Has EPA's Acid Rain Program Contributed to Decreased Acidity of Precipitation in New England?

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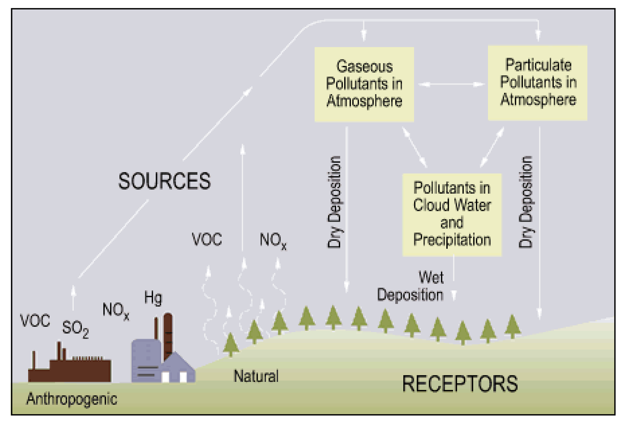
Introduction:

Acid deposition, in its wet and dry forms, is an environmental issue that has a lasting effect on both humans and the natural world. It affects the Northeast and Midwest regions of the United States in particular because of their tightly packed pollution centers, including power plants and other sources. Emissions of sulfur dioxide (SO2) and nitrogen oxides (NOx), the two main causes of acid deposition, are overwhelmingly from anthropogenic sources. It is estimated that two thirds of US emissions of these compounds originate from electric power plants burning fossil fuels.

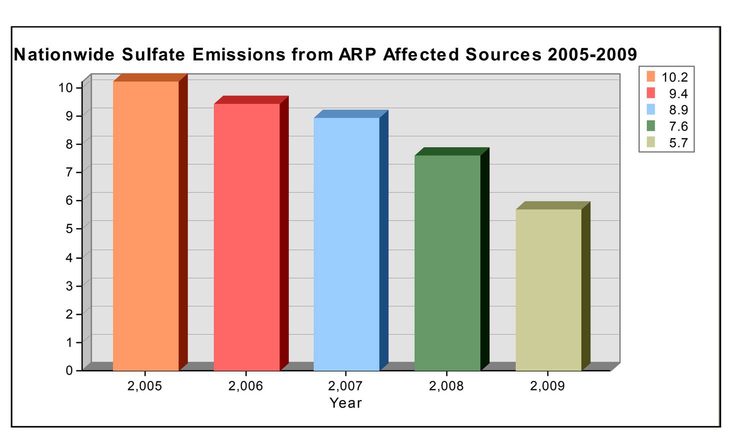
Deposition is qualified as "acidic" when the levels of sulfuric and nitric acid are higher than normal. Deposition can fall in dry form, when gaseous or particulate pollutants combine with dust or smoke, or in wet form when these particles combine with atmospheric moisture and fall as acid fog, rain or snow. The increased acidification of soils and waters has a devastating effect on the terrestrial and aquatic life they support. In addition to acid deposition falling directly into streams and lakes, these bodies of water also incorporate acid rain from surrounding soils and forests, making them that much more susceptible to acidification. Once a lake can no longer buffer the increased presence of acids, it is said to become acidic. When its "buffering capacity" is low, cations such as aluminum start to be leached from the surrounding soils, quickly creating a toxic environment for aquatic organisms. Biodiversity starts to decrease as fish and aquatic plants cannot survive in the acidic environment. Terrestrial organisms such as trees are affected by acid rain and the leaching of cations as well. Certain soils have a greater buffering capacity and are able to neutralize the acid, but in many areas vulnerable to acid deposition, such as high mountainous regions, the soil is thin and not of a certain composition. In addition to directly damaging trees' leaves, acid rain dissolves and leaches important nutrients from the soil and releases toxic aluminum.



Source: EPA

The effects on human health and man-made structures is also important to consider. Although humans are not harmed by being exposed to acid rain as trees are, the pollutants SO2 and NOx form particles in the atmosphere that can travel long distances and be inhaled into human lungs, contributing to asthma and bronchitis. These particles also have a noticeable effect on visibility in many of our national parks where scenic vistas abound. Acid deposition contributes to the breaking down of cement, brick and other building materials, as well as paint such as on automobiles. Acid deposition is an environmental, health and financial issue.

Fortunately, the Environmental Protection Agency implemented the Acid Rain Program (ARP) in 1995 under the Clean Air Act to increase restrictions on plants powered by fossil fuels such as coal, oil and gas. The introduction of this program has had a noticeable effect on nationwide levels of SO2 in the atmosphere. Phase I of the program affected 445 units across the United States, which are estimated to have decreased their SO2 emissions by forty percent during the Phase I period. Phase II began in the year 2000 and affected over 2000 units. Although Phase II was set to culminate in 2010, the progress reports for the final year are yet to be publicized by EPA.

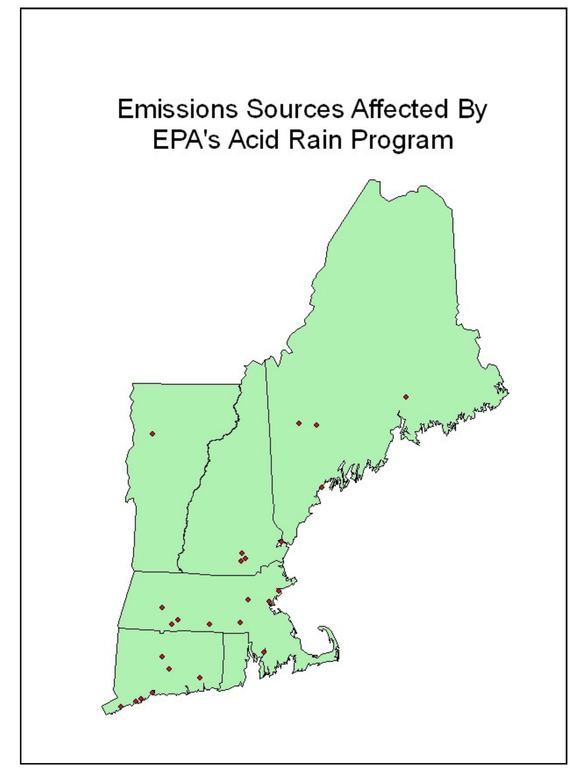


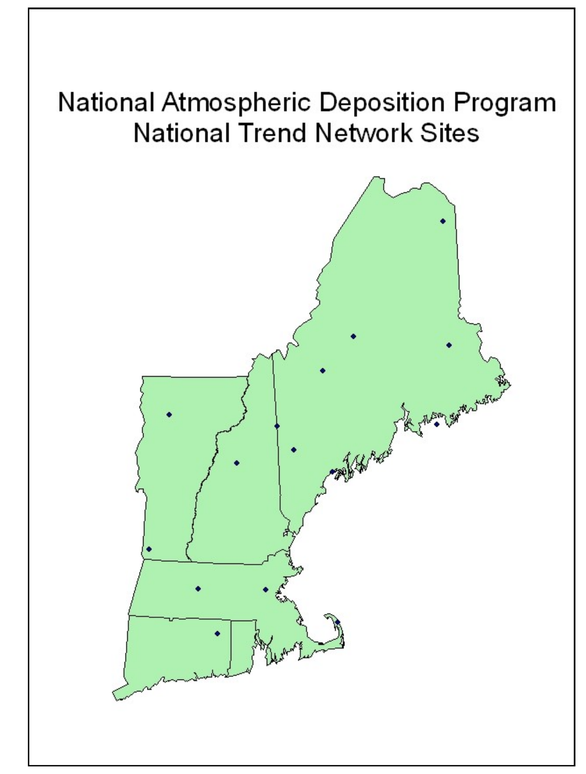
Sulfate emissions from sources affected by the ARP have decreased from 2005 to 2009, the second half of Phase II of EPA's Acid Rain Program.

I became interested in using GIS to examine the effect of the reduction in emissions of SO2 on the measure of sulfates in the atmosphere, and if a conclusive relationship could be drawn. Mainly I was looking to see if the change in emissions over time, specifically the period from 2005-2009, reflected an equal change in the observed sulfates over time. Below I describe my methods for exploring this problem.

Methods:

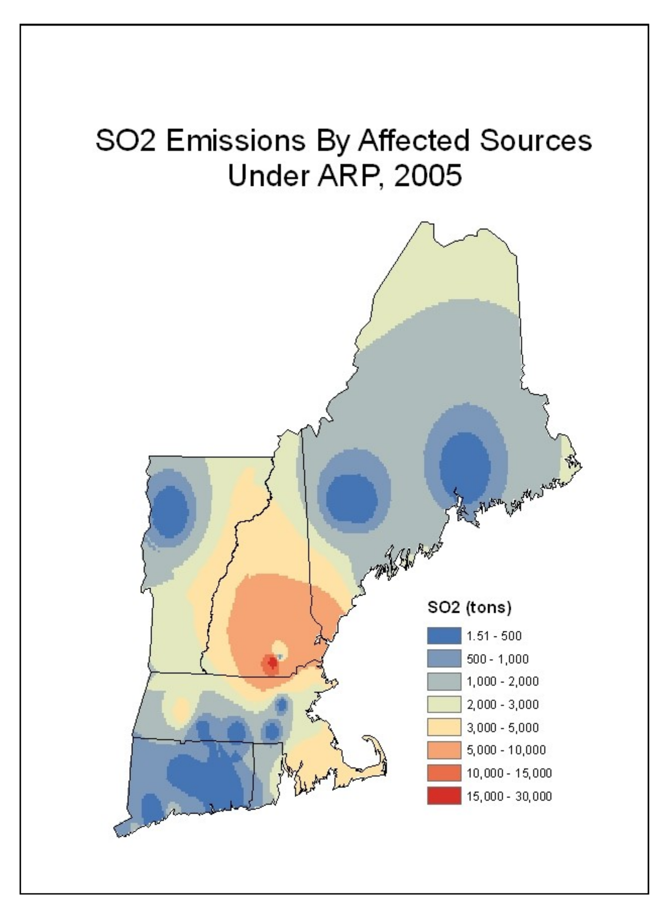
After gathering data from EPA and NADP (National Atmospheric Deposition Program), I needed to prepare it for analysis. This included putting the raw data in the appropriate format to be added to ArcGIS and eliminating extraneous information. I found the data for sulfate measures for the last 20 years from NADP, and after joining this table to that containing the geographic locations of the measurement sites, plotted the locations of the sites on a map of New England. I got the emission data from EPA itself and after eliminating those sites not in Connecticut, Massachusetts, Vermont, New Hampshire or Maine, I too added the data and plotted the geographic locations of the sources on a map.

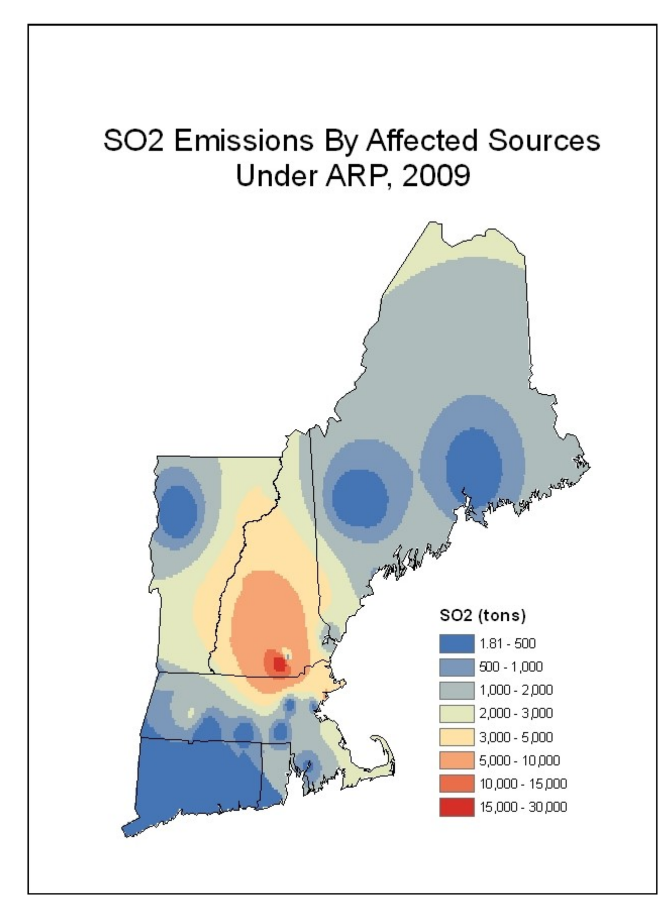




Tracking Analyst was utilized to explore the trend of SO2 emissions and of sulfate measures over time. To do this, I created a shapefile from the source and site data and added it to Tracking Analyst based on the "Year" field. Although this analysis provided an interesting look at the data over time, it was not appropriate for the poster format and was merely used it to explore the data visually using the animated result. Interpolated raster maps provided the best and most accurate visual depiction of the data, and would allow direct comparison. I used Spatial Analyst to interpolate the data with the Inverse Distance Weighted (IDW) method. Raster maps for source emissions in 2005 and 2009, and site measurements for those same years were produced. I then clipped the resulting rasters to the shape of New England and reprojected them for display. After changing the symbology of the rasters to reflect the same range of values within sources and sites, I could examine the change over time in SO2 emissions and sulfate measures.

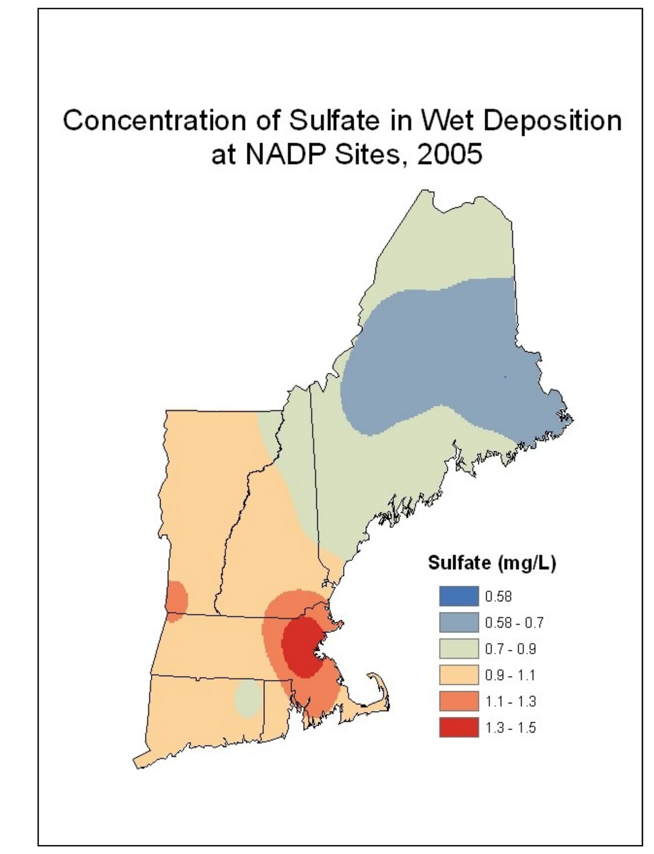
Results:

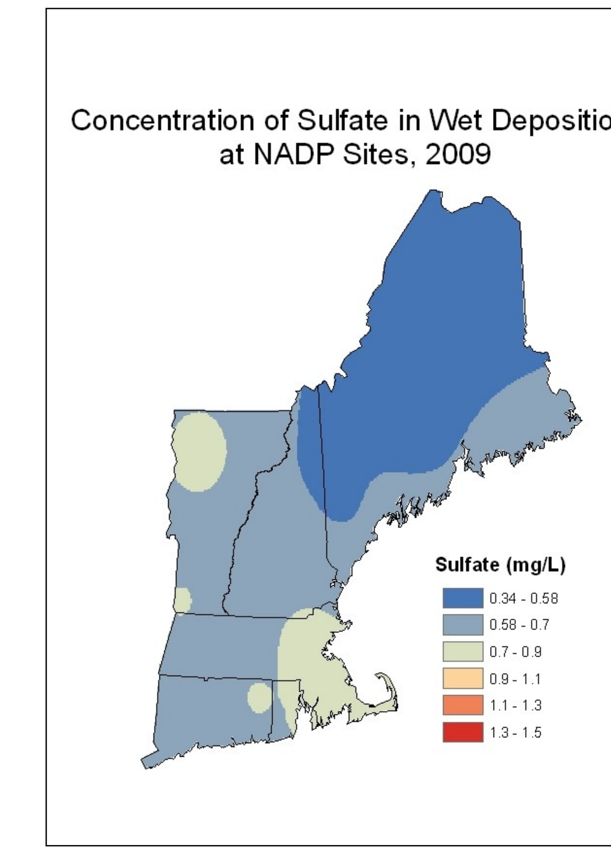




Observing from left to right, the maps show SO2 emissions in 2005 and 2009. The data was interpolated from 25 different sources across New England, meaning that in locations where data was unavailable, a value was given that was in accordance with the observed values. The trend in SO2 emissions is unclear. In some areas, such as the highest values represented in red, the emissions seem to have concentrated to a smaller area over the course of the five years observed. In other places, such as Connecticut and Cape Cod, emissions seem to have decreased, as shown by the larger prevalence of the darker blue color and light green color, respectively.

Results:





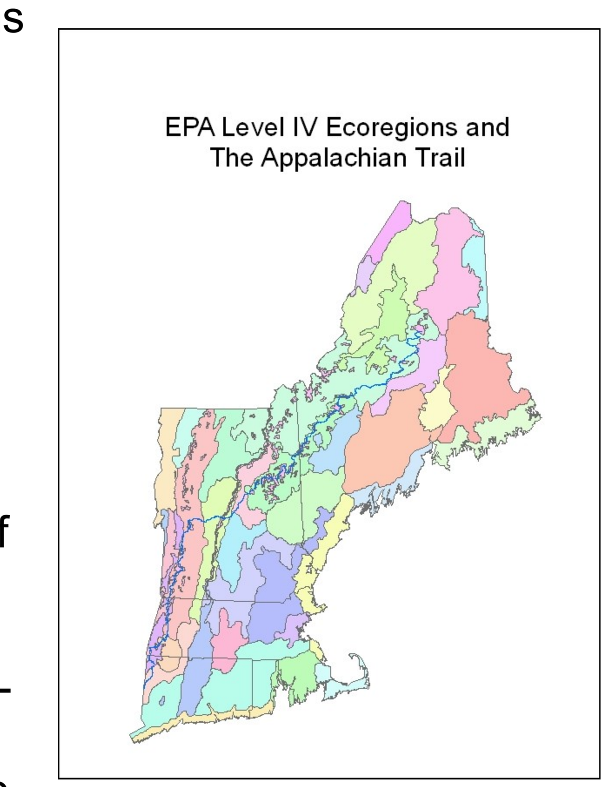
Observing from left to right, the maps show measured concentrations of sulfate in wet deposition in 2005 and 2009. The data was interpolated from 15 different NADP sites using the method described previously. In this case, there is a clear decrease across the board for sulfate measured. The highest values observed, represented in red, have all but disappeared, and other regions show a similar decrease.

Conclusions:

In comparing the two sets of maps above, it is difficult to say conclusively whether a decrease in emissions at the sources affected by EPA's Acid Rain Program during the period of 2005-2009 produced a corresponding decrease in observed sulfate in wet deposition. The region certainly saw a decrease in sulfate during this period, meaning that some action taken has been successful. The colors shown represent a different range and measurement in values, in the case of sources, in millions of tons of SO2, and in the case of the sites, concentration of sulfate in mg/L, and as such cannot be directly compared. In addition, the representation of the data should be subject to critical analysis because although it is represented as a continuum, in reality it was interpolated from a small number of sites. I believe that given the nature of emissions and acid deposition to spread over large areas, this could be an effective way to represent it, however, it does not take into account weather patterns and other factors.

Application: The Appalachian Trail

I had a particular interest in exploring the effects of acid rain on the Appalachian Trail. The AT is a recreational hiking trail that extends from Springer Mountain in Georgia to Mount Katahdin in Maine. It runs along the spine of the Appalachians, through fifteen unique ecoregions, traversing areas particularly vulnerable to acid rain due to their elevation, exposure to the elements and fragility of soil and plant species. It was not feasible to do an entire project on this topic because of the lack of acid rain data specifically relating to the AT, but I did want to mention the possible application of my analysis to this topic. The Trail represents one of the United States' great cultural resources, one of the criteria defined as vulnerable to acid rain by EPA. The many panoramic vistas are at times clouded by acidic mist and the tree and plant species shadowing the trail are under threat, not to mention the diversity of aquatic life that can be observed in lakes and streams along the way. The natural environment prized and sought by many thru-hikers could be at risk of degradation and as such we have to think ever critically about human actions within ecosystems and our role in cleaning up the pollution our energy needs have produced.



Level IV ecoregions represent the most specific classification of areas by EPA and are based on factors including climate, plant and animal species and soil type. The AT traverses 15 unique ecoregions.

Sources:
US Environmental Protection Agency, http://www.epa.gov
Progress Reports from Acid Rain Program: http://www.epa.gov/airmarkets/progress/progress-reports.html
Massachusetts Office of Geographic Information, http://www.mass.gov/mgis/
National Atmospheric Deposition Program, http://nadp.sws.uiuc.edu/