Chapter 8: Acid Deposition

Acid deposition, commonly known as "acid rain," is a broad term referring to the mixture of wet and dry deposition from the atmosphere containing higher than normal amounts of sulfuric acids and nitric acids. The precursors of acid deposition are primarily the result of emissions of SO_2 and NO_x resulting from fossil fuel combustion, however natural sources, such as volcanos and decaying vegetation also contribute a small amount.

Analysis and Background Information

Acid Deposition

As SO_2 and NO_x gases react in the atmosphere with water, oxygen, and other chemicals, they form various acidic compounds that get deposited to the ground in the form of wet and dry acid deposition.

Monitoring network data show significant improvements in the primary acid deposition indicators. For example, wet sulfate deposition (sulfate that falls to the earth through rain, snow, and other precipitation) has decreased since the implementation of the ARP in much of the Ohio River Valley and northeastern United States. Some of the most dramatic reductions have occurred in the mid-Appalachian region, including Maryland, New York, West Virginia, Virginia, and most of Pennsylvania. Along with wet sulfate deposition, reductions in precipitation acidity, expressed as hydrogen ion (H^+) concentration, have also decreased by similar percentages.

Reductions in nitrogen deposition recorded since the early 1990s have been less pronounced than those for sulfur. As noted earlier, emission changes from source categories other than ARP and CAIR sources contribute to changes in air concentrations and deposition of nitrogen.

Monitoring Networks

The Clean Air Status and Trends Network (CASTNET) provides long-term monitoring of regional air quality to determine trends in atmospheric nitrogen, sulfur, ozone concentrations, and deposition fluxes (the rate of particles and gases being deposited to a surface) of sulfur and nitrogen pollutants in order to evaluate the effectiveness of national and regional air pollution control programs. CASTNET now operates more than 90 regional sites throughout the contiguous United States, Alaska, and Canada. Sites are located in areas where urban influences are minimal.

The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) is a nationwide, long-term network tracking the chemistry of precipitation. NADP/NTN provides concentration and wet deposition data on hydrogen ion (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations. NADP/NTN has grown to more than 200 sites spanning the continental United States, Alaska, Puerto Rico, and the Virgin Islands.

Together, these complementary networks provide long-term data needed to estimate spatial patterns and temporal trends in total deposition.

Key Points

Wet Sulfate Map

- The Northeast and Mid-Atlantic have shown the greatest improvement with an overall 64 percent reduction in wet sulfate deposition from 1989-1991 to 2011-2013.
- A decrease in both SO_2 emissions from sources in the Ohio River Valley and the formation of sulfates which are transported long distances have resulted in reduced sulfate deposition in the Northeast. The reductions in sulfate documented in the region, particularly across New England and portions of New York, were also affected by lowered SO_2 emissions in eastern Canada.[10]

Wet Inorganic Nitrogen Map

- Wet deposition of inorganic nitrogen decreased an average of 27 percent in the Mid-Atlantic and Northeast but decreased only 5 percent in the Midwest from 1989-1991 to 2011-2013.
- Reductions in nitrogen deposition recorded since the early 1990s have been less pronounced than those for sulfur. Emission changes from other source categories (e.g., mobile sources and manufacturing) contribute to changes in air concentrations and deposition of nitrogen.

Regional Trends in Deposition

- Between 1989-1991 and 2011-2013, the Northeast and Mid-Atlantic experienced the largest reductions in wet sulfate deposition, 65 percent and 63 percent, respectively.
- The reduction in total sulfur deposition (wet plus dry) has been of similar magnitude as that of wet deposition with an overall average reduction of 68 percent from 1989-1991 to 2011-2013.
- Decreases in dry and total inorganic nitrogen deposition have generally been greater than that of wet deposition with average reductions of 52 percent and 29 percent, respectively. In contrast, wet deposition from inorganic nitrate reduced by an average of 19 percent from 1989-1991 to 2011-2013.

More Information

Acid Rain http://www.epa.gov/acidrain/what/index.html
Clean Air Status and Trends Network (CASTNET) http://epa.gov/castnet/javaweb/index.html
National Atmospheric Deposition Program (NADP) http://nadp.isws.illinois.edu/

References

10. 2014 Canada-United States Air Quality Agreement Progress Report; ISSN 1910-5223 Cat. No.: En85-1/2014E-PDF

Figures

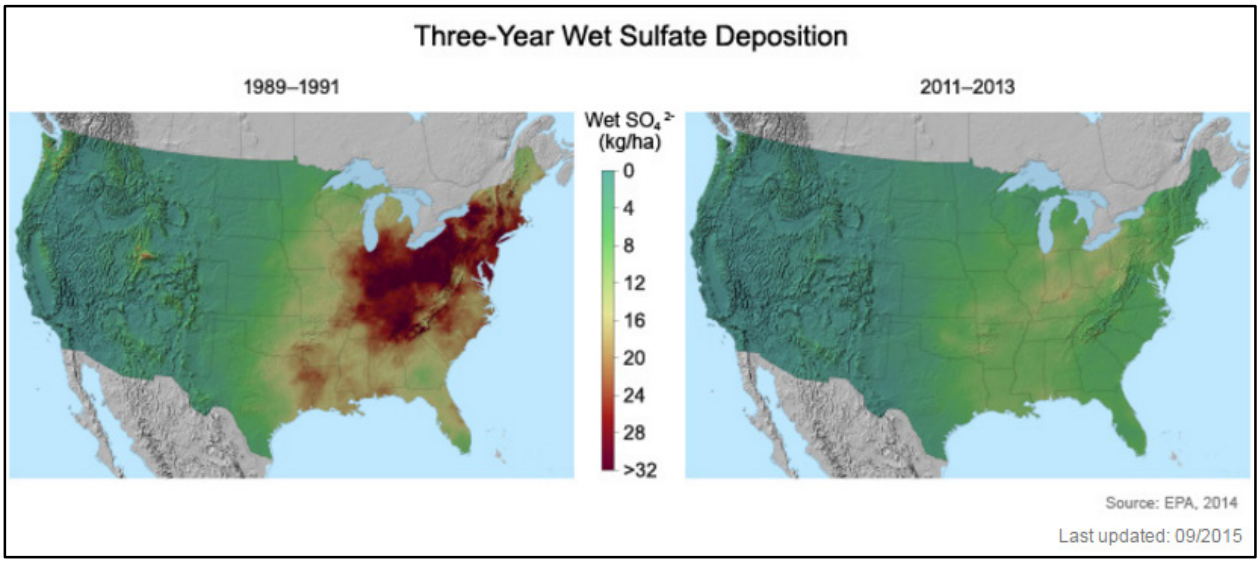

Figure 1. Three-Year Wet Sulfate Deposition

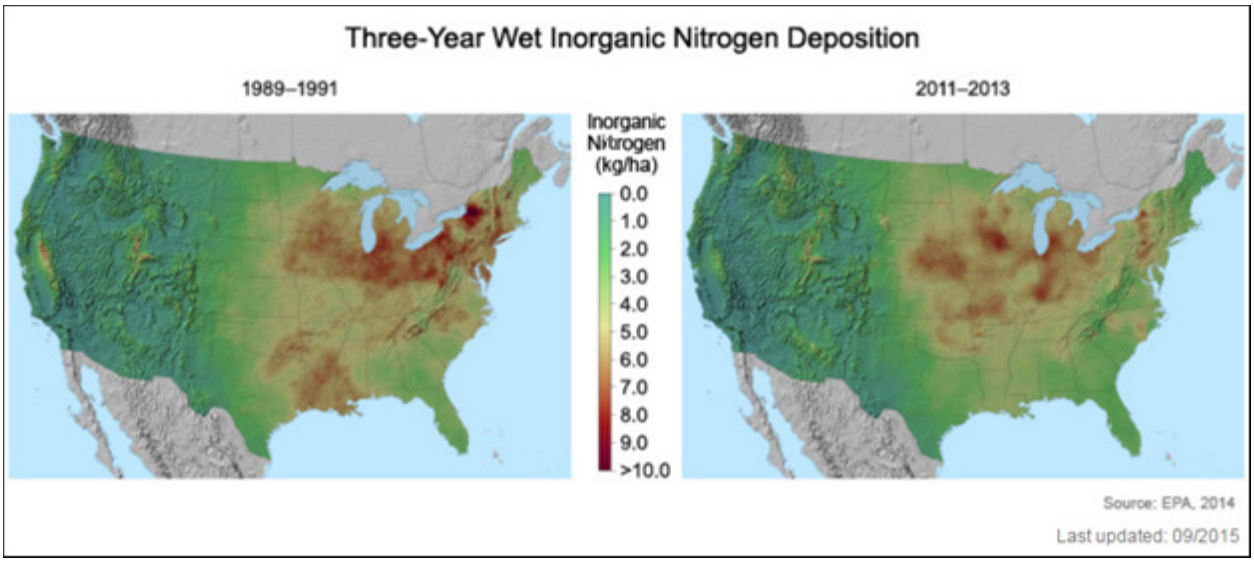

Figure 2. Three-Year Wet Inorganic Nitrogen Deposition

Regional Trends in Deposition

Measurement	Region	Annual Average, 1989-1991	Annual Average, 2011-2013	Percent Change	Number of Sites	Statistical Significance
Dry inorganic nitrogen deposition (kg-N/ha)	Mid-Atlantic	2.5	1.1	-56	12	***
	Midwest	2.4	1.4	-42	9	***
	Northeast	1.3	0.5	-62	3	
	Southeast	1.7	0.9	-47	8	***
Dry sulfur deposition (kg-S/ha)	Mid-Atlantic	7.0	1.2	-83	12	***
	Midwest	6.5	1.6	-75	9	***
	Northeast	2.6	0.5	-81	3	
	Southeast	3.1	0.7	-77	8	***
Total inorganic nitrogen deposition (kg-N/ha)	Mid-Atlantic	8.8	5.6	-36	12	***
	Midwest	8.6	7.0	-19	9	***
	Northeast	6.6	4.4	-33	3	
	Southeast	6.4	4.7	-27	8	***
Total sulfur deposition (kg-S/ha)	Mid-Atlantic	16.0	5.0	-69	12	***
	Midwest	15.0	5.0	-67	9	***
	Northeast	9.5	2.9	-69	3	
	Southeast	10.4	3.5	-66	8	***
Wet nitrogen deposition from inorganic nitrogen (kg-N/ha)	Mid-Atlantic	6.2	4.6	-26	11	***
	Midwest	5.8	5.5	-5	27	***
	Northeast	5.7	4.1	-28	16	***
	Southeast	4.4	3.6	-18	23	***
Wet sulfur deposition from sulfate (kg-S/ha)	Mid-Atlantic	9.2	3.4	-63	11	***
	Midwest	7.1	3.3	-54	27	***
	Northeast	7.5	2.6	-65	16	***
	Southeast	6.1	2.6	-57	23	***

Source EPA, 2014

Last updated: 09/2015

Notes:

- Averages are the arithmetic mean of all sites in a region that were present and met the completeness criteria in both averaging periods. Thus, average concentrations for 1989 to 1991 may differ from past reports.
- Total deposition is estimated from raw measurement data, not rounded, and may not equal the sum of dry and wet deposition.
- Statistical significance was determined at the 95 percent confidence level ($p < 0.05$). Changes that are not statistically significant may be unduly influenced by measurements at only a few locations or large variability in measurements.

Figure 3. Regional Trends in Deposition