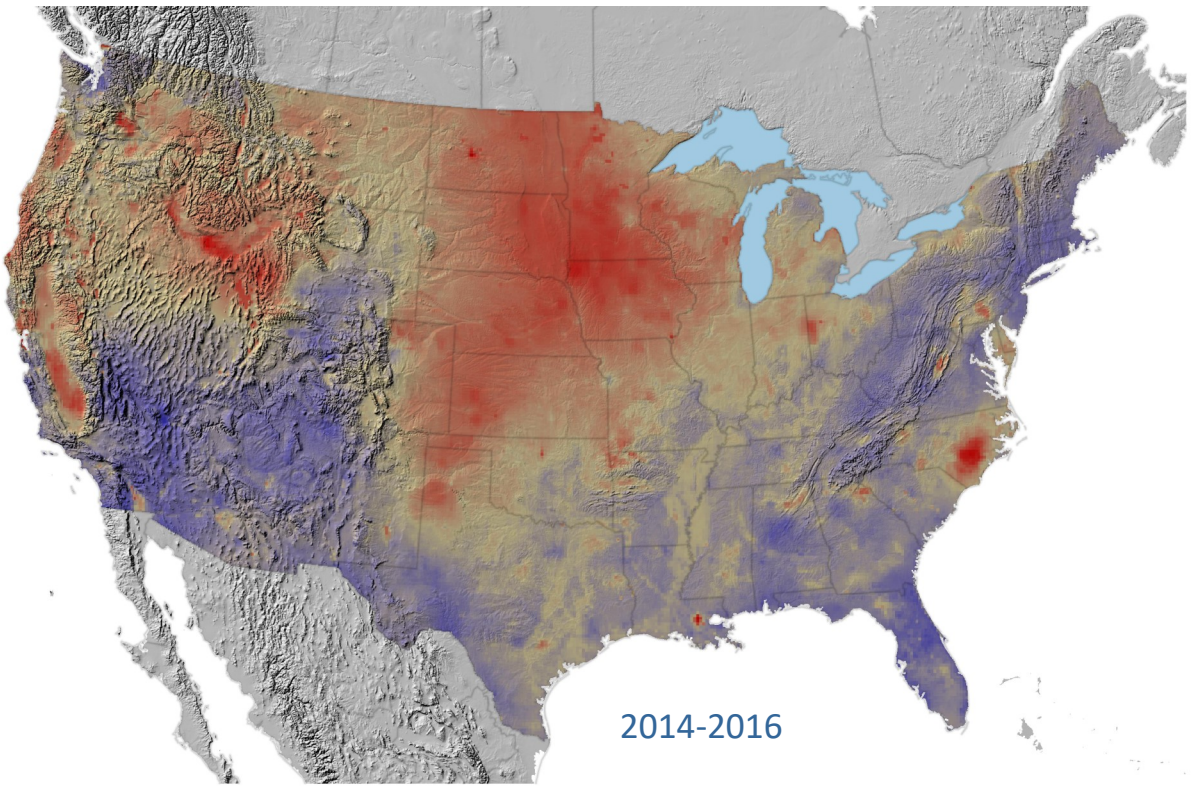
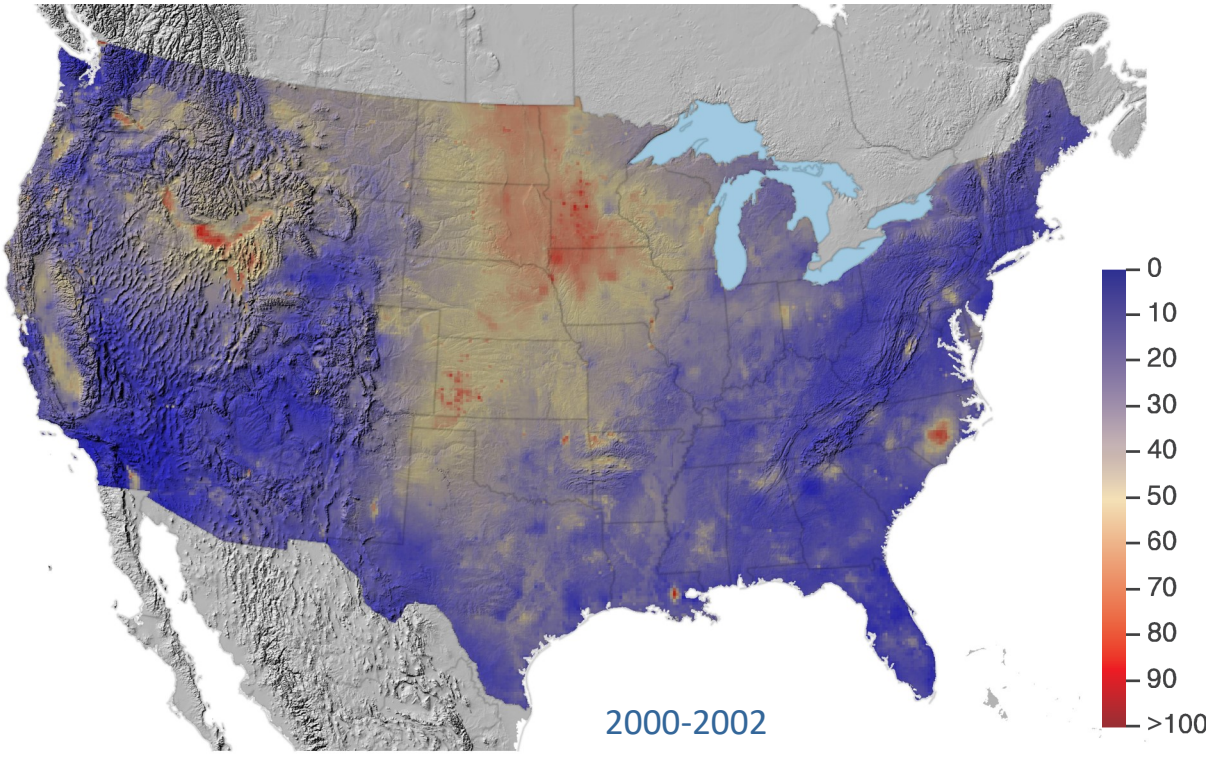
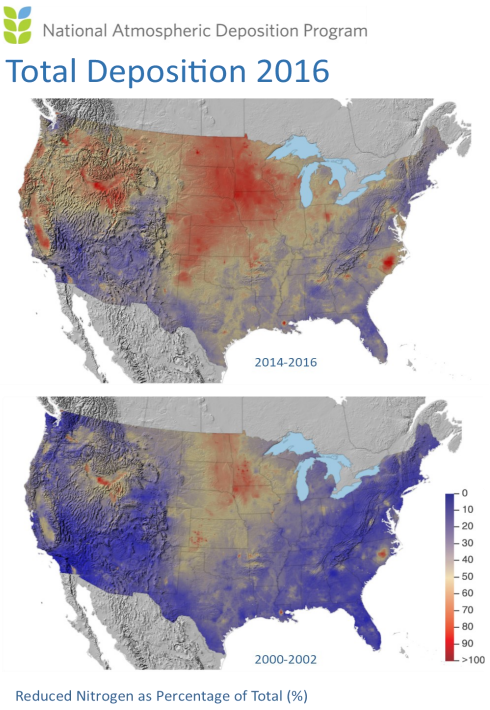
National Atmospheric Deposition Program

Total Deposition 2016





Reduced Nitrogen as Percentage of Total (%)



On the cover: Comparison of the 3-year averages of reduced nitrogen deposition as a percentage of total reactive nitrogen deposition for the periods 2000-2002 and 2014-2016. Significant reductions in oxidized nitrogen deposition have occurred over the last decade due to implementation of emission control programs for both the power and transportation sectors, whereas emissions and deposition of reduced forms of nitrogen have held steady or increased during the same time period.

Suggested Acknowledgement and Citation:

Data users that present and/or publish research based on total deposition values derived from this multi-organization effort should acknowledge the Total Deposition (TDep) Science Committee and the National Atmospheric Deposition Program (NADP). A suggested acknowledgement is:

"We acknowledge the Total Deposition (TDep) Science Committee of the National Atmospheric Deposition Program (NADP) for their role in making the TDep data and maps available."

To cite data or maps from this summary, please use the following citation:

National Atmospheric Deposition Program, 2019. Total Deposition 2016 Annual Map Summary. Wisconsin State Laboratory of Hygiene, University of Wisconsin, WI.

Contents

About the Total Deposition Maps

In October 2011, the National Atmospheric Deposition Program (NADP) Executive Committee formed the Total Deposition (TDep) Science Committee. The mission of TDep is to improve estimates of atmospheric deposition by advancing the science of measuring and modeling atmospheric wet, dry, and total deposition of species such as sulfur, nitrogen and mercury by providing a forum for the exchange of information on current and emerging issues within a broad multi-organization context including atmospheric scientists, ecosystem scientists, resource managers, and policy makers. For more information regarding TDep, please visit the NADP-TDep web page at http://nadp.slh.wisc.edu/committees/tdep.

What is Total Deposition?

Total deposition fluxes are derived from summing wet and dry deposition. Members of this multi-organization committee worked to develop a "hybrid approach" to mapping total deposition that combines measured and modeled values. One of the initial goals of TDep was to provide estimates of total sulfur and nitrogen deposition across the U.S. for use in critical loads and other assessments, where deposition results in the acidification and eutrophication of ecosystems. Measured values are given more weight at the monitor locations, while modeled data are used to fill in spatial gaps and provide information on chemical species that are not measured by routine monitoring networks. One of the main advantages to this approach is that it will provide continuous spatial and temporal coverage of total deposition estimates in the U.S. (beginning in 2000), which until this point, have been unavailable.

Methodology

The original method was published in:

Schwede, D.B. and G.G. Lear, 2014. A novel hybrid approach for estimating total deposition in the United States, Atmospheric Environment, 92, 207-220.

Updates to the methodology have occurred since the publication of the manuscript and will continue to occur as the science evolves and new information is available. A Revision History and other important information are available at

ftp://ftp.epa.gov/castnet/TDep/Total_Deposition_Documentation_current.pdf .

In brief, the method for making TDep maps is as follows:

- Precipitation amounts (p. 8) are obtained by combining measured values of precipitation from NADP networks with precipitation estimates from the Parameter-elevation Regression on Independent Slopes Model (PRISM).
- Wet deposition values are the product of measured values of precipitation chemistry from NADP networks and the precipitation amount calculated above.

- Dry deposition values are obtained by combining measured air concentration data, principally from rural locations with CASTNET sites (https://www.epa.gov/castnet), with modeled concentrations and deposition velocities from the Community Multiscale Air Quality (CMAQ) model. In general, where measurements are available modeled values have been bias adjusted using measured concentrations. However, modeled Ammonia values have not been bias adjusted because there is a nonlinear relationship between Ammonia concentration and the bi-directional deposition velocity.

- Deposition values for unmeasured species (i.e., dry deposition of gaseous PAN, N_2O_5, NO, NO_2, HONO and organic nitrates) are estimated from the CMAQ model (p. 14).

- Dry deposition values are combined with the wet deposition values to produce the final estimates of total deposition.

- Ammonia deposition is estimated using a bidirectional air-surface exchange module in CMAQ. For terrestrial surfaces, flux pathways include the soil, leaf stomata, and leaf cuticle. Gross ammonia deposition (p. 15) refers to the total amount of ammonia deposited to soil and vegetation within a model grid cell and is the amount used in calculating total nitrogen deposition.

- Ammonia re-emission is calculated by subtracting non-point source emissions, such as those from soils and leaf surfaces, from the gross deposition derived from the bidirectional model. Although point source emissions such as those from confined animal feeding operations and industrial sources are used in calculating air concentrations of ammonia and other air pollutants, they are not included in the re-emission amounts. Positive values indicate deposition to the landscape, whereas negative values indicate emission.

- S + N equivalent deposition (p. 17) is one measure of the combined acidifying effect of nitrogen and sulfur deposition on ecosystems and is a common metric in critical load determinations. This measure is calculated from the molar equivalents of sulfur and nitrogen deposition and assumes 1 equivalents/mole for nitrogen compounds and 2 equivalents/mole for sulfur compounds. The percentage of total S+N equivalent deposition as nitrogen describes the proportion of potential acidity that is due to nitrogen deposition.

Availability of Maps and Data

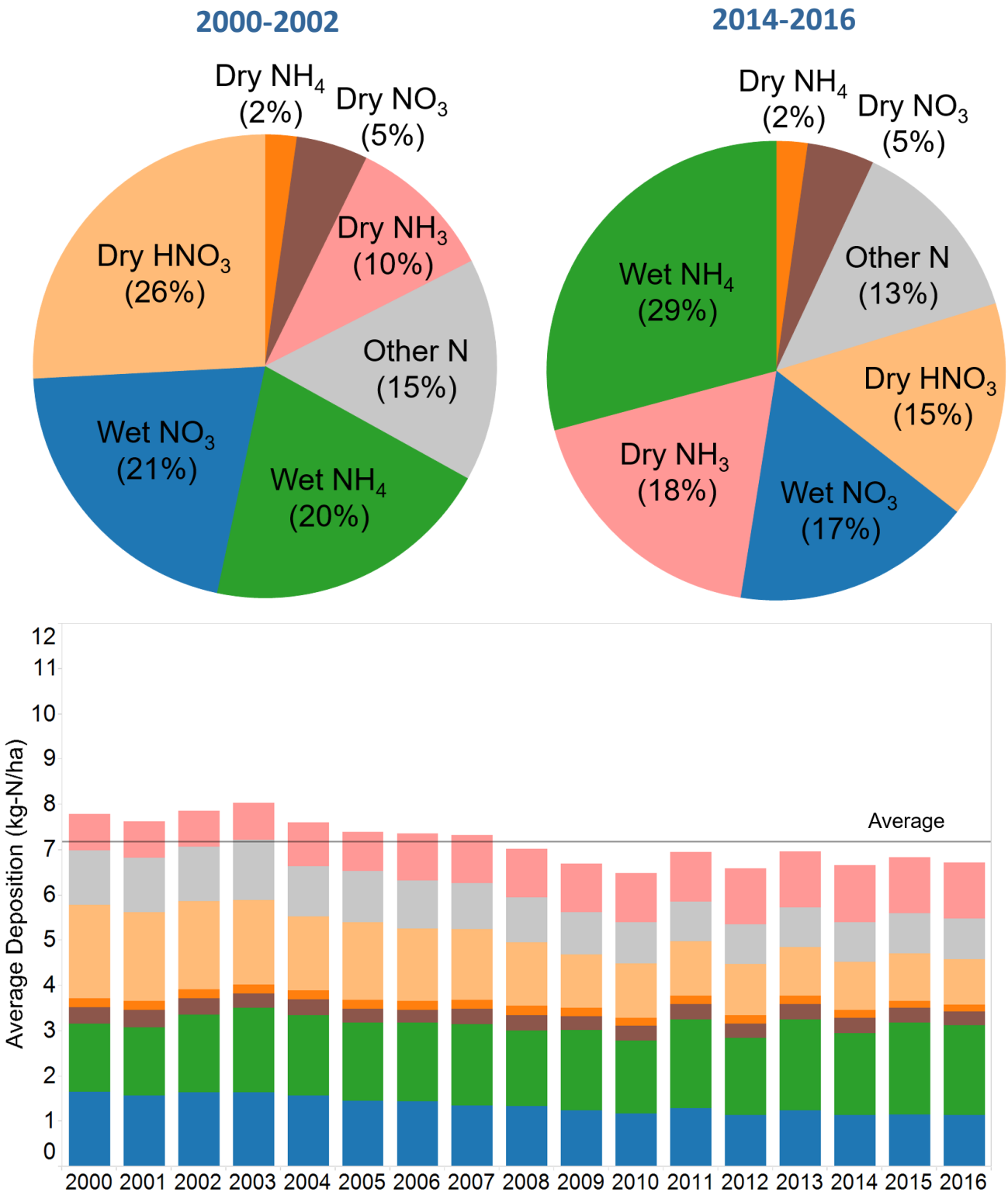
The hybrid maps are available for years 2000-2016 and for select 3-year averages for all components of total sulfur and nitrogen deposition. The most recent version is available as ESRI Grid™ files and maps, which can be downloaded from the NADP website at http://nadp.slh.wisc.edu/committees/tdep/tdepmaps/. This data set will be updated each year as new data, both modeled and measured, become available and as the methodology evolves.

Use and Limitations

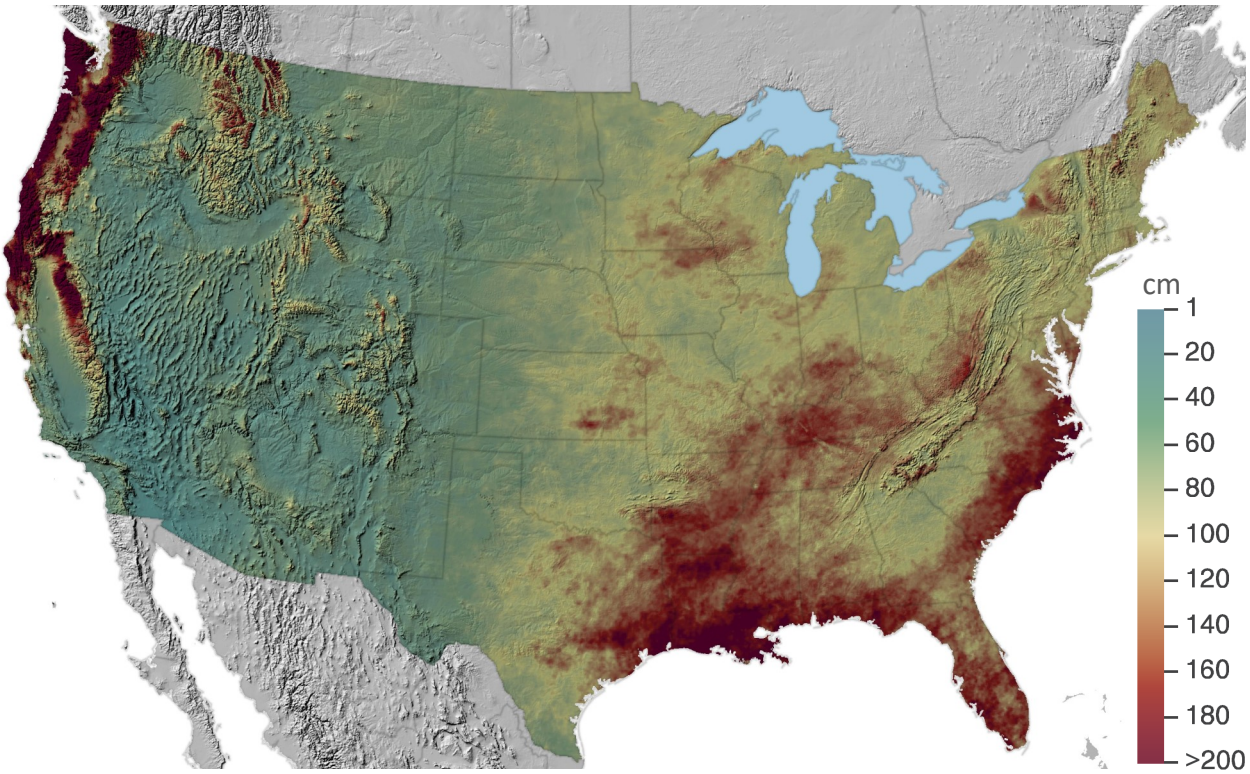
The TDep maps have been used by the TDep Science Committee to identify areas of research that are critical to advancing our understanding of accurately estimating total deposition. The maps are also being used by resource managers to assess ecosystem health. Critical load exceedances can be identified by combining maps of total deposition and critical loads. The TDep maps provide the best available estimates of total deposition based on the most recent information, however, there are limitations, including but not limited to the following:

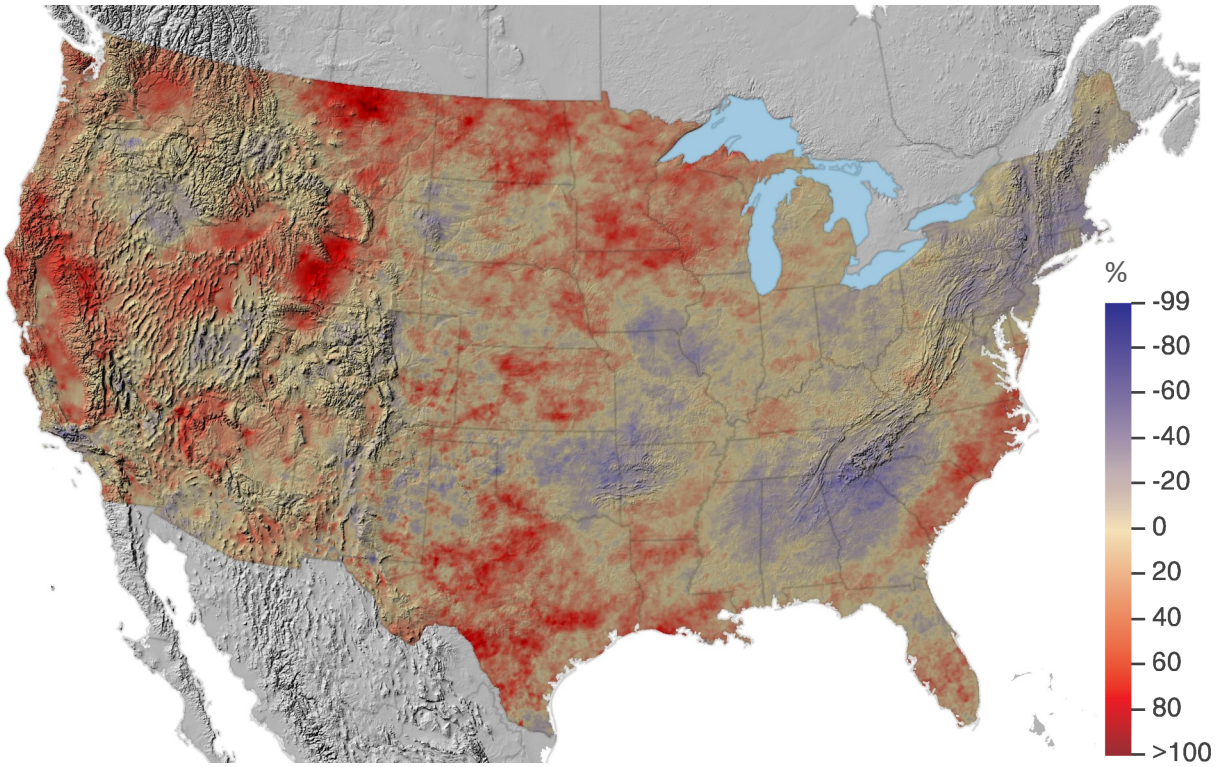
- Interpolation techniques inherently minimize extreme values, so more variability would be expected if more spatially resolved observations were available for use.
- The use of monitoring data is limited to sites and times that meet network completion criteria to ensure that measurements are representative of actual conditions.
- Discontinuities in temporal and spatial trends at specific locations may occur where monitoring data are intermittent.
- The methodology used to develop the wet deposition grids differs from that used for the NADP network precipitation grids.
- Ammonia data from the NADP Ammonia Monitoring Network (AMoN) are only used for model evaluation and are not included in the development of the concentration surfaces because a method for combining a concentration measurement with a bidirectional flux has not yet been developed.
- There is likely an incomplete characterization of the wet and dry organic nitrogen components due to lack of measurements resulting in an underestimate of total nitrogen deposition.
- Since the measurement sites used in the method are located in primarily rural areas, deposition in urban areas may not be well represented.
- Occult deposition is poorly understood and may not be accurately characterized in modeling.

The TDep Science Committee is open to anyone that wants to participate and meets twice a year. Scientific contributions and collaboration towards this work are welcome. For more information, please contact the Chair or Co-Chair of the TDep Science Committee (http://nadp.slh.wisc.edu/committees/tdep/contacts.aspx).

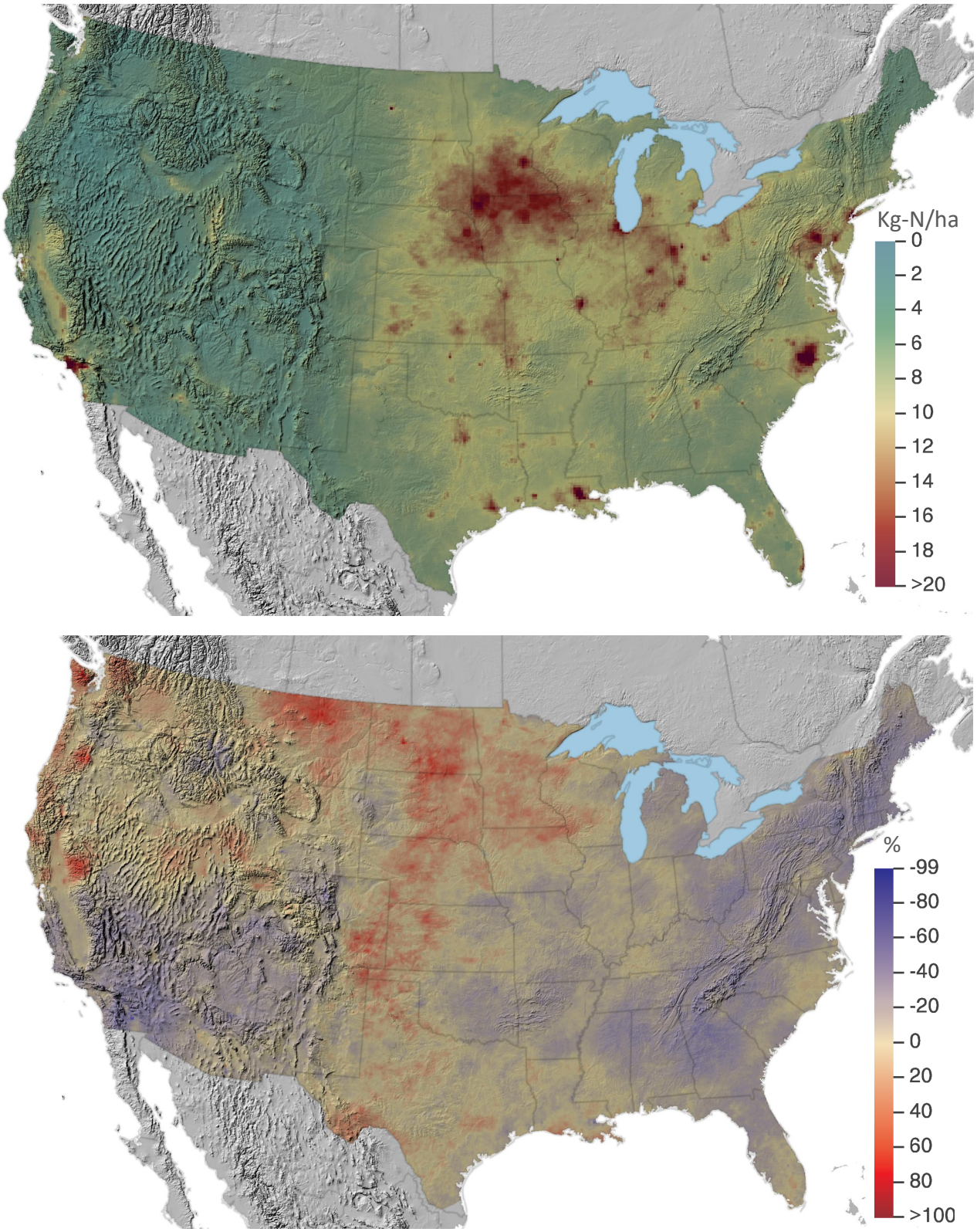


Speciated composition of nitrogen deposition (as percentages of the total) averaged from the TDep grid values for 2000-2002 (upper left) and 2014-2016 (upper right). Historical average annual total nitrogen deposition and the species contributions from 2000 to 2016 are shown in the bar chart (bottom).

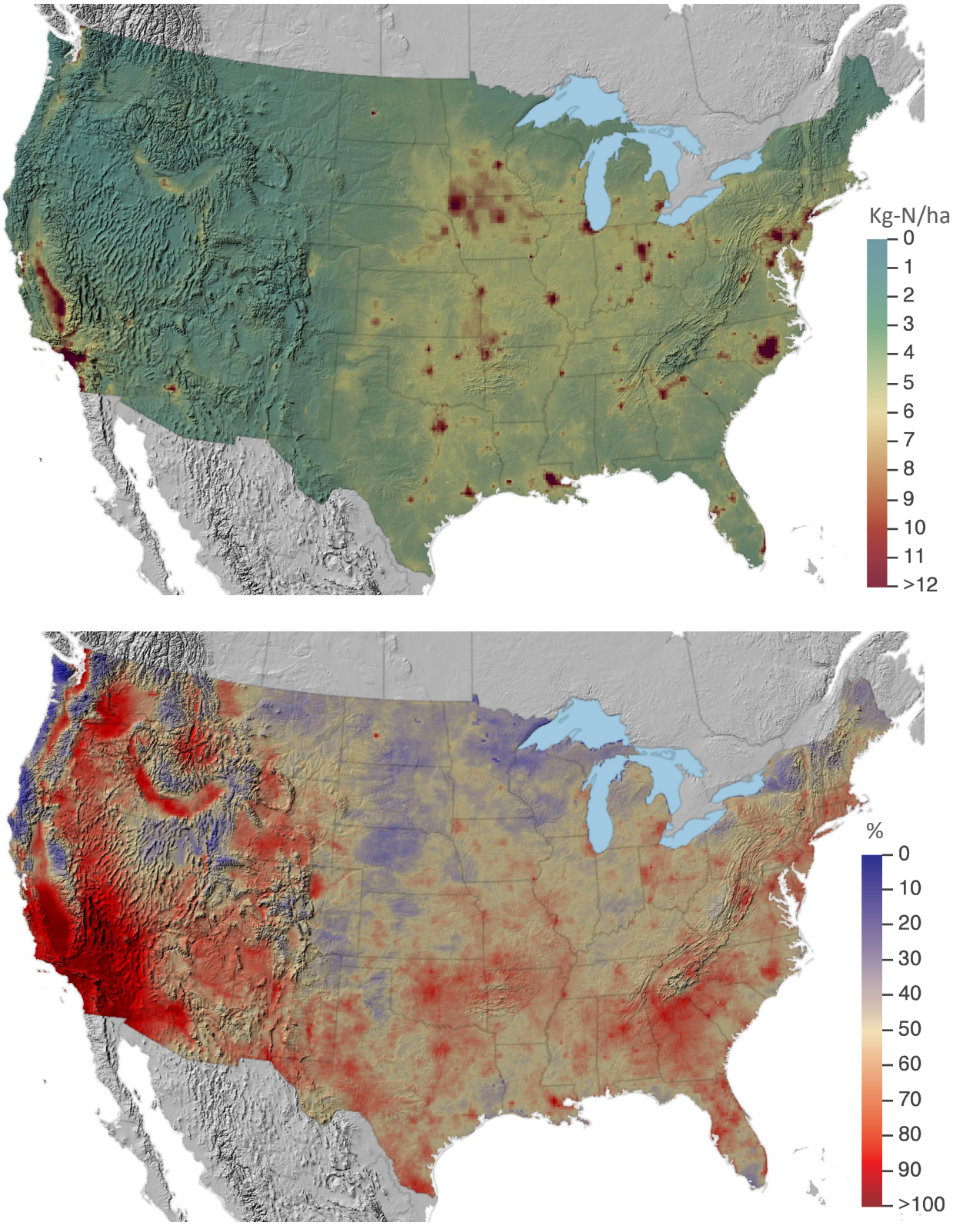




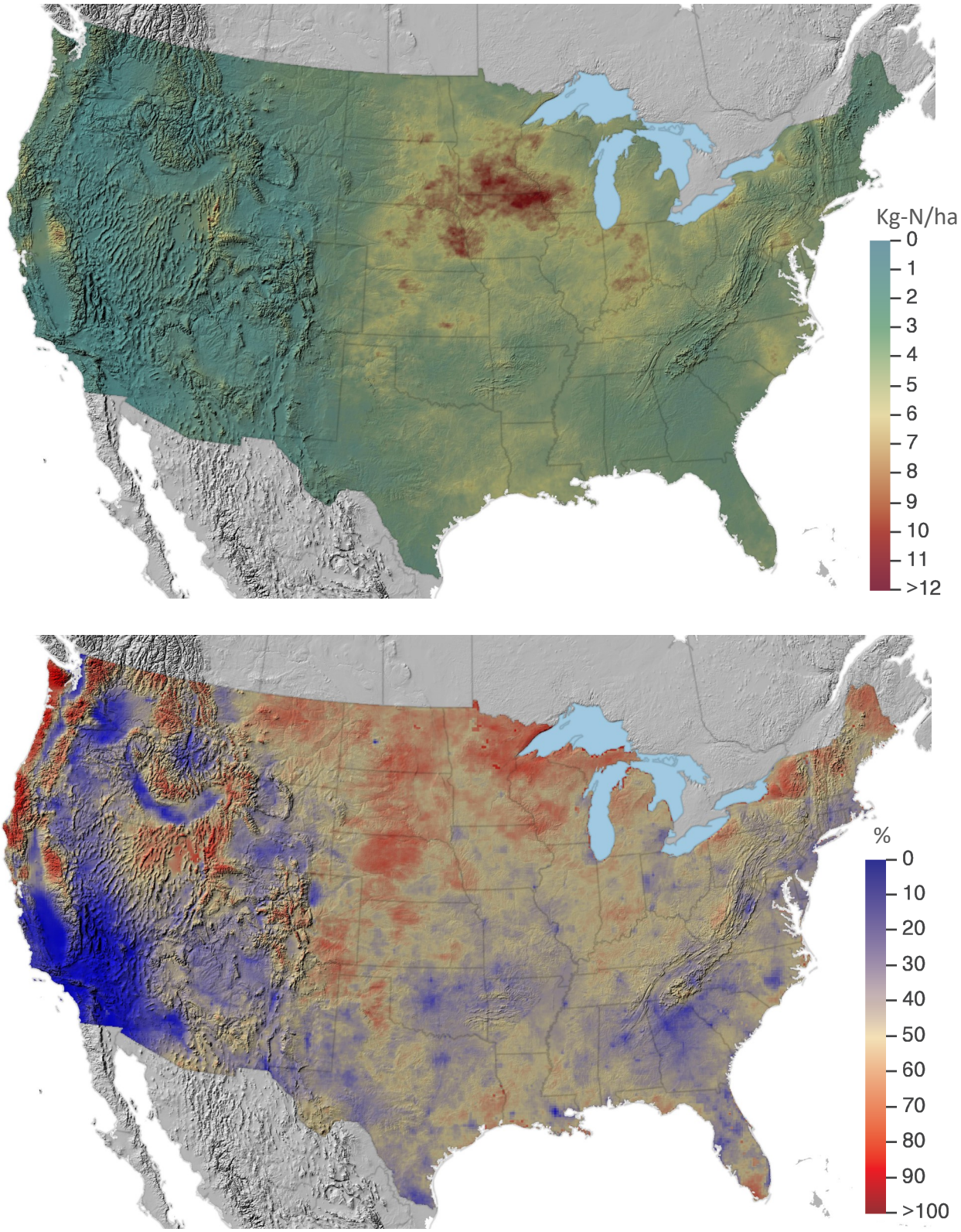
Total annual precipitation in 2016 (top), and percent deviation of 2016 precipitation values compared to the annual average of 2000-2016 (bottom)



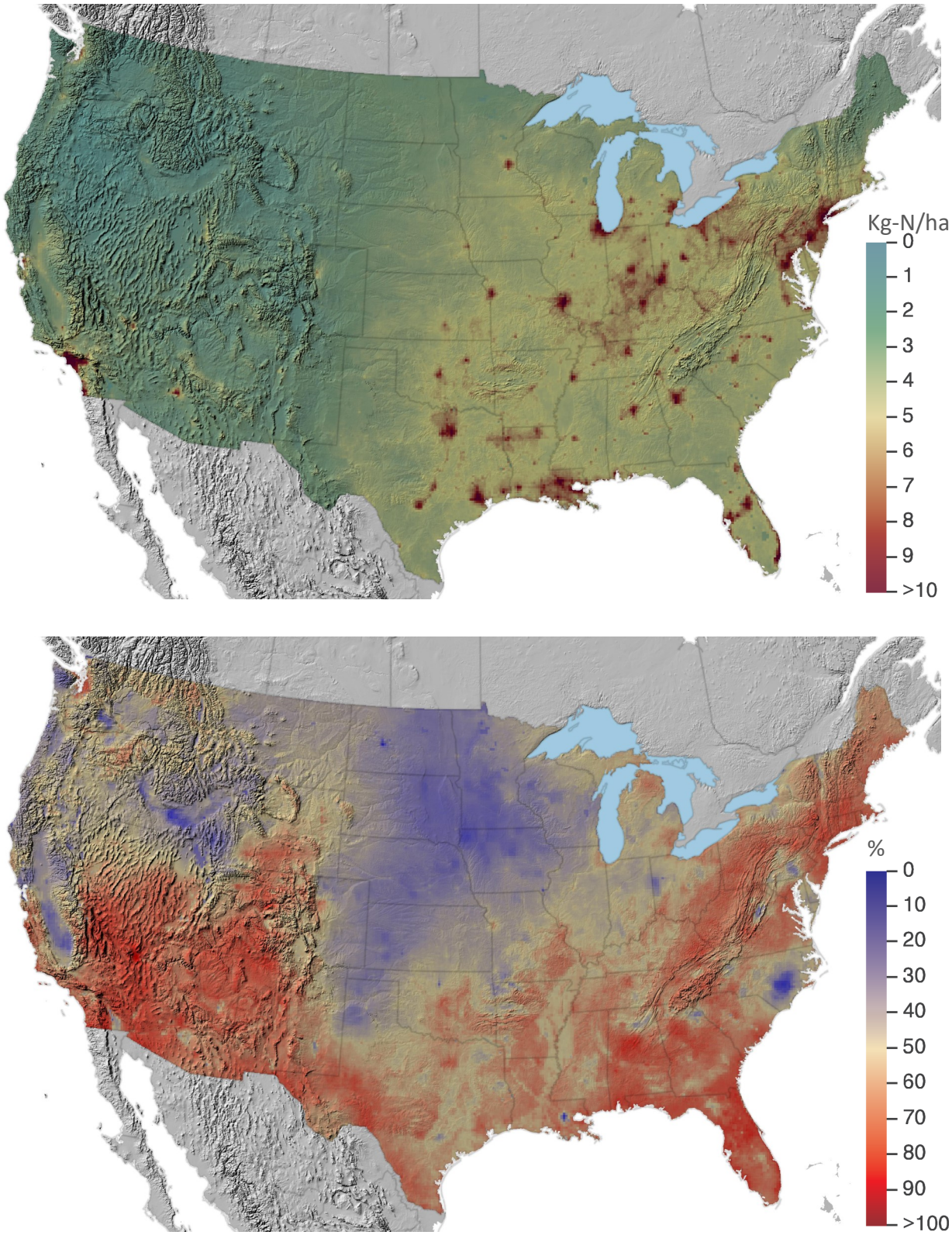
Total nitrogen deposition in 2016 (top), and percent deviation of 2016 nitrogen deposition values compared to the annual average of 2000-2016 (bottom)



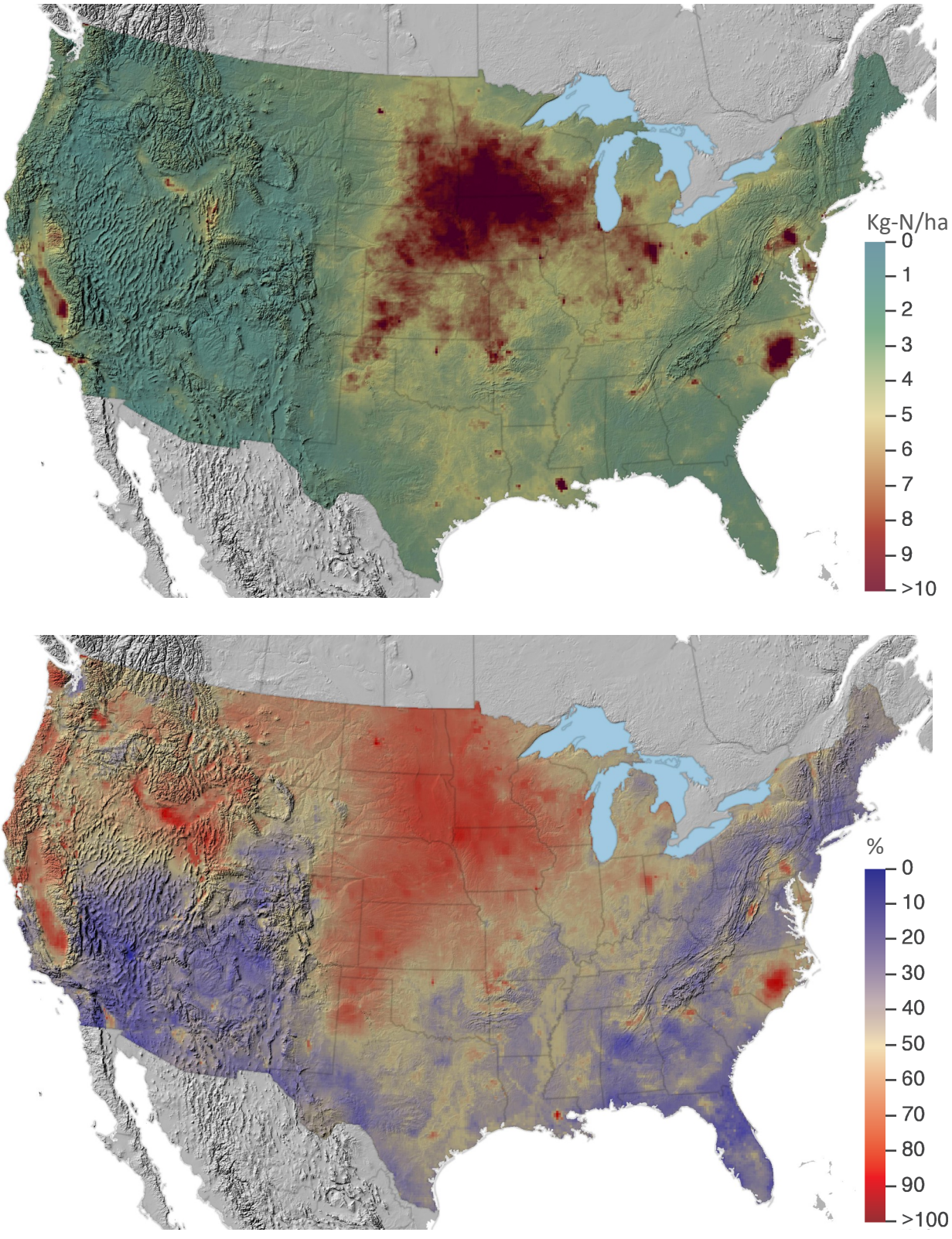
Annual dry nitrogen deposition in 2016 (top), and percent of total nitrogen deposition as dry deposition in 2016 (bottom)



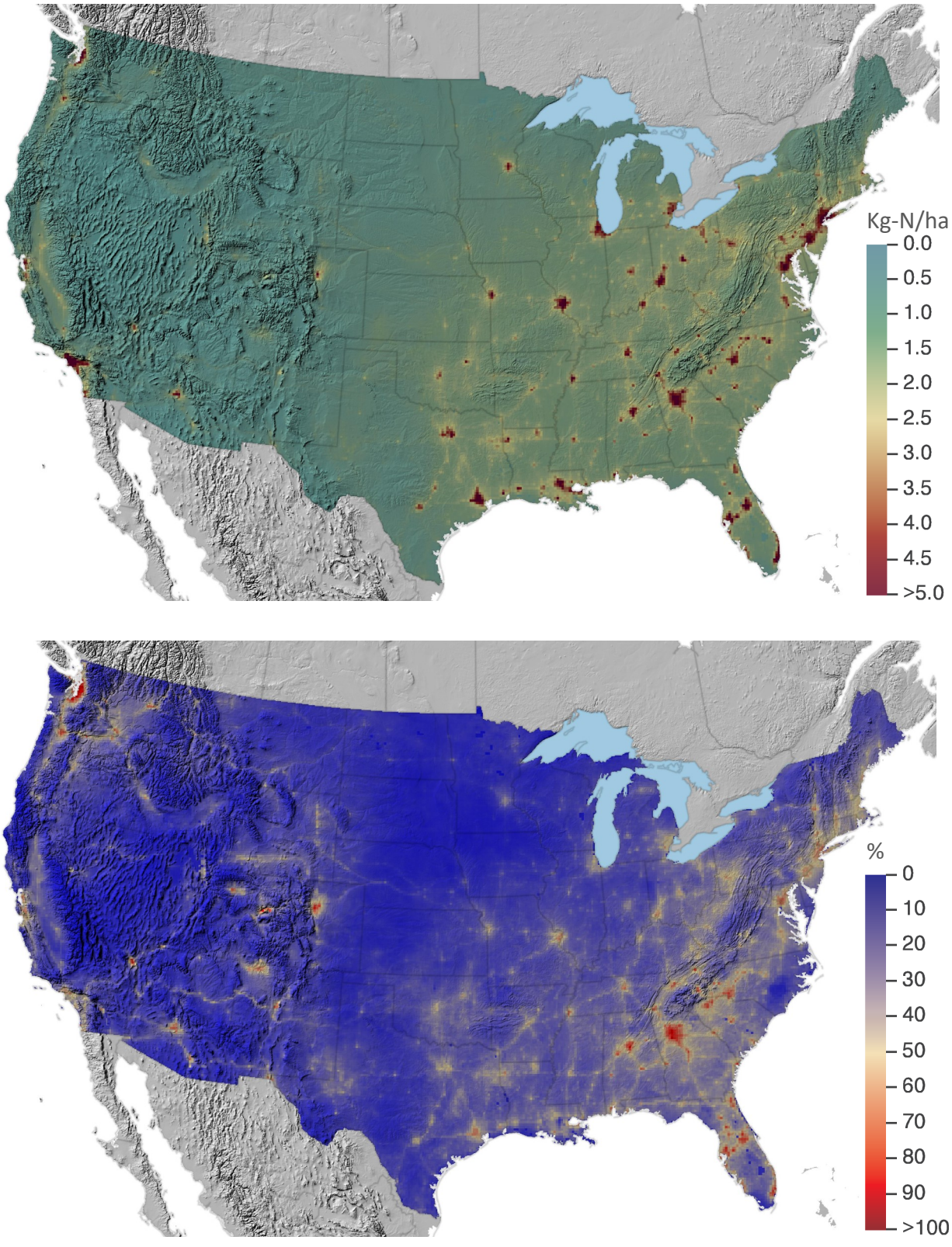
Annual wet nitrogen deposition in 2016 (top), and percent of total nitrogen deposition as wet deposition in 2016 (bottom)



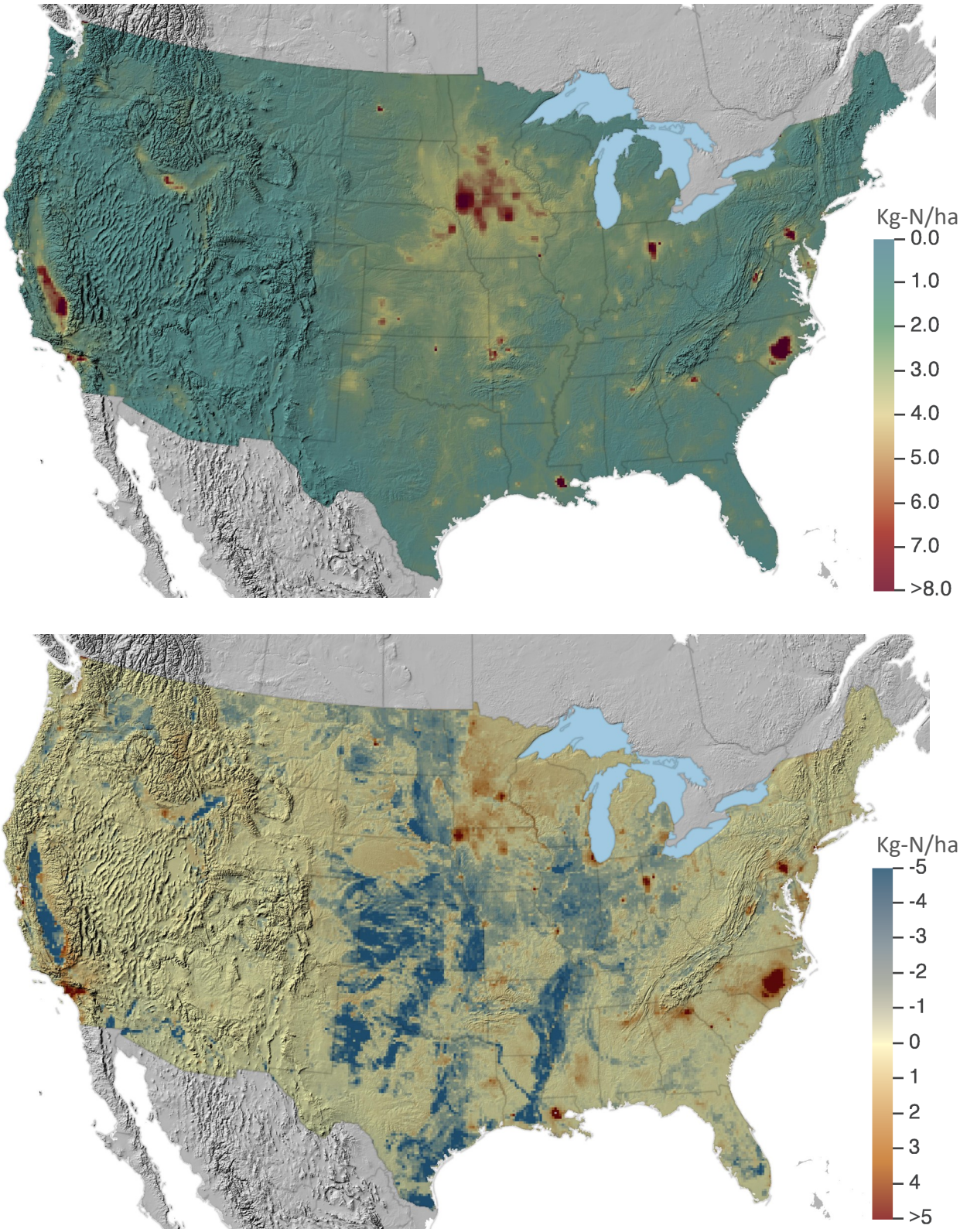
Annual oxidized nitrogen deposition in 2016 (top), and percentage of total nitrogen deposition as oxidized nitrogen in 2016 (bottom)



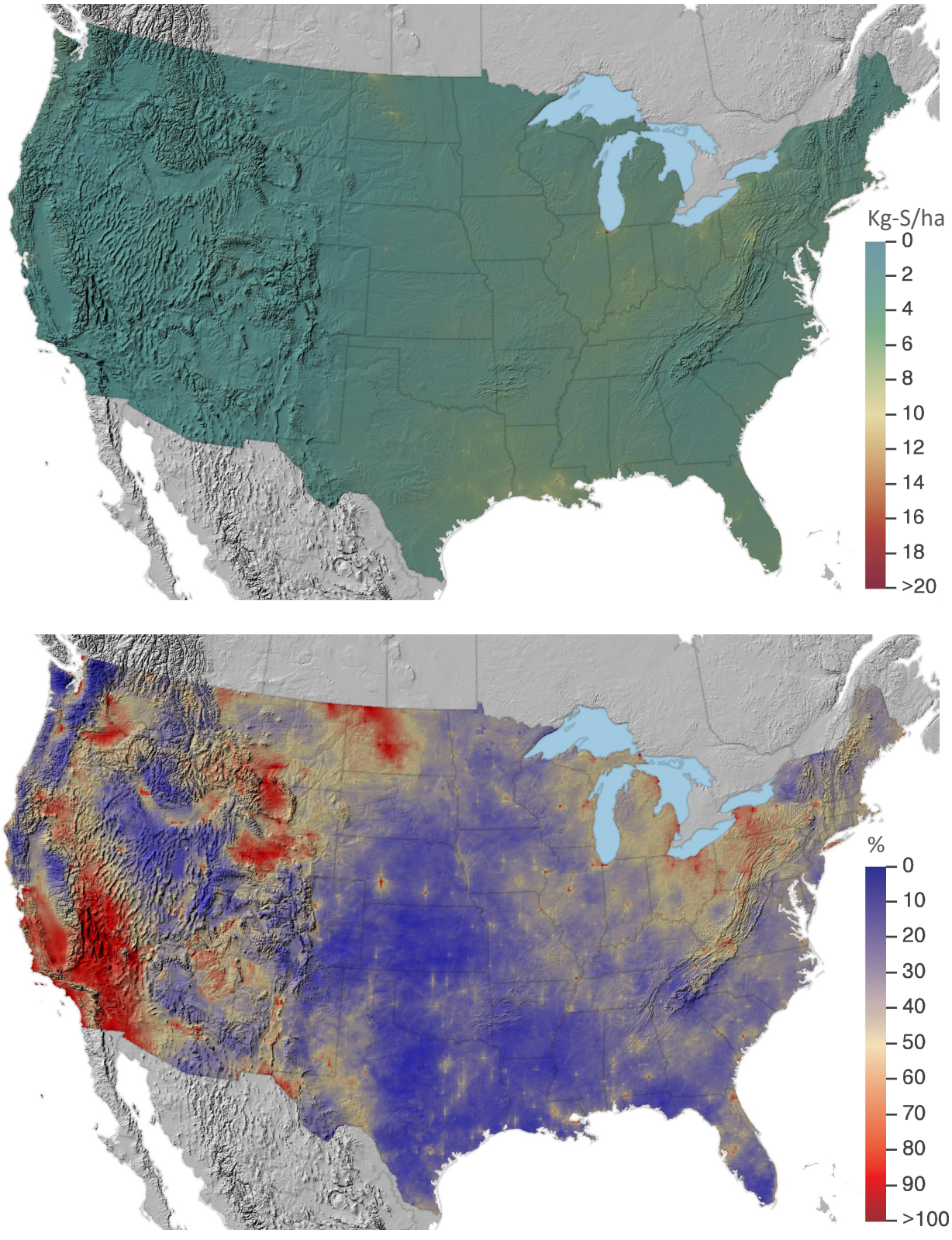
Annual reduced nitrogen deposition in 2016 (top), and percentage of total nitrogen deposition as reduced nitrogen in 2016 (bottom)



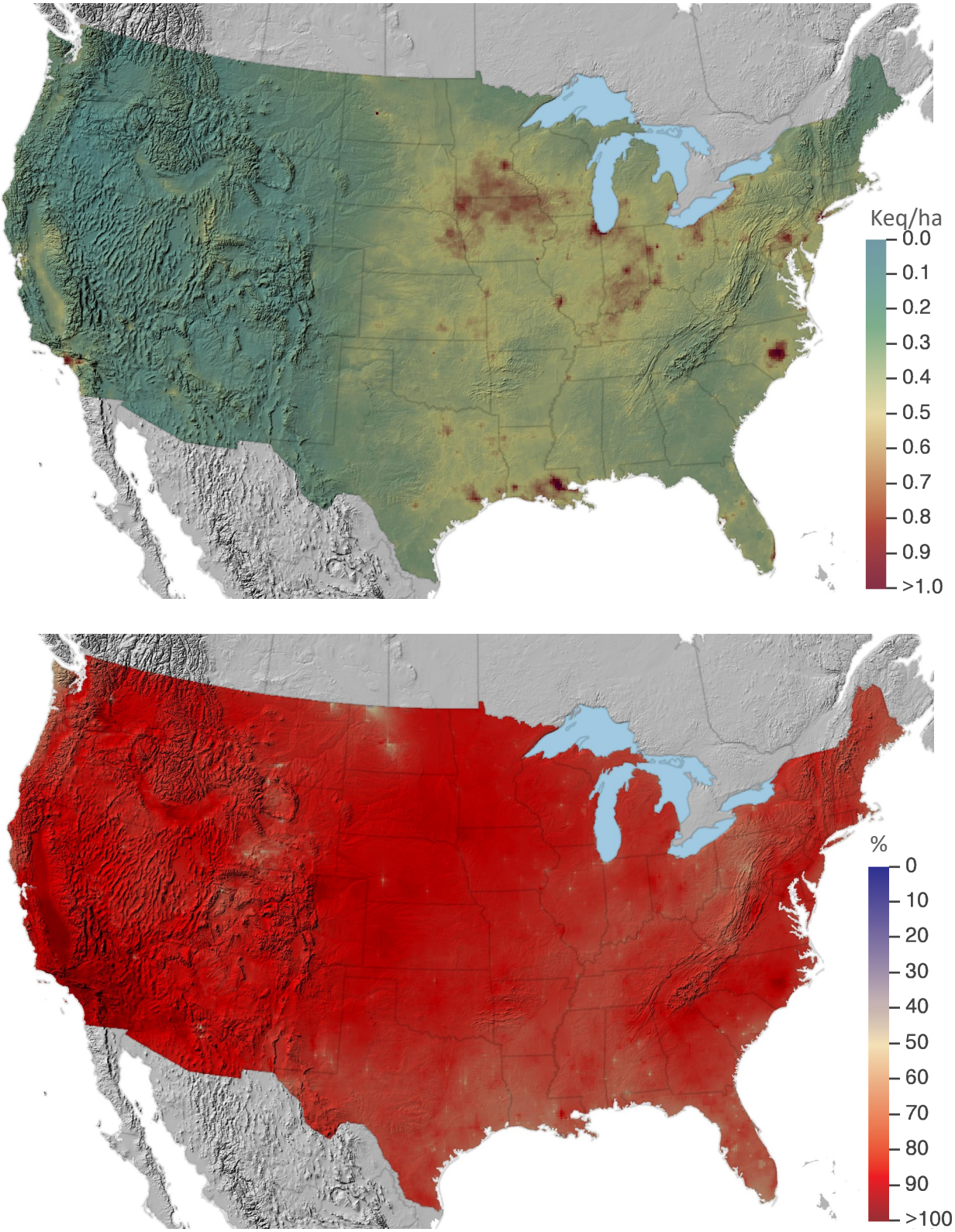
Annual deposition of unmonitored nitrogen compounds in 2016 (top), and percentage of total nitrogen deposition as unmonitored nitrogen compounds (bottom).



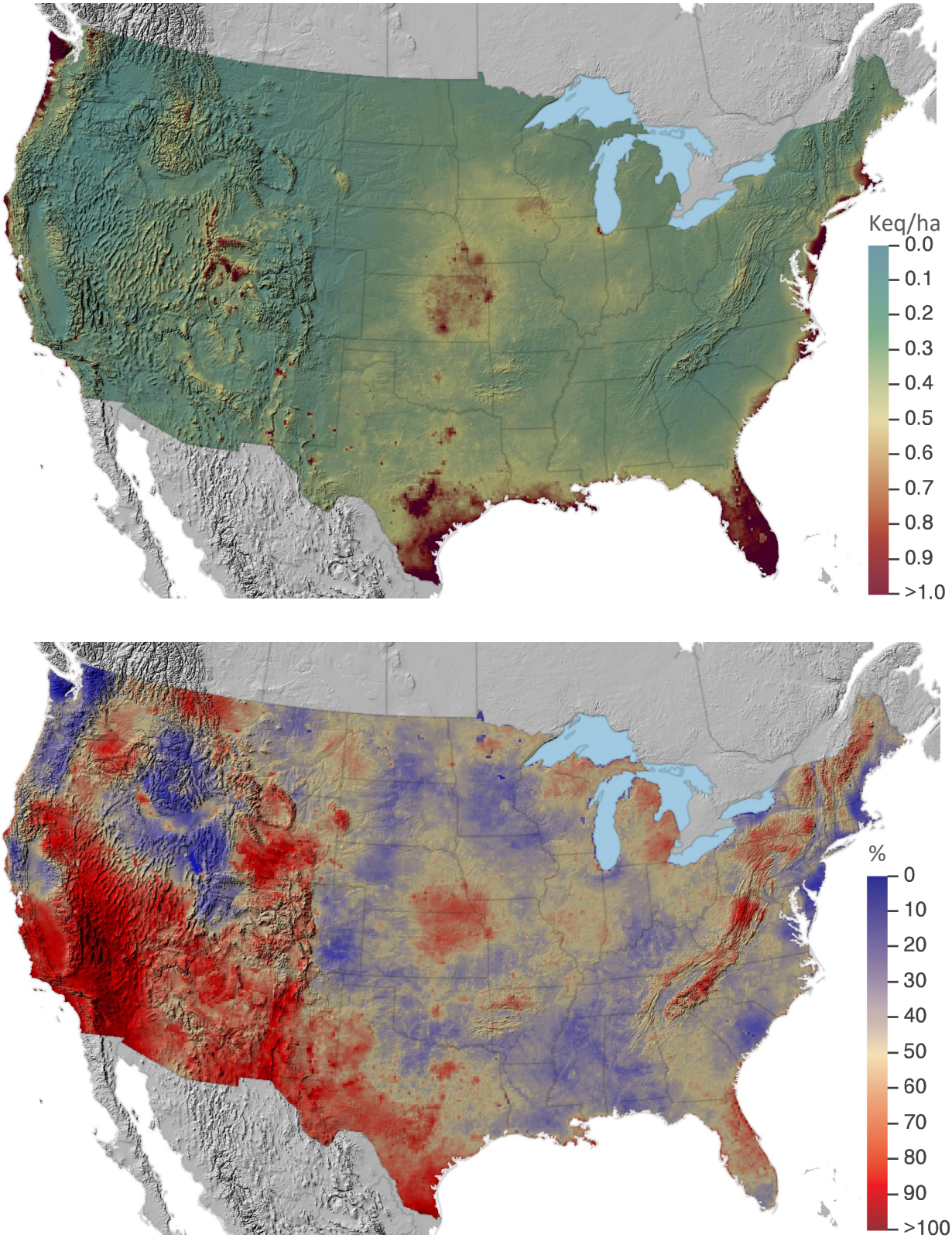
Annual gross ammonia deposition in 2016 (top), and net ammonia deposition in 2016 (bottom)



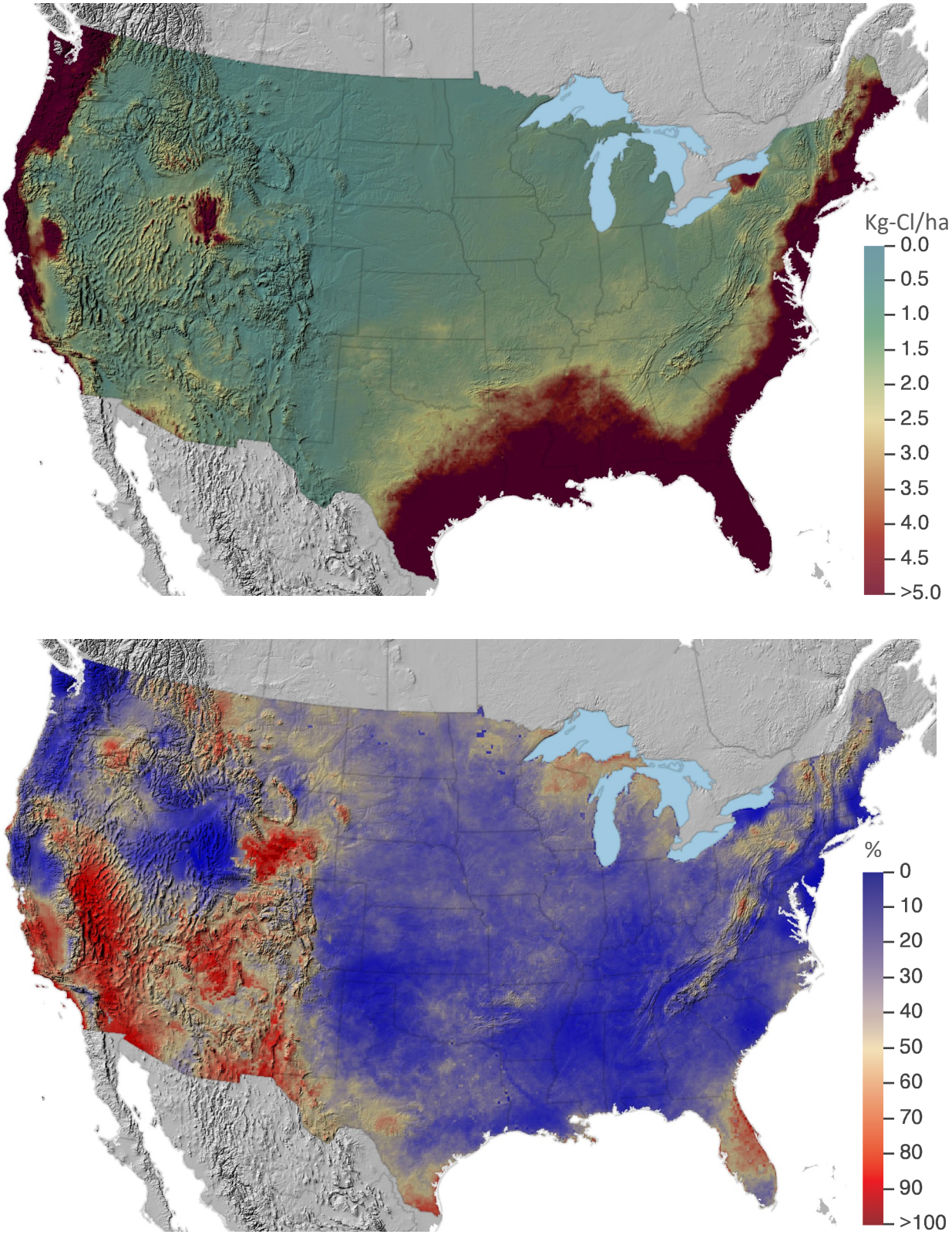
Annual sulfur deposition in 2016 (top), and percentage of total sulfur deposition as dry deposition in 2016 (bottom)



Annual S+N equivalent deposition in 2016 (top), and the percentage of S+N equivalent deposition as nitrogen in 2016 (bottom).



Annual base cation deposition in 2016 (top), and percentage of total base cation deposition as dry deposition in 2016 (bottom)



Annual chloride deposition in 2016 (top), and percentage of total chloride deposition as dry deposition in 2016 (bottom)

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 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. 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 sponsors or the University of Wisconsin.

Madison, WI: March 2019

Editor: Greg Beachley; Review: Gary Lear, Total Deposition Steering Committee

All NADP data and information, including color contour maps in this publication, are available from the NADP website: http://nadp.slh.wisc.edu/. Alternatively, contact: NADP Program Office, Wisconsin State Laboratory of Hygiene, 465 Henry Mall, University of Wisconsin, Madison, WI 53706, Tel: (608) 263-9162, E-mail: nadp@slh.wisc.edu.