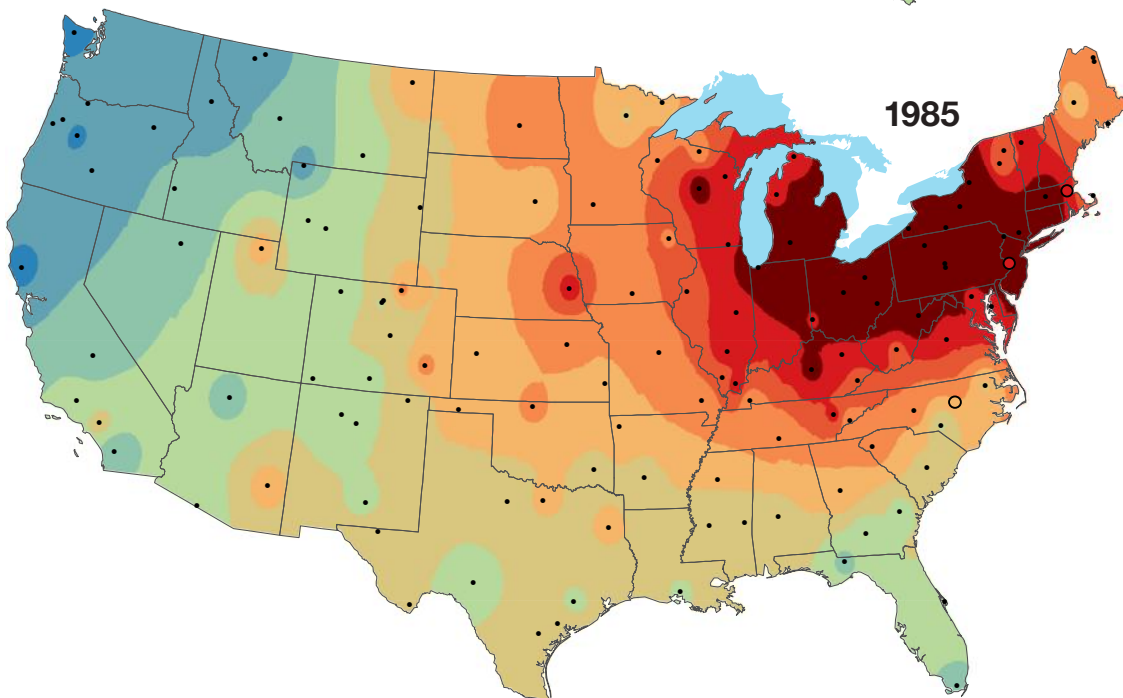
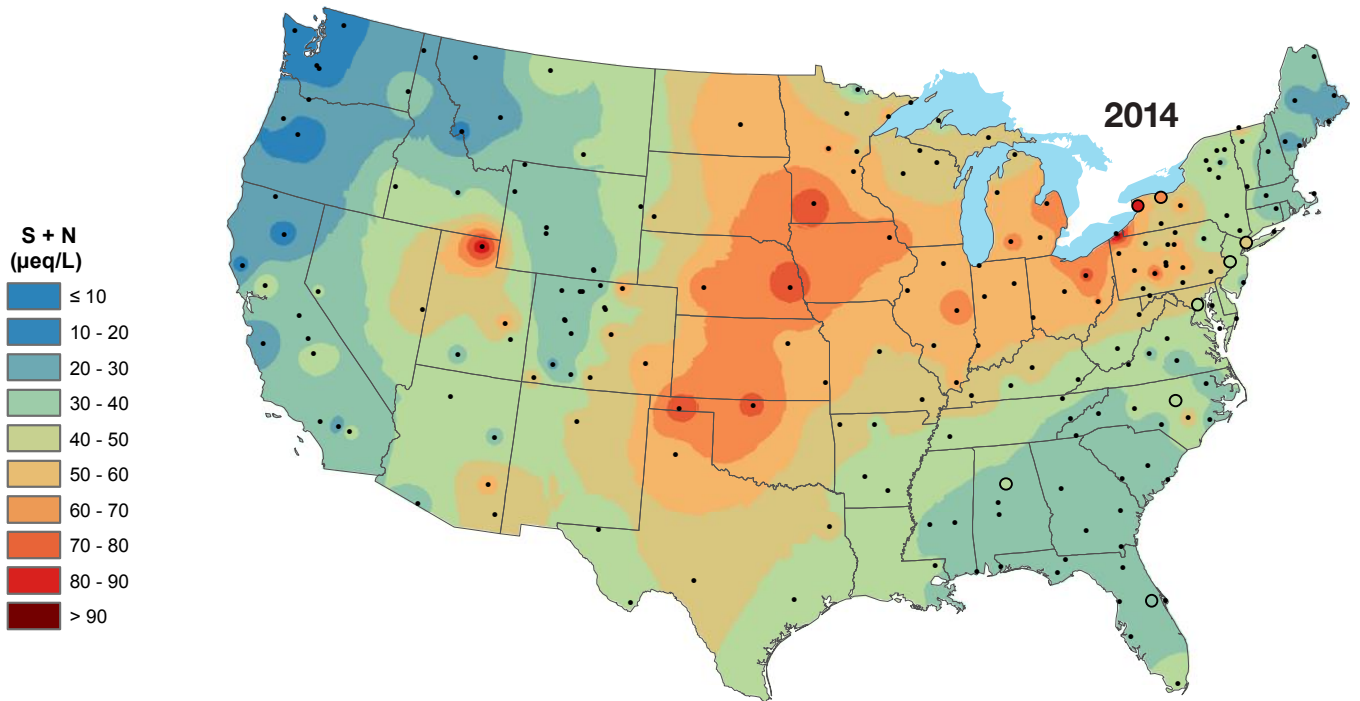


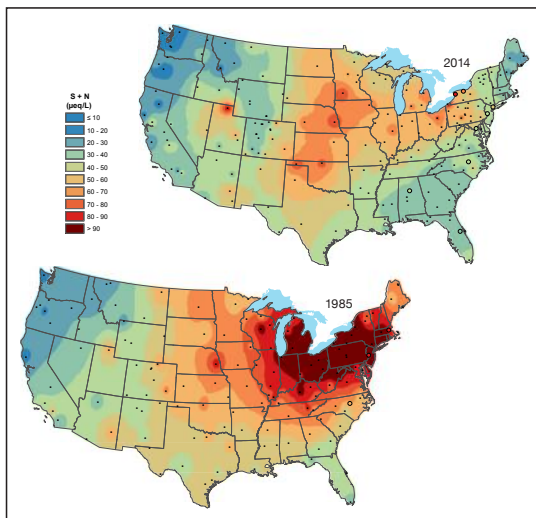


National Atmospheric Deposition Program

# 2014 Annual Summary



Sulfur + Nitrogen Concentration



**On the cover:** These maps are recent additions to the standard annual NADP map suite, and are a product of the CLAD subcommittee. Similar maps using the standard NADP color scheme are shown on page 11. Both sets of maps are available on the NADP website. The two concentration maps (1985, 2014) represent the combined annual precipitation-weighted concentration of sulfate, nitrate, and ammonium, expressed as S + N in equivalents per liter. The comparison of these maps shows the westerly shift and decrease in maximum area of the maximum concentrations.

*When referencing maps or information in this report, please use the citation: National Atmospheric Deposition Program, 2015. National Atmospheric Deposition Program 2014 Annual Summary. NADP Data Report 2015-01. Illinois State Water Survey, University of Illinois at Urbana-Champaign, IL.*

# Contents

2014 Highlights.....	4
NADP Background.....	6
About the Maps.....	8
National Trends Network (NTN).....	10
Atmospheric Integrated Research Monitoring Network (AIRMoN).....	20
Mercury Deposition Network (MDN) .....	22
Atmospheric Mercury Network (AMNet).....	24
Ammonia Monitoring Network (AMoN) .....	26

# 2014 Highlights

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

The NADP is composed 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 Ammonia Monitoring Network (AMoN). The table below summarizes the number of measurements made by each network in 2014.

**Summary of Network Measurements, 2014**

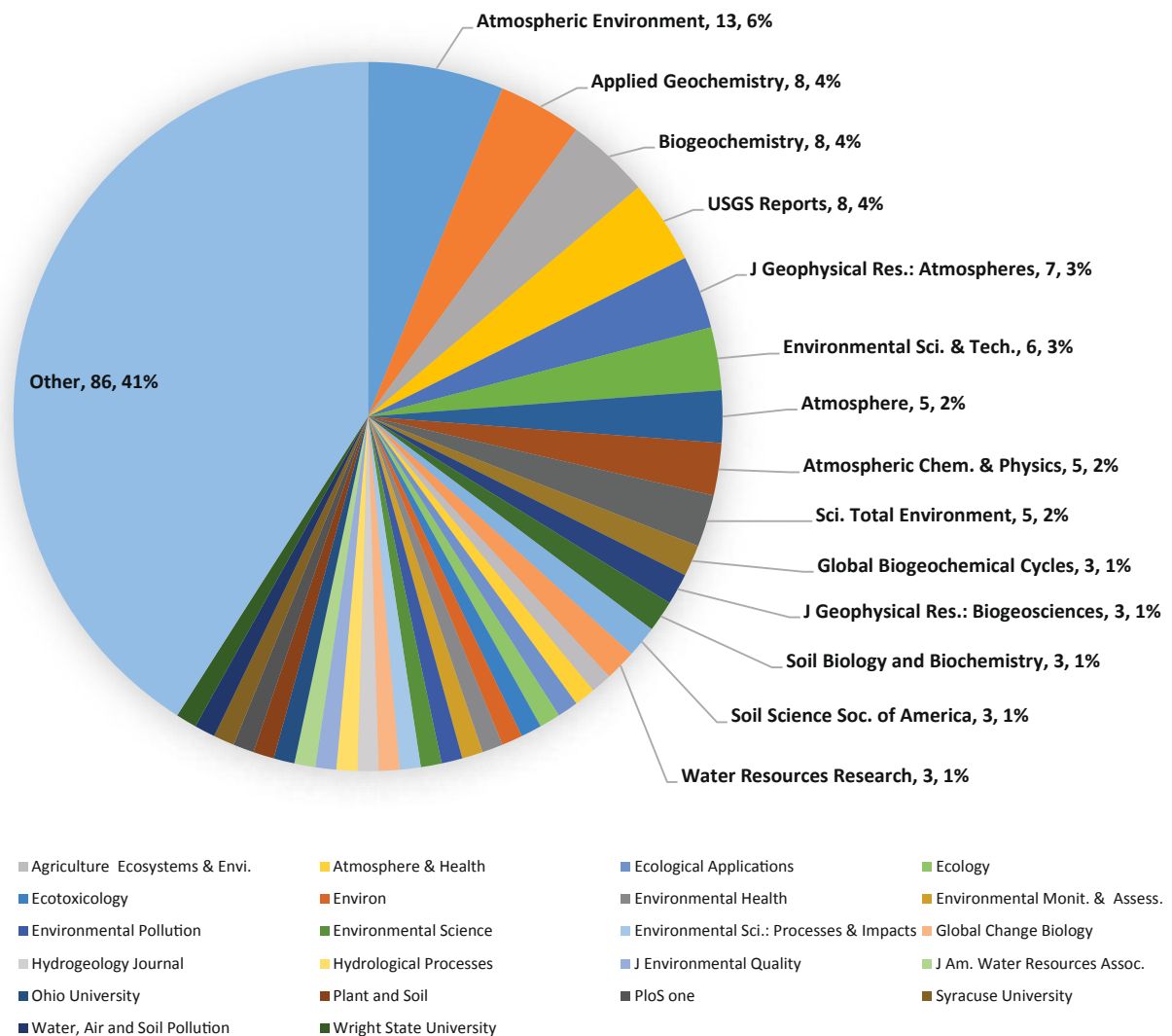
Network	Measurements	Period	No. of sites
NTN	13,638	weekly	261
MDN	7,578	weekly	113
AIRMoN	867	daily	6
AMNet	52,200	hourly	20
AMoN	2,052	two week	68

## Highlights:

- 236 journal articles and other publications used the NADP data.
- The NADP data were used in 10 dissertations, 15 master's theses, one text book ("Atmospheric Pollution and Environmental Change", Metcalfe

& Derwent, Routledge), and one workshop proceeding (Sutton, Mason, Sheppard, Sverdrup, Haeuber, & Hicks). See <http://nadp.isws.illinois.edu/lib/bibliography.aspx> for the full publications listing.

- The NADP implemented an outreach program, hiring an outreach coordinator.
- A quarterly eNewsletter (inaugural edition September 2014) and social media pages on both Facebook and Twitter (@NADProgram) were started. The eNewsletter and social media will increase the information dissemination and overall reach of NADP beyond just researchers and scientists.
- The NADP's Fall Meeting and Scientific Symposium was held in Indianapolis, IN (October 19-23, 2014) and focused on "The Global Connection of Air and Water". The meeting included 120 attendees, six sessions, including sessions on international deposition, agriculture emissions and depositions, and urban deposition (<http://nadp.isws.illinois.edu/nadp2014/>).
- The 2014 Spring NADP Meeting was held in Ft. Lauderdale, FL on April 14-17, 2014.
- Among the 5 networks of NADP, we now sample at 336 individual sampling locations (see map page 7).
- The U.S. Geological Survey-led Mercury Litterfall Initiative continued operation with 14 sites collecting litterfall (leaves, twigs, etc.) for measurement of mercury. More information is available at <http://nadp.isws.illinois.edu/newissues/litterfall>.



**Journals, reports and universities (dissertations, theses) using NADP network data during 2014 (name, number of publications, percent of total publications). Journals with two publications are listed in the legend above. Journals with a single publication are in the "Other" category.**

# 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. Chemical analysis was performed 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 the National Research Support Project No. 3 (NRSP-3), which it remains to date. The latest renewed was in Federal Year 2010. 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 Precitation 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. Due to 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.

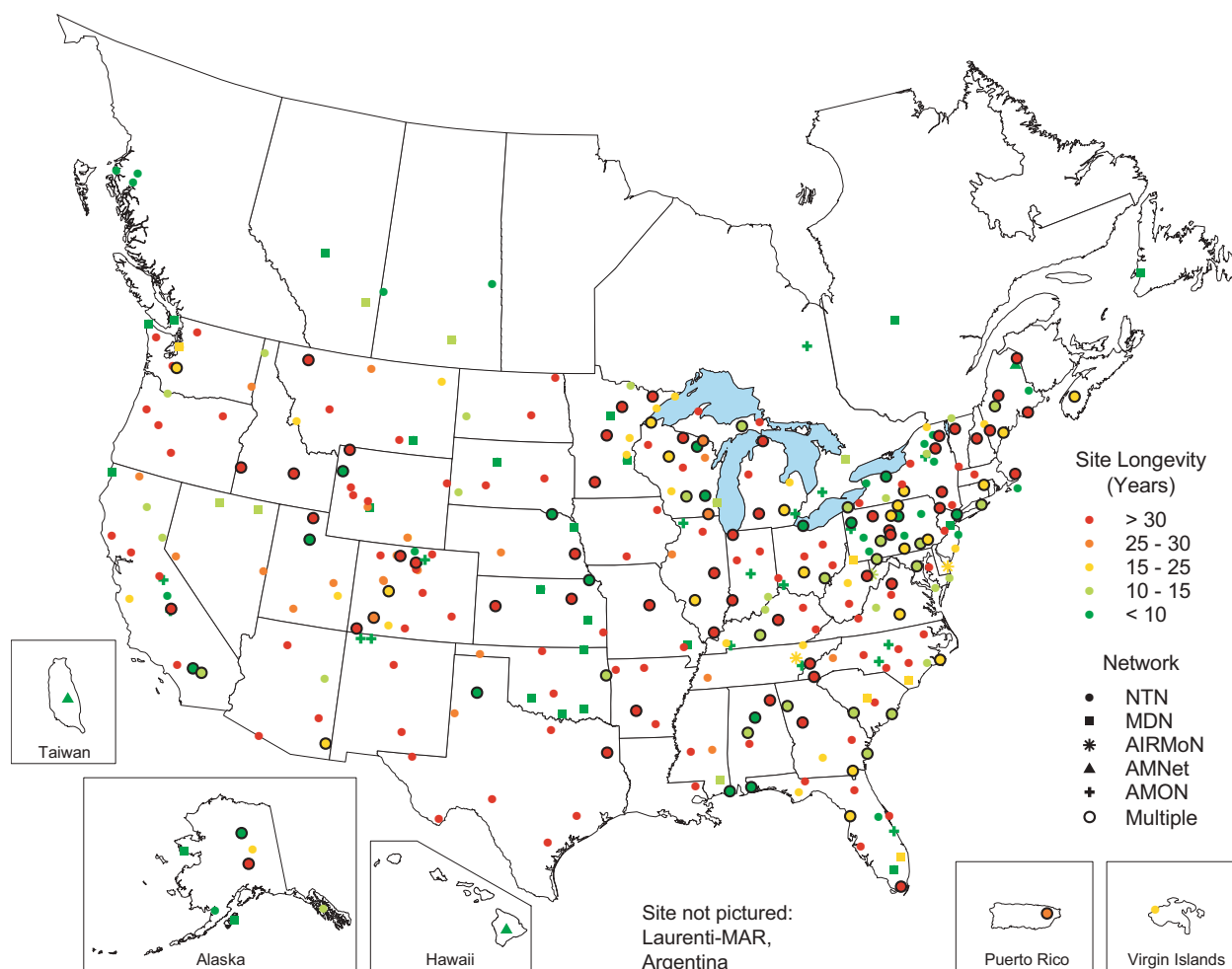
In October 1992, the AIRMoN was formed from the Multistate Atmospheric Power Production Pollution Study (MAP3S), which was operated by the Department of Energy and the National Oceanic and Atmospheric Administration (NOAA). MAP3S measured wet deposition and estimated dry deposition (since discontinued) for the same analytes. AIRMoN sites collect samples daily when precipitation occurs, and are analyzed for the same analytes as NTN samples.

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 its fourth network. AMNet measures the concentration of atmospheric mercury on an hourly and 2-hourly basis.

In October 2010, AMoN joined the NADP, measuring atmospheric ammonia concentrations using passive samplers on a two-week basis.

As of December 2014, there are 20 NTN sites that have been operating for each of NADP's 37 years of operation. The map on the facing page shows active sites in each of the five networks, and the length of time that each site has been operating.



Site longevity of active NADP sites in each network.

# About the Maps

This 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 and related geographic information are available on the NADP website.

All map products are restricted to sites that meet completeness criteria (see the NADP website for details). Black dots mark site locations that met NADP completeness criteria in 2014. Open circles designate urban sites, defined as having at least 400 people per square kilometer (km<sup>2</sup>) within a 15-km radius of the site. Other sites (e.g., Canadian sites) are too far removed from other observations to extend the contouring, and are represented as circles as well.

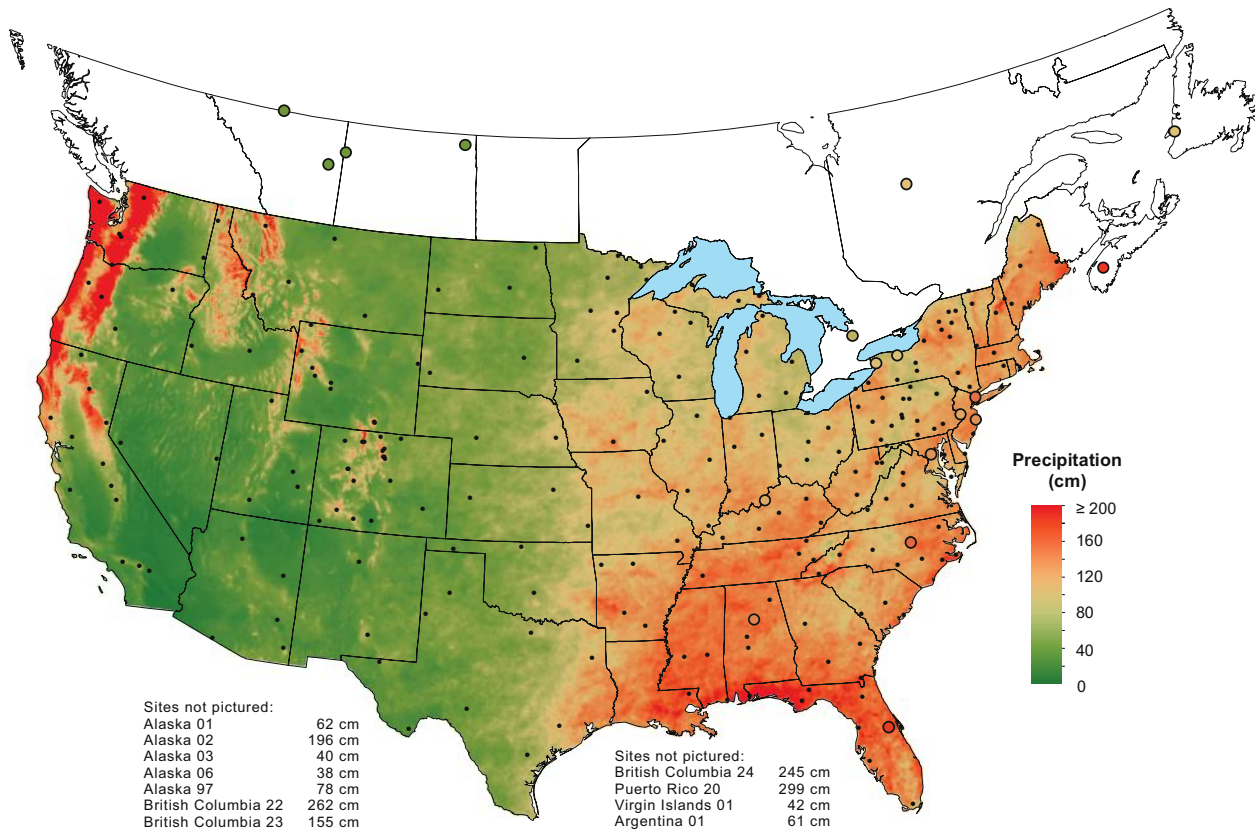
The map contour surface represents a gridded interpolation. Grid points within 500 km of each site are used in computations. Urban sites do not contribute to the contour surface. Colors represent interpolated values of concentration, deposition, or precipitation. Precipitation values are an adapted version of the U.S. precipitation grid developed by the PRISM Climate Group ("Parameter-elevation Regressions on Independent Slopes Model," <http://prism.oregon-state.edu>, Sept. 2015). These annual precipitation estimates incorporate point data, a digital elevation

model, and expert knowledge of complex climatic extremes to produce continuous 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 based solely on NADP precipitation data. The resulting precipitation map is used to generate the deposition maps.

The precipitation figure on the facing page 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 centimeters (cm) extending above 200 cm (dark red). The concentration and deposition maps follow this same format, with specified units on each map. All maps back to 1985 are available in this format from the NADP website.





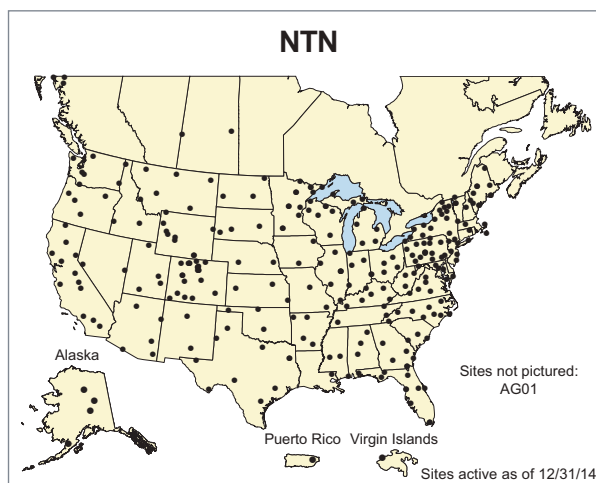
**Total annual precipitation for 2014, using precipitation measurements from the NADP and PRISM (in cm).**

# National Trends Network (NTN)

The NTN is the largest North American network that provides a long-term record of precipitation chemistry. Sites are mostly located away from urban areas and point sources of pollution, although a few urban sites participate. 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 ( $Cl^-$ ), bromide ( $Br^-$ ), 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 available on the NADP website (<http://nadp.isws.illinois.edu/ntn/>).

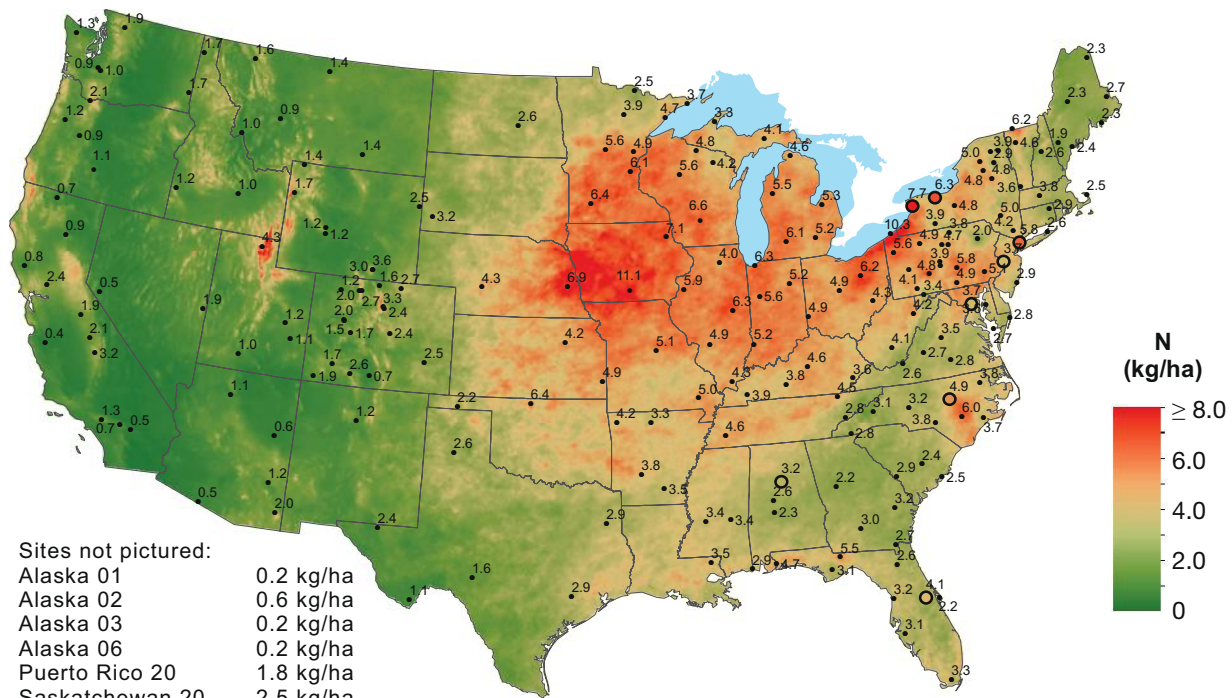
## NTN Maps

The maps on pages 11 through 19 show precipitation-weighted mean concentration and annual wet deposition for select acidic ions, nutrients, and base



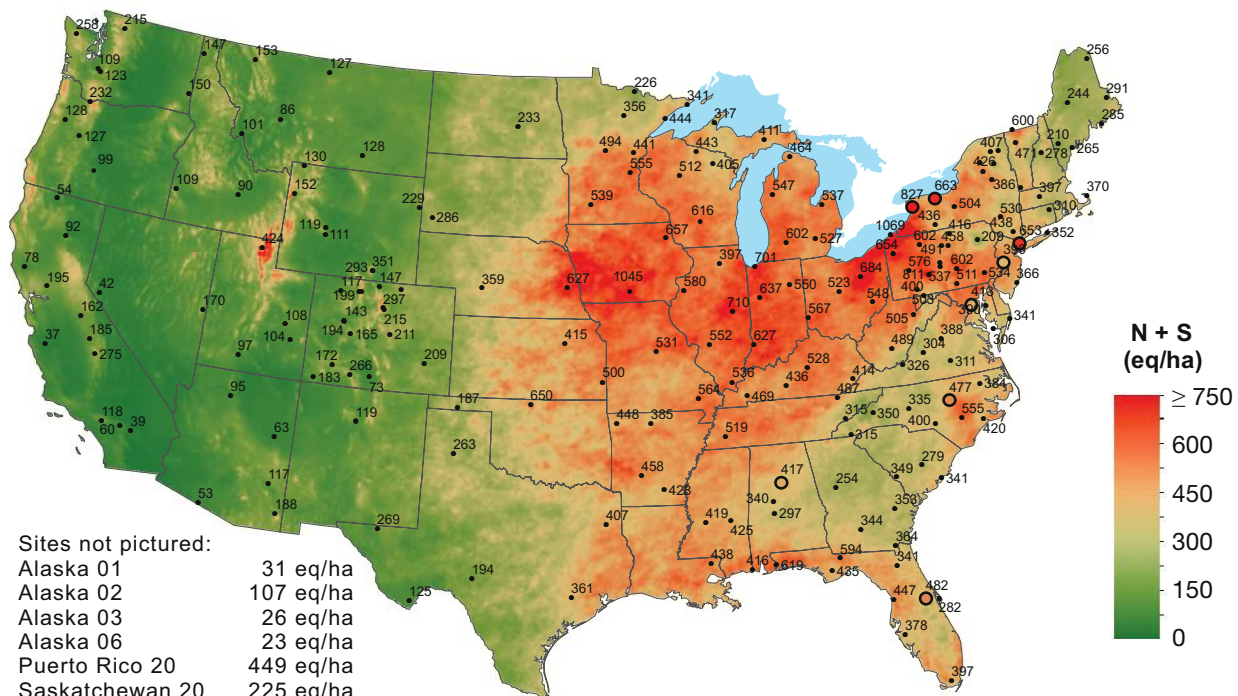
cations. Spatial variability in these species can be seen both on a regional and a national scale. In 2014, 220 of the 261 active sites met NADP completeness criteria. Concentration and deposition maps are included for  $SO_4^{2-}$ ,  $NO_3^-$ ,  $NH_4^+$ , pH,  $Ca^{2+}$ ,  $Mg^{2+}$ ,  $Cl^-$ , and  $Na^+$ . Maps of  $Br^-$  and  $K^+$  are not included in this report, but are available from the NADP website.

Annual 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 (eq/ha).



Sites not pictured:

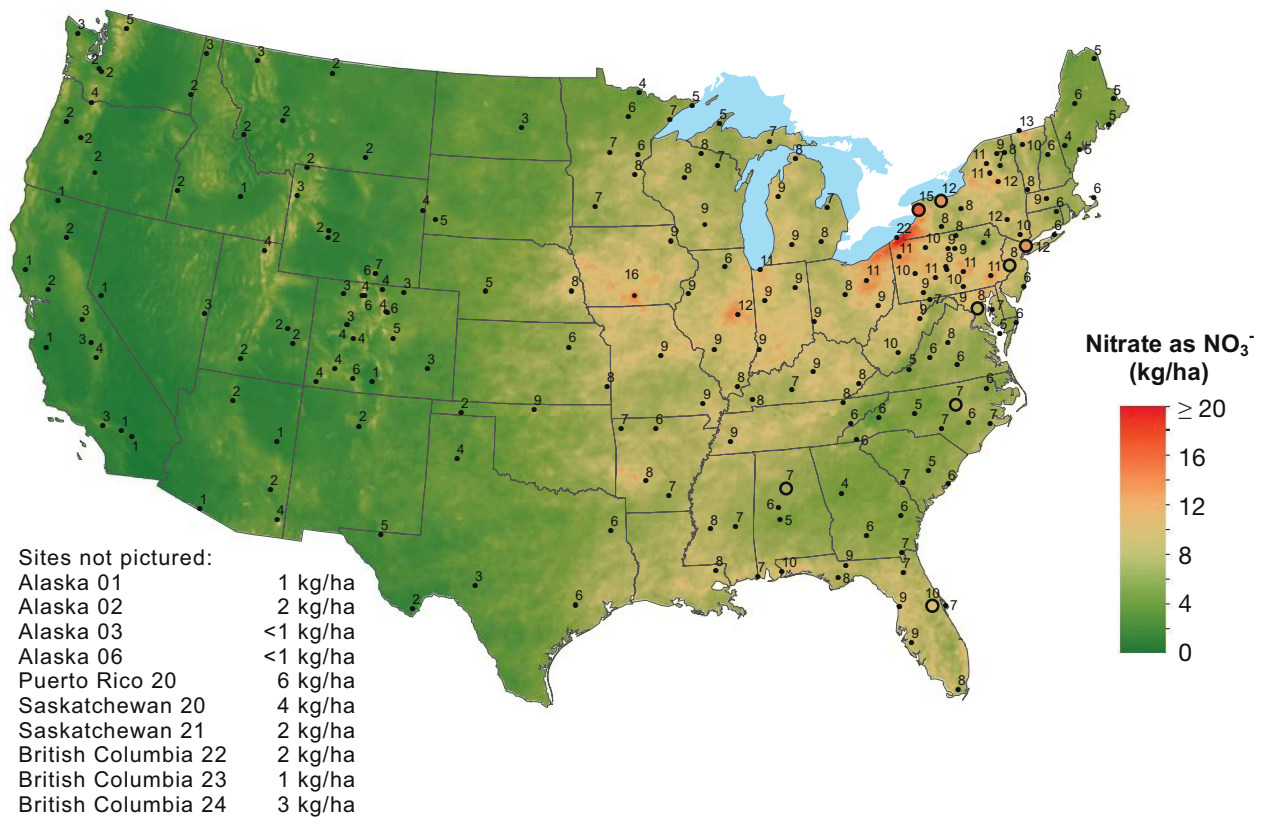
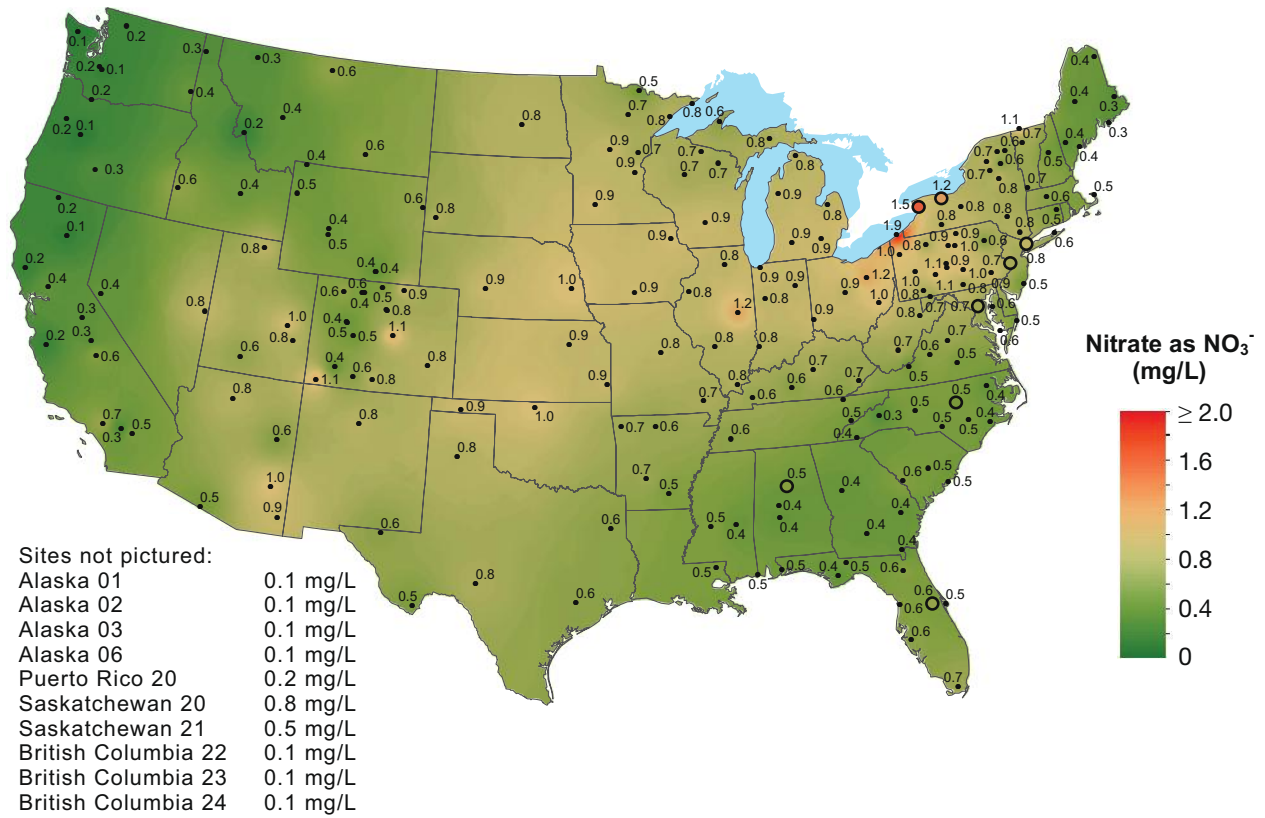
Alaska 01	0.2 kg/ha
Alaska 02	0.6 kg/ha
Alaska 03	0.2 kg/ha
Alaska 06	0.2 kg/ha
Puerto Rico 20	1.8 kg/ha
Saskatchewan 20	2.5 kg/ha
Saskatchewan 21	1.2 kg/ha
British Columbia 22	1.3 kg/ha
British Columbia 23	0.5 kg/ha
British Columbia 24	1.0 kg/ha



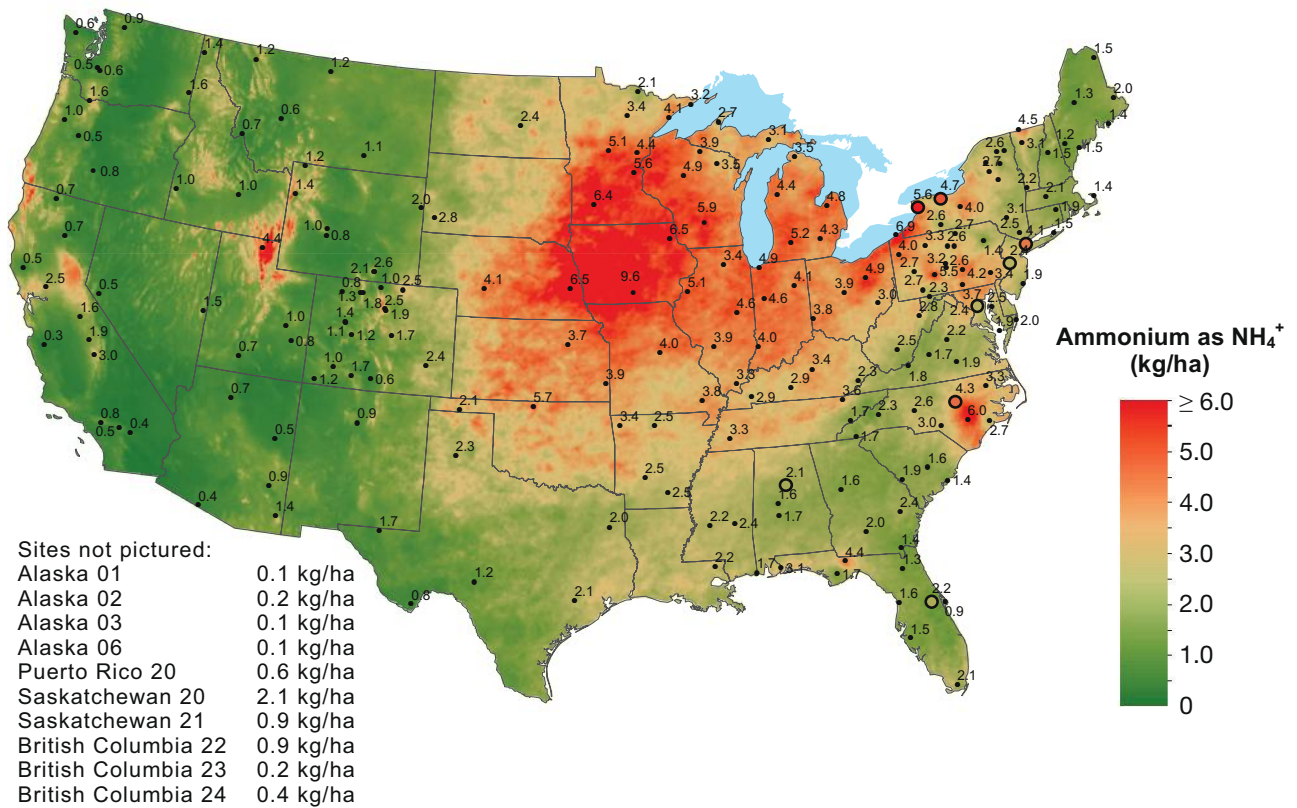
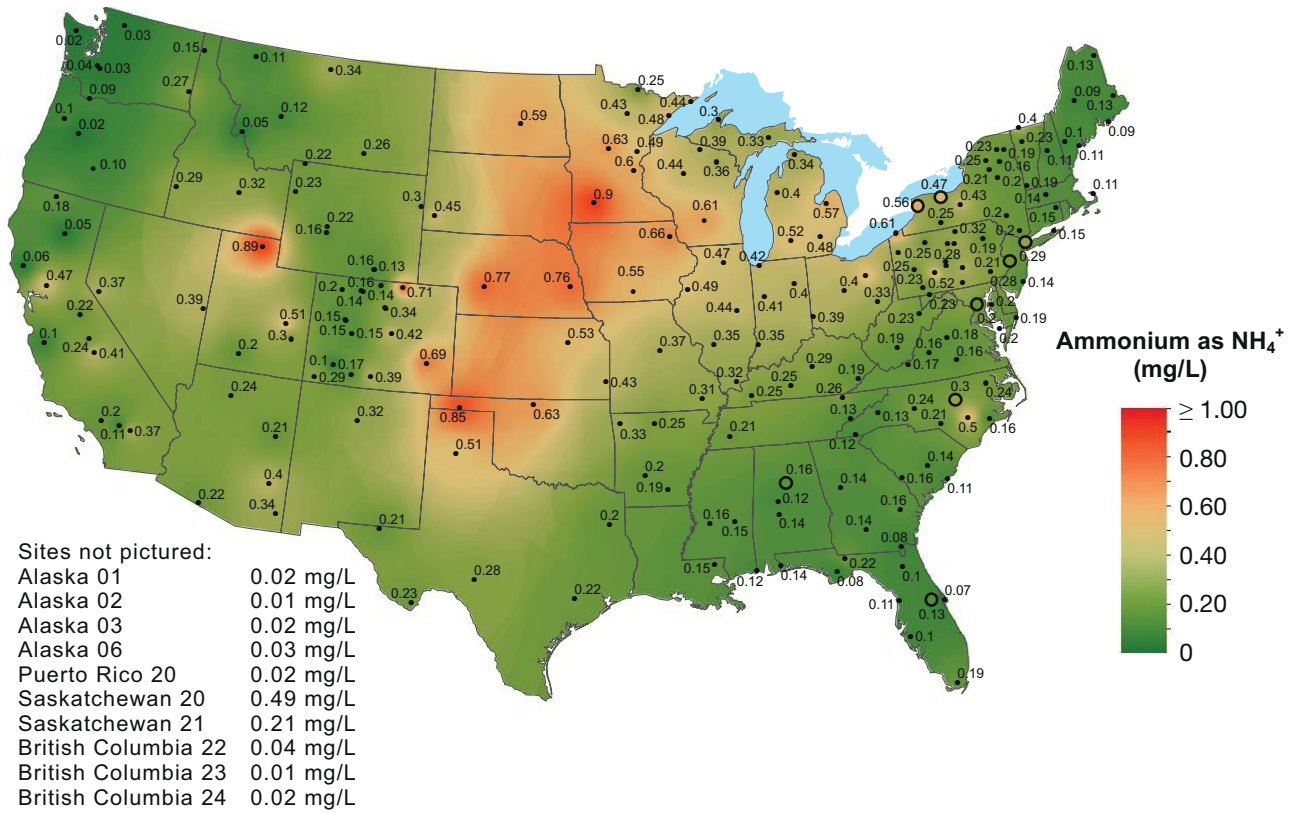
Sites not pictured:

Alaska 01	31 eq/ha
Alaska 02	107 eq/ha
Alaska 03	26 eq/ha
Alaska 06	23 eq/ha
Puerto Rico 20	449 eq/ha
Saskatchewan 20	225 eq/ha
Saskatchewan 21	111 eq/ha
British Columbia 22	543 eq/ha
British Columbia 23	79 eq/ha
British Columbia 24	181 eq/ha

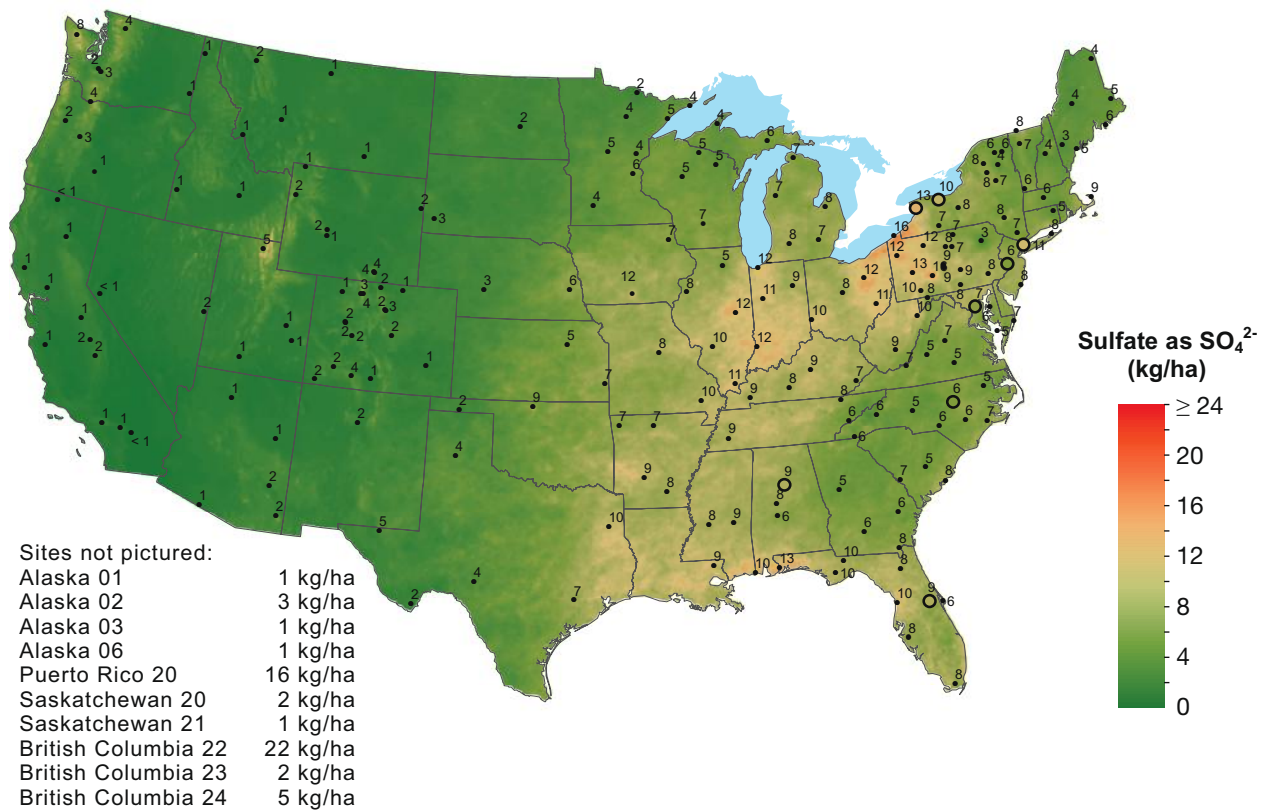
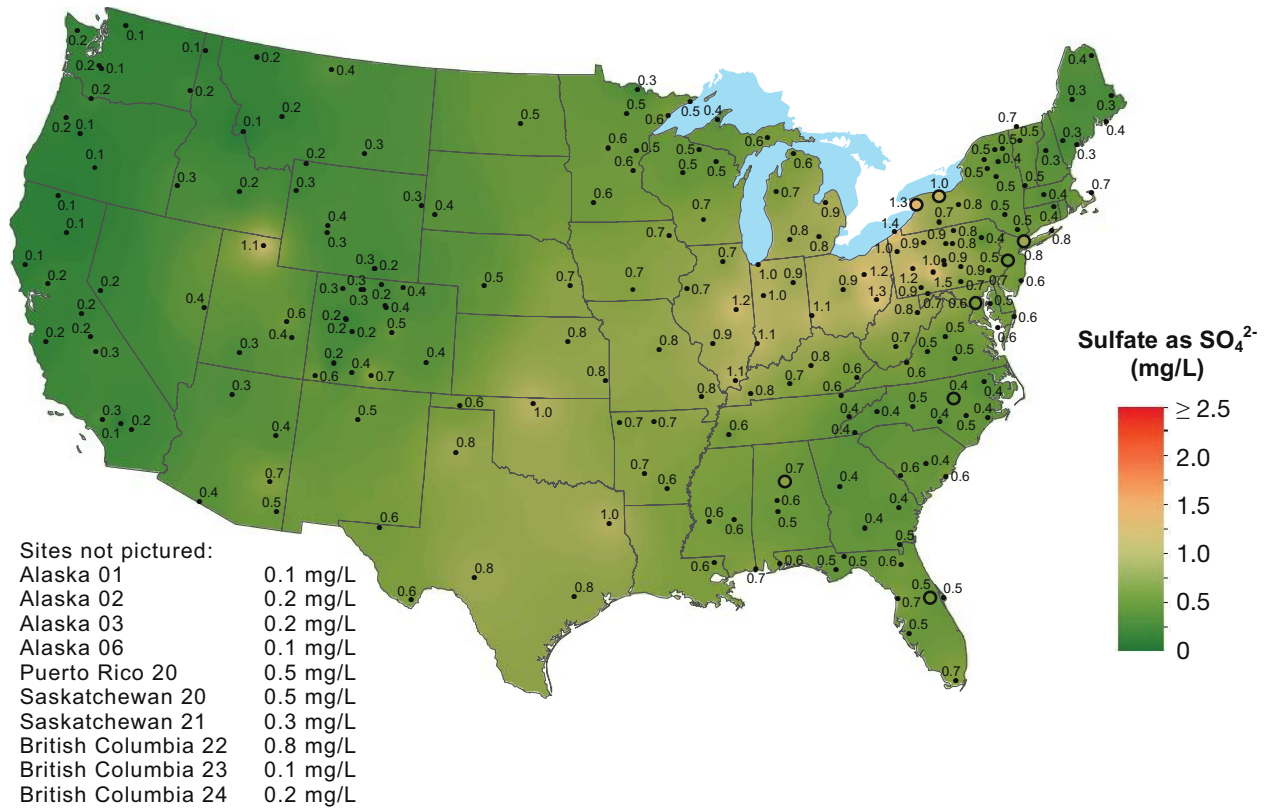
Inorganic nitrogen wet deposition from nitrate and ammonium (top) and nitrogen plus sulfur wet deposition from nitrate, ammonium, and sulfate (bottom), 2014.



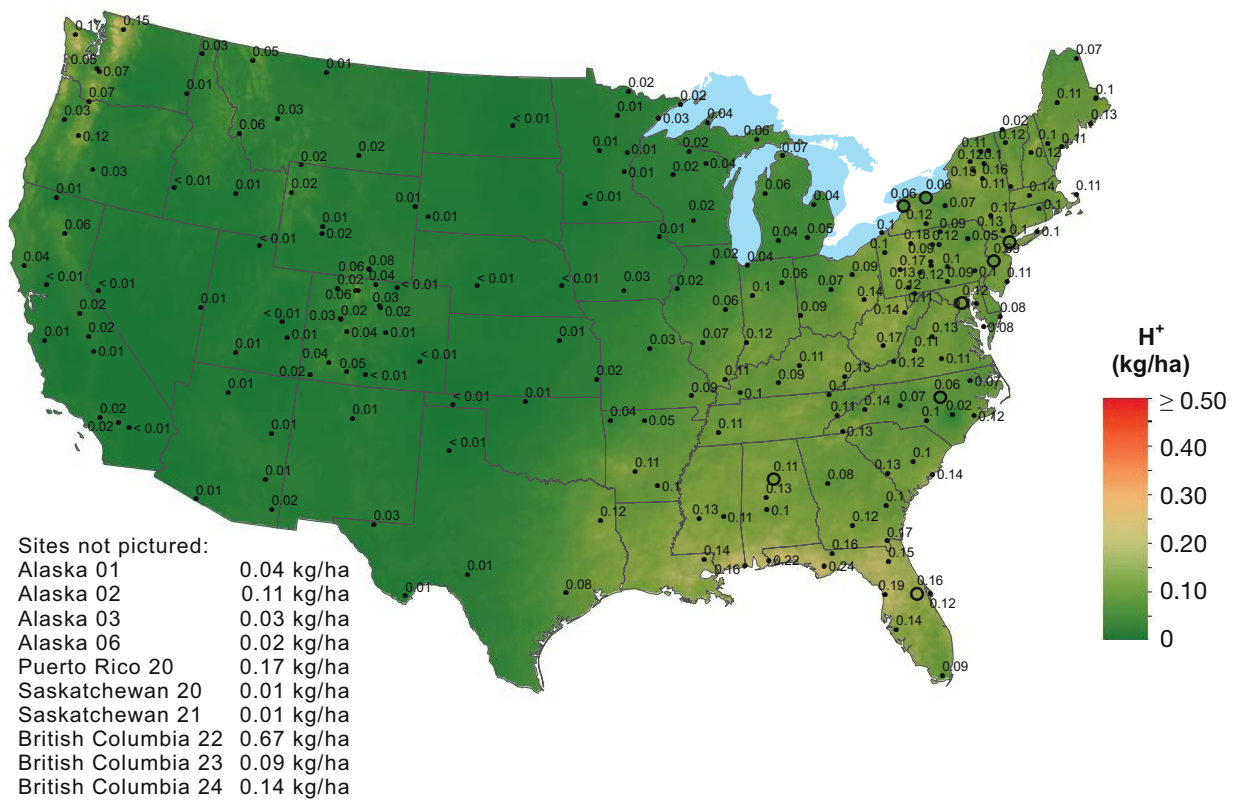
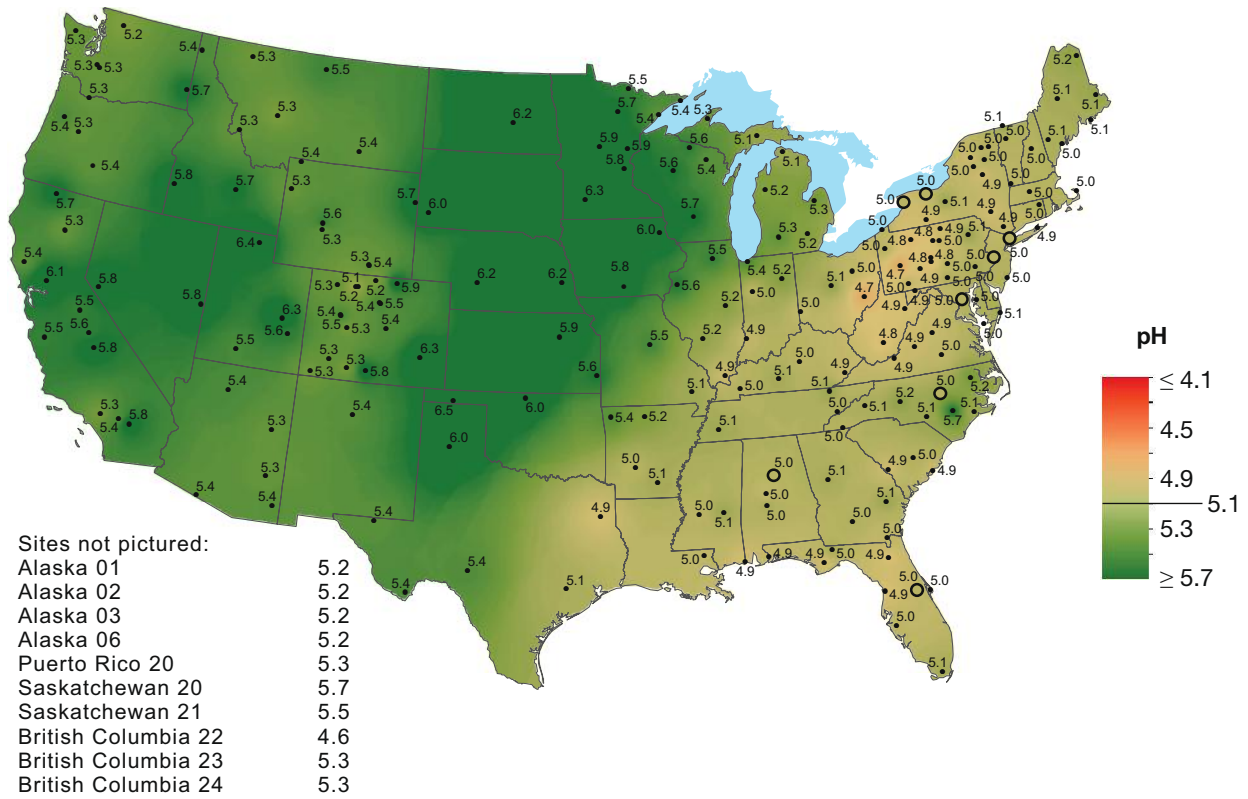
Nitrate ion concentration (top) and wet deposition (bottom), 2014.



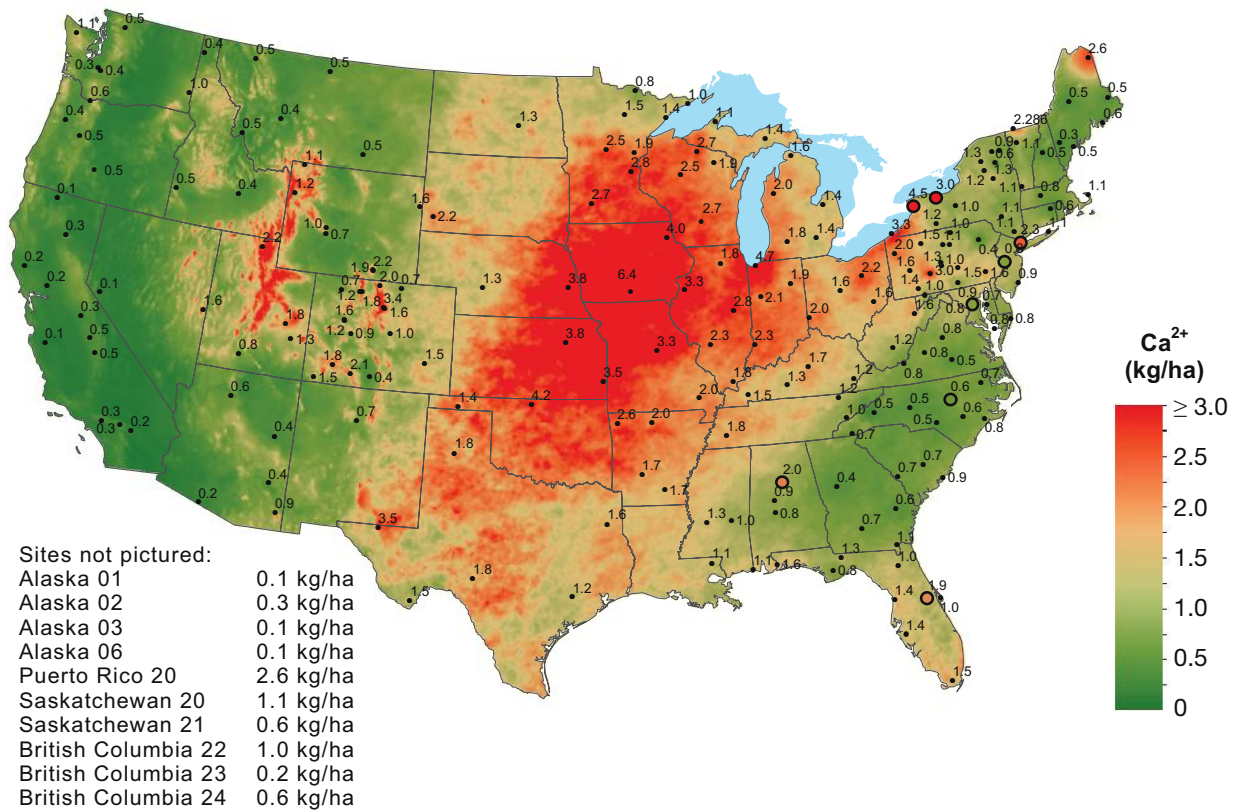
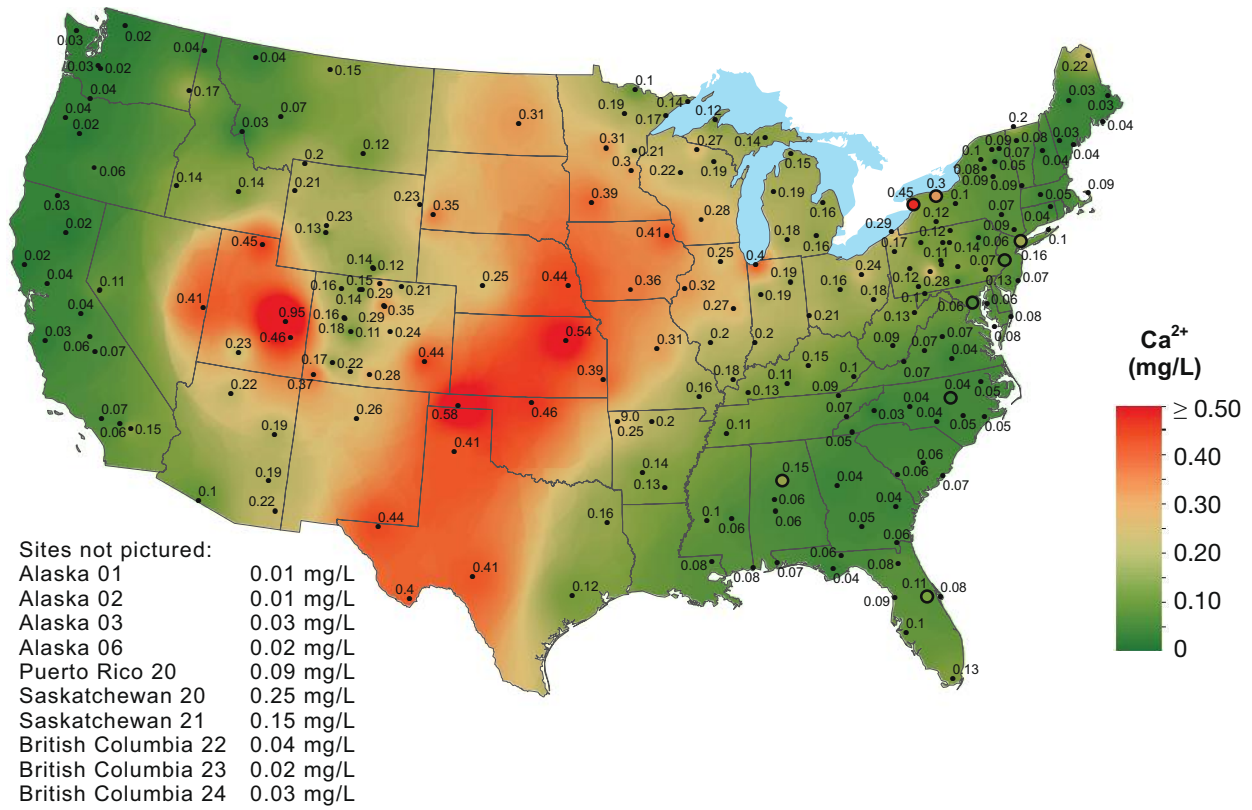
Ammonium ion concentration (top) and wet deposition (bottom), 2014.



Sulfate ion concentration (top) and wet deposition (bottom), 2014.

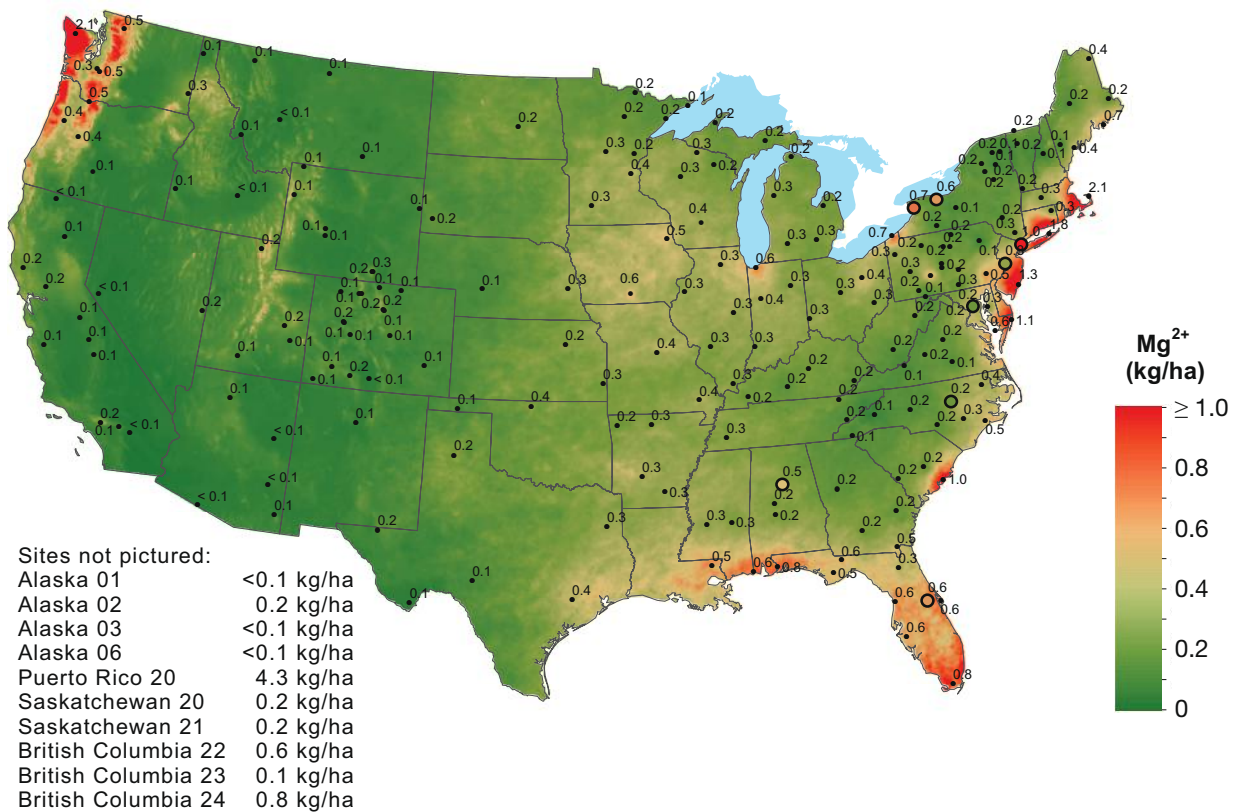
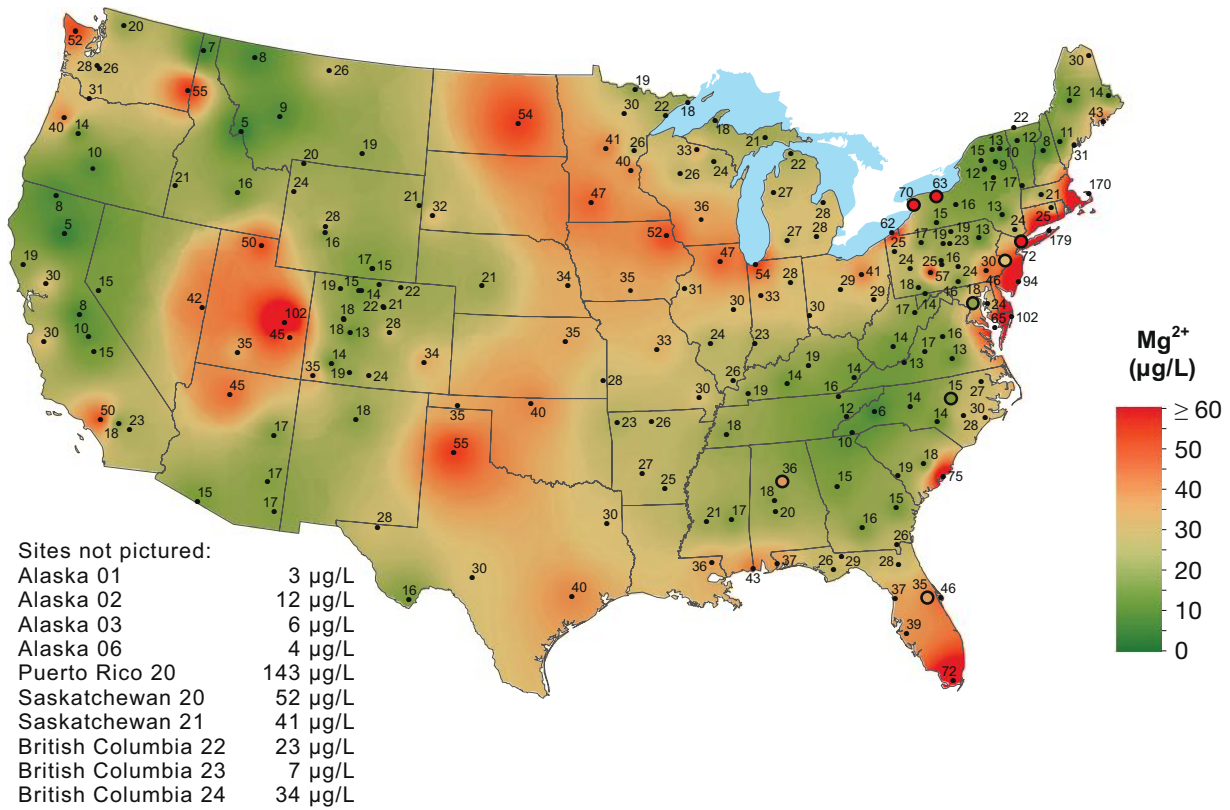


Hydrogen ion concentration as pH (top) and wet deposition (bottom), 2014.  
Typically, a precipitation pH of less than 5.1 is considered acidic.

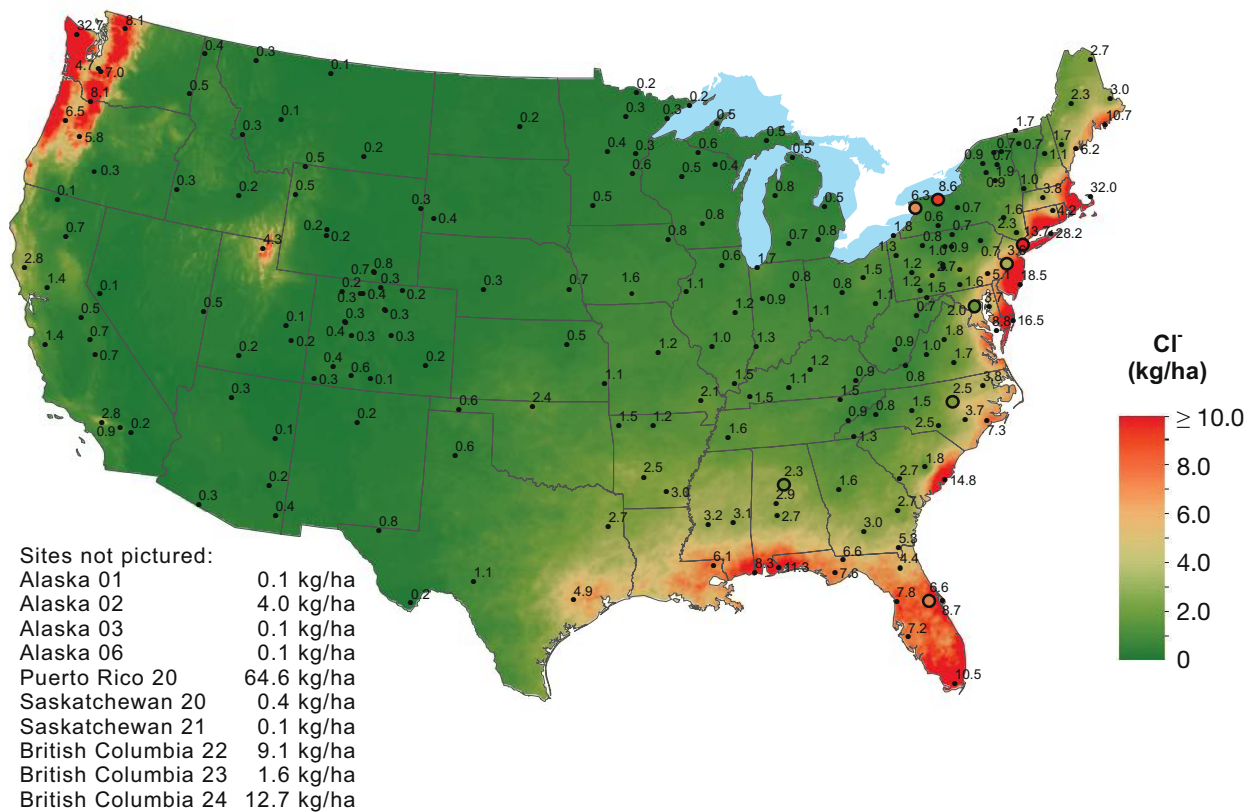
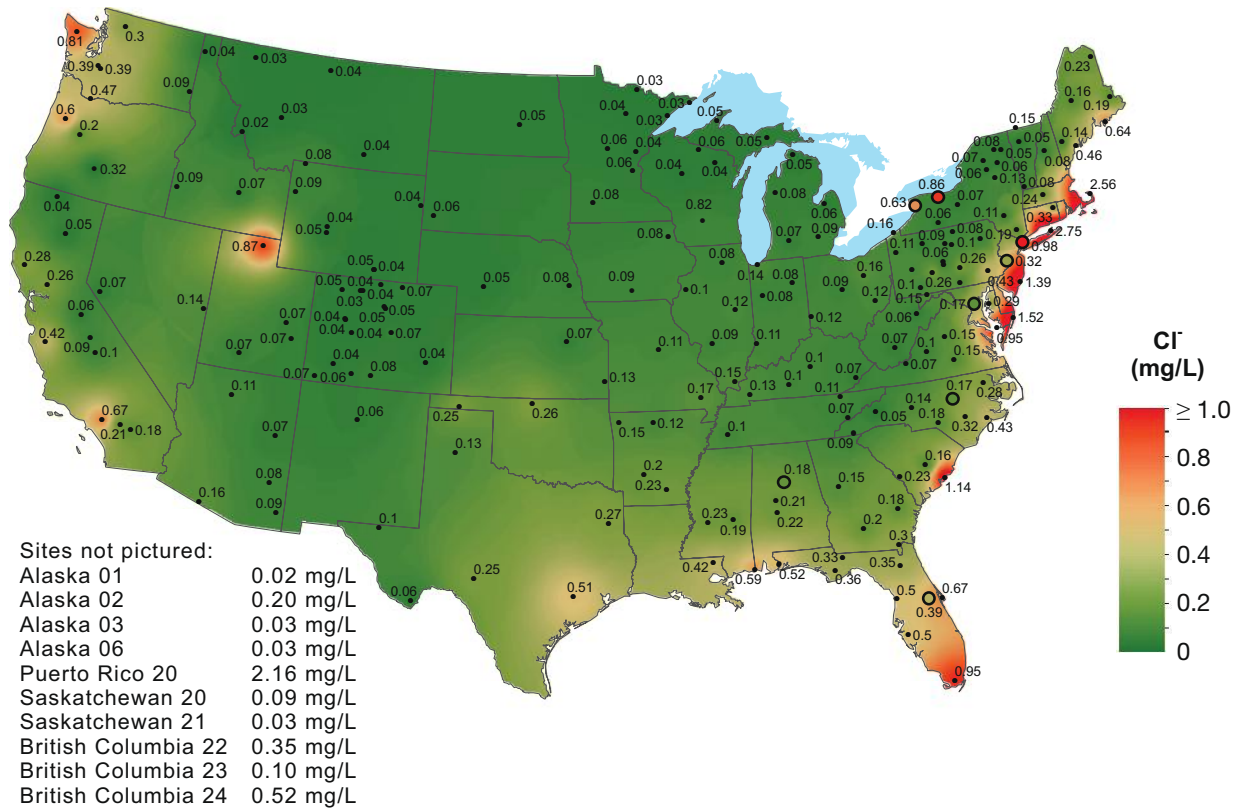


Calcium ion concentration (top) and wet deposition (bottom), 2014.

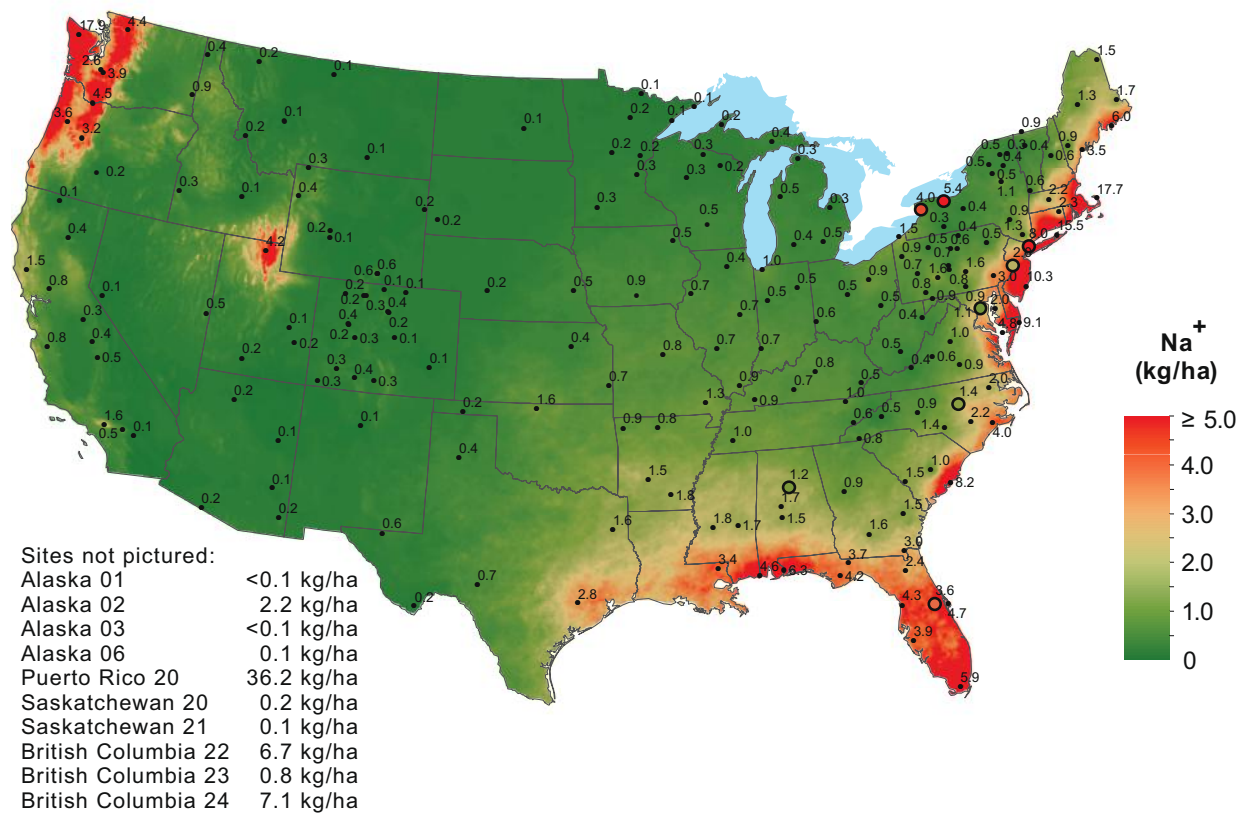
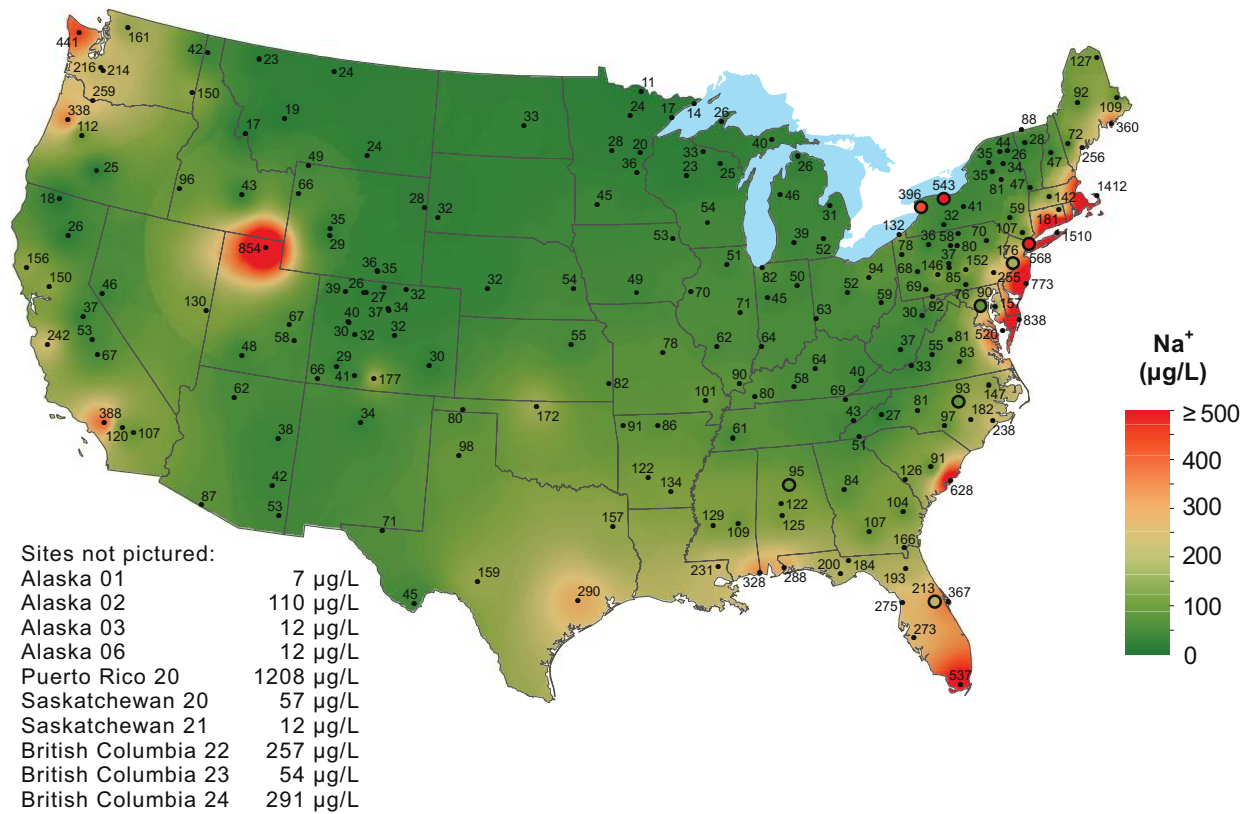




Magnesium ion concentration (top) and wet deposition (bottom), 2014.



Chloride ion concentration (top) and wet deposition (bottom), 2014.



Sodium ion concentration (top) and wet deposition (bottom), 2014.

# 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, such as the NOAA/HYSPLIT fate and transport model. Back trajectories for all AIRMoN samples are provided at <http://nadp.isws.illinois.edu/AIRMoN>. Rapid release of data is an AIRMoN goal.

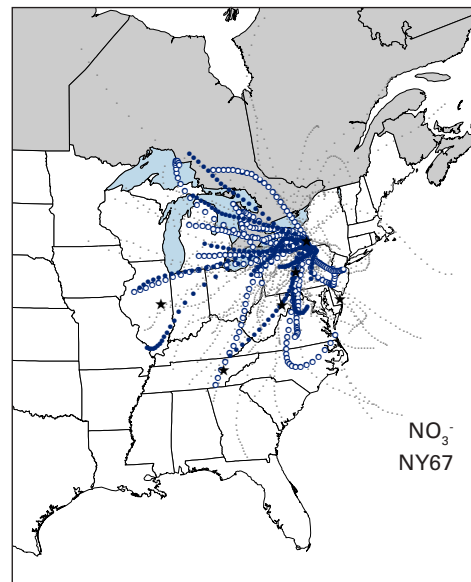
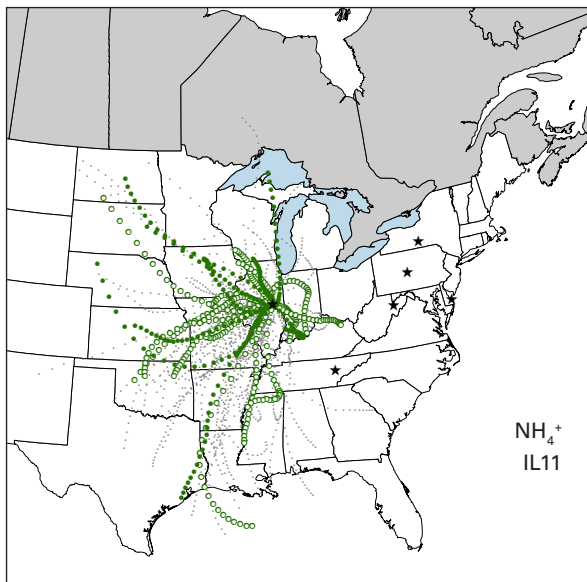
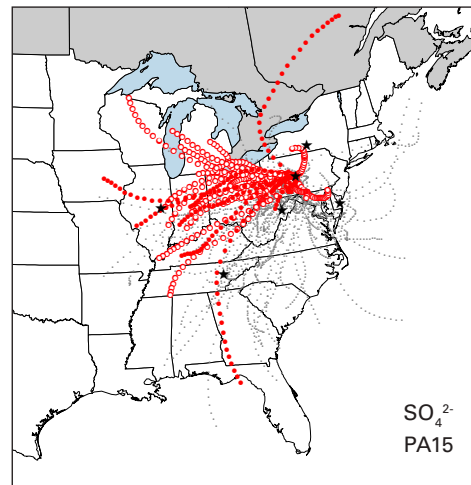
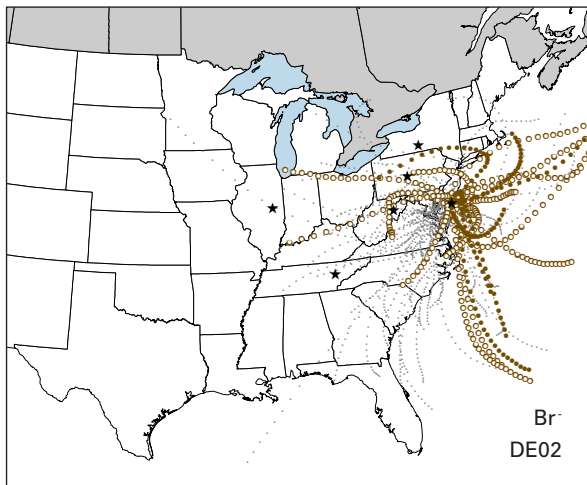
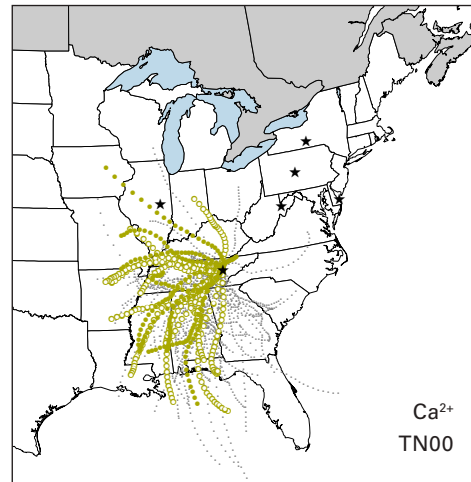
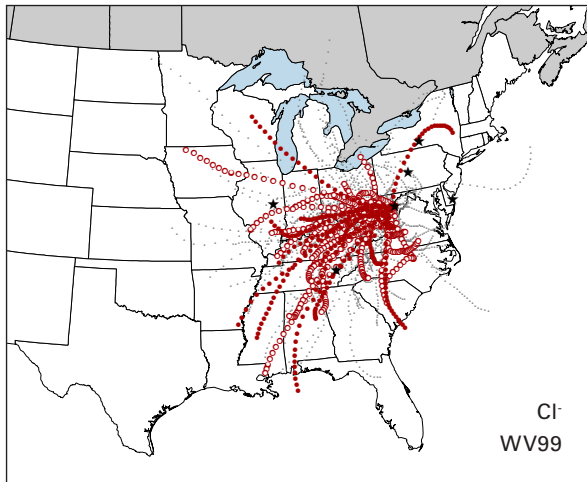
AIRMoN sites are equipped with the same wet-only deposition collector used at NTN sites. All AIRMoN sites operate digital raingages for reporting total precipitation. Each site also has a standard stick-type precipitation gage as a backup.

Samples are refrigerated after collection and are shipped in chilled, insulated containers to the CAL for analysis. Samples remain refrigerated until they are analyzed. Refrigeration retards potential chemical changes, such as with  $H^+$ ,  $NH_4^+$ , and  $PO_4^{3-}$ . Chemical analyses and data screening procedures for AIRMoN and NTN are similar. Data from the AIRMoN are available on the NADP website (<http://nadp.isws.illinois.edu/airmon/>).

The twenty-four hour back trajectory plots (using NOAA's HYSPLIT (Revision 664) model, originating at 1000 meters above each station) on page 21



illustrate the 2014 trajectory paths of the individual chemical components found in NADP wet deposition samples reaching the individual sites. The trajectories are shaded to indicate the relative concentration of each analyte: filled color circles represent samples with concentration greater than the 90th percentile of all valid samples in 2014; open circles represent the 75th to 90th percentile sample trajectories, and the small grey dots represent the 1st to 75th percentile sample trajectories. Six different chemical component concentrations are represented at the individual AIRMoN sampling locations of DE02, IL11, NY67, PA15, TN00, and WV99. Analytes were selected based on site location and proximity to sources.



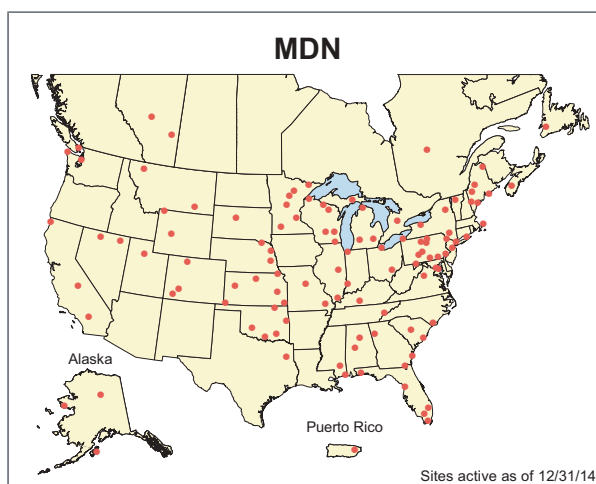
Twenty-four hour back trajectory pathways, originating at 1000 meters above each AIRMoN station at the time of precipitation. Symbols represent the relative concentration of each analyte: filled color circles represent samples with concentrations greater than the 90th percentile for all valid samples in 2014; open circles represent the 75th to 90th percentile sample trajectories, and the small grey dots represent the 1st to 75th percentile sample trajectories.

# 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. MDN sites follow standard procedures and use approved 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 2014, the Yorkville site in northwestern Georgia (GA40), the Birmingham site in Alabama (AL19), and the Pensacola, Florida site (FL96) collected daily samples. Chemical analysis of the MDN samples is performed by the Mercury Analytical Laboratory (HAL) at Eurofins Frontier Global Sciences, Inc., Bothell, Washington.

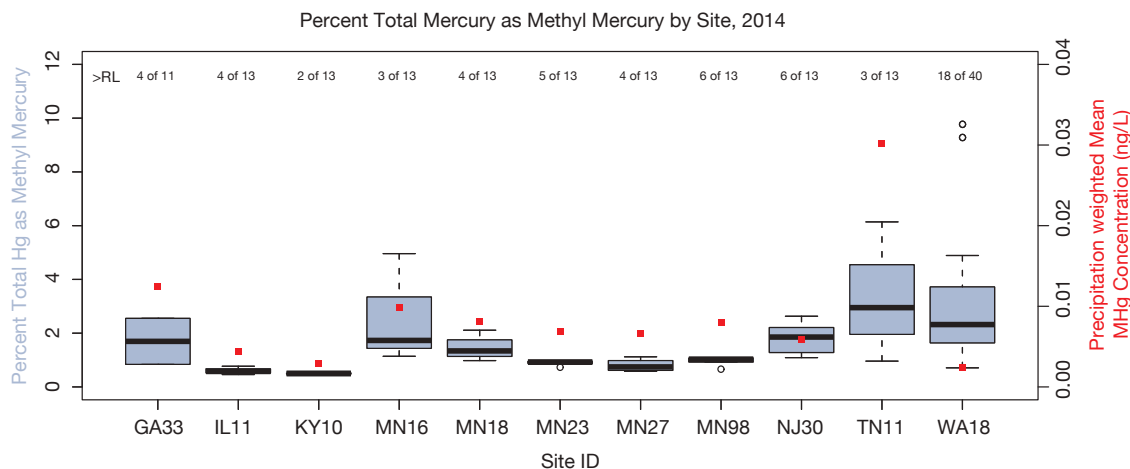
All MDN samples are analyzed for total mercury concentration. The HAL reviews field and laboratory data for accuracy and completeness, and identifies samples that were mishandled, compromised by equipment failure, or grossly contaminated. Data from the MDN are available on the NADP website (<http://nadp.isws.illinois.edu/mdn>).

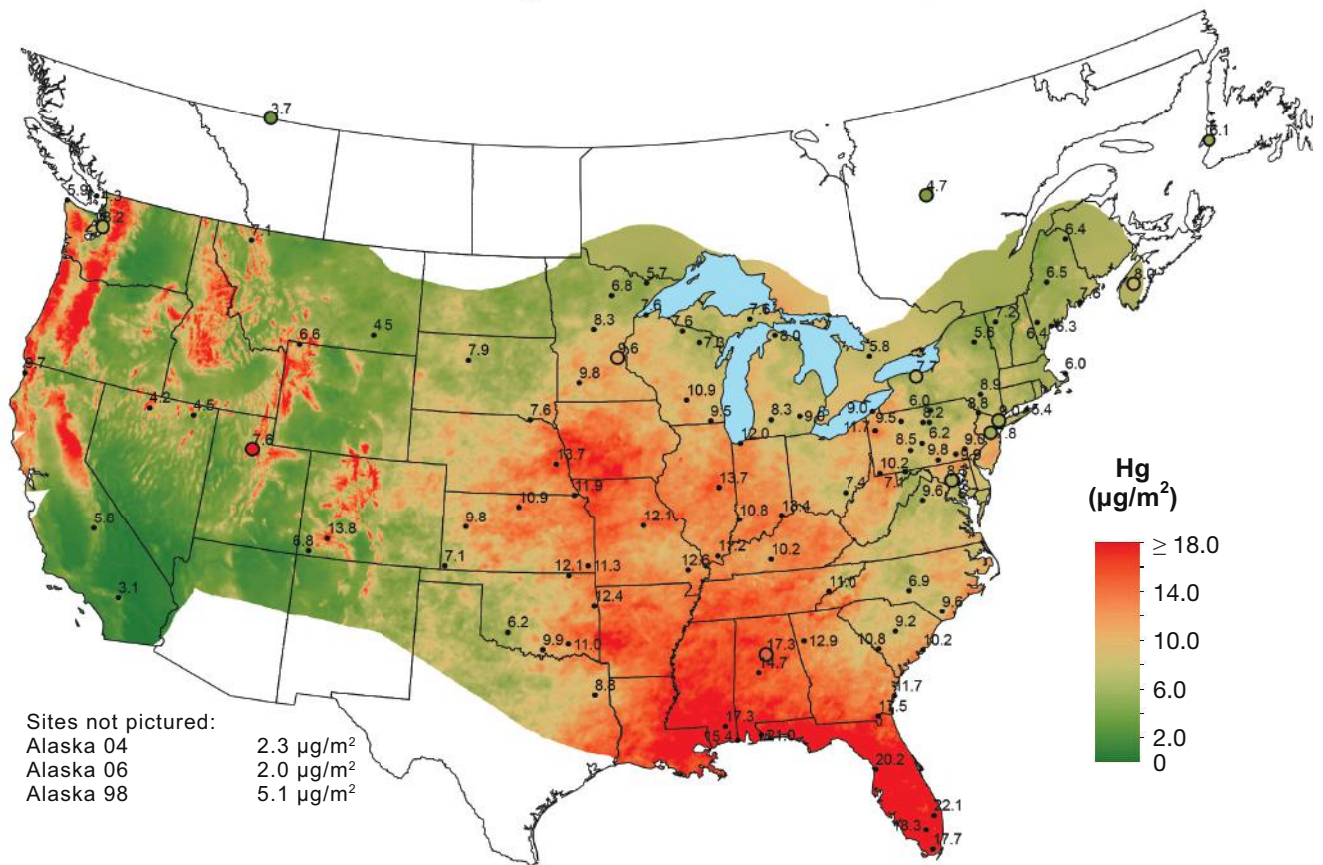
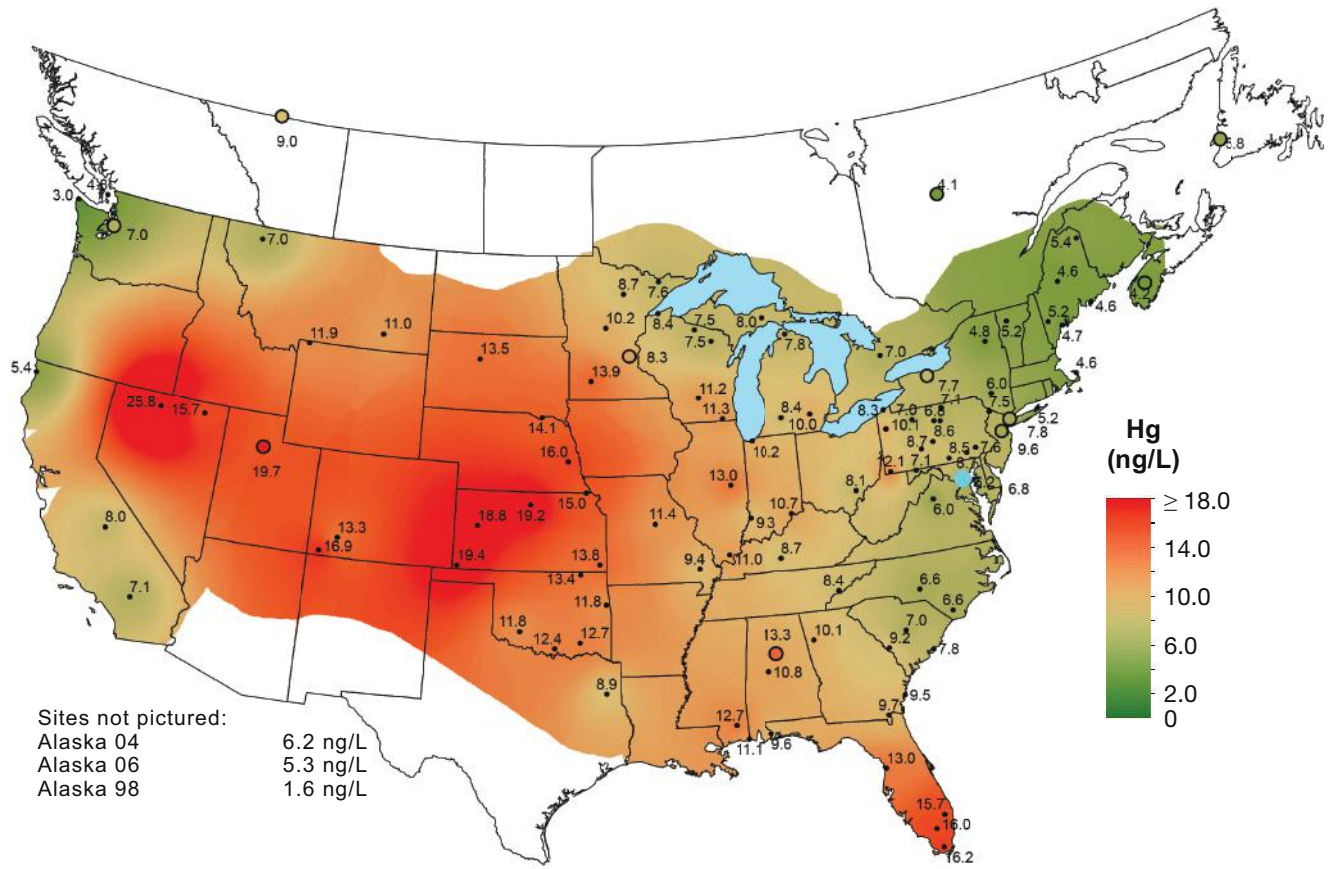
Subsamples of MDN precipitation were analyzed for methyl mercury (MeHg) at 11 NADP sites. Details about sample collection and analysis are available at the NADP website.



## MDN Maps and Graphs

The maps on page 23 show spatial variability in the precipitation-weighted mean concentration and wet deposition of total mercury. Only sites meeting NADP completeness criteria are included. In 2014, 107 of 113 active sites met these criteria. Spatial variability of total mercury can be seen on a regional and a national scale. The graph below shows the distribution of methyl mercury concentrations (shaded boxes) as percentage of total mercury. The precipitation-weighted mean of the methyl mercury concentrations in ng/L is represented by the red dot.





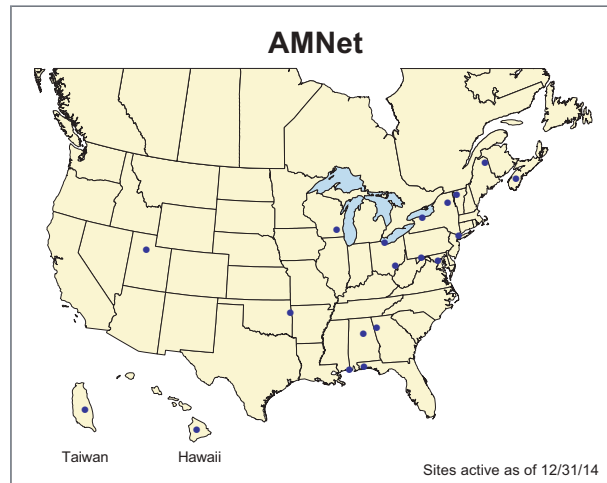
Total mercury concentration (top) and wet deposition (bottom), 2014.

# Atmospheric Mercury Network (AMNet)

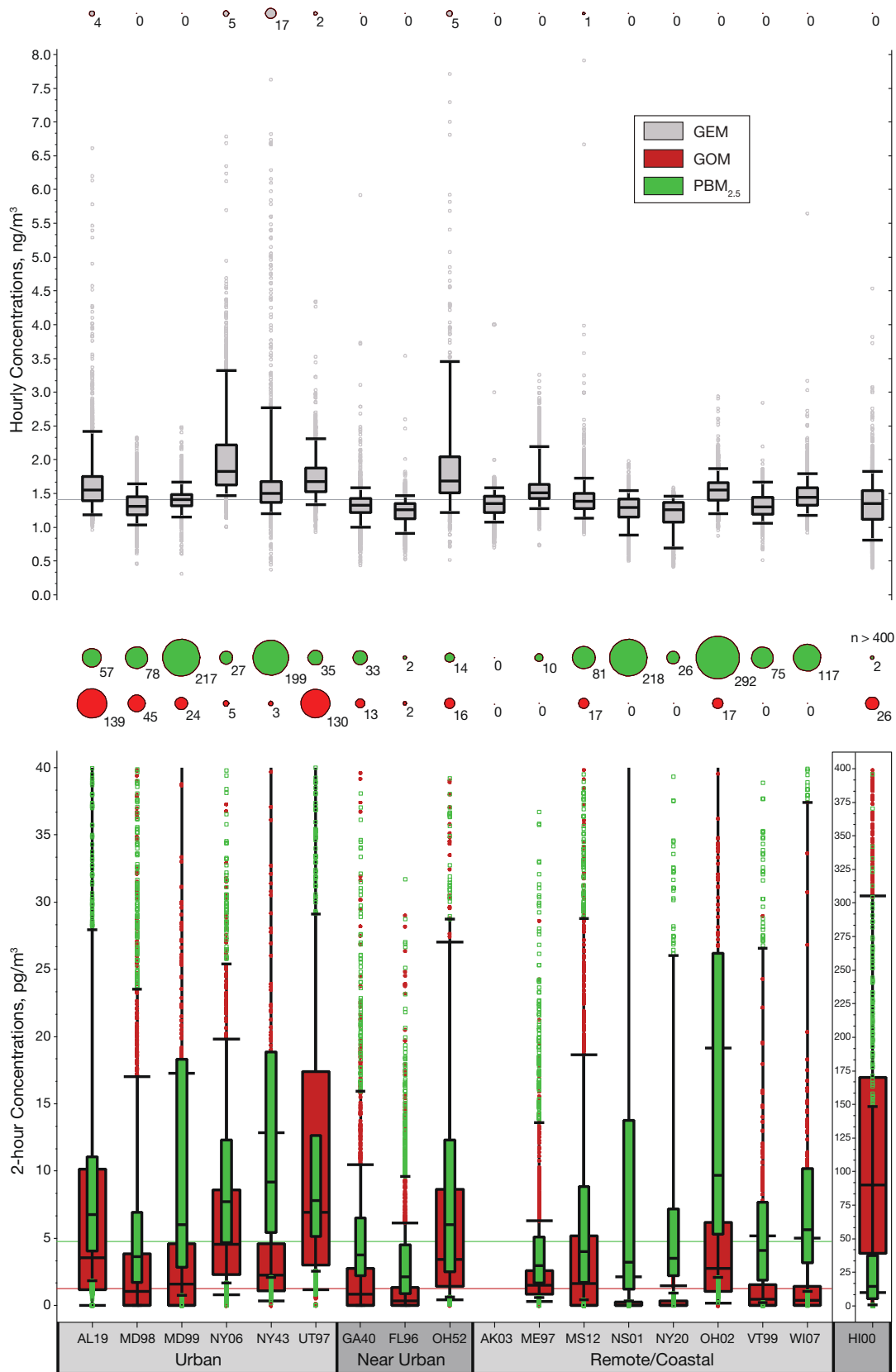
AMNet sites measure atmospheric mercury that contributes to mercury deposition using automated, continuous measurement systems. Measurements are made using NADP standardized methods, and are quality assured.

AMNet measurements are made continuously (five-minute and two-hour averages). Data are qualified and averaged to one-hour (gaseous elemental mercury, GEM) and two-hour values (gaseous oxidized mercury, GOM, and particulate bound mercury,  $PBM_{2.5}$ ). As of December 2014, there were 20 AMNet sites. Data from the AMNet are available on the NADP website (<http://nadp.isws.illinois.edu/amn/>).

The figures on page 25 show the distribution of atmospheric mercury concentrations for each site in 2014. The top figure shows the distribution of GEM (grey shaded area) in nanograms per cubic meter ( $ng/m^3$ ). The bottom figure shows the distribution of two-hour atmospheric concentrations of GOM (red shaded area), and  $PBM_{2.5}$  (green shaded area) in picograms per cubic meter ( $pg/m^3$ ).







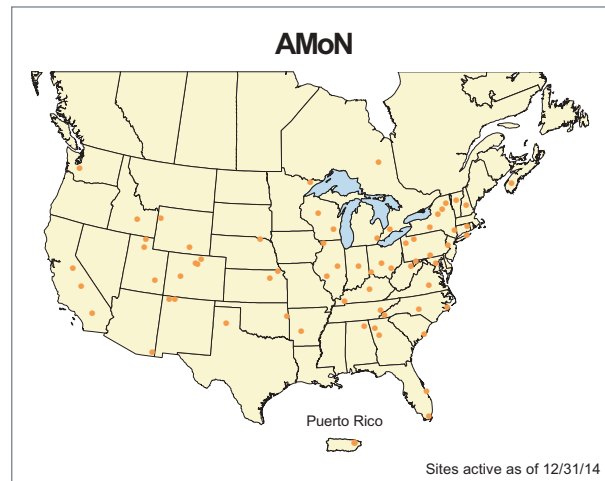
Hourly GEM concentrations in ng/m<sup>3</sup> for each AMNet site (top) and 2-hour GOM and PBM<sub>2.5</sub> concentrations in pg/m<sup>3</sup> for each AMNet site (bottom), 2014. The bubble charts indicate the number of valid observations for GEM values above 8 ng/m<sup>3</sup>, and GOM and PBM<sub>2.5</sub> above 40 pg/m<sup>3</sup> (400 pg/m<sup>3</sup> for H100), the upper limit shown with the box plots. Horizontal lines in each graph represent the respective 2014 median values. Note the different scale for H100 in the bottom plot.

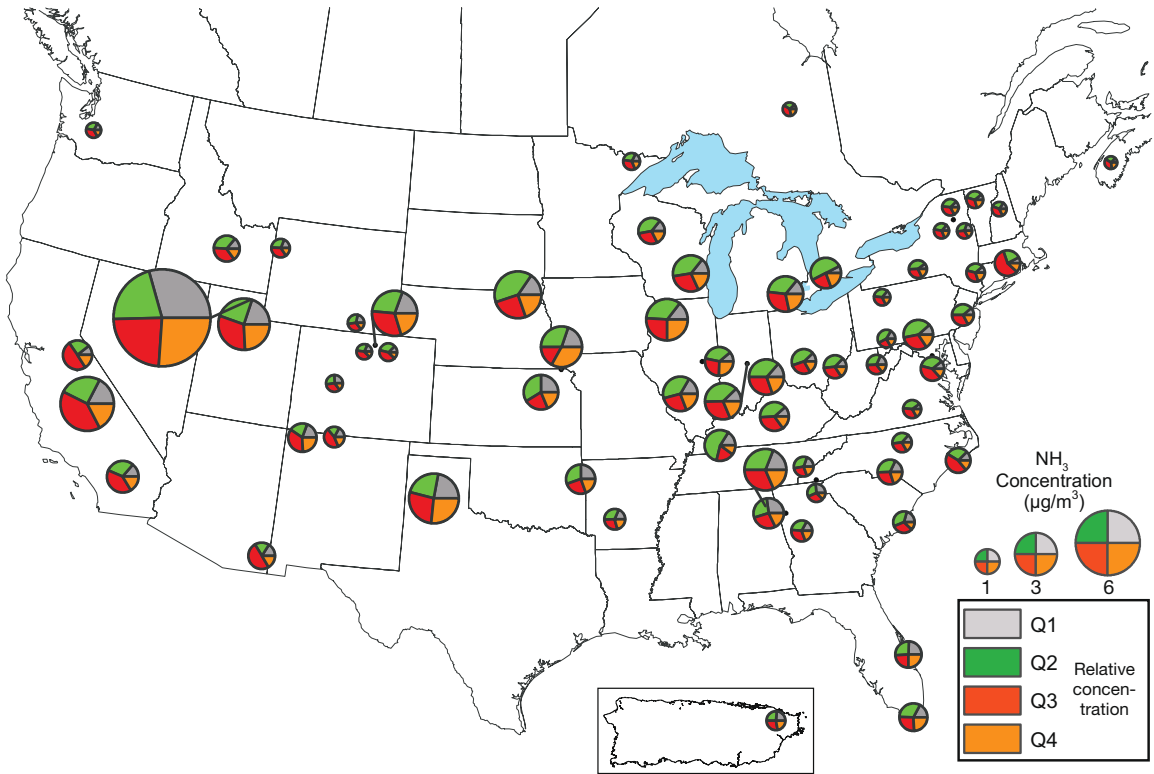
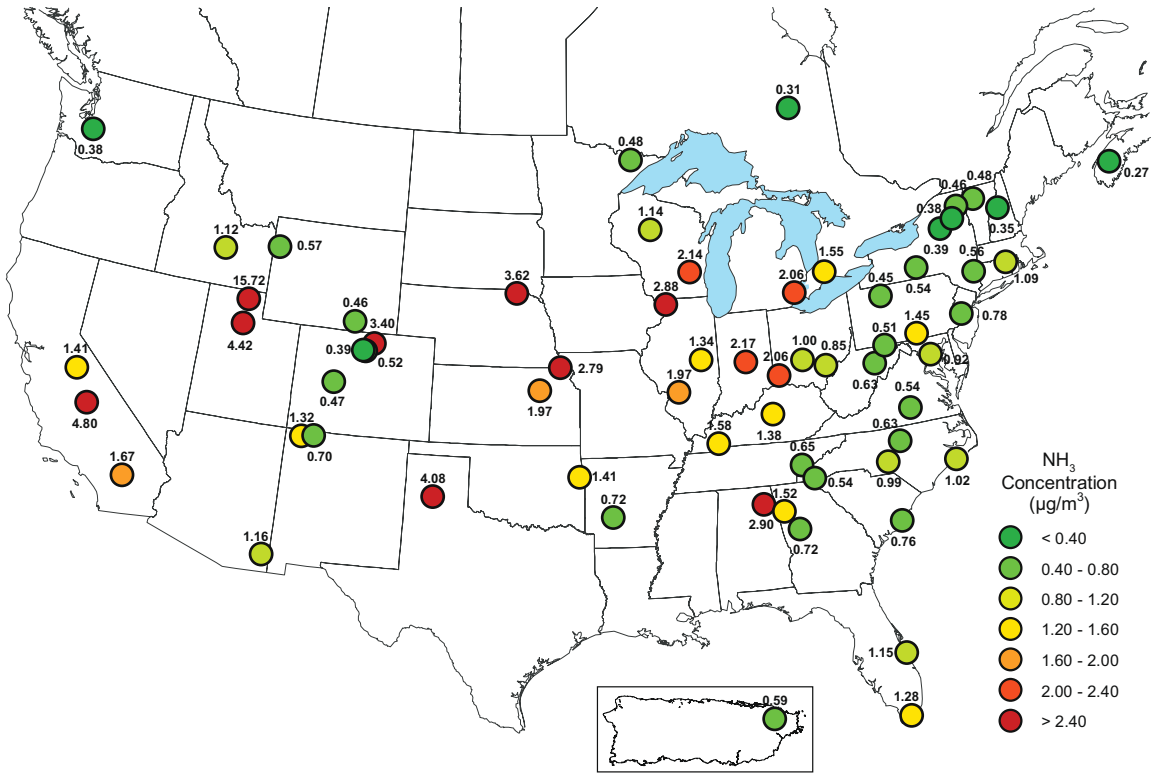
# Ammonia Monitoring Network (AMoN)

The AMoN measures atmospheric concentrations of ammonia ( $\text{NH}_3$ ) gas. The network uses one passive diffusion-type sampler. This allows for cost-effective, straightforward, and simple measurements. Observations are made over a two-week period with some sites measuring in triplicate. This provides an integrated and quality-assured estimate of ammonia in the air. These data are used to assess both long-term  $\text{NH}_3$  trends, changes in atmospheric chemistry, and provide information for model development and verification.

As of December 2014, there were 68 AMoN sites. Data from the AMoN are available on the NADP website (<http://nadp.isws.illinois.edu/amon/>).

The figures on page 27 show the distribution and seasonality of gaseous ammonia concentrations for each site meeting completeness criteria. In 2014, 65 of 68 active sites met these criteria. In the top figure, circles represent annual average concentrations in micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ) at each site. In the bottom figure, the relative concentration for each site is shown for each calendar quarter. The size of the wedge is the relative percentage for the quarter. The area of the pie chart is proportional to the annual average for the site.





**Average ammonia concentrations as measured by AMoN (top), and quarterly relative percentage (Q1 = January, February, March, etc.) for each AMoN site (bottom), 2014. Size of the symbol in the bottom plot is relative to the annual concentration.**



## National Atmospheric Deposition Program

The NADP is the 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 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. 2012-39138-20273. 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 program sponsors or the University of Illinois.

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All NADP data and information, including color contour maps in this publication, are available free of charge 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](mailto:nadp@isws.illinois.edu).

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