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Project Summary

Haze Climate of the United States

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The historical data base of visual range at 137 surface synoptic meteorological stations is examined. The original observations of visual range each noon are converted to light extinction coefficient, BEXT= 24 / VISIBILITY, a measure of haziness. The b_{ext} is summarized for each calendar quarter from 1948 to 1983 as percentiles of the distribution function, namely the 25th, 50th (median), 75th and 90th percentile. Detailed examination of station by station behaviour indicate that the median is often obscured by an upper threshold of visual range reported; thus, 75th percentile results are used to illustrate the secular trend of haziness at each site. The results consist of trend graphs, as well as seasonal contour maps for each decade of the time period. The most pronounced changes over the 35 year period have been in the summer season over the Eastern U.S. The past decade has seen strong increases in haziness in the southeastern U.S. and, more recently, in the deep South.

This Project Summary was developed by EPA's Atmospheric Sciences Research 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

This is a climatic atlas of the haze over the contiguous United States for the time period 1948 to 1983. It covers the spatial and temporal pattern of atmospheric haziness in a climatic sense: in terms of synoptic distribution and secular trends. It also contains a rough attribution of haze between man-induced and natural causes. The attribution of the man-made haze to specific sources is beyond the scope of this atlas.

The spatial and temporal distribution as well as the man-made causes of atmospheric haze have received considerable attention from researchers on this continent since the late 1970's. Much of the recent literature deals with physical-chemical properties of haze and has the aim of understanding its sources and formation mechanisms. Over the years various investigators have reported haze maps covering parts of North America.

This report is one of a series on the continuing haze research at Center for Air Pollution Impact and Trend Analysis (CAPITA) that was initiated in 1976. Since 1982, EPA has supported through Cooperative Agreements the maintenance and updating of a visibility data base. This report is a product of that data acquisition, maintenance and analysis. The availability of such large scale data base on a timely basis permits the monitoring of the regional shifts in atmospheric haziness. Undoubtedly, such data can be of benefit for the monitoring of the nation's atmospheric environment, effectiveness of existing control strategies, and the development of future ones.

Visibility Data Base

The sources and the gross features of visibility data have been described in the past by almost all investigators dealing with the subject. The following discussion will be limited to those items that are directly relevant to the climatic maps and trend graphs in this atlas.

The trend data base consists of 137 stations for which computerized data exists since the 1948-1952 period. The spatial coverage of stations is particularly dense in the Northeast. The temporal coverage for most stations started in 1948, although some stations only have computerized data since 1952. The main data base of 3-hourly weather observations resides on over 50 magnetic tapes. For purposes of spatial-temporal trend analysis, raw visibility observations were summarized as monthly averages of noontime light extinction coefficient (24 / visual range, miles). For each month and station, three different extinction coefficients were calculated: the first set includes all visibility data regardless of weather and pollutant conditions (BX); the second group (FX) is composed of extinction coefficients excluding precipitation (rain and snow) and fog events; the third group (RX) excludes precipitation, fog and includes an RH correction that was performed to compensate for water and vapor effects. This latter parameter is closely related to the dry fine particle aerosol mass concentration. The correction, RX = BX/f(RH), serves primarily to reduce the apparent extinction coefficient at relative humidities above 80%.

A problem with visual range measurements is that there is always a furthest marker beyond which the visual range is not resolved. This translates to a lower threshold value for the computed extinction coefficient. For this reason, the mean is inappropriately biased upward, and more reliable, nonparametric statistical indices are more useful. In our analysis, the 25th, 50th, 75th and 90th percentiles of each of the three extinction coefficients are calculated monthly for each station. Other statistical quantities such as means and standard deviations can be computed from the percentiles once it is established which percentile is valid, i.e. above the threshold.

The utility of the computer percentile values is demonstrated in Figure 1. For Sioux City, IA, the trend graph shows that from 1948 to 1968, the threshold extinction coefficient (FX) was at 16, and then dropped to 8 x $10^{-6}m^{-1}$. Since the 50th percentile was near the high initial threshold, this median would indicate a drop in the later periods; the mean would show a strong decrease in the late 1970's. The 90th percentile, however, appears to be a robust reliable measure which is above the threshold influence; it indicates a clear increase in extinction over the entire period. Thus, depending on whether one follows the 50th or 90th percentiles, one would arrive at opposite conclusions about the trend.

The excellent spatial and temporal coverage of the visibility data base can be utilized only after careful site by site scrutiny for anomolous behaviour such as this. The following results were compiled after extensive examination at each site's percentile trends. The advantageous feature of systematic threshold offset is that the properly presented data can identify its limitations and provide remedies for them.

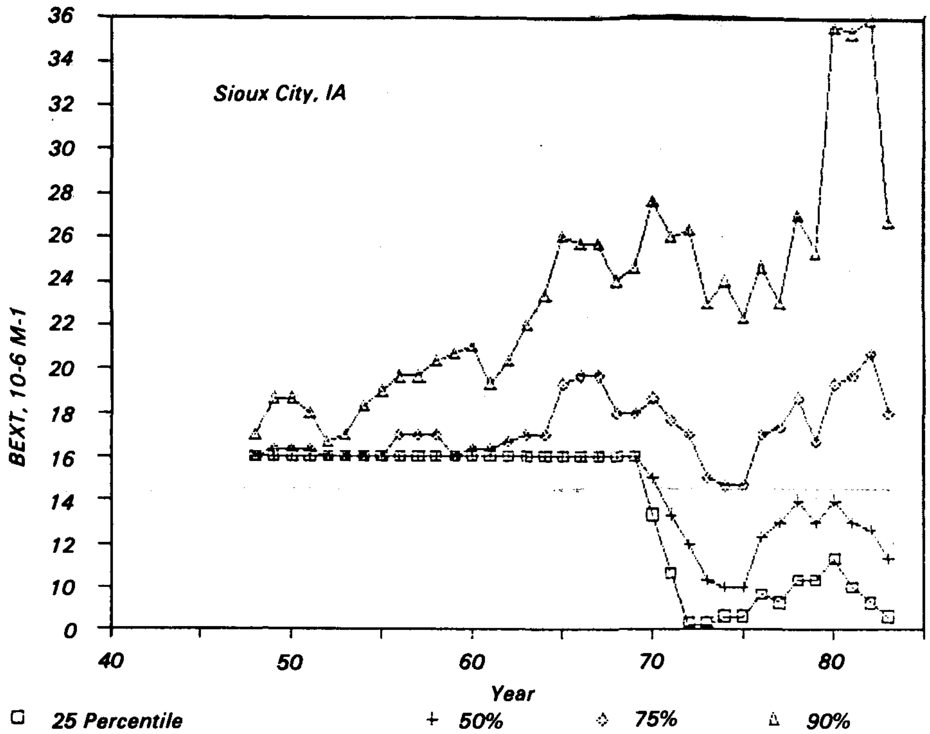

Figure 1. Trends of percentiles at Sioux City, IA.

Climatic Maps of the U.S. Haze

The essence and the summary of the present haze atlas is given in Figure 2. The specific parameter that is plotted is the 75th percentile of the extinction excluding precipitation and fog and corrected to RH = 60%. While this is unconventional, it constitutes the safest approach in that it did not require any extrapolations or other adjustments to the data. More conventional statistical measures can be estimated as follows: from previous research it is known that the extinction coefficient is roughly lognormally distributed with typical logarithmic standard deviation of 2.5. For such a distribution, the 50th percentile is 0.5 times the 75th percentile, and the mean is 0.76 times the 75th percentile. Thus, if one is to convert the maps, the scales of the intervals must be multiplied by the appropriate fractions. We recognize that even if the haze is lognormally distributed everywhere, its log standard deviation will tend to vary geographically and seasonally. The available data suggest, however, that its range is confined to 1.6 to 3.4.

Figure 2 is a composite of 16 maps, each representing four time periods and four seasons. The time periods are selected to center around 1950, 1960, 1970 and 1980, while the four quarters are Jan.-March, Apr.-June, etc. These maps are indicative of the dry fine particle concentration over the nation. Hence, they represent a "pollution index" for visual air quality. The winter season "dry" haziness is most pronounced over the Great Lakes states, California and the Gulf states. Pennsylvania and New York show declines of dry haze from the 1950's to the 1980's. Ohio has not changed significantly. The California stations, particularly in the south coast basin, show increased winter dry haze, particularly from 1940 to 1950. The most significant wintertime increase is noted for the Gulf states, LA, AL, MS, and GA. Second and third quarter haziness shows an increase over all states east of the Rocky Mountains. The increase is most pronounced for the Gulf states, and least over the northeast and California. Quarter four closely resembles the spatial and temporal trends over the first quarter. Again, not-

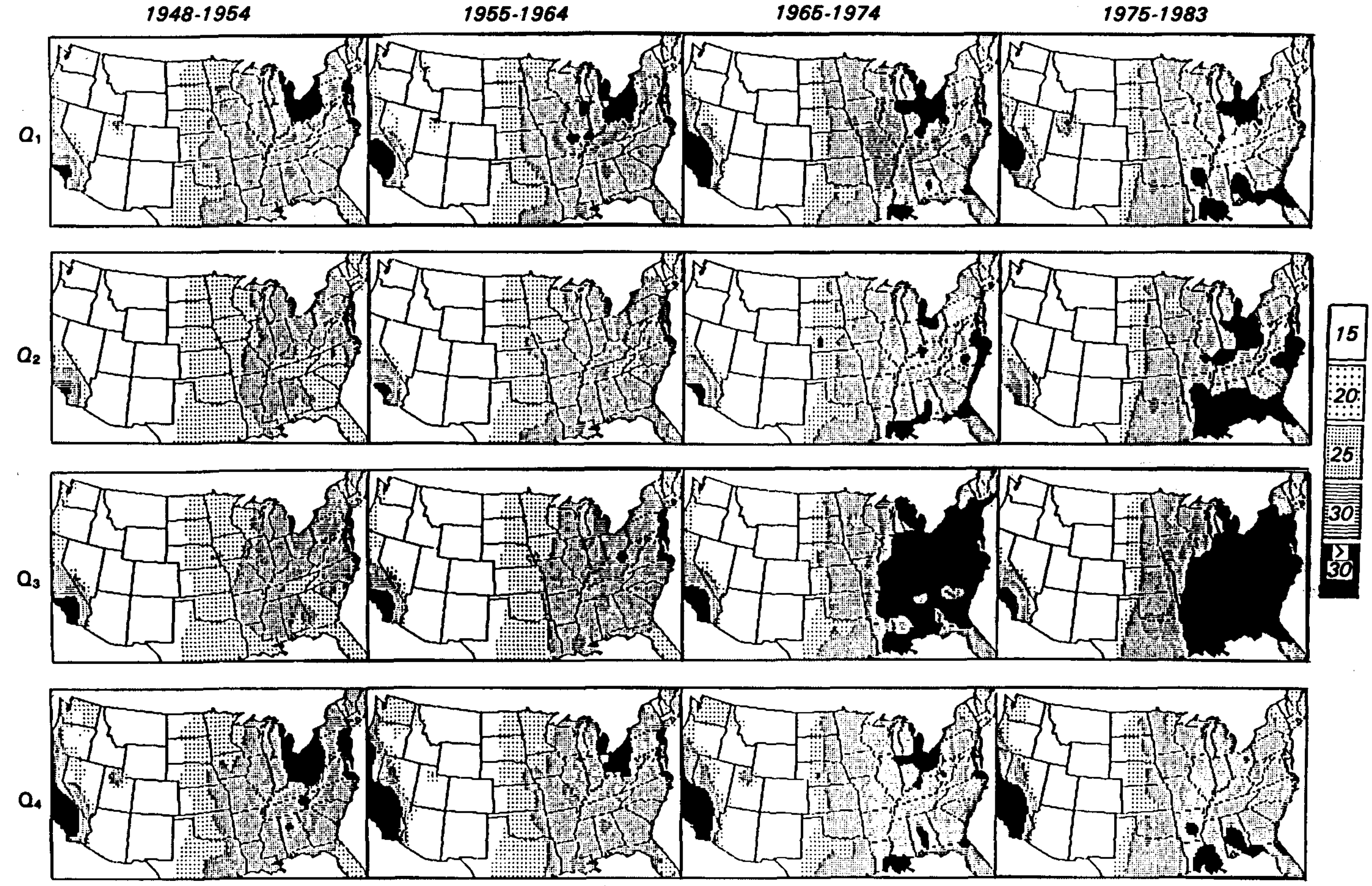

Figure 2. *Trend maps for U.S. haziness for winter (Q1), spring (Q2), summer Q3), and fall (Q4). The units are mean extinction coefficient, $10^{-6}\,m^{-1}$.*

able exceptions are the improved late fall visibility in the Ohio region.

Trends of Haze at Selected Sites

The secular midday summertime trends of RH BEXT percentiles for all stations are presented in the Appendix of the full Report. A few sites representative of regional behavior will be discussed briefly. The haziness at Long Beach, CA, was among the worst in the nation in the 1950's and 1960's, with median visibility of about 6-8 miles. Beginning in the early 1970's, the visibility has shown a clear and consistent trend to improved visibility. Generally low levels of extinction have been present at Phoenix, AZ, throughout the period since 1948, with clear indications of reduced haziness since about 1974. There is no evident trend in the median haziness at Des Moines, IA, particularly since much of the trend is obscured by the threshold problem up to 1970. The higher percentiles, however, appear to exhibit an upward trend over the entire period. Madison, WI trends also indicate a consistent secular increase in haziness, although the 25th and 50th percentile information is lost until 1980. A sharp increase in haziness is evident about 1978, likely due to local influences. The trends indicate that New Orleans, LA, has experienced increased haziness since the late 1950's. A rather sharp jump in the lower percentiles occurred about 1968. The trend at Jackson, MS, indicate a rapid rise in haze at the lower percentiles, including the median, beginning about 1976. The median extinction coefficient rose by 50% in the past decade. At Columbus, OH, the gradual increase in haziness from about 1960 reversed itself in the mid-70's, indicating little change over the past decade in summertime haziness there.

Our earlier studies, found evidence of remarkably rapid increase in average haziness at Charlotte, NC from the mid 1960's to 1974. The current analysis of percentiles shows that the strong increases have halted about 1974, with no evidence of further trend over the past decade. In New York City, visual range observations at LaGuardia airport show a flat secular trend, with some improvement in visibility in the upper percentiles since the mid 1960's. Nearby sites, e.g. Newark, NJ, are similar. Evidently the haze in the industrialized northeast has not worsened.

Finally, the Burlington, VT, site may be regarded as a remote receptor of regional haze. The median extinction coefficient there has changed very little over the last thirty years, while substantial swings have occurred at upper percentiles. Where such a receptor is periodically hit with heavily polluted air masses, the highest percentiles serve as an index of the aerosol pollution contributed by upwind sources. Here it appears that the higher percentiles increased during the 1960's decade, but have declined since about 1970.

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***William E. Wilson** is the EPA Project Officer (see below).*
The complete report, entitled "Haze Climate of the United States," (Order No. PB 87-141 057/AS; Cost: $18.95, subject to change) will be available only from:
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