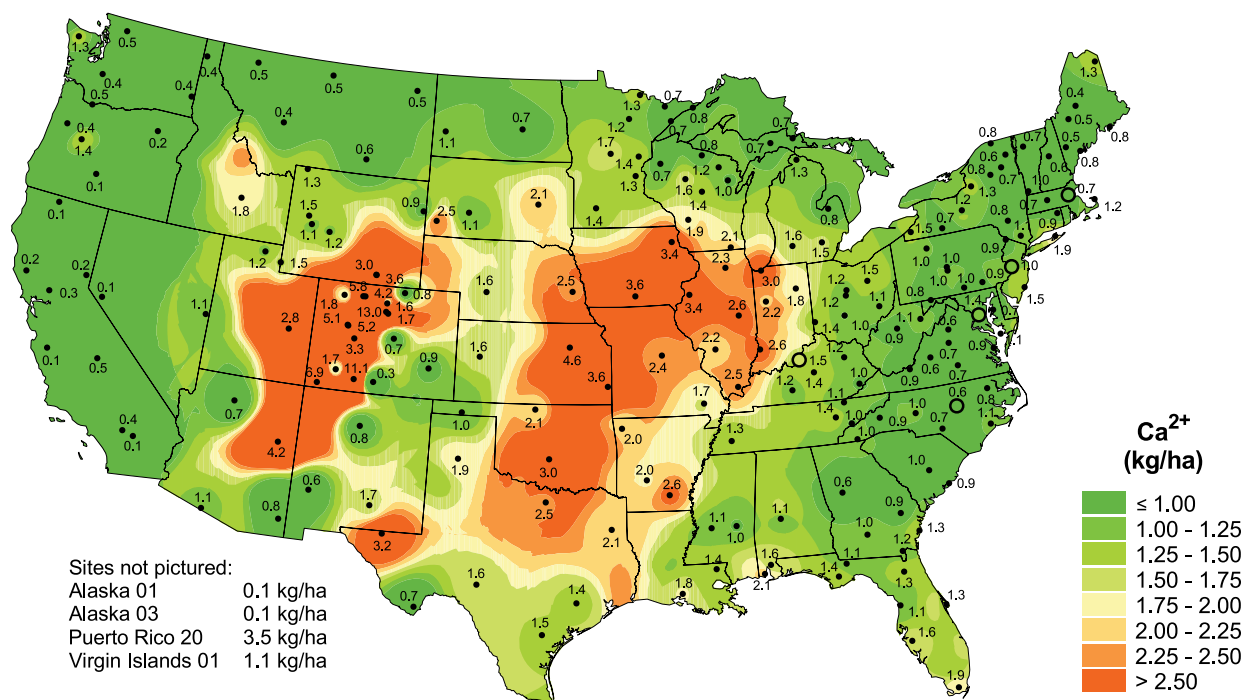
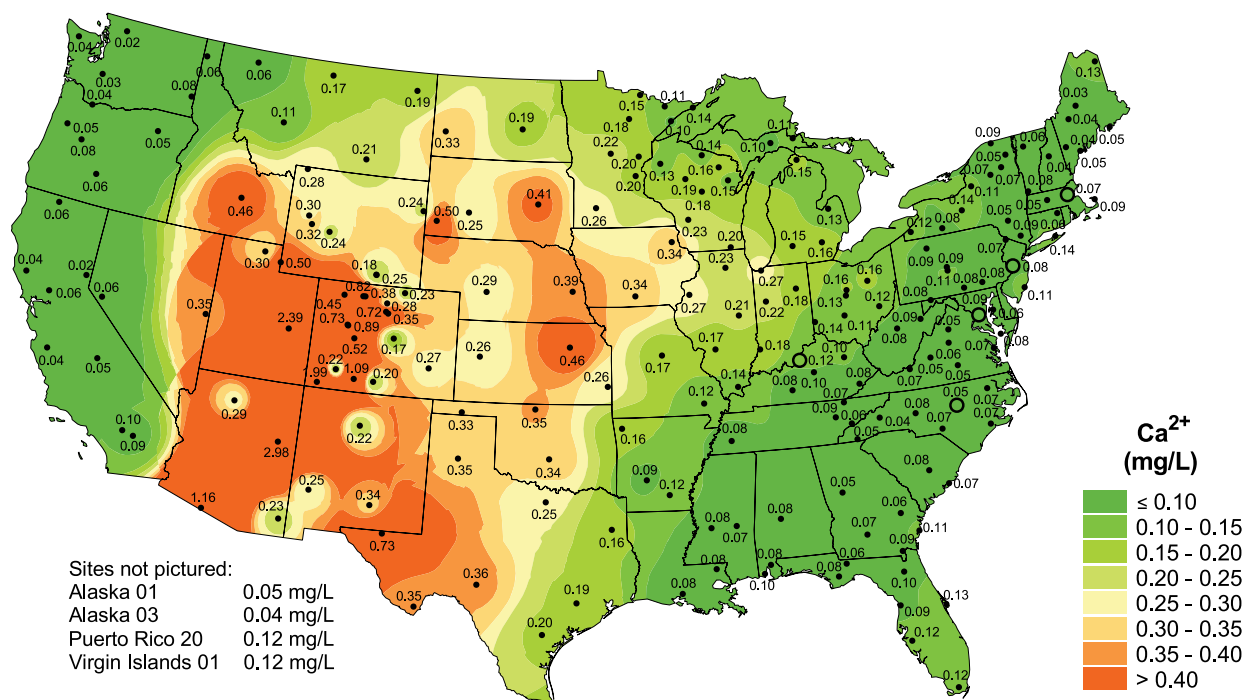
Ammonium ion concentration (top) and wet deposition (bottom), 2009.



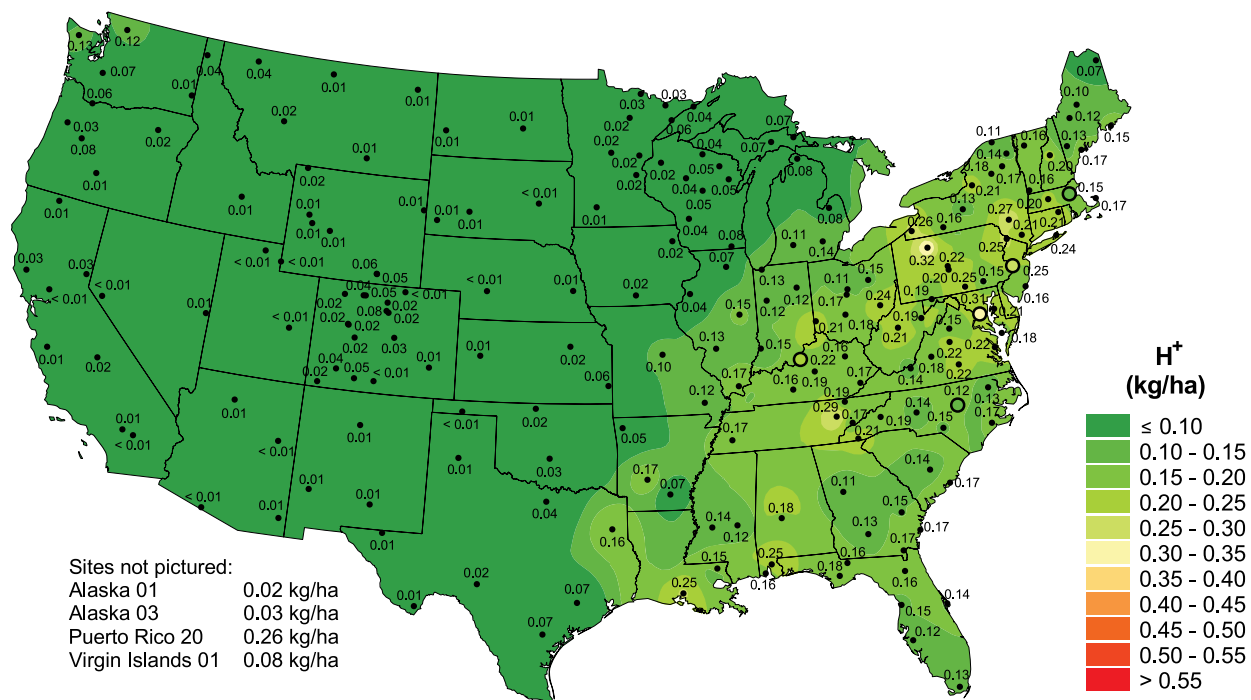
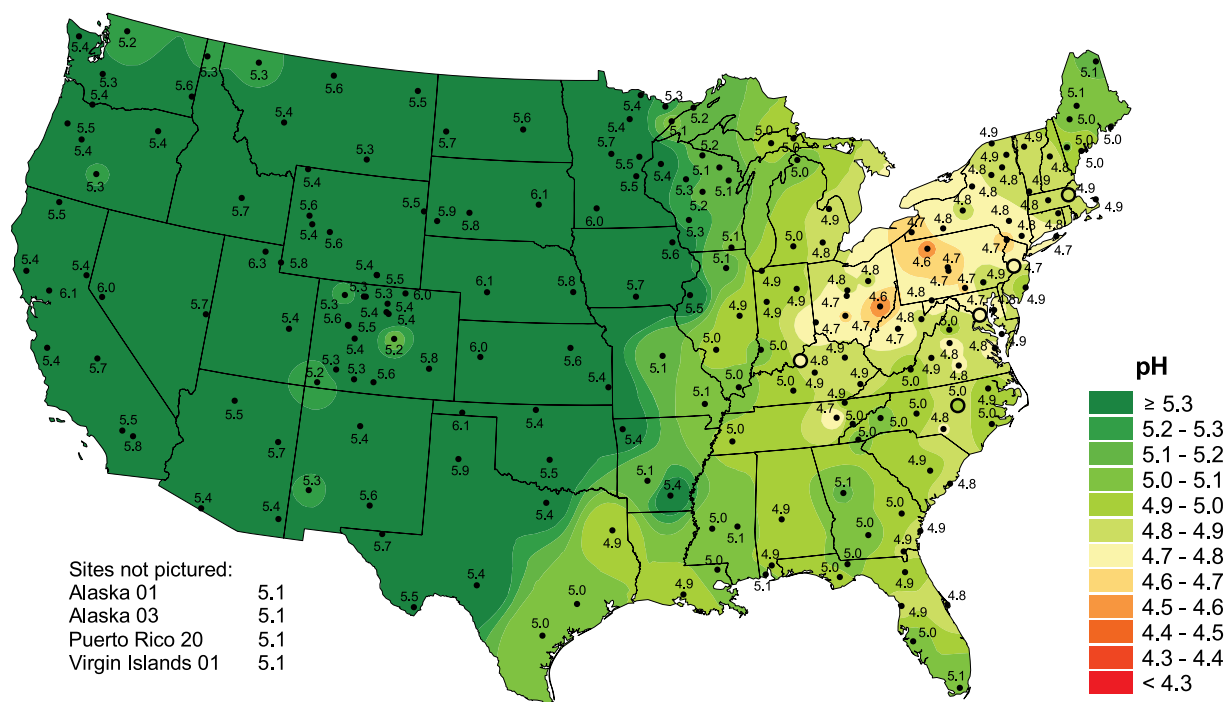
Nitrate ion concentration (top) and wet deposition (bottom), 2009.



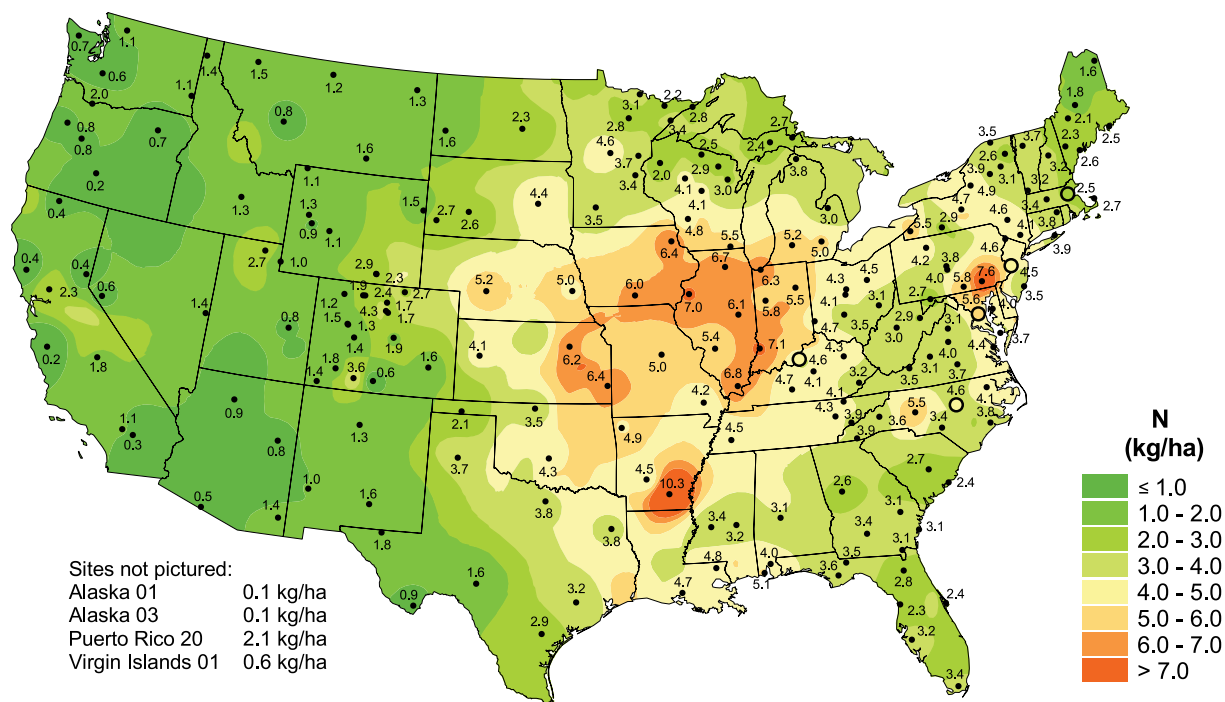
Sulfate ion concentration (top) and wet deposition (bottom), 2009.



Calcium ion concentration (top) and wet deposition (bottom), 2009.



Hydrogen ion concentration as pH (top) and wet deposition (bottom), 2009.



Inorganic nitrogen wet deposition from nitrate and ammonium, 2009.

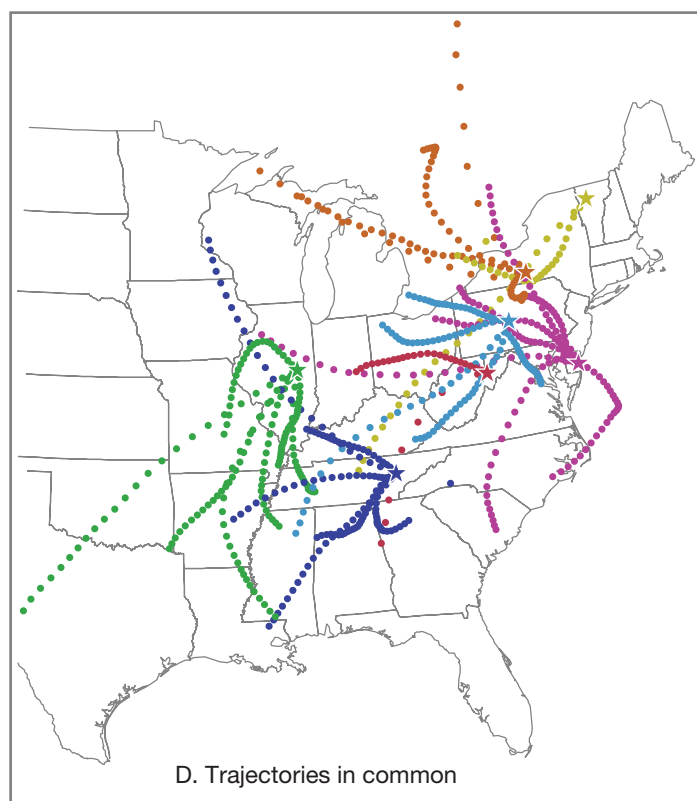
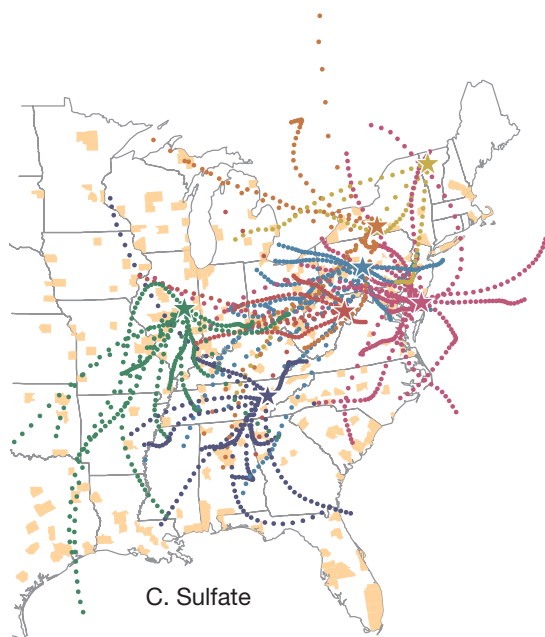
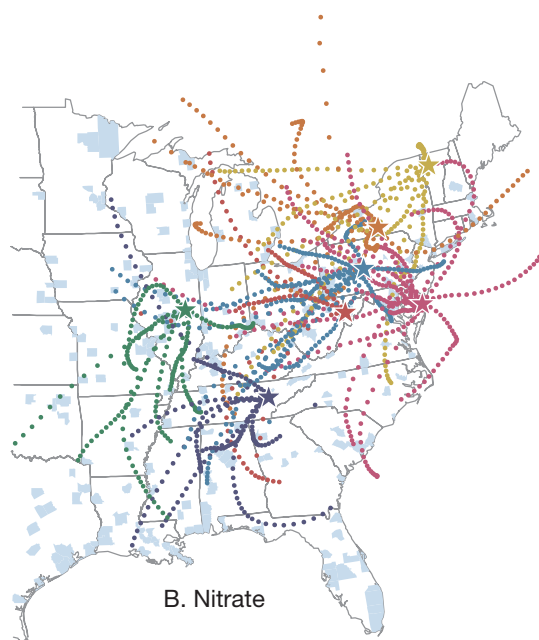
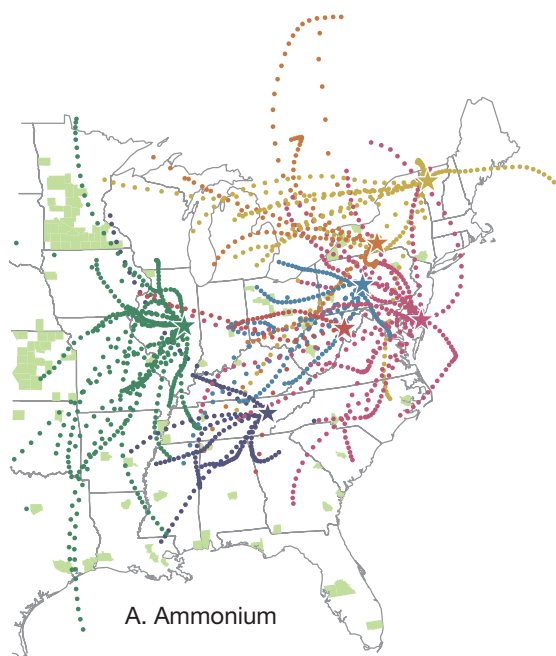
Atmospheric Integrated Research Monitoring Network (AIRMoN)

At AIRMoN sites, samples are collected daily within 24 hours of the start of precipitation, often providing data for individual storm events. 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. AIRMoN sites are equipped with the same wet-only deposition collector used at NTN sites. Each site also has a National Weather Service (NWS) standard gage for reporting storm total precipitation. Samples are refrigerated after collection and are sent in chilled, insulated shipping containers to the CAL; samples remain refrigerated until they are analyzed. This retards potential chemical changes, such as with NH_4^+ and PO_4^{3-} . Chemical analyses and data screening procedures for AIRMoN and NTN are similar. The National Oceanic and Atmospheric Administration (NOAA) is the principal funder of AIRMoN.

The maps on page 15 show 24-hour back trajectories for all storm events at AIRMoN sites. The back trajectories were generated using NOAA's HYSPLIT model (http://www.arl.noaa.gov/HYSPLIT_info.php). Each site and its accompanying trajectories are



differentiated by color. Maps A–C show back trajectories for the highest tenth percentile sample concentrations for NH_4^+ , NO_3^- , and SO_4^{2-} . The shaded background indicates those counties that are in the top tenth percentile for emissions of ammonia (green), nitrogen oxides (blue), and sulfur dioxide (orange), as reported in the 2005 USEPA national emissions inventory. There is spatial correlation between the high concentration trajectories and high emission rate counties. Map D shows back trajectories that are common to maps A–C.

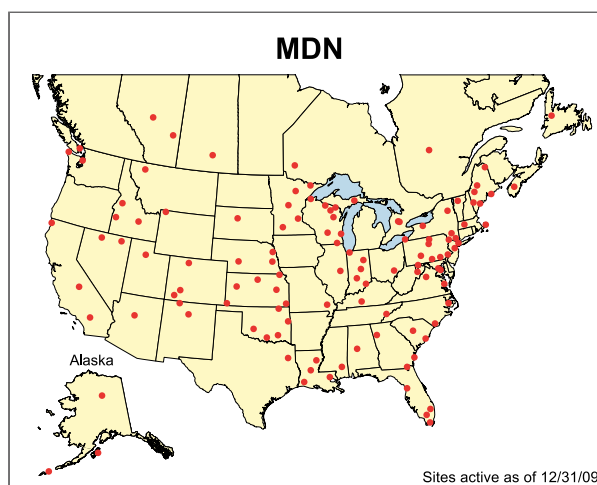


Concentration back trajectories for the highest tenth percentile of A) ammonium, B) nitrate, and C) sulfate, 2009. Map D shows back trajectories common to the three species.

Mercury Deposition Network (MDN)

The MDN is the only network providing a long-term record for the concentration of mercury (Hg) in precipitation in North America. Select sites are co-located with the Atmospheric Mercury Network (AMNet), as discussed on page 18. All MDN sites follow standard procedures and have uniform precipitation collectors and raingages. The automated collector is similar to the NTN collector, but it is modified to preserve mercury. Site operators collect samples either every Tuesday morning or daily within 24 hours of the start of precipitation. In 2009, the Devil's Lake site in south-central Wisconsin (WI31), the Underhill site in northern Vermont (VT99), and the Yorkville site in northwestern Georgia (GA40) opted to collect daily samples. With each MDN sample, the entire sampling train is replaced with one that is provided by the Mercury Analytical Laboratory (HAL) at Frontier Geosciences, Inc., Seattle, Washington.

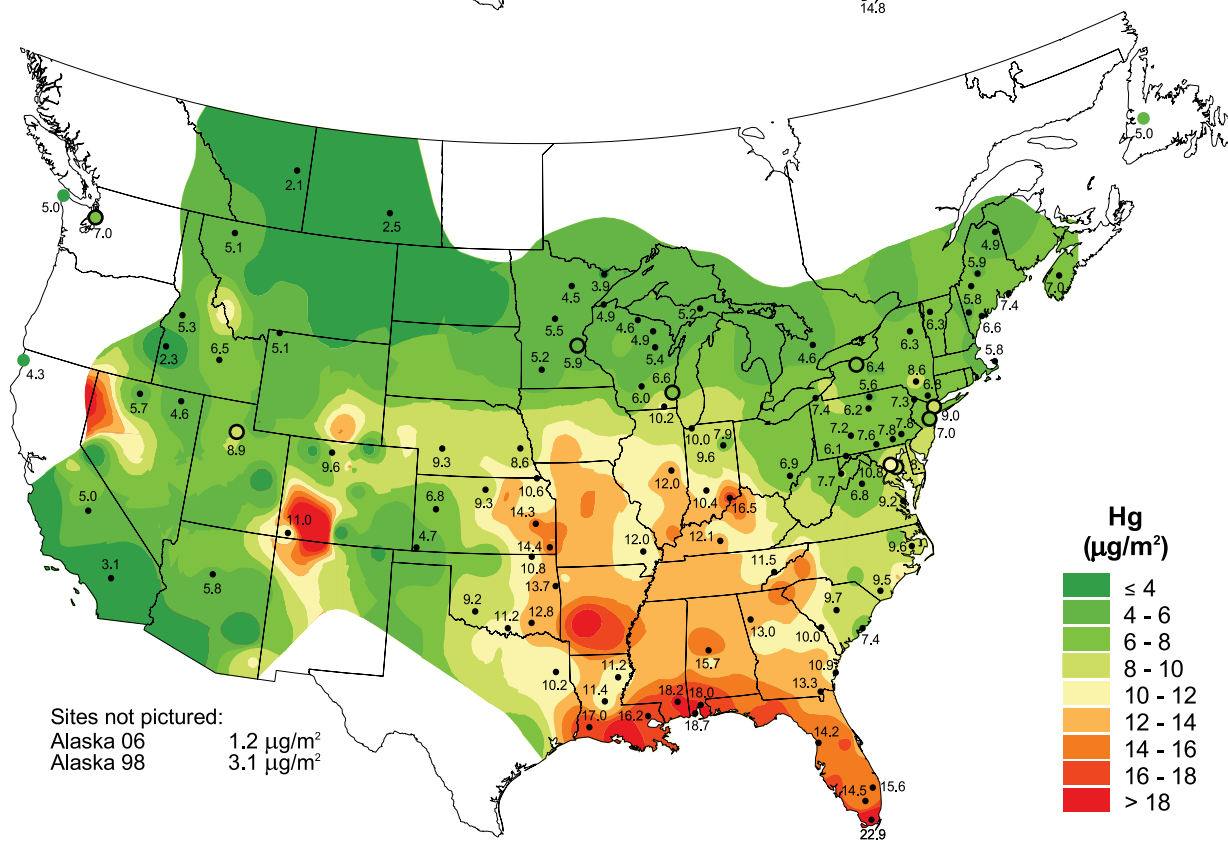
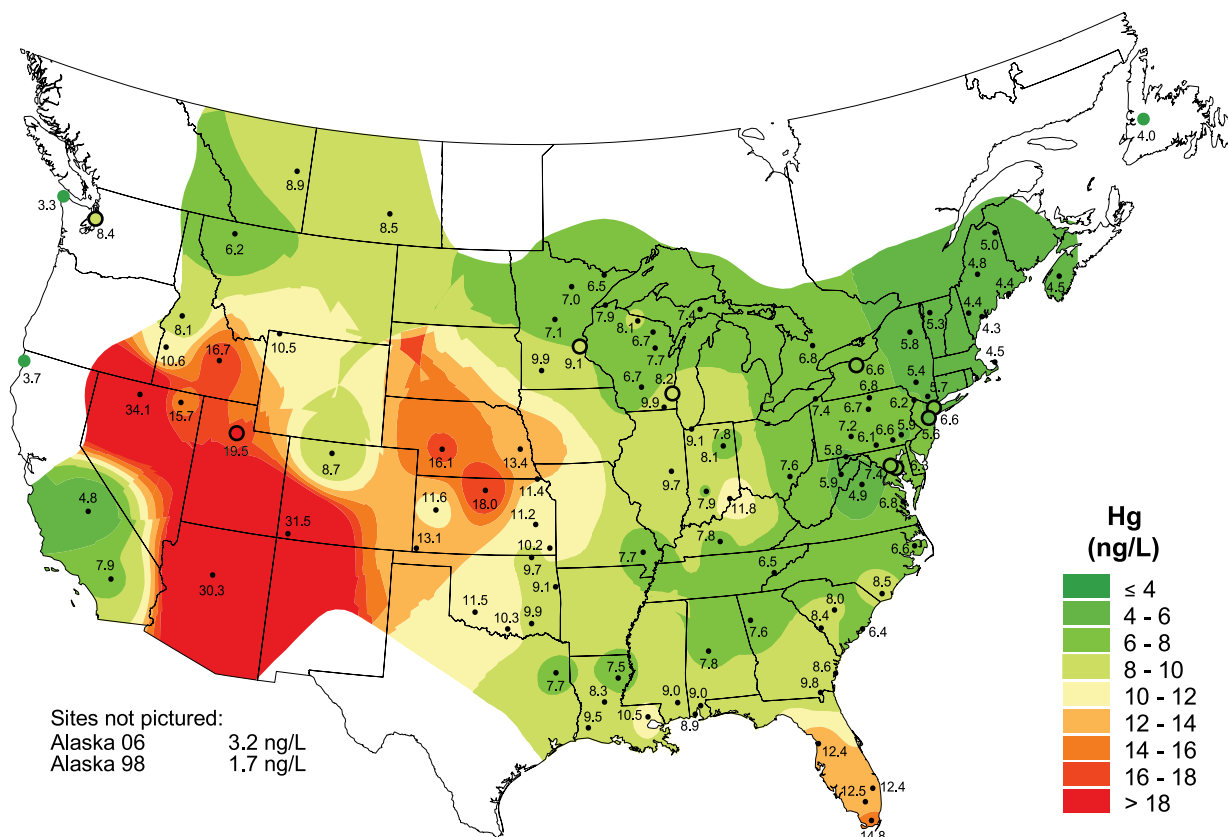
All MDN samples are analyzed for total mercury concentration. In 2009, 26 MDN sites also opted to measure methyl mercury concentrations. The HAL reviews field and laboratory data for accuracy and completeness, and flags samples that were mishandled, compromised by precipitation collector failures, or



grossly contaminated. Data are made available on the NADP website (<http://nadp.isws.illinois.edu/mdn>).

MDN MAPS

The maps on page 17 show spatial variability in the precipitation-weighted annual average concentration and wet deposition of total mercury. Only sites meeting NADP completeness criteria are included. In 2009, 108 sites met these criteria.



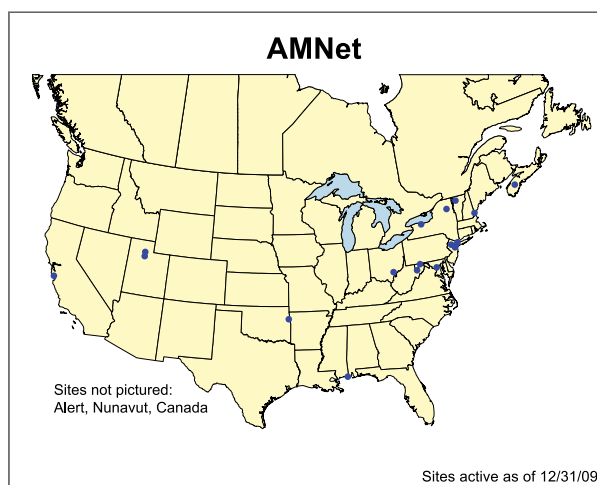
Total mercury concentration (top) and wet deposition (bottom), 2009.

Atmospheric Mercury Network (AMNet)

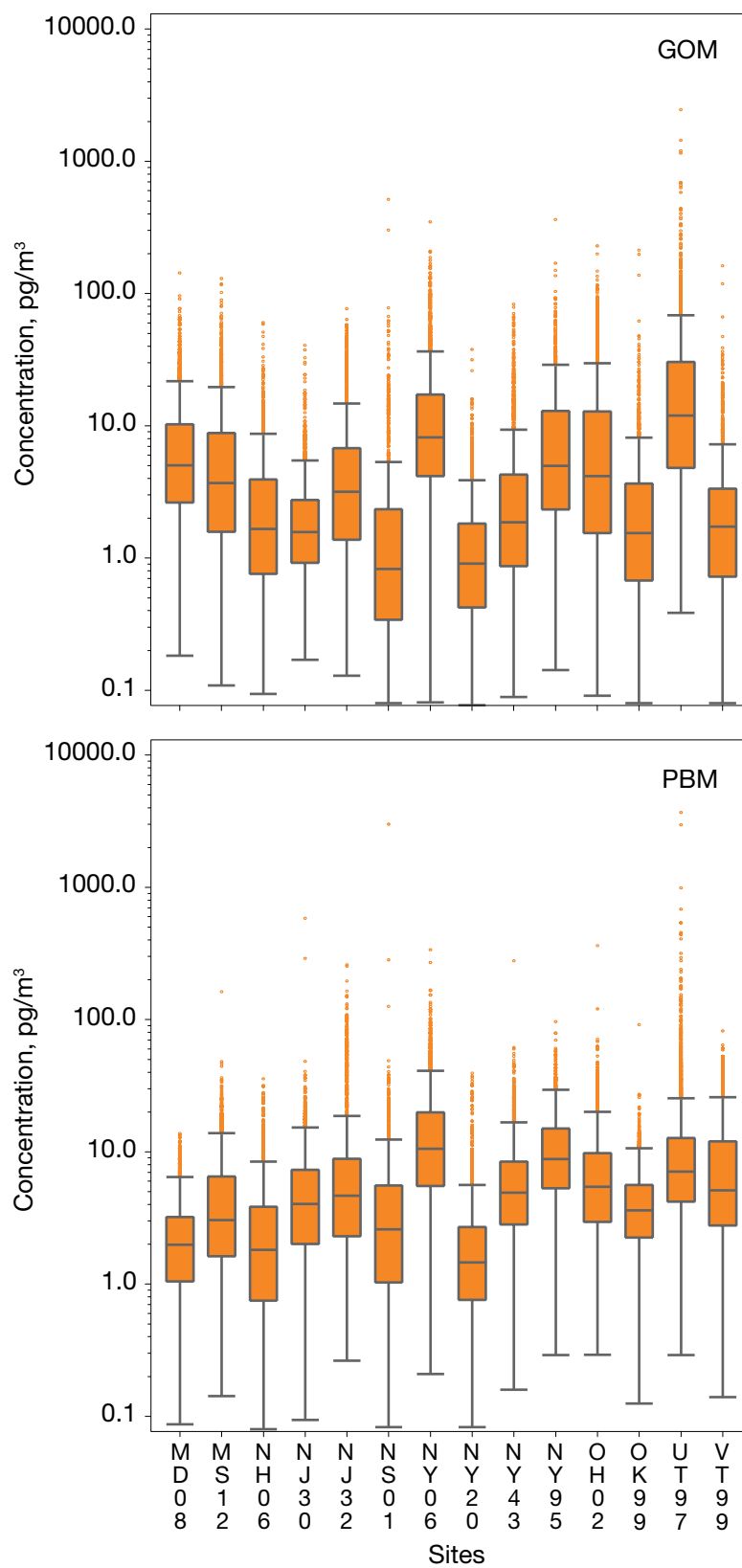
The AMNet was established in 2009. AMNet sites measure atmospheric mercury fractions that contribute to total mercury deposition. Sites measure concentrations of atmospheric mercury species: gaseous oxidized (GOM), particulate-bound (PBM), and gaseous elemental (GEM) using automated, continuous measuring systems. AMNet sites are co-located with both MDN sites and meteorological instruments. This provides data necessary for modeling the deposition of mercury. Measurements are made using standardized methods. AMNet data are available on the NADP website (<http://nadp.isws.illinois.edu/amn>).

AMNet measurements are made in different time periods (five-minute and two-hour averages). Measurements are quality-assured and then averaged to one-hour and two-hour values.

The graphs on the cover and page 2 show two-hour average concentrations for 2009 at several network sites (MD08, MS12, NY06, OK99, UT97, VT99). Hourly GEM is shown in nanograms per cubic meter (ng/m^3). Values for GOM and PBM are presented in picograms per cubic meter (pg/m^3). The whisker plots on page 19



show the distribution of valid data at each location. Each plot shows the 25th and 75th quartile value (lower and upper bound of shaded box), the median value (bar inside the box), and the 5th and 95th percentile (whisker lines below and above the box). Outlier values above the 95th percentile (dots) are also included. Whisker plots for GEM are not shown.



Whisker plots for GOM and PBM. Sites have valid data for at least half the potential time periods (i.e. >1500 time periods), 2009.

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 - National Institute of Food and Agriculture, under agreement no. 2008-39134-19508. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the sponsors or the Illinois State Water Survey.

Champaign, IL

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Editor: Lisa Sheppard

Layout: Sara N. Olson

All NADP data and information, including color contour maps in this publication, are available from the NADP website: <http://nadp.isws.illinois.edu>. Alternatively, contact: NADP Program Office, Illinois State Water Survey, 2204 Griffith Dr., Champaign, IL 61820, Tel: (217) 333-7871, Fax: (217) 333-0249, E-mail: nadp@isws.illinois.edu.

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The NADP Program Office is located at the Illinois State Water Survey, a division of the Institute of Natural Resource Sustainability at the University of Illinois at Urbana-Champaign.