Combining Air Quality and Precipitation Quality Data to Reveal Changes in Atmospheric Composition

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Summary

A new method for extracting air pollution trends information from air and precipitation concentration observations has been tested, and found to conform with expectations. Surface air quality data obtained at long-term stations operated by the Air Resources Laboratory under its AIRMoN program (AIRMoN – the Atmospheric Integrated Research Monitoring Network) are combined with precipitation chemistry data from the National Atmospheric Deposition Program to construct indicators of air chemistry in the lower atmosphere starting in 1985/6. The analysis is based on data from seven stations east of the Mississippi River. On the whole, levels of airborne sulfur reached a maximum in the late 1980s; since then levels have been declining steadily at a rate of about 2.8% per annum, but with an increase to about 5% per annum for a period of the 1990s. There is no clear-cut step function that could be attributed to the initiation of emissions trading and resulting SO_2 emissions reductions in about 1995. Instead, the data appear to indicate that the new regulatory trading philosophies continued the long term improvement in overall air quality that was already under way. The data from individual sites indicate that the benefits of emissions decreases are not necessarily evident at all locations. Improvements appear to be moderated to a considerable extent by local factors, that may dominate in some situations. Overall, the air quality data correlate well with changes in emissions of sulfur as reported by the EPA. The analysis shows that the percentage improvement in sulfur concentrations in the planetary boundary layer east of the Mississippi corresponds one-to-one to the percentage change in emissions from electric utilities (within the statistical uncertainties involved). The results support the hypothesis that regional air quality is governed by the largest point-source emitters, rather than by the integral of all upwind sources.

This work has been published in the Journal of Geophysical Research.

> "Trends in eastern U.S. sulfur air quality from the Atmospheric Integrated Research Monitoring Network," B. B. Hicks, R. S. Artz, T. P. Meyers, and R. P. Hosker, 2002. J. Geophys. Res., 107 (D12) ACH6, 10.1029/2000JD000165.

Background

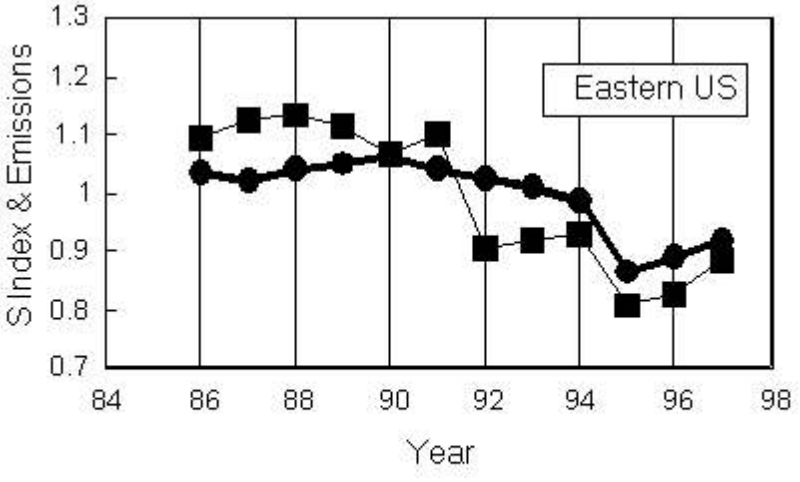
The Clean Air Act Amendments of 1990 (CAAA) imposed a new series of controls on emissions of sulfur dioxide from major industrial sources in the USA. The new cutbacks were to be phased in, starting in 1995. The Act mandated a monitoring program to assess the benefits of the emissions trading approach.

The major US network obtaining air quality data as part of a dry deposition program is the Clean Air Status and Trends Network (CASTNet) of the EPA, which started reporting in 1989. The

research network on which CASTNet was based is the Air Resources Laboratory's Atmospheric Integrated Research Monitoring Network (AIRMoN). AIRMoN has two distinct components, addressing concentrations of pollutants in air (AIRMoN-dry) and in precipitation (AIRMoN-wet). AIRMoN-dry started measuring surface air concentrations of SO_2 and $SO_4^=$ in 1985. CASTNet provides a greater spatial coverage and AIRMoN a longer time record. Both networks are designed to help quantify dry deposition; the measurement of air concentrations is not their main goal but is necessary to the derivation of dry deposition rates. Both networks use filterpack techniques for measuring near-surface concentrations of sulfur dioxide, nitric acid vapor, and a variety of particulate species primarily including sulfate but also nitrate and ammonium. Concentrations measured in surface air are clearly not an optimal basis for assessing the adequacy or effectiveness of the emissions reductions, since surface concentrations are unavoidably influenced by local surface emissions more than are concentrations measured aloft. To look for an air quality response to emissions reductions of the CAAA, it would be better to employ some measure of concentration integrated through the column of air in which the emissions are confined — specifically the Planetary Boundary Layer (PBL) and perhaps the portion of the troposphere immediately above it.

Methodology, and Results

Clouds scavenge pollution from the air surrounding them and deliver it to the ground via precipitation. The falling hydrometeors also scavenge pollution from the air through which they fall. Regardless of which of these two mechanisms dominates, and in contrast to air concentration data, it is clear that concentrations of pollution in precipitation are indicative of concentrations in air aloft, rather than at the surface.



Changes in sulfur air quality east of the Mississippi and national changes in emissions of sulfur from all sources (solid line) and from electric utility point sources alone (dashed line). The air quality indices are averages of the air chemistry and precipitation chemistry results.

Many authors have searched for trends in precipitation chemistry data. Lynch [1995], for example, reports that the NADP record of concentrations in rain supports the hypothesis that the CAAA emission reductions have had the expected beneficial consequences. There is, however, about as much year-to-year variation in precipitation chemistry data as there is in surface concentrations. Part of this variability is doubtlessly due to variations in the amount of precipitation. A dilution effect is well known. To minimize the consequences of dilution

effects, Shannon [1999] formulates an index of air quality by combining two features of wet deposition -- chemical concentrations in the precipitation and wet deposition. In the analysis now described, a procedure is used to correct for dilution effects on a site-specific basis. After this correction is applied, the resulting normalized precipitation chemistry values will bear a one-to-one proportionality with air concentrations at the level of the atmosphere where scavenging occurs. The final step is to combine the air and corrected precipitation chemistry data into a single index, constructed as the linear average of the air and corrected precipitation concentrations (of sulfur) after each is normalized against its own long-term average. The diagram above illustrates the result. Also shown are emissions data for sulfur dioxide, after treatment in the same way.

Other analyses, based on air quality data or precipitation concentration data alone, have suggested the unlikely result that a 1% reduction in emissions corresponded to a much greater reduction in PBL air quality. The present analysis suggests an explanation. Previous analyses have used emissions from the entire national inventory. If this approach were used in the present analysis, a similar result would be found. However, the sites used in this analysis are regional, and are likely affected mostly by emissions from major point sources. The data illustrated in the diagram represent changes in power plant and other major industrial emissions only. The PBL sulfur index data track these emissions data almost exactly, with no significant difference from a one-to-one relationship. Note that the analysis presented here stops in 1997. Subsequent data are now available but await analysis.

There is no strong evidence of any step-function response to the imposition of emissions trading by the Clean Air Act Amendments of 1990. Instead, many of the stations show that, for airborne sulfur, there has been a steady and continuing improvement in air quality starting in the late 1980s and following an apparent maximum occurring then. But likewise, there is no evidence that emissions reductions are not working as intended by the Clean Air Act Amendments. The lack of a clear step function attributable to the imposition of emissions trading under the CAAA is by no means disappointing. In practice, it is now clear that the sulfur roll-back momentum generated through the acid rain decade of the 1980s has continued, no doubt due in large part to the enthusiastic acceptance by industry of the emissions trading approach.

Future Work

The utility of the methodology has been demonstrated. It is now planned to apply the technique to the larger array of CASTNet observations, and to extend the analysis to the present day.