United States
Environmental Protection
Agency

Atmospheric Research and
Exposure Assessment Laboratory
Research Triangle Park NC 27711

Research and Development

EPA/600/S3-89/062 Sept. 1989

EPA

Project Summary

Trends of Seasonal Haziness and Sulfur Emissions Over the Eastern U.S.

Rudolf B. Husar

The seasonal sulfur emission trends for individual regions are compared to the measured trends in atmospheric haziness. The monthly sulfur emissions for individual states going back to the 1800's were reconstructed using yearly emission trends contributed by earlier studies. The seasonal emission rates prior to 1975 were estimated from seasonal fuel consumption; data monthly sulfur emissions are available from 1975-1984. Our results indicate that, before 1970, emissions were greater in winter than in summer, but since 1970 the summer emissions have become comparable in magnitude. In the Southeast there was a clear crossover from a winter peak before 1970 to a summer peak after 1970. The patterns of sulfur emissions and haziness in the Northeast generally correspond with each other — showing a decline in the winter season and an increase during the summer — although the haziness generally shows more random fluctuation. In the southeastern states there is also a close correspondence between emissions and haze patterns, particularly in the summer season. The correspondence between sulfur emissions and extinction coefficient, when these are disaggregated on a regional and seasonal basis, suggests that this relationship can be used as a first indication of how visibility might change with changes in emissions of sulfur dioxide.

This Project Summary was developed by EPA's Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The reduction of visual range is caused primarily by particles between 0.1 and 1 micrometers in size. From the point of view of visibility, the most significant chemical species of submicron particles are sulfates. Therefore, it is expected that the spatial distribution and temporal trend of man-made haziness will, to some extent, correspond to the spatial-temporal patterns of sulfur emissions.

This report examines the sulfur emission-haze relationship using seasonally disaggregated SO_2 emission and visual range data. This study was motivated by observations of the regional and seasonal dependence of haziness. Across most of the northeastern states, for example, the wintertime haziness generally has been increasing in all areas of the eastern U. S The question examined in this study is whether the differences in seasonal haziness trends can be attributed to seasonal shifting of the emission trends.

Sulfur Emission Trends

The emissions of sulfur oxides exhibit a strongly seasonal pattern over most of the country. The seasonal trend is driven largely by climatic variables such as temperature. In the winter season, the low temperatures in some areas cause higher emissions due to heating in the residential and commercial sector. Simi-

larly, in the summertime, cooling requirements cause high electricity consumption —and therefore high emissions—in many areas. Because both heating and cooling demands depend strongly on geography the resulting seasonal amplitude varies from state to state. In the eastern part of the country, the northern states have a winter peak, while the southern states exhibit a peak during the summer.

For purposes of summary and comparison with the haze data, the seasonal emission trends have been aggregated over two regions: the Northeast (Illinois, Indiana, Ohio, Pennsylvania, and New York), and the Southeast (Tennessee, North Carolina, South Carolina, Georgia, Alabama, and Louisiana). In the Northeast, winter (January) emissions were about 50% higher than summer (July) emissions over most of the century but by the 1970's the two seasons' emissions became comparable in magnitude. In the Southeast, there was a clear shift from a strong winter peak to a summer peak; the crossover occurred in the late 1970's.

Regional Haze Trends

In this section, visibility data are analyzed to determine regional haze trends over the eastern U.S. Haziness is the inverse of the visual range. The visual range is the maximum distance at which an observer can discern the outline of a black object against the horizon sky. Values of ground-level visual range are recorded every hour at several hundred National Weather Service meteorological stations within the U.S. The visibility trend database consists of 137 stations for which computerized data are available for the years since 1948. The quantitative measure of haziness is the extinction coefficient, b_{ext} which is calculated from the visual range using the Koschmieder relationship b_{ext} = 24/(visual range in miles). The constant 24 results from the assumption that the eye can just detect a 2% contrast difference between a black object and the horizon sky.

Within geographic regions, individual stations show coherent trends. However, the patterns of the trends differ significantly between the Northeast and the Southeast. In the Northeast, the January haziness shows about a 40% decline between 1948 and 1983, while in the Southeast there was about a 10% increase in the January haze. The July haziness in the industrialized northeastern states shows a general increase of about 40% from the 1950's to the 1960's, with evidence of a decline after 1978. In the southeastern states, on the other hand, summer haziness increased by more than a factor of two, mainly between the 1950's and the 1960's.

Comparison of Trends

The seasonal sulfur emission trends for individual regions are compared to the measured trends in atmospheric haziness in Figure 1. The patterns of sulfur emission and haziness in the Northeast show a rough correspondence: a decline in the winter and an increase during the summer; the haziness generally shows more random fluctuation. In the southeastern states, there is also a close correspondence between emission and haze patterns, particularly in the summer

Conclusions

The results of this study show an interesting relationship between sulfur emission trends and trends in haziness when examined by region and season, although such qualitative comparisons do not provide conclusive evidence of a cause-effect relationship. Also, the patterns of haze and sulfur emissions for the Northeast and Southeast tend to deviate from each other at times. The causes of such deviations may include variabilities due to meteorology as well as potential errors in both emission and haze data. Such deviations would probably be reduced if three month averages were compared rather than single months. Finally, a one-to-one relationship cannot be expected, since the haziness in one region may be influenced by emissions in neighboring regions. If the emission trends differ between each region, atmospheric processes would tend to average out the regional haze trend. A more detailed emission-haze trend analysis could be conducted using a regional haze model that incorporates both the changes in the emissions as well as the meteorological data for individual years. Both emission and wind data sets are available for such retrospective model studies.

The relative significance of chemical species and source types that influence visibility, other than sulfur, were not examined in this analysis. Other compounds may have emission and trend patterns similar to sulfur's. Future studies could examine the emission trends of other potential visibility-reducing species, such as organics, flyash, and soot, in order to estimate their contributions.

From other information it is known that in the eastern U.S. at least in the last decade sulfate, formed in the atmosphere from sulfur dioxide, and the ammonium and condensed water associated with the sulfate, dominate the light-scattering particulate matter in the ambient air. The remarkable correspondence between sulfur emissions and extinction coefficient, when these are disaggregated on a regional and seasonal basis, suggests that this relationship can be used as a first indication of how visibility might change with changes in emissions of sulfur dioxide.

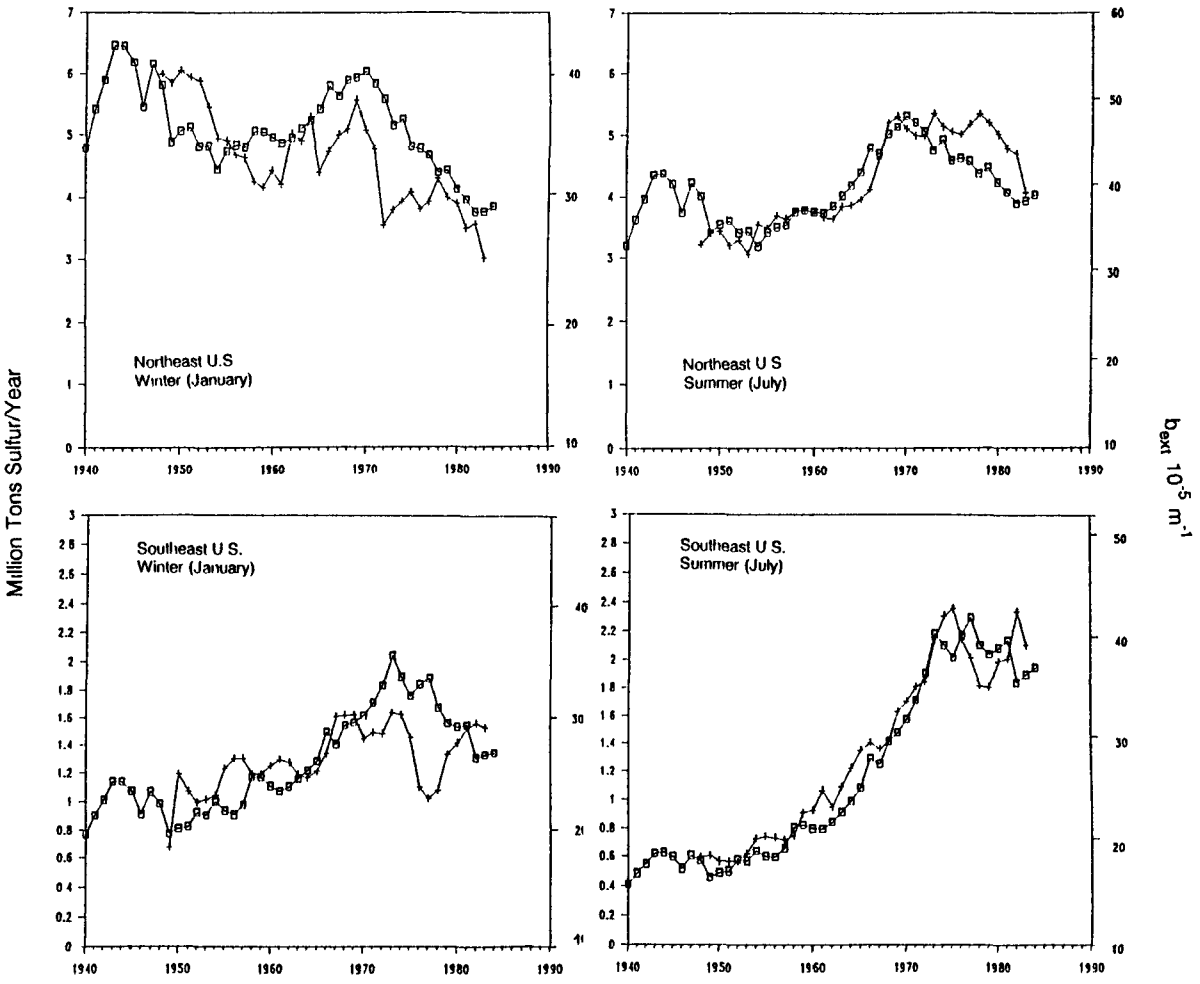
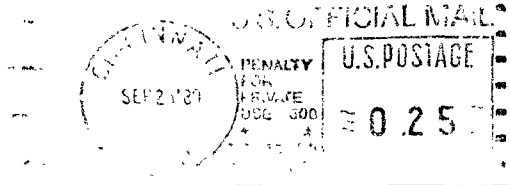


Figure 1. *Comparison of trends of sulfur emissions and 75th percentile extinction coefficient for northeast and southeast U.S. for January and July. □ Emissions + extinction coefficient.*

Rudolf B. Husar is with Washington University, St. Louis, MO 63130.
***William E. Wilson** is the EPA Project Officer (see below).*
The complete report, entitled "Trends of Seasonal Haziness and Sulfur Emissions over the Eastern U.S.," (Order No. PB 89-220 511/AS; Cost: $13.95, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Atmospheric Research and Exposure Assessment Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268



Official Business
Penalty for Private Use $300

EPA/600/S3-89/062