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Project Summary

The National Air Pollution Background Network 1976-1980

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The U.S. Environmental Protection Agency in cooperation with the U.S. Forest Service has established a network of air monitoring stations designed to measure levels of ozone in remote areas within the contiguous 48 states. There are currently eight sites, at various National Forests, which measure ozone, wind speed and direction, temperature, relative humidity, and solar radiation. This is a study of the network data gathered from 1976 through 1980 with analytical emphasis on the year 1979, for which the most complete meteorological and ozone records were available.

The mean ozone level for 1979 at these sites fell within the range of 0.025 ppm to 0.04 ppm. At most sites, there were several days in 1979 when hourly concentrations of ozone exceeded 0.08 ppm. The maximum 1-hr ozone concentration observed was 0.125 ppm. The report provides analyses of the statistical distributions of the ozone data from these remote sites, their relationships with local meteorological data, and the possible impact of air parcel history upon ozone concentration.

Examination of several individual days in 1979 with relatively high ozone levels using a back trajectory model showed that in almost all of these cases, the air had passed over large urban areas within the previous three days. The hypothesis is presented that high levels of ozone at remote sites may be due in part to the long range transport of ozone and/or its precursors.

This Project Summary was developed by EPA's Environmental Monitoring Systems 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 National Ambient Air Quality Standard (NAAQS) for photochemical oxidants (measured as ozone) was initially set in 1971, at an hourly average concentration not to exceed 0.08 parts per million (ppm) more than once per year. At that time only sparse ozone data were available from rural and remote areas; ozone concentrations in these areas were believed to be low and inconsequential relative to the standard. Ozone from background areas also was thought to be largely removed by chemical scavengers upon entry into an urban environment. Subsequent investigations, however, have suggested that rural areas experience a greater range of variation than originally supposed and that ozone transported from rural to urban areas cannot always be disregarded. In the mid-1970's, the U.S. Environmental Protection Agency (EPA) conducted several field monitoring studies of summertime ozone concentrations in the Eastern United States. These studies confirmed that ozone concentrations in

predominantly rural areas may occasionally exceed the NAAQS level then existing (the NAAQS level was changed to 0.12 ppm in 1979).

In response to these findings, EPA decided to establish a nationwide network of remote ozone monitoring stations. The network was started in 1976 as a joint effort between EPA's Environmental Monitoring Systems Laboratory (EMSL) and the Office of Air Quality Planning and Standards (OAQPS), located in Research Triangle Park (RTP), NC. The Forest Service of the U.S. Department of Agriculture also participated in the project by providing three sites in National Forest (NF) areas and by performing routine operations at the monitoring stations. The network was expanded to six sites in 1978 and to eight sites in 1979.

Currently, the National Air Pollution Background Network (NAPBN) collects continuous measurements of ozone concentrations by the chemiluminescence technique at eight remote monitoring stations across the continental United States. In addition, continuous measurements are made of wind direction and speed, temperature, relative humidity, and solar radiation. Site locations are shown in Figure 1, and station descriptions are provided in Table 1.

The network provided a reasonably long-term and continuous record of ozone concentrations and patterns in areas well removed from anthropogenic sources of air pollution and made these data available to EPA and other interested researchers. All valid data from the NAPBN are on file and may be accessed through the National Aerometric Data Bank (NADB) at RTP. In this report, network ozone data are examined, relationships with on-site meteorological measurements are explored, and possible influences from mesoscale air mass movements are investigated.

Results and Discussion

A cumulative frequency distribution is presented in Table 2 for the ozone data collected during 1979 at each of the eight monitoring sites. Because the sites in Arizona and Oregon were added late in the year (September and October, respectively), the number of hourly measurements available (column 2) is considerably less than for the six sites which were operational for the entire year. Direct comparisons involving these sites are, therefore, of somewhat limited utility.

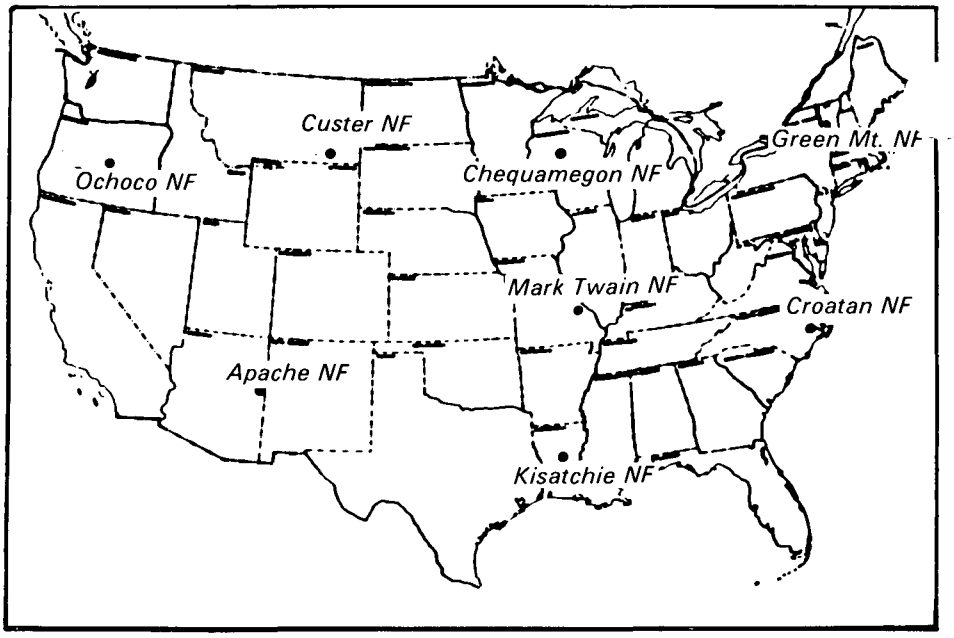

Figure 1. Location of remote ozone monitoring sites.

Table 1. Description of Remote Ozone Monitoring Sites

Site	Elevation (msl)	Latitude/ Longitude	Start date
Green Mountain NF VT	390 m	43° 56' 00" N/ 73° 02' 00" W	10/25/76
Kisatchie NF LA	65 m	31° 30' 00" N/ 92° 28' 20" W	5/26/76
Custer NF MT	1250 m	45° 14' 00" N/ 106° 15' 00" W	8/26/76
Chequamegon NF WI	440 m	45° 12' 00" N/ 90° 37' 00" W	8/10/78
Mark Twain NF MO	350 m	37° 28' 00" N/ 90° 11' 00" W	12/09/78
Croatan NF NC	13 m	34° 59' 05" N/ 77° 11' 24" W	3/10/78
Apache NF AZ	2500 m	33° 45' 00" N/ 109° 00' 00" W	9/16/79
Ochoco OR	1350 m	44° 13' 30" N/ 119° 42' 25" W	10/04/79

Of the six NAPBN stations operational for the entire year, all but the site of Custer NF in Montana recorded ozone concentrations in 1979 which were in excess of 0.08 ppm. A listing by site and month of these occurrences appears in Table 3. As shown by this table, most hours of elevated ozone concentration (>0.08 ppm) occurred in the spring and early summer months. Also, a disproportionate share of such instances occurred at the Mark Twain NF in Missouri, where over 2 percent of all hourly averages exceeded 0.08 ppm ozone in 1979.

Average 1979 ozone concentrations by hour-of-day in local time are shown on a quarterly basis in Figure 2. Values plotted are a composite of the six sites operating throughout 1979 (i.e., all except the Arizona and Oregon sites) since these sites exhibited very similar diurnal and seasonal patterns. Ozone concentrations typically began to build

Table 2. *Cumulative Frequency Distributions of 1979 NAPBN Ozone Data (ppm)*

	YEAR	No.	MIN	10	30	50	60	70	80	90	95	98	MAX	ARITHMETIC MEAN	ARITHMETIC STD	GEOMETRIC MEAN	GEOMETRIC STD
Arizona																	
Apache NF	79	2427	LD	.035	.045	.050	.050	.055	.055	.060	.065	.070	.080	.0493	.0097	.0482	1.246
Louisiana																	
Kisatchie NF	79	6993	LD	.010	.020	.025	.030	.035	.040	.045	.055	.060	.100	.0269	.0145	.0225	1.916
Missouri																	
Mark Twain NF	79	8371	LD	.020	.030	.035	.040	.045	.055	.065	.075	.085	.125	.0394	.0181	.0348	1.711
Montana																	
Custer NF	79	8488	LD	.015	.025	.030	.035	.040	.045	.045	.050	.055	.070	.0315	.0122	.0287	1.594
North Carolina																	
Croatan NF	79	8262	LD	LD	.015	.025	.030	.035	.040	.050	.060	.065	.085	.0279	.0166	.0223	2.087
Oregon																	
Ochoco NF	79	2096	.010	.020	.025	.030	.030	.035	.035	.040	.040	.040	.050	.0292	.0067	.0284	1.286
Vermont																	
Green Mountain NF	79	6423	LD	.010	.025	.030	.035	.045	.040	.050	.065	.075	.105	.0317	.0165	.0270	1.860
Wisconsin																	
Chequamegon NF	79	7684	LD	.020	.025	.035	.035	.045	.040	.055	.060	.070	.110	.0353	.0148	.0321	1.581

LD: less than .010 ppm

Table 3. *Occurrences of Concentrations Exceeding 0.08 ppm Ozone**

	SITE				
Month	Kisatchie NF	Mark Twain NF	Croatan NF	Green Mt NF	Chequamegon NF
January					
February					
March		1/3		1/2	
April	1/2	5/27		1/4	
May		5/27		1/2	1/9
June		8/45		8/34	8/32
July		7/74		4/17	2/12
August			1/7	1/3	
September		5/24		1/1	
October	1/3	1/3			
November					
December					
Total '79	2/5	32/203	1/7	17/63	11/53
Percent hours '79	0.1	2.3	0.1	0.7	0.6

*Number of days/hours > 0.08 ppm by site and month for 1979.

at about 7 a.m., reached a maximum shortly after 12 noon, and then declined throughout the evening and early morning hours. The average levels were highest in the second quarter (April through June), with a small decrease in the third quarter (July through September), and with relatively low average levels during the remainder of the year.

To determine to what extent local meteorological conditions may be used to predict ozone concentrations in remote areas, linear models were constructed using the 1979 NAPBN data. Ozone, the dependent variable, was modeled as an additive function of the independent meteorological variables. Linear modeling by sites and by a combination of sites produced a substantial number of significant variables in the stepwise regression procedure, but the amount of the variance ascribed to meteorological variables was consistently small (i.e., ≤ 0.50).

To examine the possibility of transport as an important contribution to ozone at the NAPBN sites, synoptic-scale trajectory analyses were conducted for selected cases (days) of measured high ozone concentrations. For this analysis, 1979 ozone measurements at the NAPBN sites were first screened to identify days with high ozone concentrations. A high ozone day at a particular site was defined as a day when at least one hourly average ozone concentration exceeded 0.08 ppm.

The distribution of high ozone days by month indicates that most of the cases occurred during June through September when the potential for photochemical formation of ozone in the boundary layer (lower troposphere) was greatest. However, high ozone was measured, on occasion, during the spring at Mark Twain, Chequamegon, Kisatchie, and Green Mountain National Forests. The seasonal pattern in ozone observed at the NAPBN sites is tied to the types of sources contributing to background ozone concentrations.

At Mark Twain, Green Mountain and Chequamegon National Forests, the cases examined were chosen at random from the subgroup of high ozone days occurring during June through September.

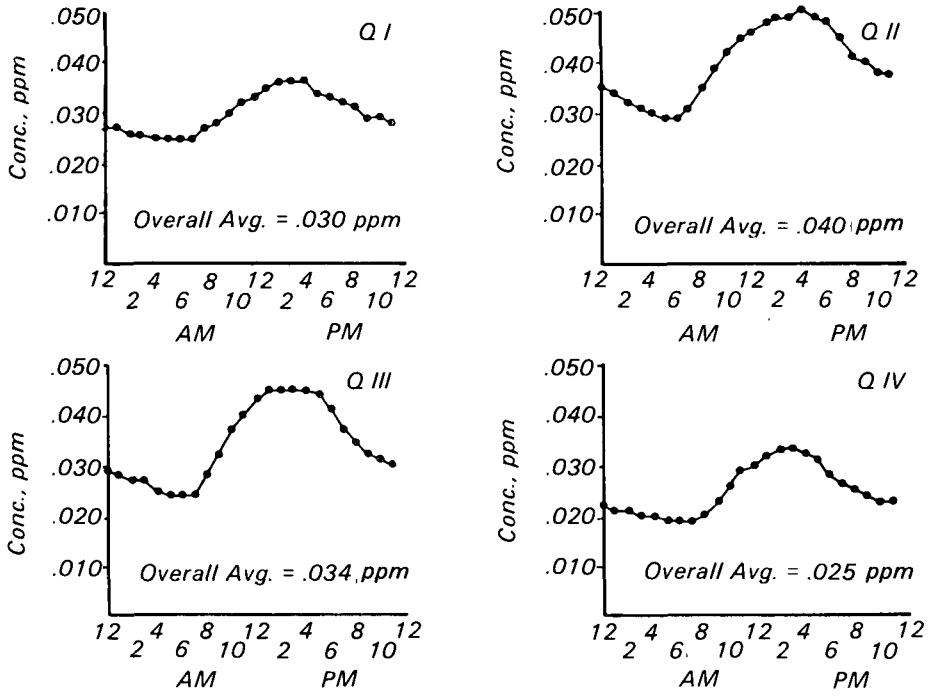

Figure 2. Diurnal plots of 1979 ozone data by quarter (6 sites).

Figure 3. Trajectory analysis plots at Mark Twain National Forest, MO: July 17, 1979.

Figure 4. Trajectory analysis plots at Mark Twain National Forest, MO: July 18, 1979.

Figure 5. Trajectory analysis plots at Mark Twain National Forest, MO: July 19, 1979.

At Kisatchie NF, the April case was selected, and at Croatan NF the single case in August was analyzed. The synoptic-scale back trajectories used to examine ozone transport were computed from the Air Resources Laboratories Atmospheric Transport and Dispersion Model (ATAD). For computing trajectories, upper-air winds were averaged within a 400-m layer centered on 1000 m AGL.

In 1979, EPA promulgated a revised NAAQS for ozone which stated that the expected number of days per calendar year with daily maximum ozone concentrations exceeding 0.12 ppm must be less than or equal to one. This new standard differs from the original in several important ways, including the specific designation of ozone, the emphasis on the daily maximum concentration, and the statistical interpretation of "expected exceedances." The most obvious difference, however, is the change in the level of the standard from 0.08 ppm to 0.12 ppm.

This higher concentration level was exceeded in only a single instance in 1979 for the entire eight-site NAPBN. The one exceedance (0.125 ppm) occurred at the Mark Twain NF in Missouri on July 21 at 3 p.m. during a week-long episode of elevated ozone levels. This period was one of those analyzed to determine the possibility of long-range transport effects. Figures 3 to 9 depict back trajectories computed from the Mark Twain NF site for July 17 through 23, respectively, beginning at the local times indicated. The trajectory segments are marked in 12-hr increments.

The dominant synoptic-scale meteorological feature in the Midwest during this period was a large high pressure system that traversed the region from west to east. The center of the high moved to the north of the Mark Twain NF site on July 19, then weakened considerably as it neared the east coast on the following day. From July 17 through July 21 (the period of increasing ozone concentration), there were clear skies in the Midwest in association with the high pressure system, with maximum temperatures in the mid-80's (°F). Thus, meteorological conditions during this period were favorable for ozone formation from anthropogenic sources. An area of low pressure, which formed over the Tennessee Valley on July 22, spread clouds and rain into the lower Midwest, diminishing photochemical activity by July 23.

On July 17, the air passing the Mark Twain NF site had crossed predominantly rural areas 36 hours earlier, and low ozone concentrations were observed.

Figure 6. Trajectory analysis plots at Mark Twain National Forest, MO: July 20, 1979.

Figure 7. Trajectory analysis plots at Mark Twain National Forest, MO: July 21, 1979.

Figure 8. Trajectory analysis plots at Mark Twain National Forest, MO: July 22, 1979.

Figure 9. Trajectory analysis plots at Mark Twain National Forest, MO: July 23, 1979.

Beginning on July 18, the air parcel paths crossed major urban centers prior to reaching the Mark Twain NF site. Specifically, the Chicago-Gary area was 24 to 36 hours upwind on July 18 and 19. On the 20th, the trajectories passed in the vicinity of Detroit, 72 hours upwind from Mark Twain NF, and then followed the Ohio River Valley, passing near Cincinnati (36 hours upwind). Emissions from St. Louis appear to have had an impact on the 21st and 22nd, when the trajectory paths indicated that the site was directly downwind of the St. Louis area. On the final day in the series, the trajectories arrived from the south and east, with Memphis being the only urban area upwind within 48 hours. However, as previously indicated, meteorological conditions were unfavorable for ozone formation.

Numerous events of high ozone concentrations were observed during the spring and summer of 1979 at several NAPBN sites. Further work is needed to establish the sources of ozone during such events. However, the early spring events may be associated with natural sources (i.e., the stratosphere), while anthropogenic sources probably contribute to most of the summer season events. Analysis of selected high ozone events indicates that long-range transport of air mass ozone burden contributed to measured peak concentrations at the remote sites. Also, the impact of relatively nearby urban areas was probable during events at Mark Twain and Kisatchie National Forests.

Examination of selected low ozone periods indicates that meteorological conditions were unfavorable for ozone formation or ozone transport from urbanized areas during such periods.

Conclusions

- Although the NAAQS level for ozone (0.12 ppm) was exceeded only once at the NAPBN sites during 1979, high ozone concentrations (>0.08 ppm) occurred at five of the sites, most frequently during the spring and summer months (April through September).
- With the exception of the Missouri site, the observed concentration distributions of ozone fell within the ranges for ozone of stratospheric origin in remote areas predicted by various researchers.
- Diurnal maximum 1-hr ozone concentrations occurred most frequently in the early afternoon (1 p.m. to 3 p.m.), and the maximum monthly means occurred in the spring (April through June).
- Mean ozone concentration increased with site altitude, maximum ozone concentrations were greatest in regions having greater density in urban and industrial development.
- Of the three network sites which have been operating since 1976, the site at Kisatchie NF, LA, reported slightly lower ozone levels in 1979 and 1980, while the others showed no detectable trends.
- Regression analyses suggest that local meteorological measurements and seasonality terms can account for just over 50 percent of the observed variation in ozone concentrations.
- Trajectory analyses indicate that some instances of elevated ozone concentrations (i.e., ozone $>$ 0.08 ppm) may be the result of transport over several hundred miles from distant urban environments.

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The complete report, entitled "The National Air Pollution Background Network: 1976-1980," (Order No. PB 83-100 412; Cost: $9.00, subject to change) will be available only from:

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