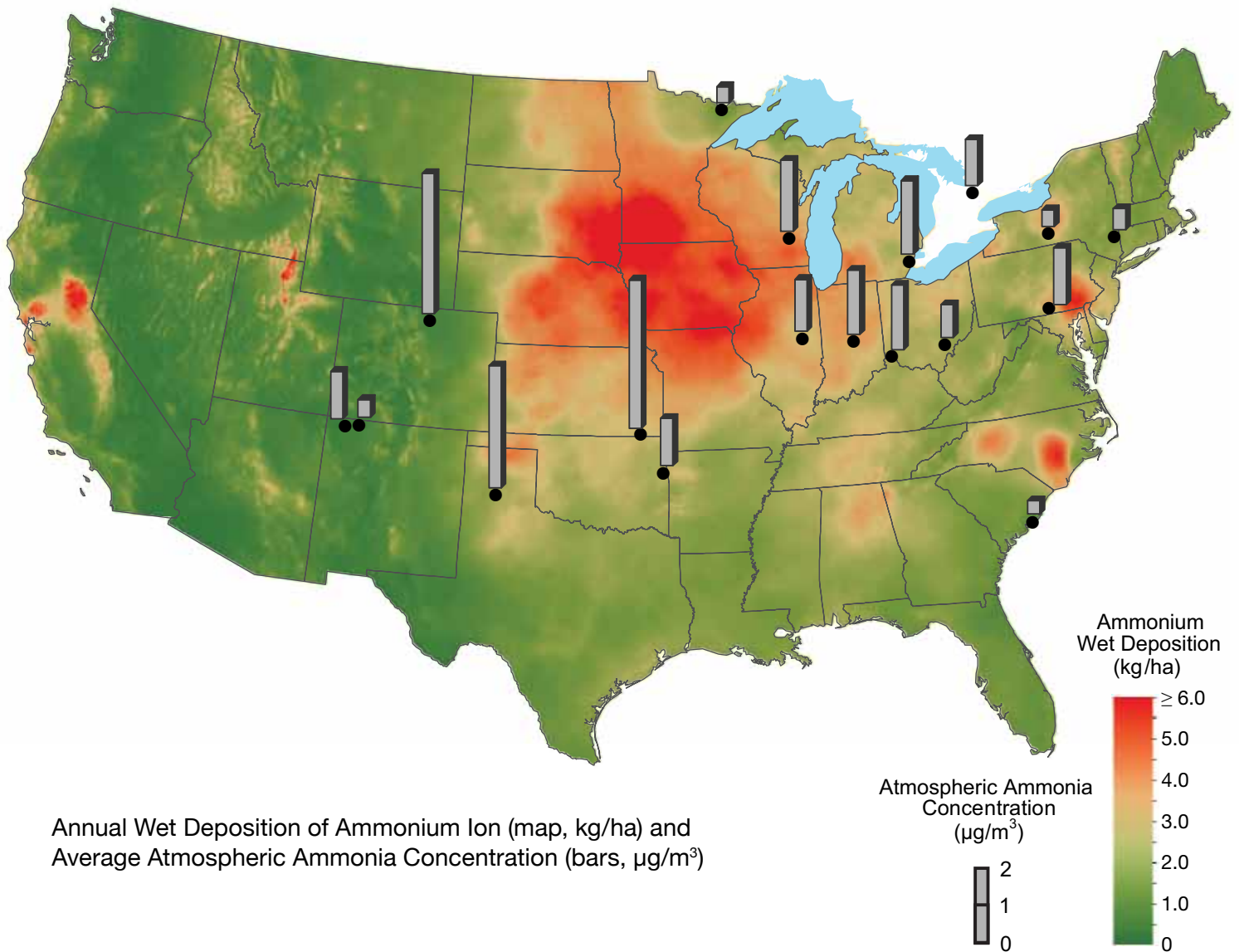
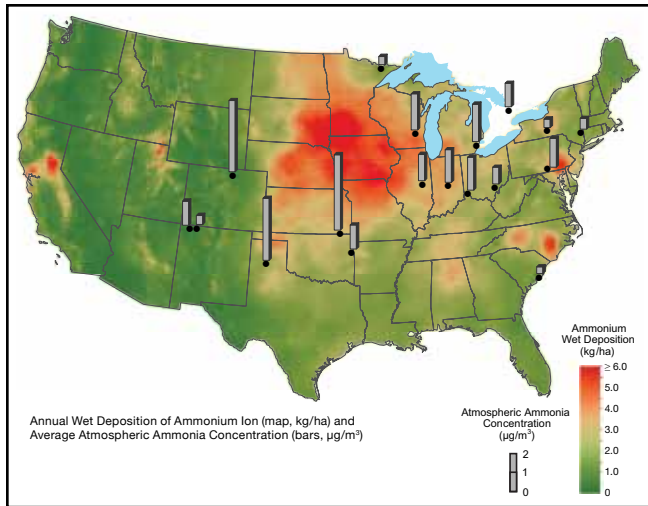




National Atmospheric Deposition Program

2010 Annual Summary





On the cover: The background gradient map represents the 2010 annual ammonium ion wet deposition flux (kilograms per hectare) over the continental United States, as measured by the National Trends Network (NTN) and using PRISM precipitation data. The grey bars represent the annual average atmospheric ammonia concentration (micrograms per cubic meter), as measured by the Ammonia Monitoring Network (AMoN).

2010 Highlights

The National Atmospheric Deposition Program (NADP) provides fundamental measurements that support informed decisions on environmental issues related to precipitation and deposition chemistry, as well as atmospheric mercury and ammonia. NADP data are relevant to scientists, educators, policy-makers, and the public. All data are available free of charge via the NADP 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.

The NADP is comprised of five networks, including the National Trends Network (NTN), the Atmospheric Integrated Research Monitoring Network (AIRMoN), the Mercury Deposition Network (MDN), the Atmospheric Mercury Network (AMNet), and the new Ammonia Monitoring Network (AMoN). The table below summarizes the measurements made by each network.

Summary of Network Measurements, 2010

Network	Measurements	Period	No. of sites
NTN	12,646	weekly	252
MDN	6,086	weekly	116
AIRMoN	1,002	daily	7
AMNet	115,800	hourly	21
AMoN	524	two week	21

The NADP website is the primary tool for disseminating data from the five NADP networks. In 2010, there were more than 39,000 registered users. Data were downloaded nearly 27,000 times by agencies, universities, and elementary schools.

NADP'S NEWEST NETWORK: AMoN

At the NADP Fall 2010 Meeting and Scientific

Symposium, the NADP voted to approve the Ammonia Monitoring Network (AMoN) as the fifth NADP network. AMoN began its operation as a special study within NADP in October 2007, with a goal of measuring atmospheric ammonia concentrations to estimate dry deposition. These data are used to understand the distribution of ammonia in the atmosphere and environment. At the end of 2010, AMoN had 21 sites. More information about AMoN can be found on page 22 and at <http://nadp.isws.illinois.edu/amon>.

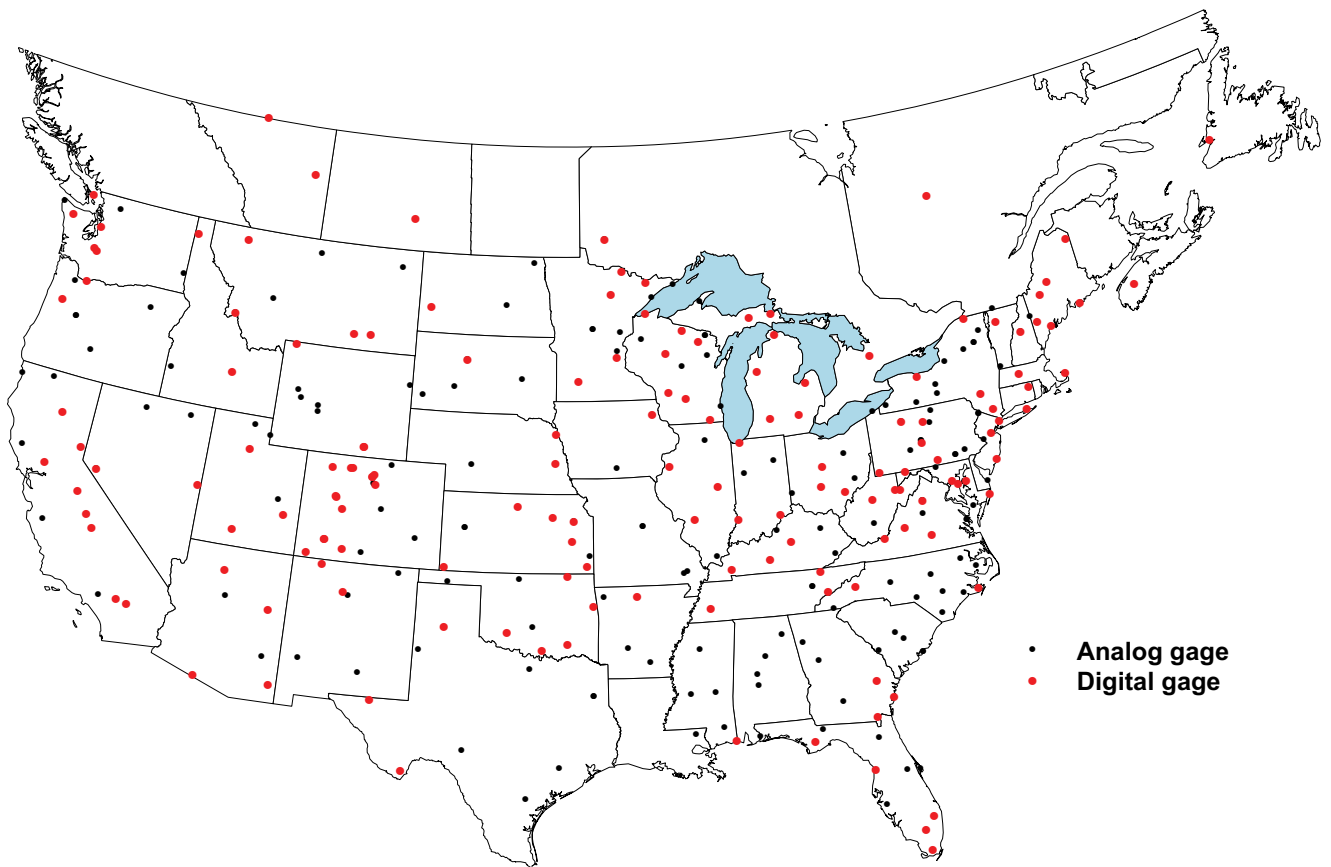
Other highlights:

- At the Spring 2011 Meeting, the NADP committees voted to modify the maps from an earlier discrete contour map style (used since 1994) to a **new continuous color gradient map style**. These new maps also use a more highly resolved precipitation data set. Specifics of the new mapping techniques are provided on page 6 of this report.
- Over the past several years, the Central Analytical Laboratory (CAL) has measured the **concentration of bromide ion** in NTN and AIRMoN samples as part of a special study with the U.S. Geological Survey (USGS). Bromide is widely used in agricultural and industrial applications, and is being evaluated as a new NADP analyte. Data are available upon request.
- NADP data and maps were used in at least 146 scientific **publications**. A list of these can be found at the NADP website.
- NADP's NTN and MDN network data were used by the U.S. EPA to evaluate the impact of the April and May **Gulf of Mexico oil fires** on the Gulf Coast and eastern U.S.

- During the year, the NADP continued the **rust spore deposition** special study with USDA Cereal Disease Laboratory (CDL) scientists at the University of Minnesota. In addition to continued soybean rust deposition monitoring (*Phakopsora pachyrhizi*, since 2005), CDL scientists began to investigate winter and spring precipitation for the presence of other pathogens, specifically wheat rusts (stem, stripe, and leaf), corn rusts (common and southern), and sugar cane rusts (brown and orange).
- U.S. EPA scientists, with NADP, continued special studies to determine whether **organic**

nitrogen deposition can be measured reliably and accurately. The results 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.

- During 2010, the NADP continued to install **new digital precipitation gages** at its wet deposition sites (see map below). As of the end of 2010, 166 sites out of 300 total sites (55%) had operating digital gages. These data are available at the NADP website.



The distribution of new digital precipitation gages that have been installed and are operating at NADP wet deposition sites, as of December 31, 2010. Remaining analog gages are also shown.

NADP Background

The NADP 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 weekly, 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 - Cooperative State Research, Education, and Extension Service (now 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 away 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

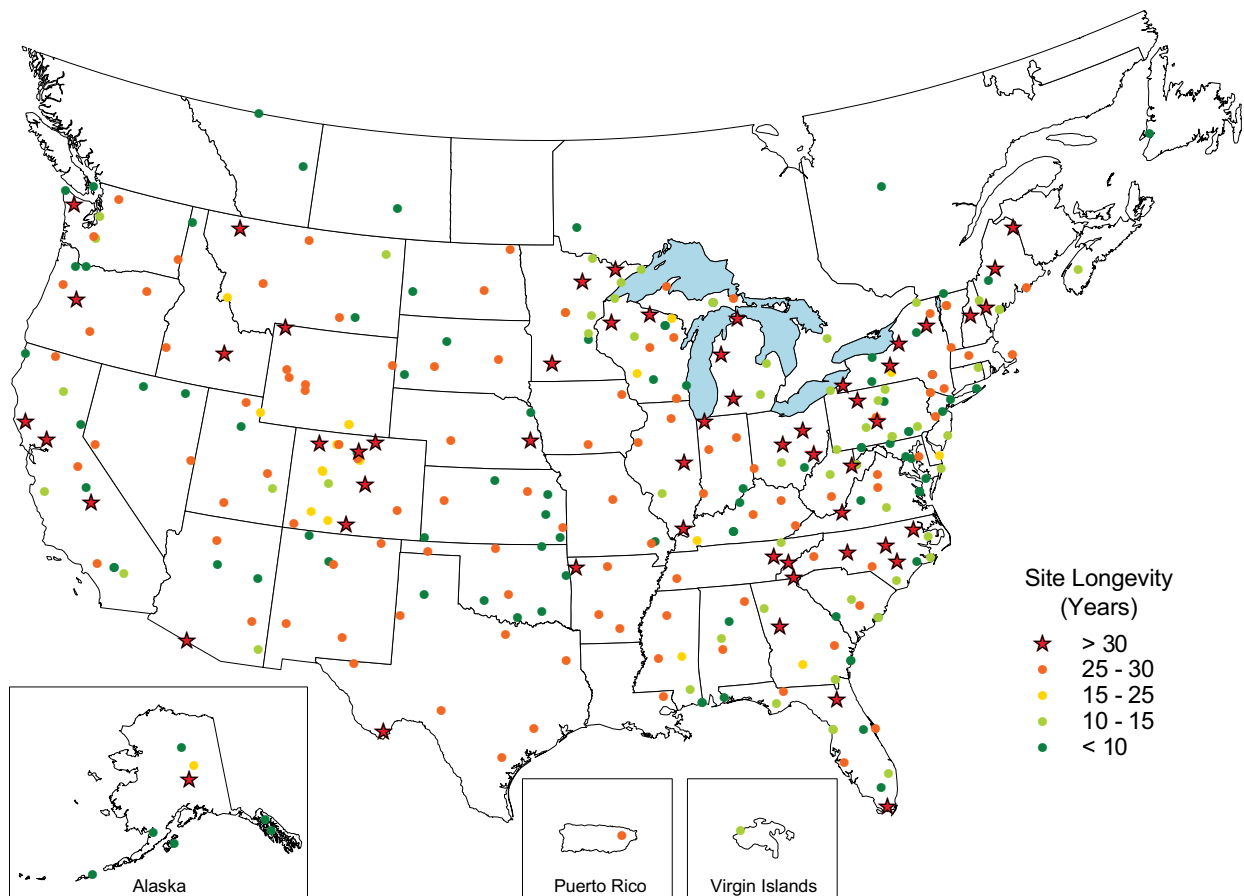
analytical laboratory, NADP and NTN merged with the designation NADP/NTN. This merger brought substantial new federal agency participation into the program. Many NADP/NTN sites were supported by the USGS, NAPAP's lead federal agency for deposition monitoring. NAPAP continues under Title IX of the federal 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.

The map on the next page shows the location and the longevity of measurements at each of the NADP wet deposition networks (NTN, AIRMoN, and MDN). Longevity of continuous measurement is a goal of the NADP.

In October 2009, AMNet joined the NADP as the fourth network. AMNet measures the concentration of atmospheric mercury. In October 2010, AMoN joined the NADP, measuring atmospheric ammonia concentrations using passive samplers.

SAES project NRSP-3 was renewed in 2009. It offers 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.



ABOUT THE MAPS

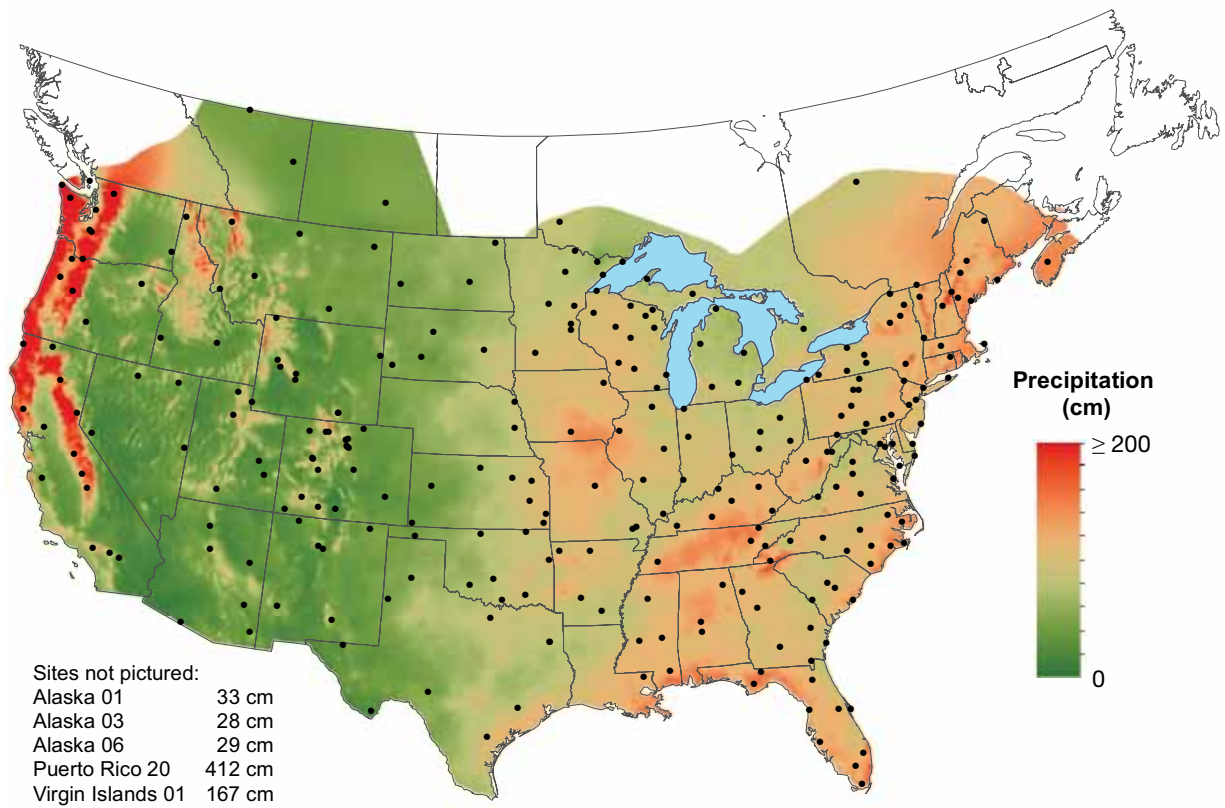
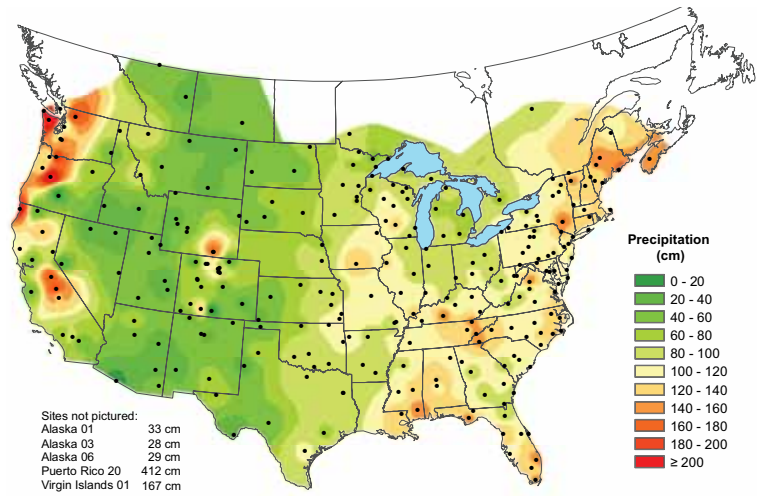
This annual report and map series is a principal product of the NADP. It summarizes the results of network operation for the most recent complete calendar year in map form. Additional maps are available on the NADP website. Black dots mark site locations that meet NADP completeness criteria (see the NADP website for details). Open circles designate urban sites, defined as having at least 400 people per square kilometer (km²) within a 15-km radius of the site.

Colors are assigned 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 contour surface. Colors represent interpolated values of concentration, deposition, or precipitation.

Beginning with this 2010 map series, the precipitation values are an adapted version of the

U.S. precipitation grid developed by the PRISM Climate Group (“Parameter-elevation Regressions on Independent Slopes Model”, <http://prism.oregon-state.edu>, July 2011). These annual precipitation estimates incorporate point data, a digital elevation model, and expert knowledge of complex climatic extremes to produce continuous, digital grid estimates. NADP precipitation observations are used to supplement the PRISM precipitation grids through an inverse distance weighting over 20 km around all NADP network sites (see the NADP website for specific information). PRISM precipitation data are strictly for the continental U.S., so the precipitation gradient north of the U.S./Canadian border is solely NADP precipitation data. This precipitation gradient is used to generate the deposition maps.

Prior to 2010, all maps used discrete color contours, as illustrated by the figure to the right. Starting in 2010, a continuous color gradient was employed. The bottom figure has a continuous gradient of color from dark green (low values) to yellow (middle values) to dark red (high values). The dark green region begins at 0.0 centimeters (cm) ranging to over 200 cm/year (dark red). The remaining concentration and deposition maps follow this same format, with specified units on each map.



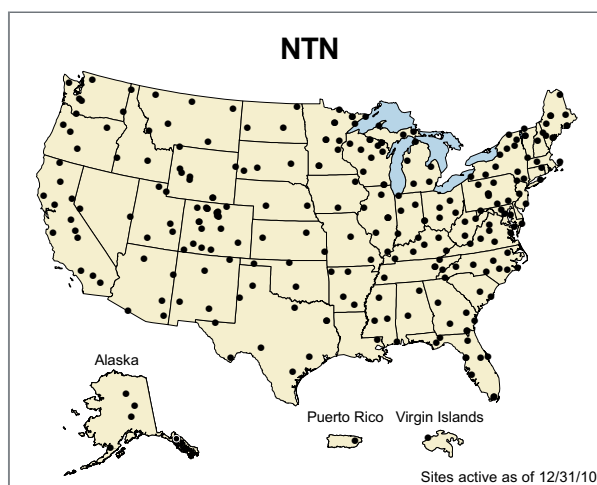
Comparison of the original contour (top) and new continuous gradient precipitation maps (bottom), using 2010 precipitation data from the NADP and PRISM.

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 operating 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 equipment failure, or grossly contaminated. Data from the NTN are freely accessible from the NADP website (<http://nadp.isws.illinois.edu/ntn/>).

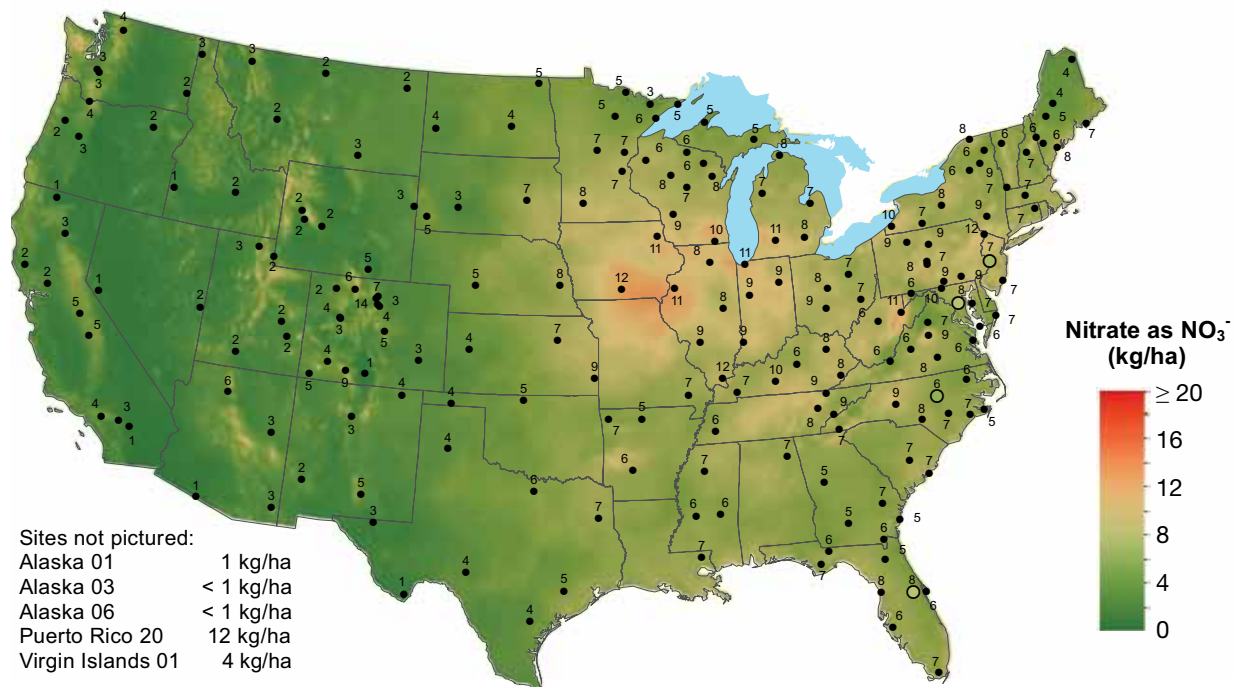
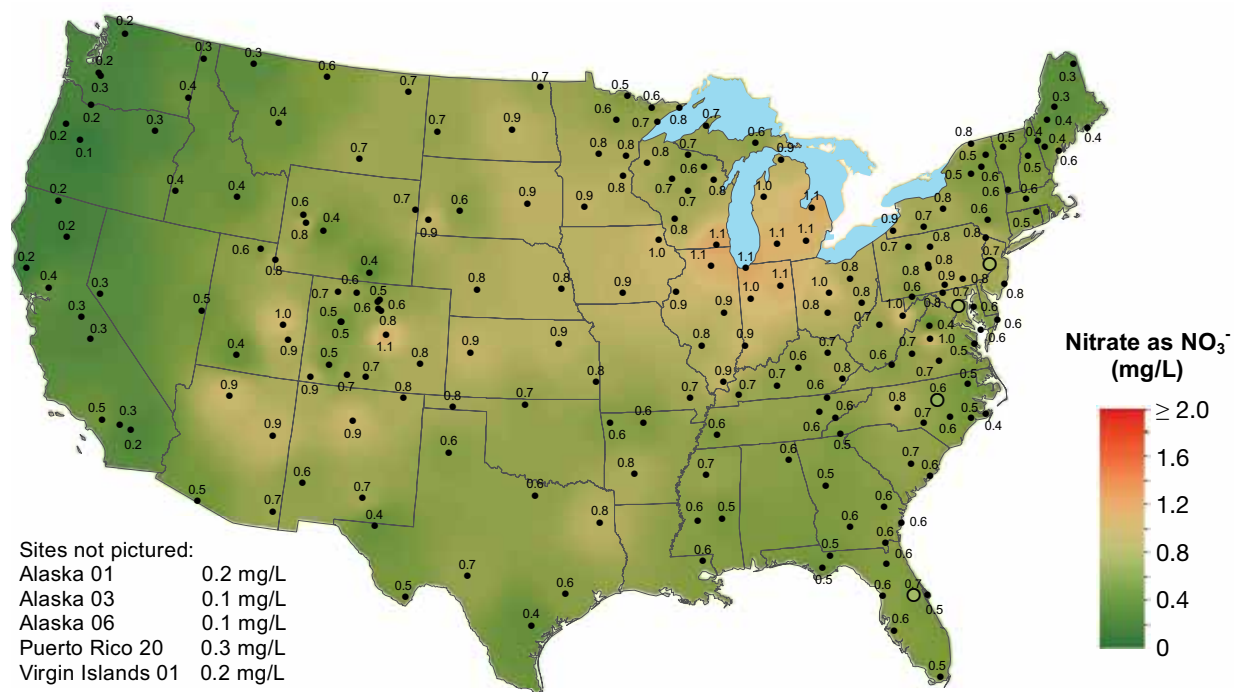
NTN MAPS

The maps on pages 9 through 15 show precipitation-weighted mean concentration and annual wet deposition for select acidic ions, nutrients, and base

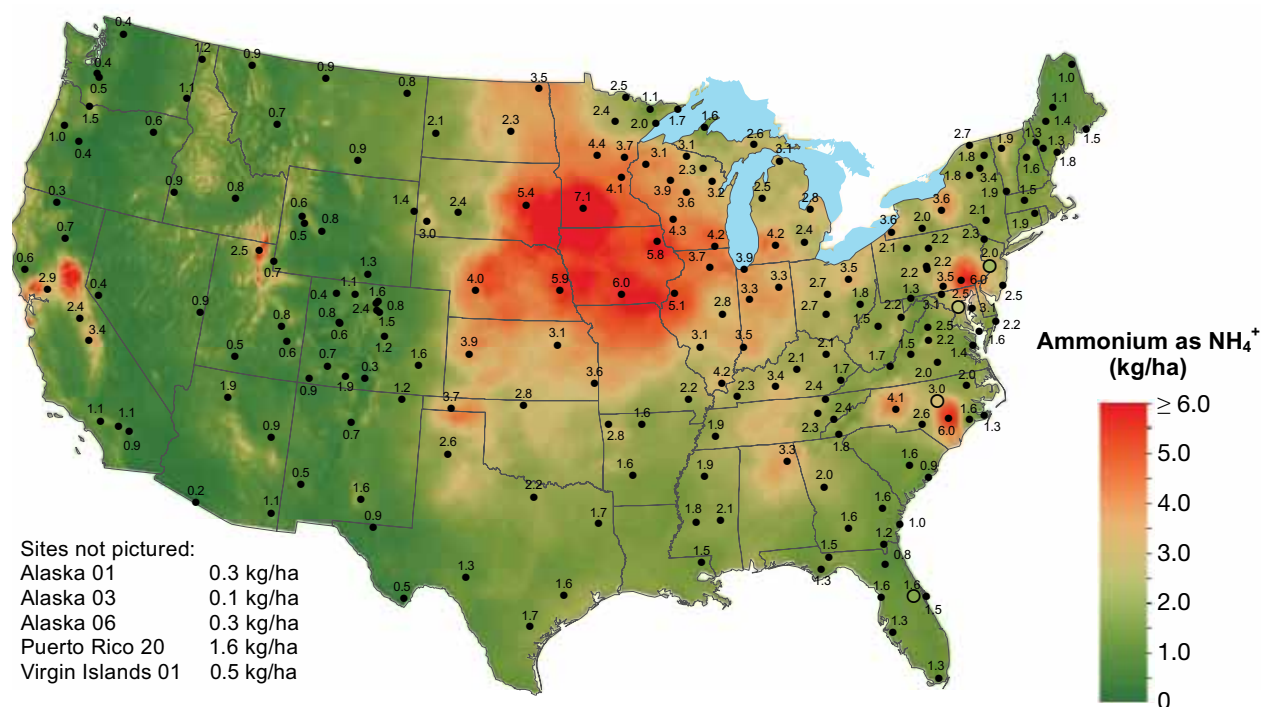
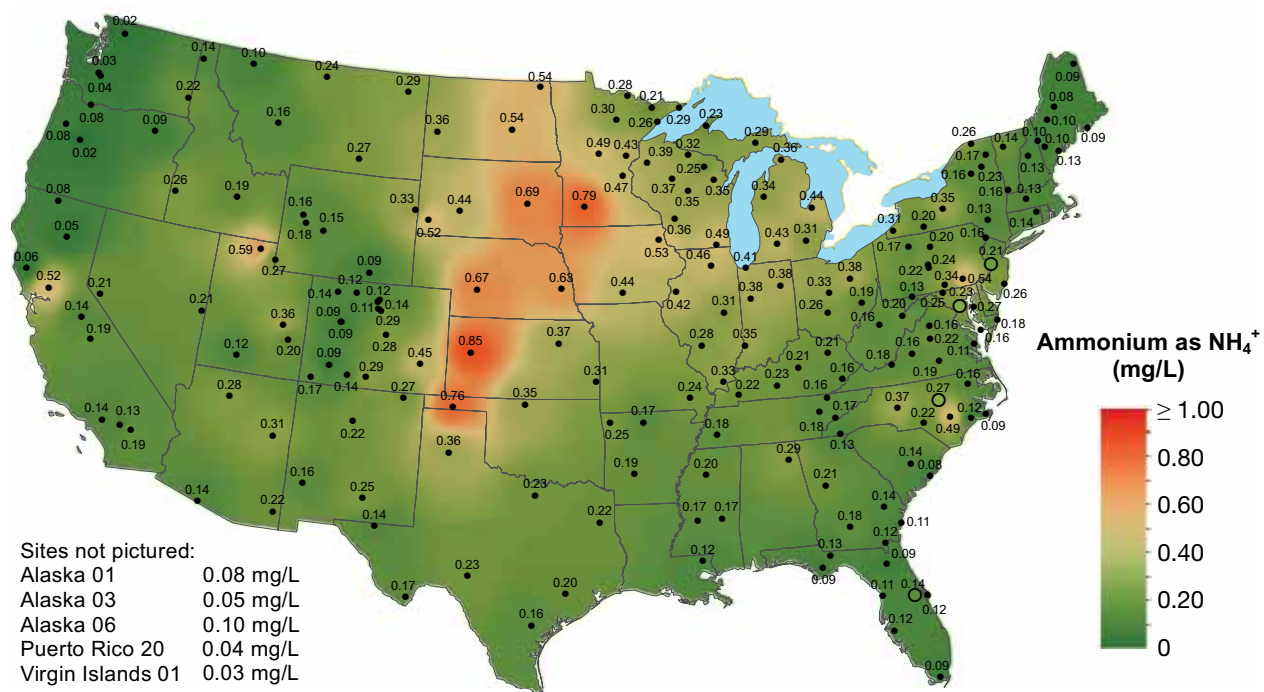


cations. Spatial variability in these species can be seen both on a regional and a national scale. In 2010, 208 of the 252 active sites met NADP completeness criteria. Concentration and deposition maps are included for NO_3^- , NH_4^+ , SO_4^{2-} , Ca^{2+} , Cl^- , and pH. Maps of Mg^{2+} , Na^+ , and K^+ are not included in this report, but are available from the NADP website.

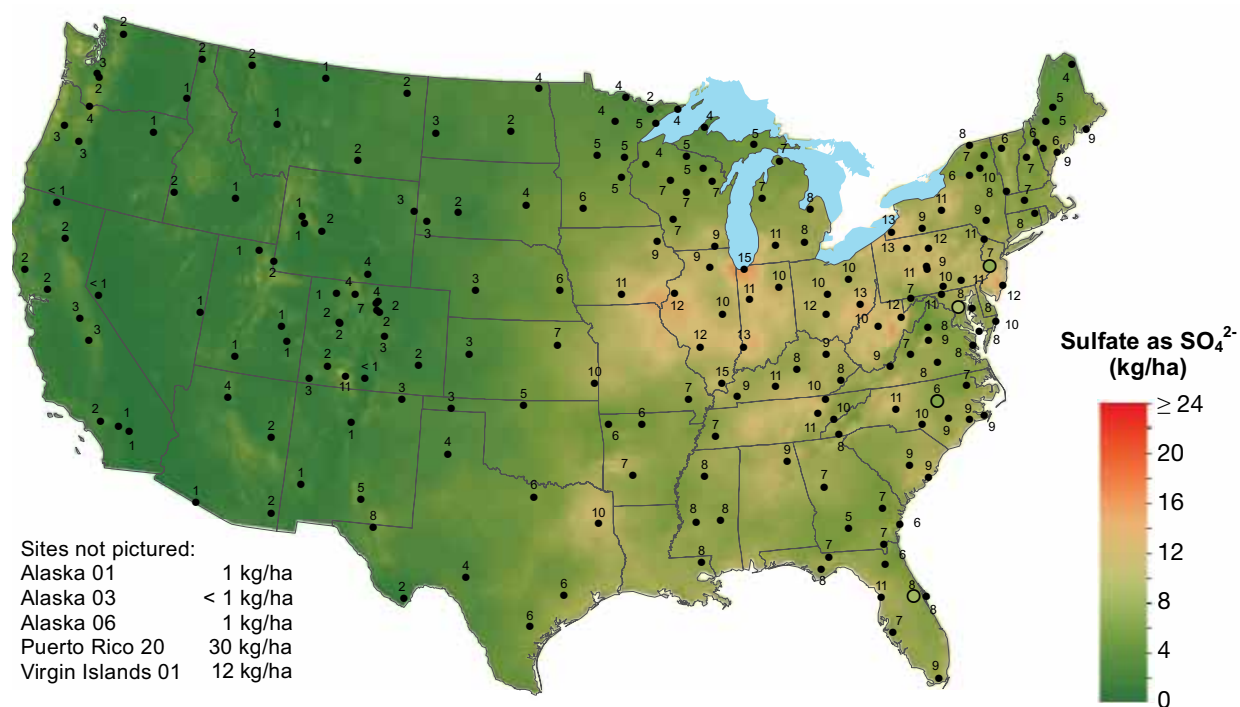
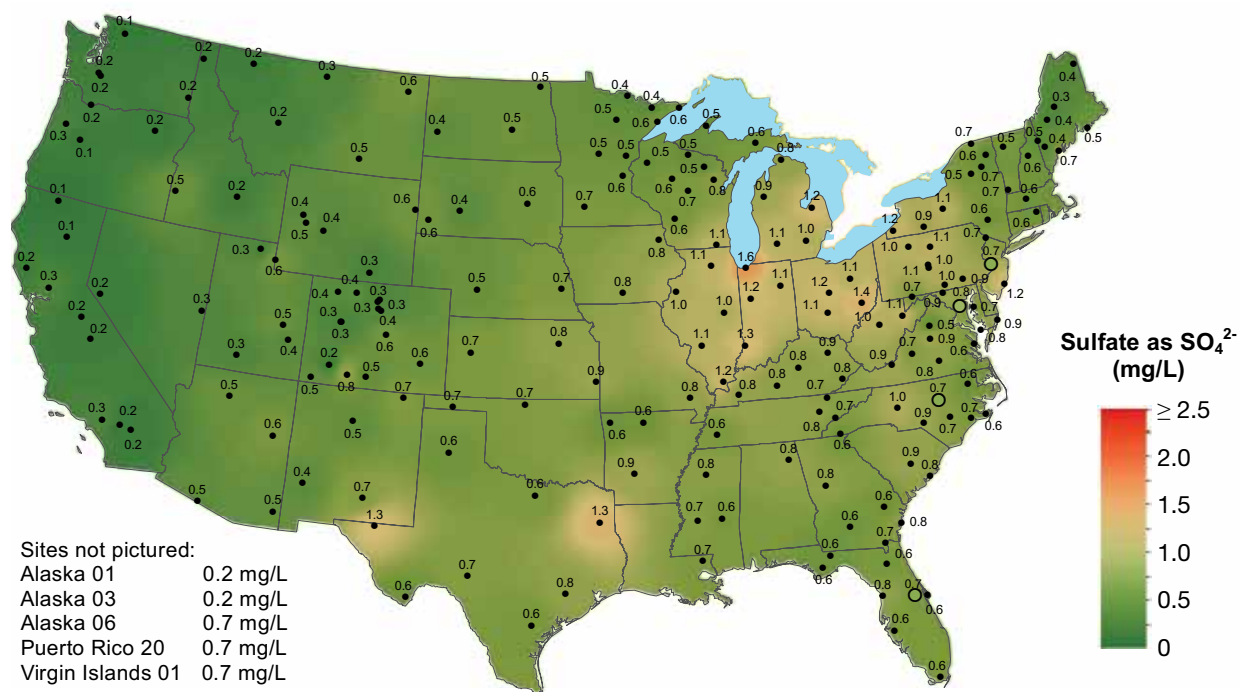
Maps for wet deposition of inorganic nitrogen (“N”, i.e., $NO_3^- + NH_4^+$) and nitrogen + sulfur (“N + S”) are also included. N + S (i.e., $NO_3^- + NH_4^+ + SO_4^{2-}$) is mapped as hydrogen ion equivalents per hectare for the year (eq/ha).



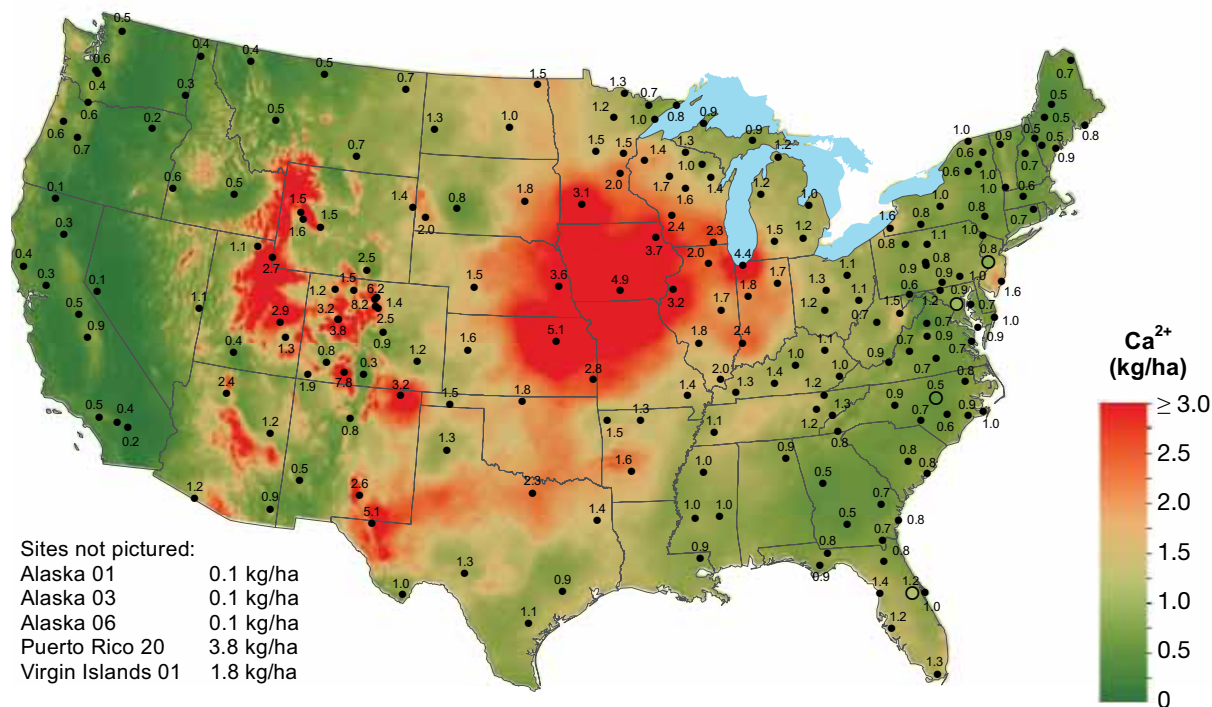
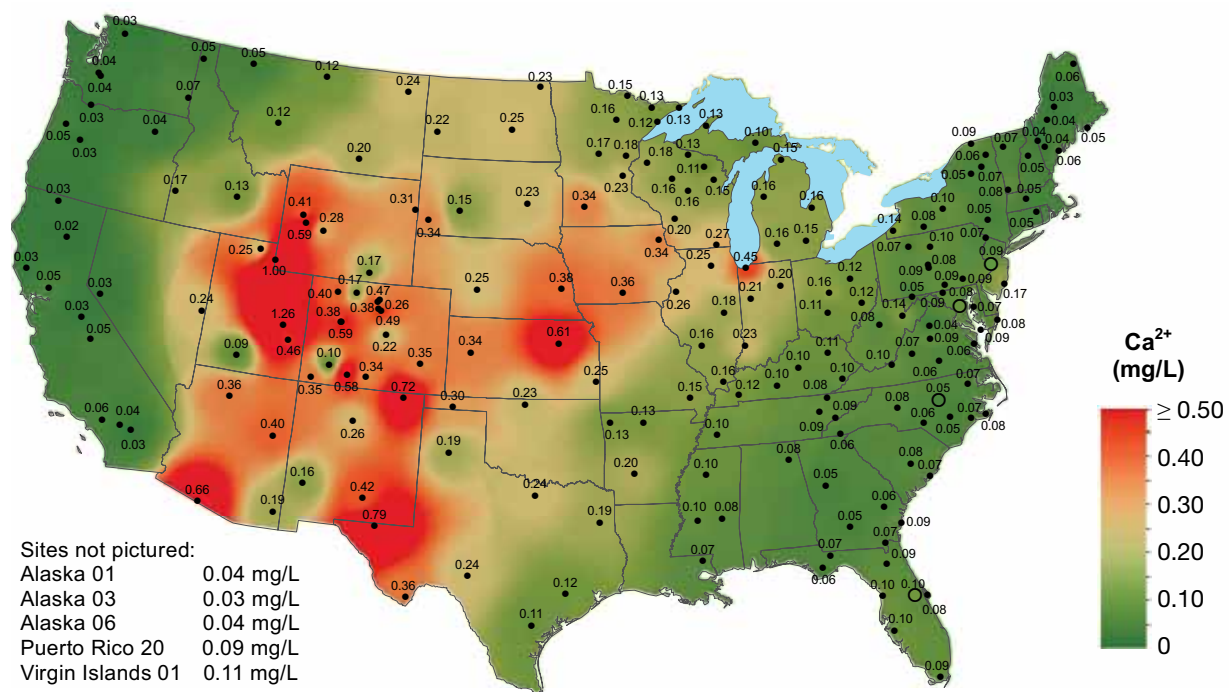
Nitrate ion concentration (top) and wet deposition (bottom), 2010.



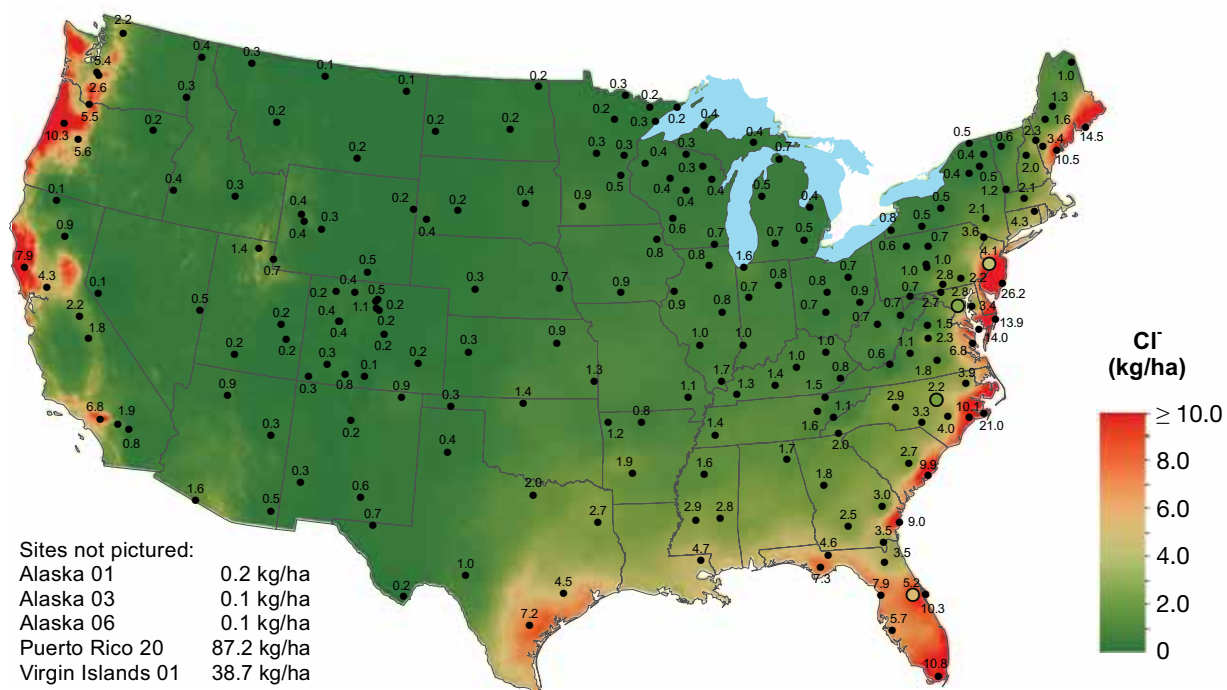
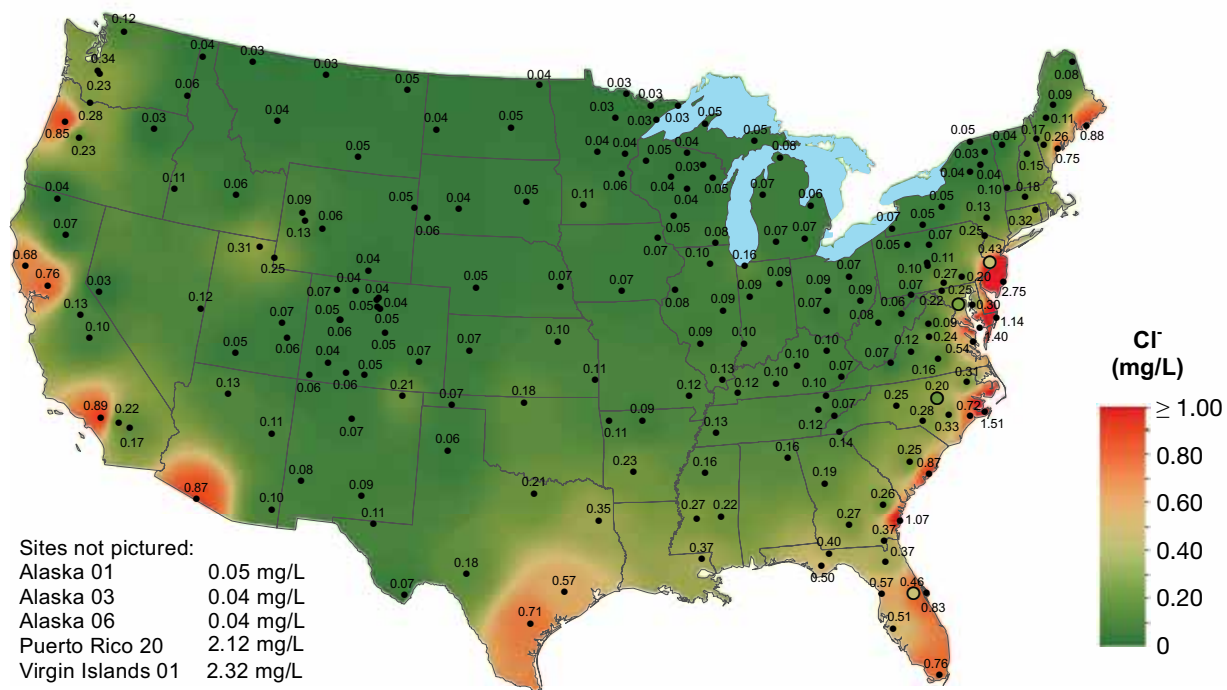
Ammonium ion concentration (top) and wet deposition (bottom), 2010.



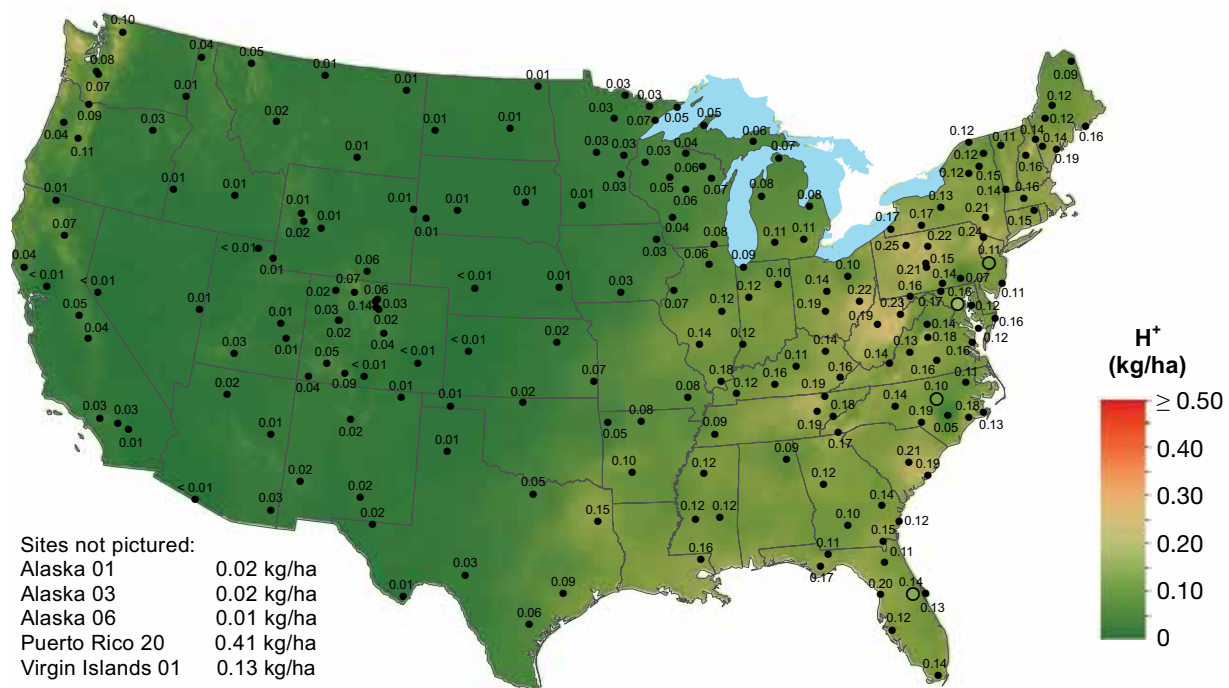
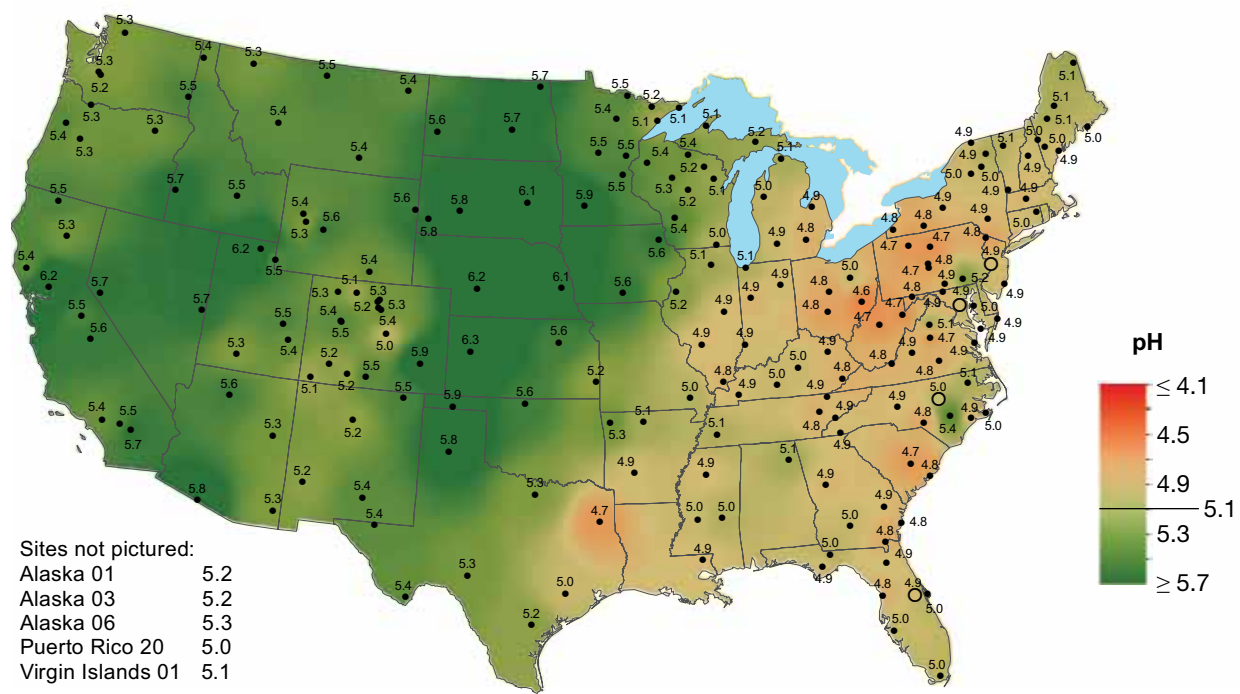
Sulfate ion concentration (top) and wet deposition (bottom), 2010.



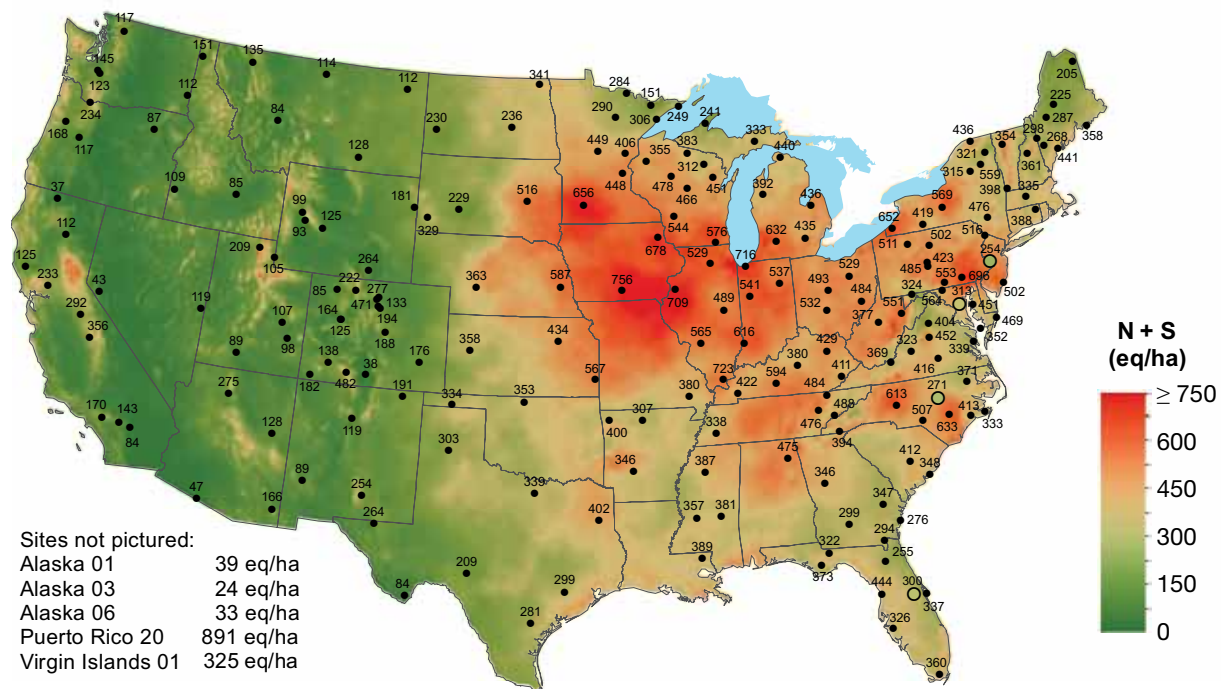
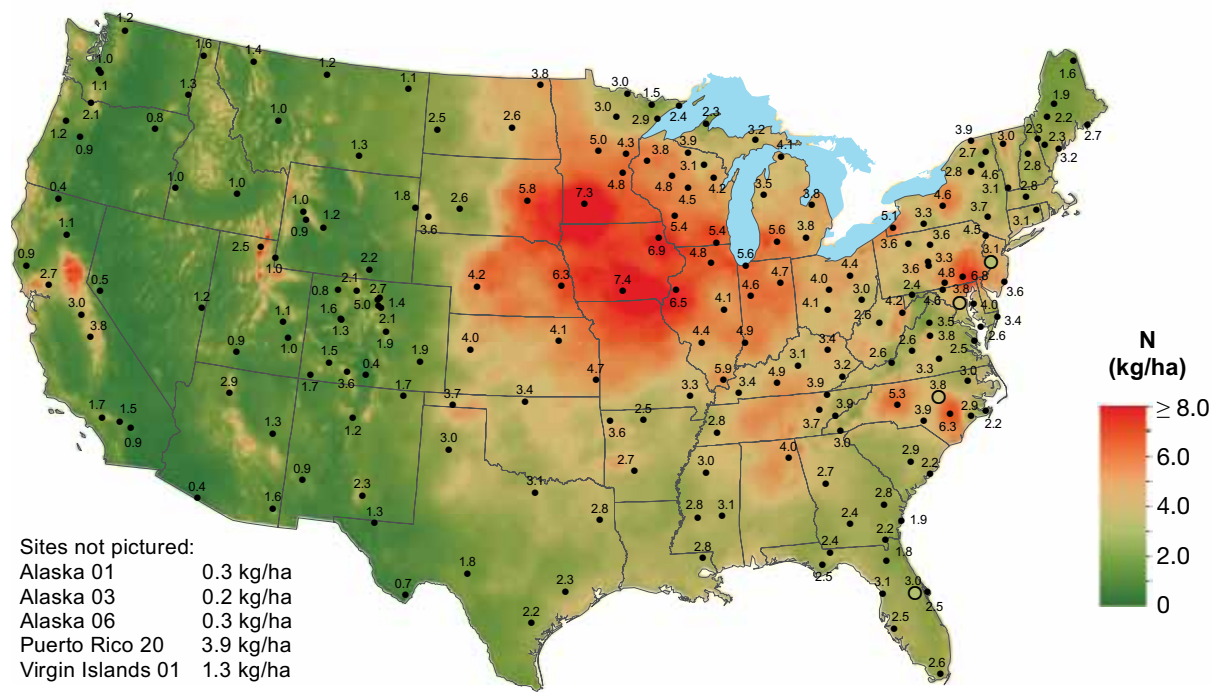
Calcium ion concentration (top) and wet deposition (bottom), 2010.



Chloride ion concentration (top) and wet deposition (bottom), 2010.



Hydrogen ion concentration as pH (top) and wet deposition (bottom), 2010.
 Typically, a precipitation pH of less than 5.1 is considered acidic.



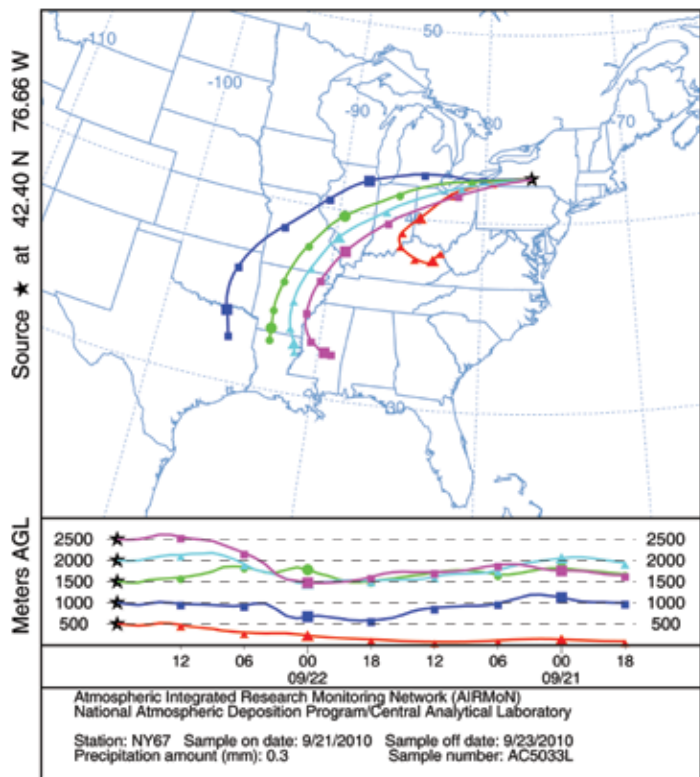
Inorganic nitrogen wet deposition from nitrate and ammonium (top) and nitrogen plus sulfur wet deposition from nitrate, ammonium, and sulfate (bottom), 2010.

Atmospheric Integrated Research Monitoring Network (AIRMoN)

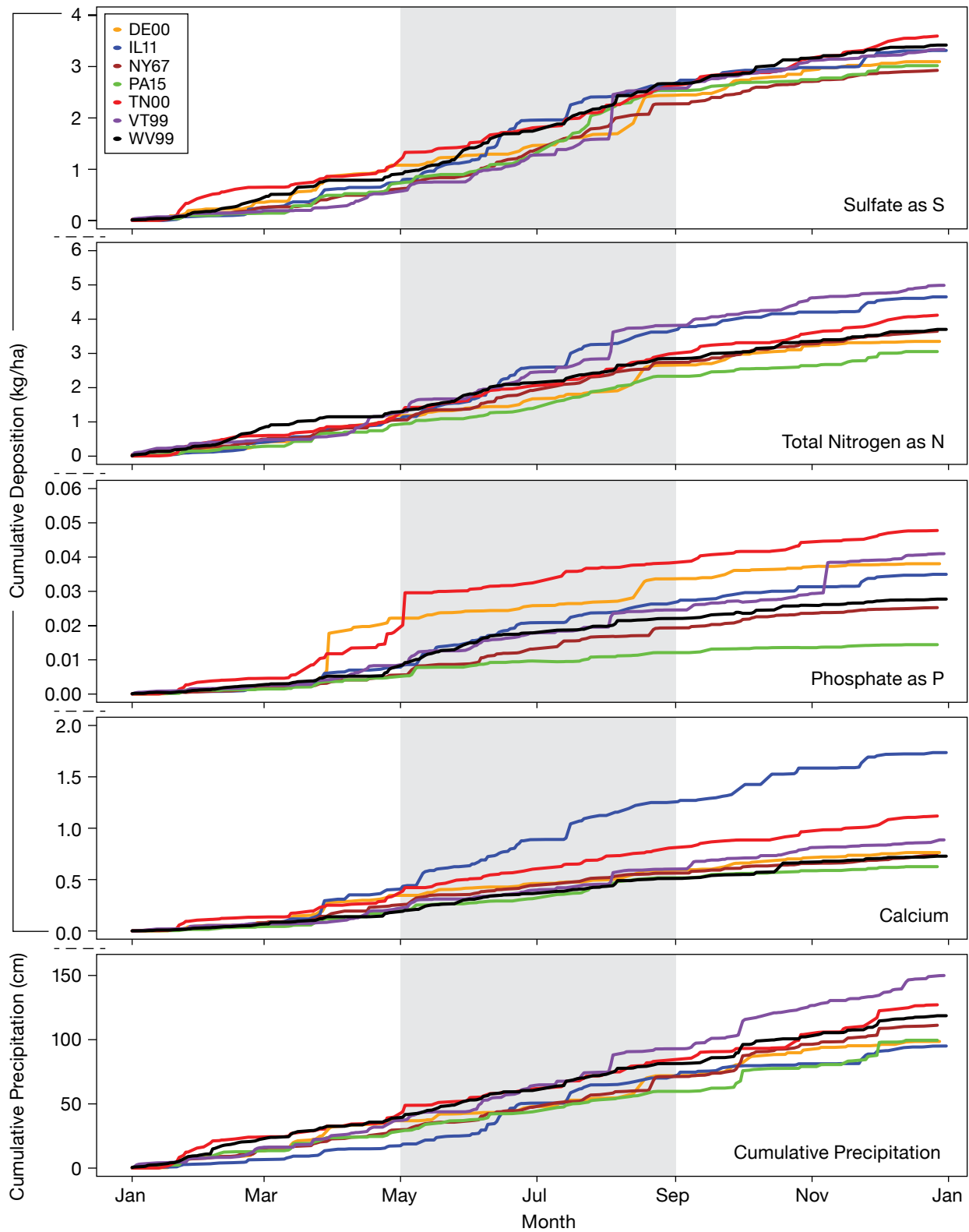
At AIRMoN sites, samples are collected daily within 24 hours of the start of precipitation, often providing data for individual storm events. Single-storm data facilitate studies of atmospheric processes and the development and testing of computer simulations of these processes. An example of a NOAA/HYSPLIT back trajectory model run is shown below. Back trajectories for all AIRMoN samples are provided at <http://nadp.isws.illinois.edu/AIRMoN>. Rapid release of data from this network is an AIRMoN goal.

AIRMoN sites are equipped with the same wet-only deposition collector used at NTN sites. Each site also has a standard stick-type precipitation gage for reporting 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. Refrigeration 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 figures on page 17 show the 2010 cumulative daily deposition for sulfate as sulfur, total nitrogen, phosphate as phosphorus, calcium, and the cumulative precipitation for each AIRMoN site.



Example back trajectories from the NOAA/HYSPLIT model.

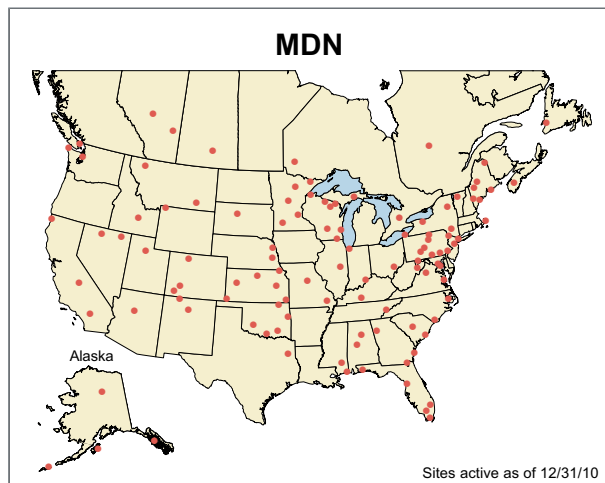


Daily cumulative wet deposition flux at each AIRMoN site during 2010 (kg/ha) of selected AIRMoN analytes, including sulfate as S, total nitrogen as N, phosphate as P, calcium, and cumulative precipitation (cm).

Mercury Deposition Network (MDN)

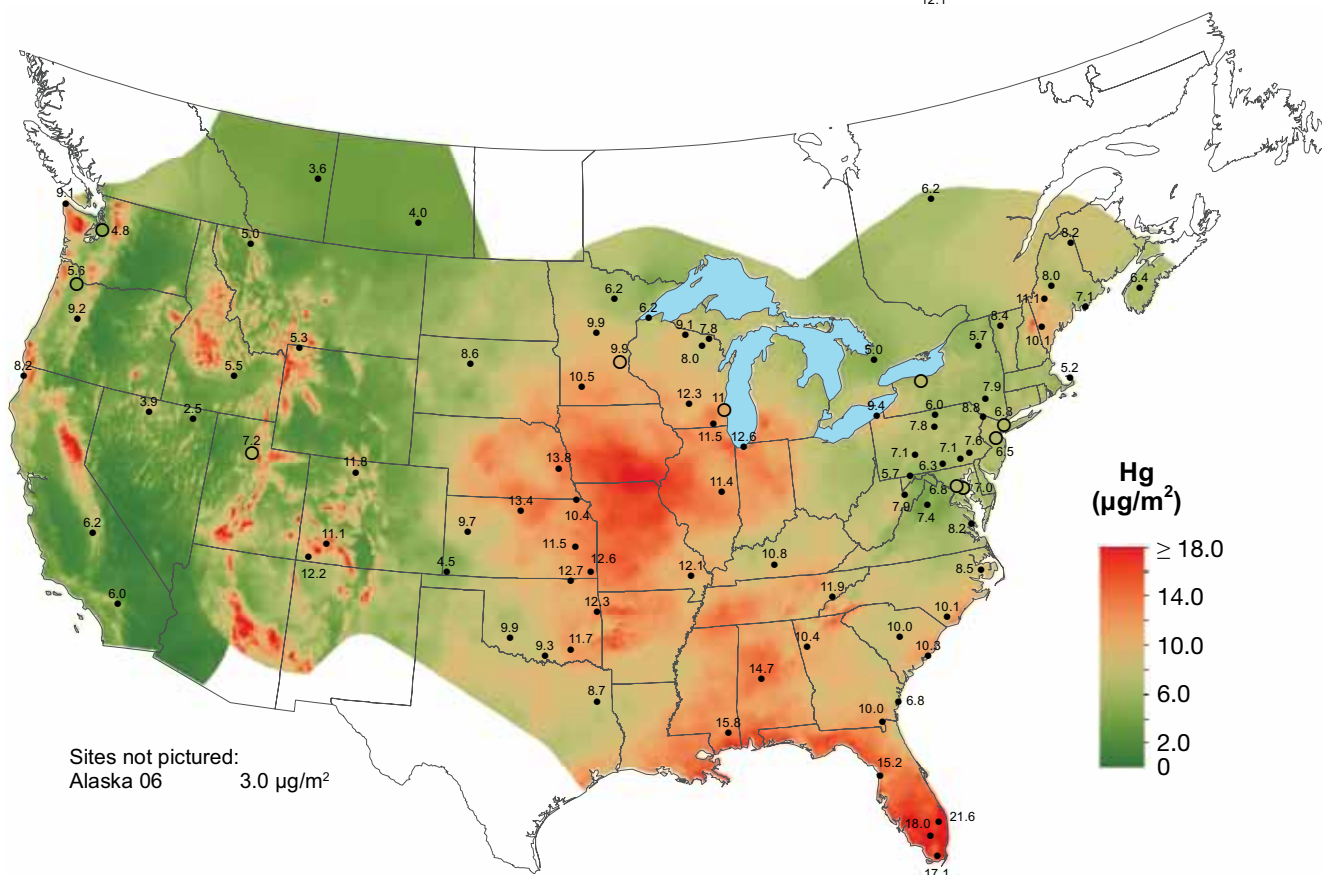
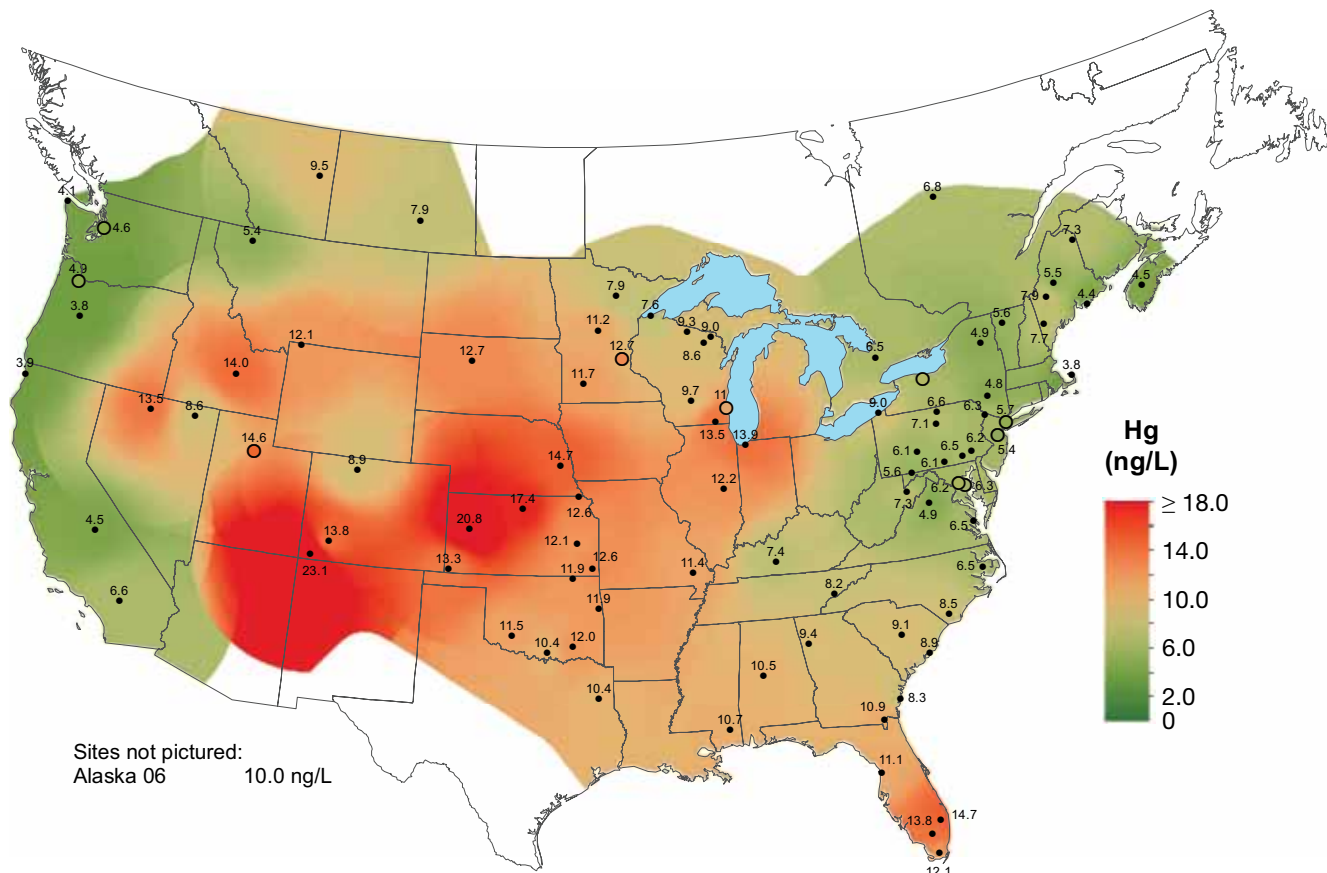
The MDN is the only network providing a long-term record for the concentration of mercury (Hg) in precipitation in North America. Select sites are co-located with AMNet sites (see page 20). All MDN sites follow standard procedures and have uniform precipitation collectors and raingages. The automated 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 2010, the Devil's Lake site in south-central Wisconsin (WI131), 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 Global Sciences, Inc., Seattle, Washington.

All MDN samples are analyzed for total mercury concentration. In 2010, 19 MDN sites opted to measure methyl mercury concentrations. The HAL reviews field and laboratory data for accuracy and completeness, and identifies samples that were mishandled, compromised by equipment failure, or grossly contaminated. Data are made available on the NADP website (<http://nadp.isws.illinois.edu/mdn>).



MDN MAPS

The maps on page 19 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 2010, 93 sites met these criteria.



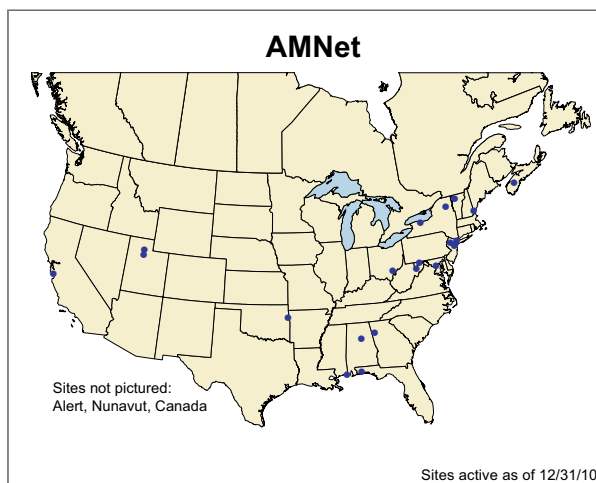
Total mercury concentration (top) and wet deposition (bottom), 2010.

Atmospheric Mercury Network (AMNet)

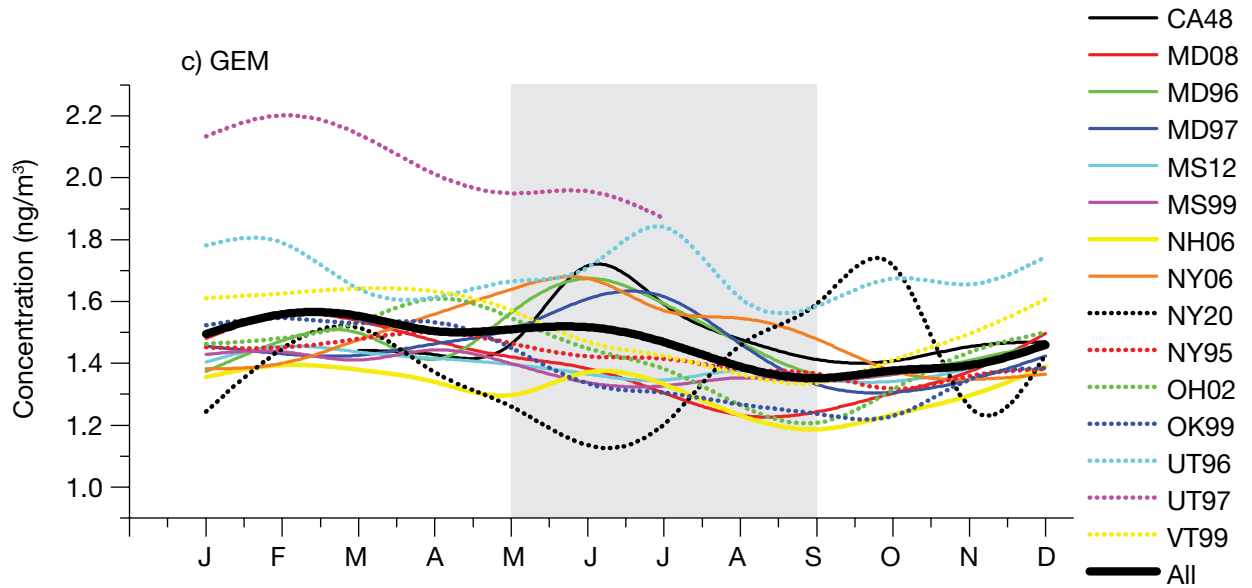
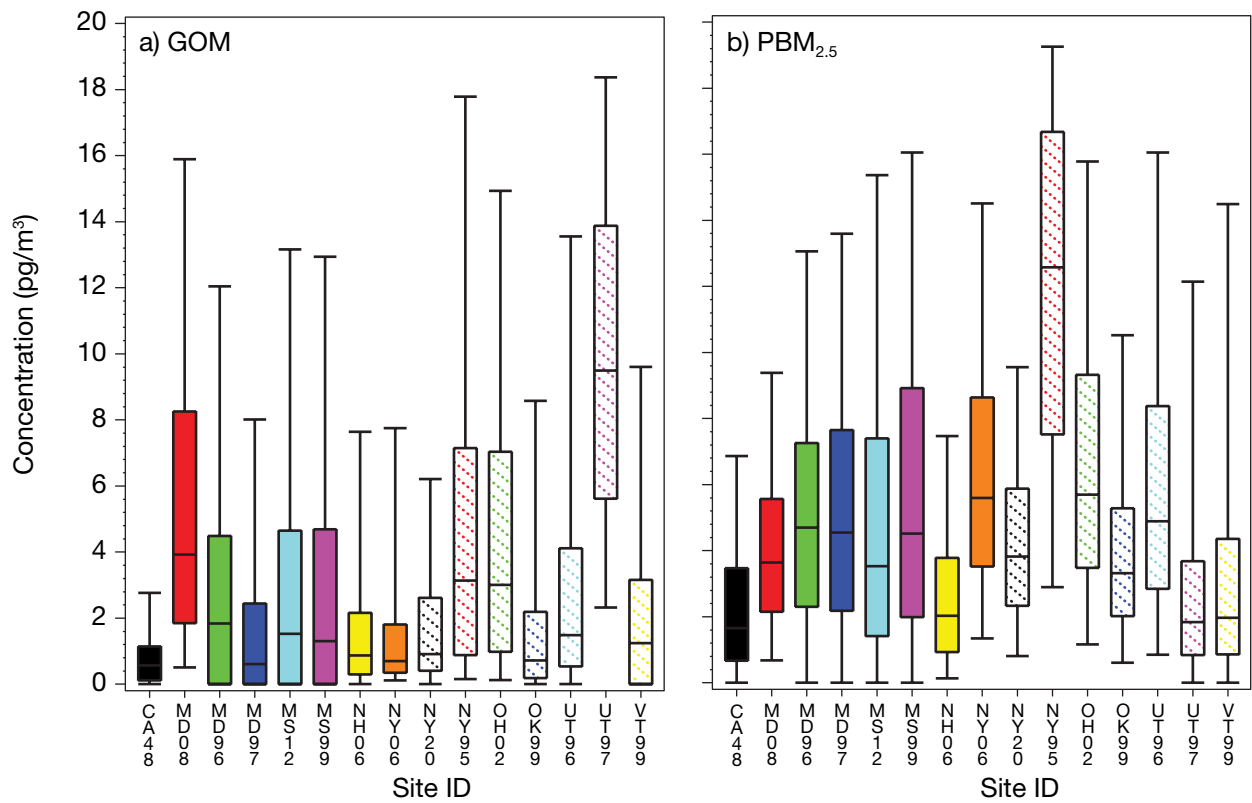
The AMNet was established in 2009. AMNet sites measure atmospheric mercury fractions that contribute to dry and total mercury deposition. Sites measure concentrations of atmospheric mercury species (gaseous oxidized, particulate-bound, and elemental) using automated, continuous measuring systems. Measurements are made using standardized methods, and are quality assured with automated and manual methods and site operator review. AMNet data are available on the NADP website at <http://nadp.isws.illinois.edu/amn/>.

AMNet measurements are made continuously (five-minute and two-hour averages). Data are qualified and averaged to one-hour and two-hour values, and are made available on the NADP website.

The figures on page 21 show the average mercury concentrations in the atmosphere for each site. Figures a and b show the distribution of annual two-hourly atmospheric concentration of gaseous oxidized mercury (GOM), and particulate bound mercury ($PBM_{2.5}$) in picograms per cubic meter for individual sites. Figure c illustrates the monthly average one-hour gaseous elemental mercury concentrations (GEM) in nanograms per cubic meter.



A typical AMNet field site (Cherokee Nation, OK).



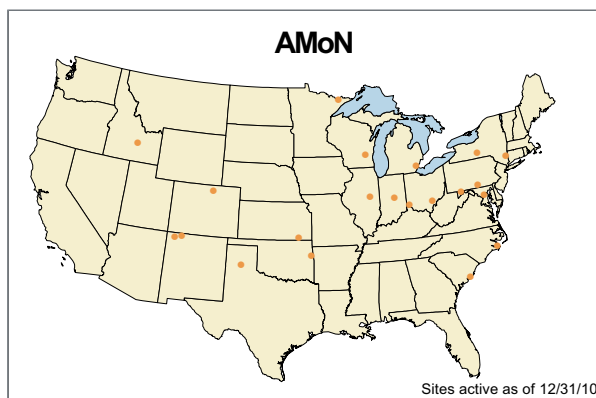
Stem and whisker plots of average mercury atmospheric a) GOM, and b) PBM, for each AMNet site (line = median, color = 25th to 75th percentiles, and whiskers= 5th and 95th percentiles, pg/m³), and smoothed line plots of monthly average c) GEM, for each site (ng/m³).

Ammonia Monitoring Network (AMoN)

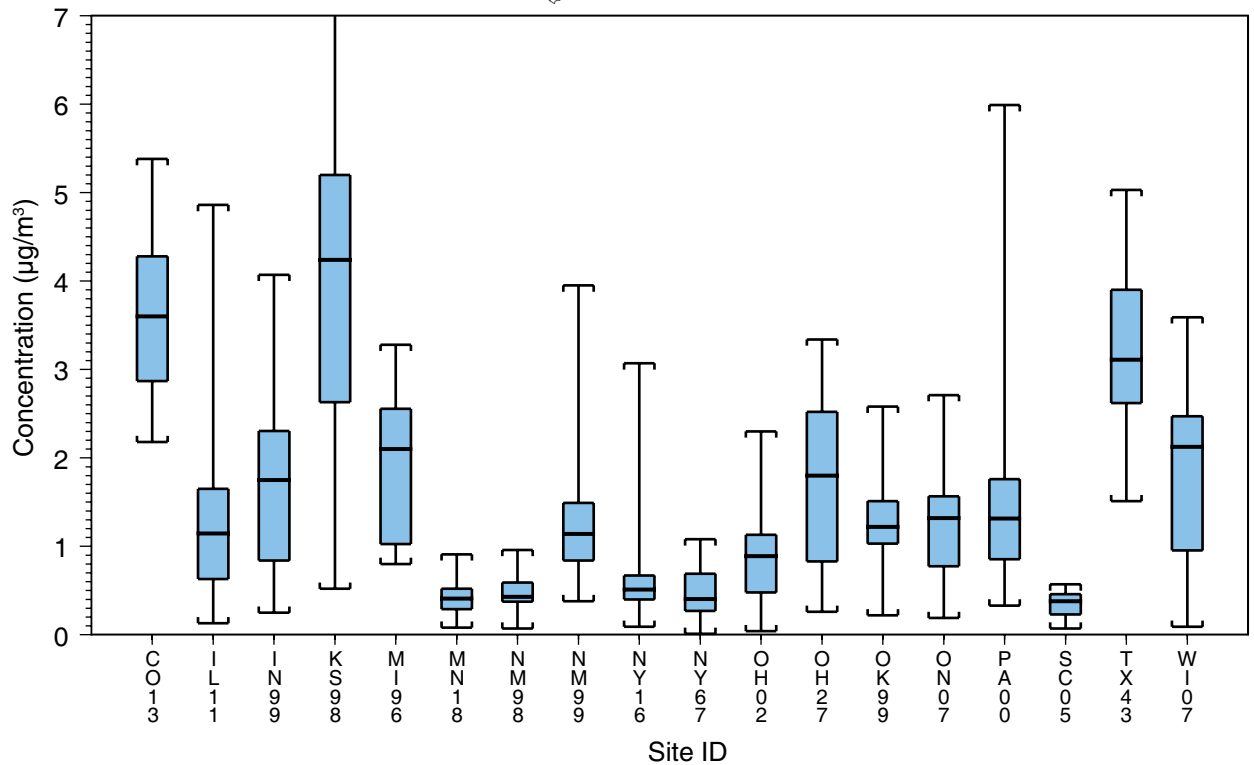
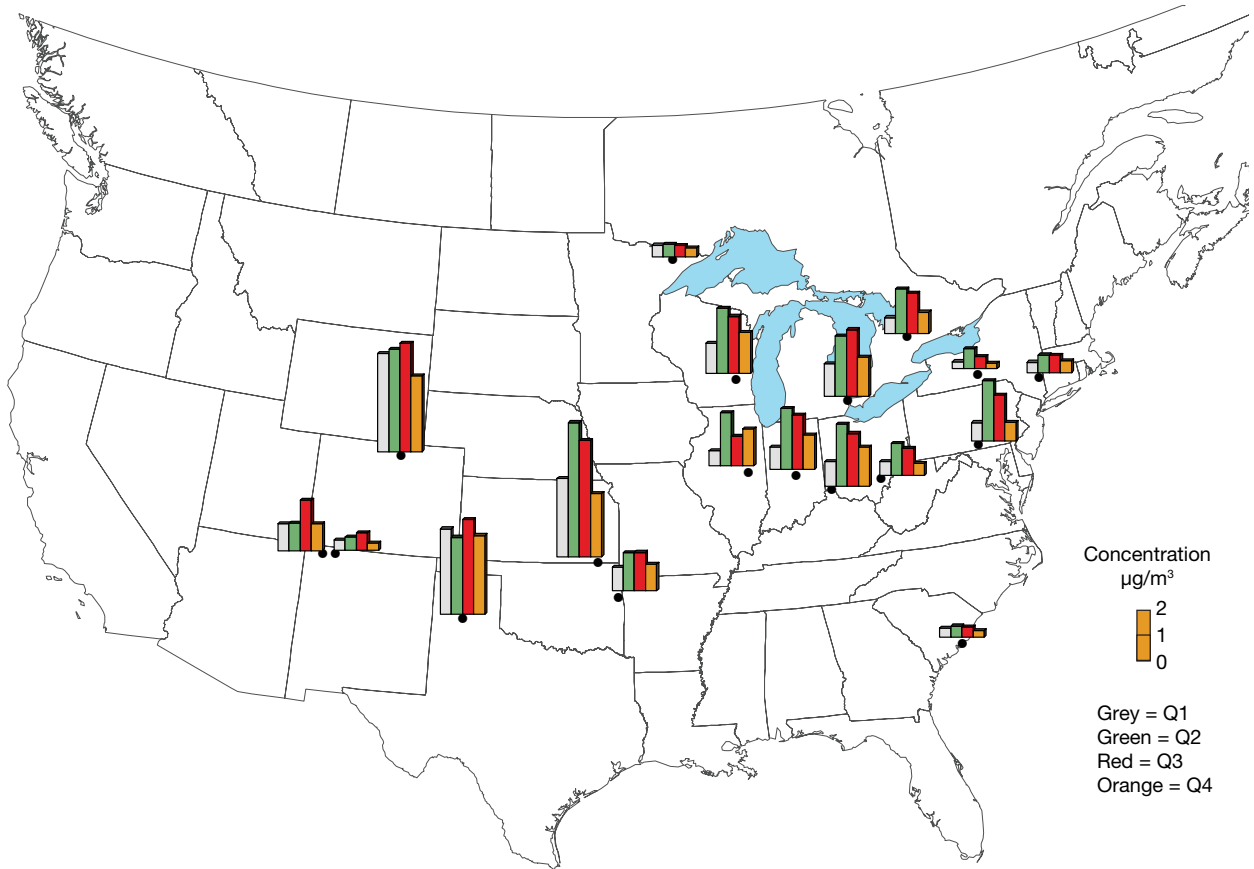
The AMoN was established in 2010, and measures atmospheric concentrations of ammonia (NH_3) gas. The network uses passive diffusion-type samplers. This allows for cost-effective, straightforward, and simple measurements. Observations are made over a two-week period in triplicate. This provides an integrated and quality-assured estimate of ammonia in the air. These data will be used to assess long-term NH_3 trends, provide necessary information for model development and verification, and to assess changes in atmospheric chemistry.

At the end of 2010, there were 21 AMoN sites. This network is expected to expand in the next few years. Data are available on the NADP website at <http://nadp.isws.illinois.edu/amon/>.

The figures on the facing page show distribution and seasonality of gaseous ammonia concentrations ($\mu\text{g}/\text{m}^3$) for each site operating during 2010. Bars on the map represent quarterly average concentrations at each site. Variability is substantial across the sites and the seasons. The distribution of the atmospheric ammonia concentrations are illustrated as stem and whisker plots in the lower figure.



A typical AMoN field site (Beltsville, MD).



Quarterly average atmospheric ammonia concentration (top, Quarter 1 or Q1 = Jan, Feb, Mar, etc.), and stem and whisker plots of average atmospheric ammonia concentration (bottom) for each AMoN site with a full year of observations during 2010 (line = median, color = 25th to 75th percentile, and whiskers = data range). Concentrations are in $\mu\text{g}/\text{m}^3$.

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 non-governmental 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 University of Illinois.

Champaign, IL

October 2011

ISWS Miscellaneous Publication 195 and NADP Data Report 2011-01

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.

Note: When referencing maps or information in this report, please use the citation: National Atmospheric Deposition Program, 2011. *National Atmospheric Deposition Program 2010 Annual Summary*. NADP Data Report 2011-01. Illinois State Water Survey, University of Illinois at Urbana-Champaign, IL.

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