



Total Annual Sulfur Deposition

This EnviroAtlas national map portrays total annual sulfur deposition (kilograms of sulfur per hectare) within each 12-digit hydrological unit ([HUC](#)) for the year 2017. The map is based on data from the Community Multiscale Air Quality modeling system ([CMAQ](#)).

Why is sulfur deposition important?

Sulfur [deposition](#) occurs when sulfur in the atmosphere is transferred to the earth's surface through [wet](#) or [dry deposition](#). Total sulfur deposition includes the wet and dry deposition of sulfur dioxide (SO₂) and particulate sulfate (SO₄). The main source of sulfur emissions is the burning of fossil fuels, although some come from natural sources such as volcanoes.

Atmospheric deposition of sulfur and nitrogen plays an important role in terrestrial, freshwater aquatic, and marine ecosystem functioning and degradation.^{1,2} Soils have an inherent buffering capacity. When acidic atmospheric deposition overwhelms this capacity, numerous harmful effects can occur.^{3,4,5} For example, deposition can cause slower plant growth, the loss of soil fertility, the injury or death of forest vegetation, and the localized extinction of fish and other aquatic species.^{6,7,8} Acidification of lakes and streams due to deposition can cause the loss of species diversity and extinction of fish and other aquatic species.^{7,8,4}

Sulfur deposition can also cause microbes to produce more methane, a [greenhouse gas \(GHG\)](#), and change mercury into an extremely toxic chemical called methyl mercury that can more easily enter the food chain and build up in human and animal tissue.⁹

How can I use this information?

The map, Total Annual Sulfur Deposition, provides information from the CMAQ model showing how exposure to sulfur deposition varies across space due to complex emissions patterns and their transport and transformation. This map provides spatially continuous values of concentration and deposition that can be used as input to ecological assessments and ecosystem management strategies. Having data on sulfur deposition will help in determining the extent to which an ecosystem will recover and the timeline for recovery.¹⁰ This map also provides important input to critical loads analyses. Critical loads can be defined on the basis of species diversity, soil chemistry, tree growth, and many other



Photo: Coal-fired Powerplant, S. Greenwood

indicators. Comparison of total sulfur deposition to critical load values allows users to identify areas where critical loads are likely to be exceeded and attention is potentially needed to avoid or mitigate damage.

How were the data for this map created?

This map is based on data from the Community Multiscale Air Quality modeling system ([CMAQ](#)). Because deposition in a HUC can come from a large area, air quality models are an important tool for translating emissions data into information about ecological exposure. Airsheds are very large in comparison to HUCs and they include emissions from multi-state regions. Local deposition is caused by a mix of airshed and distant emissions. This makes it difficult to predict the exposure that results from emissions without the use of a regional air quality model.

This map was created using output from the CMAQ Modeling System v5.3.2. Meteorology data were processed for 2017 using the [Weather Research Forecast model](#) v4.1.1 with the Pleim-Xu land surface model. Anthropogenic emissions are from the EPA's Air Quality Time Series ([EQUATES](#)) 2017 modeling platform. The output was corrected for errors in the wet deposition using [PRISM data](#) and for bias in the rainwater concentrations of TNO₃, NH_x, and sulfate using National Atmospheric Deposition Program ([NADP](#)) data. Model predicted values of dry deposition were not adjusted. Model output was summed to create total annual deposition values for each grid cell. Finally, the gridded data were summarized by taking the mean for each 12-digit HUC.

What are the limitations of these data?

All national data layers are inherently imperfect; they are an estimation of the truth based on the best available science. Calculations based on these data are therefore also estimations. Periodic updates to EnviroAtlas will reflect improvements to nationally available data.

Atmospheric deposition varies across the U.S. due to differences in climate and land surface. Measurements of dry deposition are challenging and expensive, so few are available. The National Trends Network ([NTN](#)), a part of the NADP, provides wet deposition data at numerous sites across the U.S. While monitoring data are useful, estimates of deposition between monitoring locations can miss changes in value due to the distribution of emissions and variations in the land surface. The CMAQ modeling system accounts for the complex chemistry of the atmosphere and interactions between chemicals. The chemistry and physics of the atmosphere are very complicated, and there are uncertainties in the model representations and inputs that result in uncertainties in the predicted concentrations and deposition fluxes. The data have been summarized based on HUCs, but actual atmospheric deposition will vary within the HUC.

Selected Publications

1. Driscoll, C.T., Y.J. Han, C.Y. Chen, D.C. Evers, and K.F. Lambert. 2007. [Mercury contamination in forest and freshwater ecosystems in the Northeastern United States](#). *BioScience* 57:17–28.
2. Lovett, G.M., and T.H. Tear. 2008. [Threats from above: Air pollution impacts on ecosystems and biological diversity in the eastern United States](#). The Nature Conservancy and the Cary Institute of Ecosystem Studies, New York. 17 p.
3. Sullivan, T.J., I.J. Fernandez, A.T. Herlihy, C.T. Driscoll, T.C. McDonnell, N.C. Nowicki, K.U. Snyder, and J.W. Sutherland. 2006. [Acid-base characteristics of soils in the Adirondack Mountains, New York](#). *Soil Science Society of America Journal* 70:141–152.
4. Lawrence, G., J. Sutherland, C. Boylen, S.A. Nierzwicki-Bauer, B. Momen, and B.P. Baldigo. 2007. [Acid rain effects on aluminum mobilization clarified by inclusion of strong organic acids](#). *Environmental Science & Technology* 41:93–98.
5. Sullivan, T.J., B.J. Cosby, J.R. Webb, R.L. Dennis, A.J. Bulger, and F.A. Deviney. 2008. [Streamwater acid-base chemistry and critical loads of atmospheric sulfur deposition in Shenandoah National Park, Virginia](#). *Environmental Monitoring and Assessment* 137:85–99.
6. DeHayes, D.H., P.G. Schaberg, G.J. Hawley, and G.R. Strimbeck. 1999. [Acid rain impacts on calcium nutrition and forest health](#). *BioScience* 49:789–800.
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8. Driscoll, C.T., G.B. Lawrence, A.J. Bulger, T.J. Butler, C.S. Cronan, C. Eagar, K.F. Lambert, G.E. Likens, J.L. Stoddard, and K.C. Weathers. 2001. [Acidic deposition in the northeastern United States: Sources and inputs, ecosystem effects, and management strategies](#). *BioScience* 51:180–198.
9. Greaver, T.L., T.J. Sullivan, J.D. Herrick, M.C. Barber, J.S. Baron, B.J. Cosby, M.E. Deerhake, R.L. Dennis, J.J. Dubois, C.L. Goodale, A.T. Herlihy, G.B. Lawrence, L. Liu, J.A. Lynch, and K.J. Novak. 2012. [Ecological effects of nitrogen and sulfur air pollution in the US: What do we know?](#) *Frontiers in Ecology and the Environment* 10:365–372.
10. Mitchell, M., G. Lovett, S. Bailey, et al. 2010. [Comparisons of watershed sulfur budgets in southeast Canada and northeast US: New approaches and implications](#). *Biogeochemistry*, Online First 19 May 2010.

How can I access these data?

EnviroAtlas data can be viewed in the interactive map, accessed through web services, or downloaded. Data and accuracy information for the source data sets can be found on their respective web sites.

Where can I get more information?

There are numerous resources on sulfur deposition; a selection of these resources is listed below. Information about the models used can be found at their respective websites. For additional information on how the data were created, access the [metadata](#) for the data layer from the drop down menu on the interactive map layer list. To ask specific questions about this data layer, please contact the [EnviroAtlas Team](#).

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