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RELATION
OF OXIDANT LEVELS
TO PRECURSOR EMISSIONS
AND METEOROLOGICAL
FEATURES -

VOLUME II: REVIEW
OF AVAILABLE
RESEARCH RESULTS
AND MONITORING DATA

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THE RELATION OF OXIDANT LEVELS TO PRECURSOR EMISSIONS AND METEOROLOGICAL FEATURES

Volume II: Review of Available Research Results and Monitoring Data (As of November 1975)

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I BACKGROUND, OBJECTIVES, AND LIMITATIONS OF THIS REVIEW

This review is a part of a research study being conducted for the U.S. Environmental Protection Agency (EPA). The overall study aims to answer the following questions:

- What causes the high oxidant values that are frequently observed in rural areas well removed from emission sources?

- What are the effects of synoptic and smaller-scale meteorological variables on ground-level oxidant concentrations?

- How much does ozone of stratospheric origin contribute to ground-level oxidant concentrations?

- Is it possible on the basis of relationships between oxidant concentrations and synoptic-scale meteorological conditions to identify geographic regions for uniform oxidant control strategies? If so, how?

As a logical first step in this effort, a relatively comprehensive survey of the relevant available literature and data has been carried out and is presented here. The objectives of this review are to:

- Develop a clear picture of the current scientific consensus on the oxidant problem in the eastern United States, with particular emphasis on the relation of nonurban oxidant to meteorological processes.

- Provide a compilation of appropriate available data as a basis for selection of the most available data from specific sites for further detailed analysis.

Accordingly, Sections II, III, and IV of this report provide an overview of the current state of knowledge on the oxidant problem, a descriptive listing of selected research studies, and a summary of available data sources, respectively.

Since the oxidant problem in the eastern United States is the topic of this investigation, studies and data dealing specifically with the West Coast oxidant problem have generally not been included in this report.

II REVIEW OF THE CURRENT STATE OF KNOWLEDGE ON THE RELATION OF OXIDANT LEVELS TO METEOROLOGICAL FEATURES

A. Historical Overview

In the early part of this century it was discovered that ozone[*] is synthesized in the stratosphere by chemical processes that involve photodissociation of molecular oxygen. It was found that O_3 has a unique vertical distribution with a maximum concentration of about 5-10 ppm (10^6 v/v) occurring at about 25 km (Junge, 1963). Thus the largest natural source of ozone was discovered and found to be extremely important in providing a protective (UV) shield against ultraviolet radiation for the earth.

In the early 1940s ozone was also found to be a tropospheric constituent, and the primary source was proposed to be the stratosphere. In the intervening years, it has been postulated that the downward transport of stratospheric ozone is controlled by air exchange mechanisms across the tropopause or through tropopause gaps, particularly in the vicinity of the jet stream and weather frontal zones (EPA, 1970).

Ozone took on a new role in the 1950s when it was discovered that ozone could be synthesized in the polluted air of cities by photochemical processes involving reactions between hydrocarbons and oxides of nitrogen (Leighton, 1961). Bell (1959) showed that ozone or ozone precursors could persist overnight and appear at high concentrations the next

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[*] In this report, the terms "ozone" and "oxidant" are used interchangeably for convenience, since the models predict ozone and the standards apply to oxidants, and the difference between the two is not important in our discussion.

morning at distances as far as 100 miles away from their apparent
sources in southern California. At this time it was still believed that
the principal source of world-wide tropospheric ozone was the stratos-
phere, since ozone produced in polluted urban areas was considered to
be only a localized problem, not contributing significantly to the
global budget.

Based upon observed O_3 concentrations and diffusion theory,
Frenkiel (1960) and Paetzold (1961) concluded that there must be a
large tropospheric source of ozone. McKee (1961), from the vertical
distribution of O_3 measured over Greenland, concluded that there must
be local O_3 synthesis.

Went (1960) became the first to propose that natural ozone synthe-
sis could take place in the troposphere in a manner similar to ozone
synthesis in polluted air, with "terpenoid" compounds emitted by vege-
tation replacing the simpler olefins of the polluted air. Based on
subsequent measurements, it was confirmed that both natural terpenes
and NO_2 (as NO) are emitted in great enough quantities to influence O_3
concentrations in the troposphere (Rasmussen and Went, 1965; Lodge and
Pate, 1963; Worth et al., 1967).

During the 1960s ozone began to draw serious attention as a pollu-
tant in urban areas with a potential for both health and plant damage.
The primary precursors were identified as hydrocarbons and oxides of
nitrogen emitted by both mobile and stationary sources. The focus of
photochemical pollution problems became Los Angeles, because of large
numbers of automobiles, intense sunlight, and meteorological features
leading to stagnation of air and trapping of pollutants. The diurnal
variation of O_3 was recognized, with ground-level ozone values starting
near zero in the early morning, building to a maximum in the late after-
noon, and then decreasing to low levels again by late evening. Limited

measurements in other urban areas demonstrated by the late 1960s that photochemical pollution, while most severe in Los Angeles, was to be found in almost all urban locations (NAS, 1974; Rubino, 1975; Jacobson and Salotollo, 1975; Hawke, 1974).

By 1970 the EPA promulgated National Ambient Air Quality Standards (NAAQS) for oxidants at 0.08 ppm, not to be exceeded more than once a year (EPA, 1970). To achieve this standard, abatement programs were undertaken and further steps proposed to limit hydrocarbon and NO_x emissions as a means of controlling oxidants. EPA has published procedures for determining the necessary precursor reductions (Federal Register, 1971) to be applied in local areas in which a measurable oxidant problem exists. At this time, it was still believed that ozone was a local urban problem only and that diffusive and destructive processes limited the oxidant concentrations in rural areas to insignificant levels. Therefore, control strategies (Federal Register, 1971) were based primarily on emission controls at locations in which a photochemical oxidant problem was observed.

However, in a study conducted by EPA in 1970 in a rural area of western Maryland and eastern West Virginia, oxidant values exceeding the NAAQS were frequently measured. This finding was responsible for the subsequent initiation of a number of intensive field studies covering a broad area east of the Mississippi River. It was discovered that high oxidant concentration was not limited to any given rural location but was a widespread phenomenon.

While there is no doubt that high oxidant values can be measured in rural and remote locations, the sources have become a matter of considerable controversy. It is agreed qualitatively that stratosphere and natural ozone precursors contribute to the tropospheric background. The possibility of other tropospheric sources (Chemides and Walker, 1973)

cannot be ruled out. It is also becoming more evident that processes that destroy ozone or ozone precursors are not as effective as initially believed, and large-scale transport from urban to rural areas may be a key aspect of the oxidant problem. On the basis of several recent studies, it has become clear that sources of nonurban ozone must be identified before effective control strategies can be developed.

The implications of these findings may be significant for control strategies at the national level, as discussed by Altshuller (1975). For example, regional-scale control strategies may be required to achieve the NAAQS if long-range transport of ozone is found to be important. If the "natural" ozone concentration is in excess of the current standards, the standards are too stringent.

In subsequent sections we will review the available scientific literature that deals with the following major questions:

- How much of the tropospheric oxidant can be attributed to stratospheric exchange processes, and how do these processes occur?

- What are the natural tropospheric sources and sinks of oxidant, and what is their significance to the oxidant budget?

- What is the geographical extent of the transport of oxidant or oxidant precursors, and what is its effect on air quality control strategies?

Considerable overlap between these questions occurs in the available research papers. This is to be expected since the ultimate explanation of oxidant behavior is likely to involve a number of different mechanisms.

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B. The Stratosphere as a Source of Tropospheric Ozone

  1. Mass Exchange Mechanisms

    The exchange of air masses between stratosphere and troposphere is accomplished by various mechanisms of different efficiency. These mechanisms are summarized below.

    a. Seasonal Adjustments in the Height
        of the Mean Tropopause Level

    In spite of some ambiguities in the definition, and therefore in the exact location, of the tropopause level, it is evident from statistical studies that this level in each hemisphere undergoes seasonal fluctuations, becoming lower during fall and higher during spring. Staley (1962) pointed out that his seasonal variation contributes towards a net flux of air between stratosphere and troposphere, upward or downward, depending on the season. The lowering and rising of the tropopause should not be envisioned as a continuous process, however. It comes about by an imbalance between the vertical mass fluxes produced by the mean Hadley circulation in low latitudes and by the eddy transport processes mainly in the jet-stream region of middle latitudes. There also is a compensatory horizontal mass flux within the stratosphere, directed from the summer to the winter hemisphere.

    Table 1 (Reiter, 1975a) provides an estimate of changes in the median tropopause pressure over North America between January 1963 and July 1963. Since the total mass of stratospheric air above the winter tropopause is approximately 4260×10^{17} g, the seasonal variation of tropopause heights over North America--when applied to the whole northern hemisphere--amounts to approximately 10 percent of the mass equivalent to one hemispheric stratosphere.

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Table 1
SEASONAL VARIATION OF MEDIAN TROPOPAUSE PRESSURES
(IN MILLIBARS) OVER NORTH AMERICA
(Reiter, 1975a)

Latitude (deg)	Tropopause Pressures (mb)		Δp	Mass Change $(10^{17}$ g$)$
	Winter	Summer		
0			+(25)	+28.4
5			+(25)	+56.7
10			+(25)	+55.6
15			+(25)	+55.0
20	95	120	+25	+53.3
25	100	120	+20	+41.3
30	160	120	-40	-78.9
35	200	120	-80	-148.8
40	220	120	-100	-174.6
45	250	140	-110	-177.1
50	250	200	-50	-72.6
55	240	210	-30	-38.8
60	225	225	0	0
65	230	230	0	0
70	240	240	0	0
				-400.5

b. **Transport by the Mean Meridional Circulation Across the Tropopause**

Figure 1 (from Louis, in Reiter et al., 1975) shows the distri-
bution for the four seasons of the integrated mean meridional mass flux,
ψ , i.e., the mass-weighted stream function defined by

$$\bar{v} = \frac{1}{2\pi\,R\rho}\,\frac{\partial\psi}{\partial z} \tag{1}$$

$$\bar{w} = \frac{1}{2\pi R^2\rho\,\cos\phi}\,\frac{\partial\psi}{\partial\phi} \tag{2}$$

where $\bar{v}$ is the northward component
       $\bar{w}$ is the vertical component
       R is radius of the earth
       ρ is air density
       ϕ is latitude

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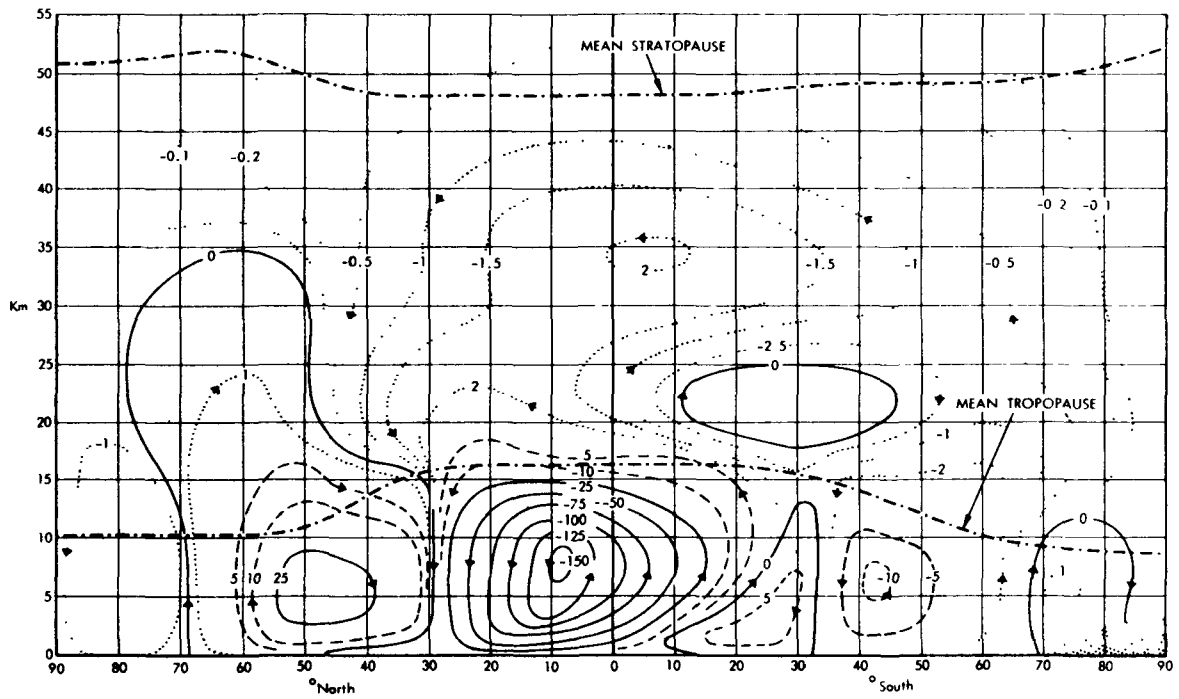
(a) DECEMBER-FEBRUARY
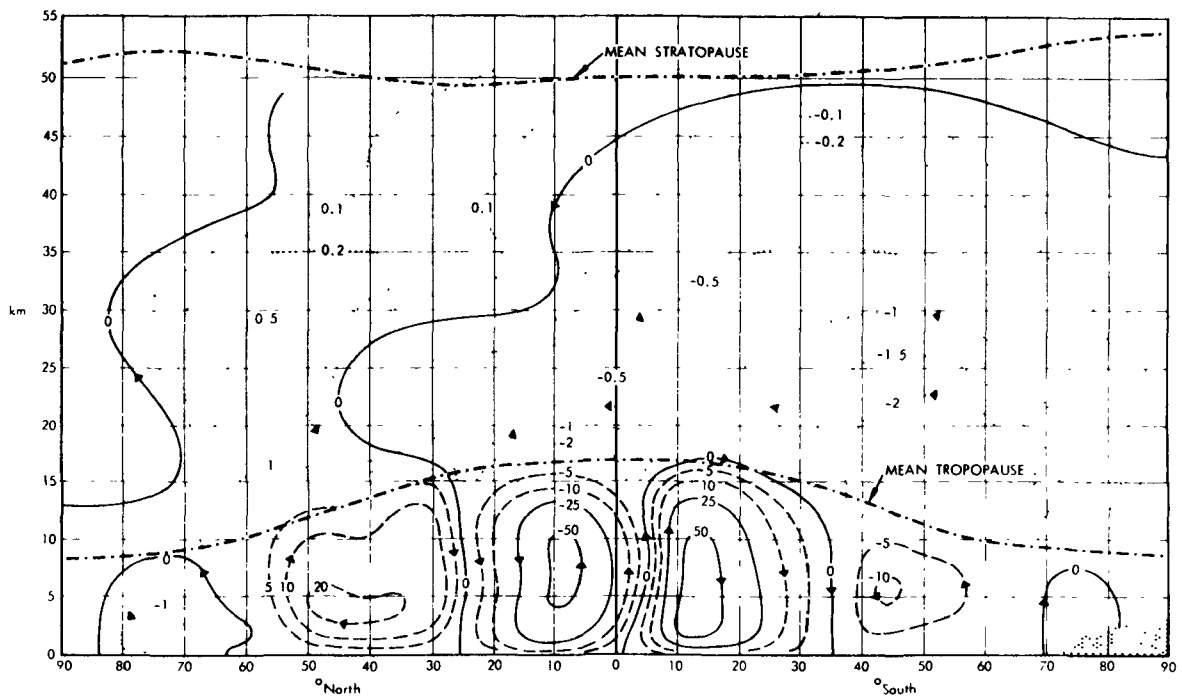
(b) MARCH-MAY

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FIGURE 1   MEAN MERIDIONAL CIRCULATION (MASS FLOW IN UNITS OF 10^{12} g s^{-1})
FOR THE FOUR SEASONS (From *Louis*)

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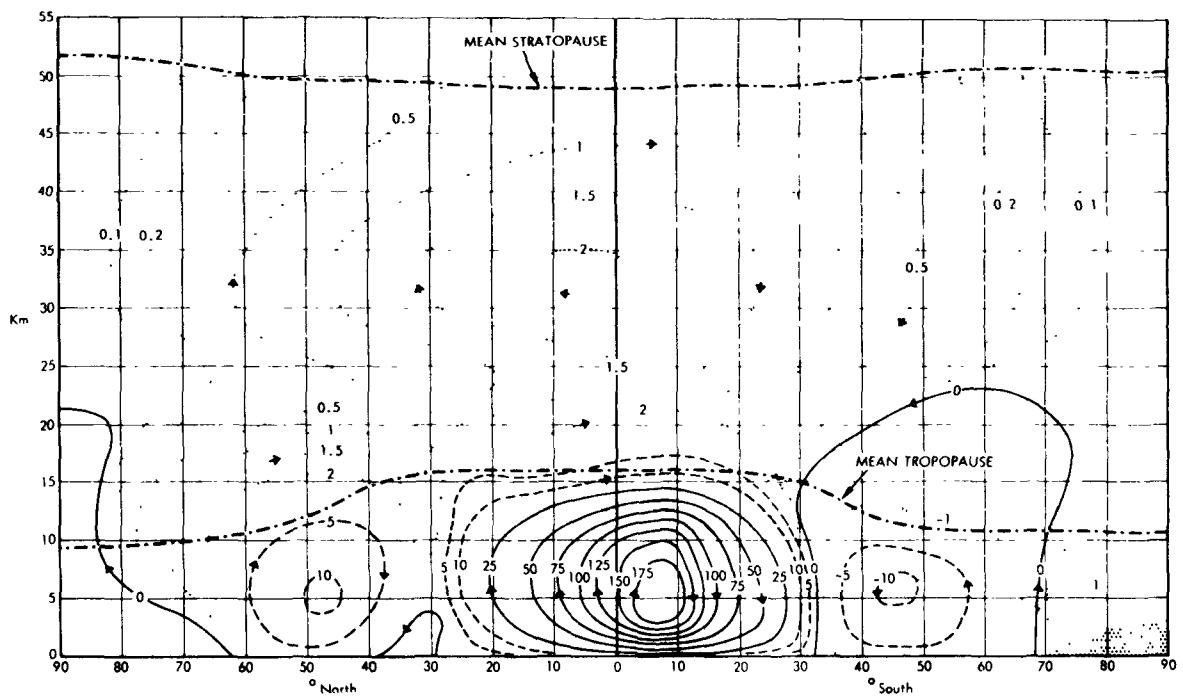
(c) JUNE-AUGUST
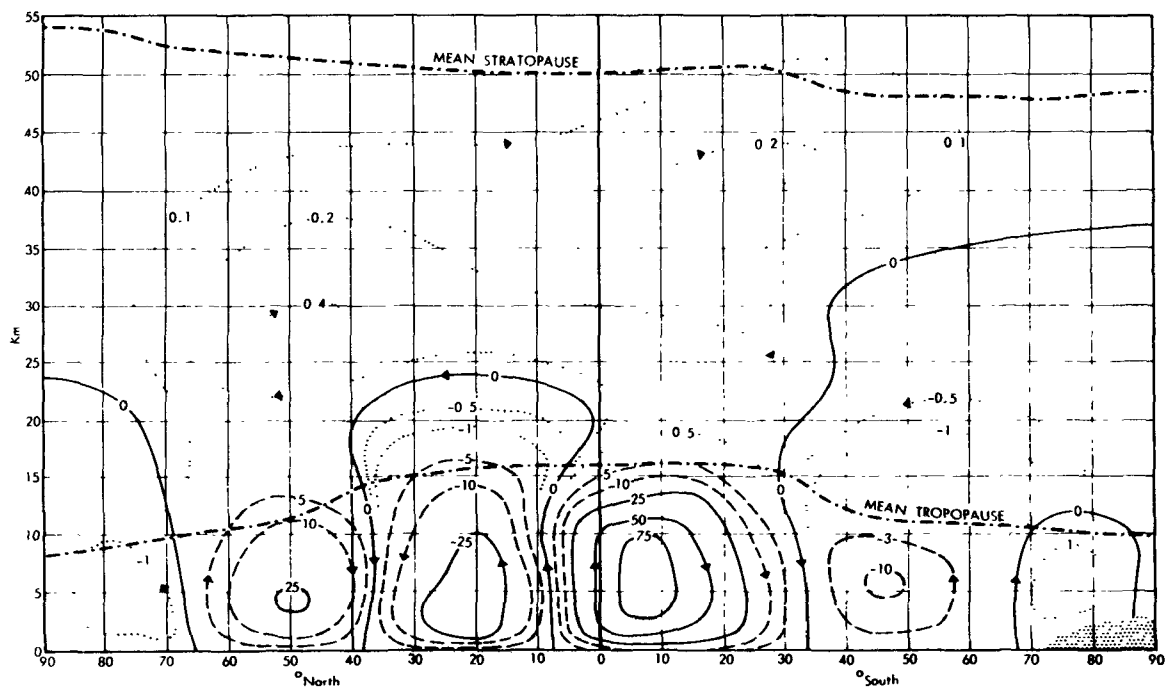
(d) SEPTEMBER-NOVEMBER

SA-4432-3

FIGURE 1   MEAN MERIDIONAL CIRCULATION (MASS FLOW IN UNITS OF 10^{12} g s^{-1}) FOR THE FOUR SEASONS (From *Louis*)   (Concluded)

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The upward fluxes from the troposphere into the stratosphere and consequently, for reasons of continuity, the downward fluxes into the troposphere accomplished by the Hadley circulation, can be obtained from Figure 1 as follows:

| Season	Mass Flow	Total Flux in 3 Months	Contribution to Northern Hemisphere
Dec. - Feb.	10×10^{12} g/s	788×10^{17} g	622×10^{17} g
March - May	4×10^{12} g/s	311×10^{17} g	272×10^{17} g
June - August	7.5×10^{12} g/s	583×10^{17} g	389×10^{17} g
Sept. - Nov.	7×10^{12} g/s	544×10^{17} g	560×10^{17} g

Annual total flux to northern hemisphere: 1843×10^{17} g

This flux corresponds to 43 percent of the mass equivalent to one hemispheric stratosphere.

c. __Transport by the Mean Meridional Circulation__
   __into the Other Hemisphere__

From Figure 1 we can also estimate the interhemispheric exchange of mass __within__ the stratosphere as a function of season. We arrive at the following numbers:

Season	Mass Flow	Total flux in 3 months into Northern Hemisphere (+)
Dec. - Feb.	6.5×10^{12} g/s	505×10^{17} g
March - May	2.0×10^{12} g/s	156×10^{17} g
June - August	-6.5×10^{12} g/s	-505×10^{17} g
Sept. - Nov.	-2.0×10^{12} g/s	-156×10^{17} g

The mass flux between the stratospheres of the two hemispheres, thus, replaces 661×10^{17} g of mass from one hemisphere within one year. This is equivalent to 16 percent of the mass of one hemispheric stratosphere.

d. Transport by Large-Scale Eddy Exchange, Mainly in the Mid-Latitude Jet-Stream Region

Intrusion of stratospheric air into the troposphere by large-scale eddy exchange occurs mainly within the jet-stream front during the tropopause-folding process, i.e., during periods of active cyclogenesis. A number of case studies illustrating this mass-transfer process are available in the literature (e.g., Danielsen, 1960, 1961, 1964, 1968; Danielsen et al., 1970; Mahlman, 1964a, b, 1965a, b, 1966; Reiter, 1963b, c, 1964, 1968; Reiter et al., 1969; Reiter and Mahlman, 1964, 1965a, b, c, d; Staley, 1960, 1962). The return flow of tropospheric air into the stratosphere occurs at levels above the jet-stream fronts and at potential temperatures characteristic of the core of the jet-stream itself (Reiter et al., 1969).

Only very few studies are available that give quantitative estimates of this eddy flux across the tropopause level (Danielsen, 1960; Reiter and Mahlman, 1965; Reiter et al., 1969). Our best guesses indicate that 22 to 23 cyclogenetic events occur per year in the polar-front jet-stream region of the North American longitude sector, with an average mass transport contribution of about 6×10^{17} g each, providing an annual mass flux out of the stratosphere of approximately 135×10^{17} g in the sector $70°$ to $180°$ W, and of approximately 405×10^{17} g around the hemisphere. This number includes only the latitude belt $40°$ to $60°$ N. If one were to allow for the effects of the subtropical and artic-front jet streams of winter, and of the tropical easterly jet stream of summer, one might estimate the total eddy mass flux from the stratosphere to the troposphere to be 800×10^{17} g. For reasons of mass continuity, an equal amount of tropospheric air will have to enter the stratosphere in eddy exchange processes. This flux corresponds to roughly 20 percent of the mass equivalent to one hemispheric stratosphere.

### e. Meso- and Small-Scale Eddy Transport Processes

Thunderstorms penetrating the tropopause level, as well as small-scale turbulence continuously present in the atmosphere, will contribute in a minor way towards the mass exchange between troposphere and stratosphere. Since these processes are either very slow-acting (due to the relatively small vertical eddy exchange coefficients normally effective at tropopause level), or are present with significant magnitude only sporadically (e.g., clear-air turbulence at tropopause level, or thunderstorms penetrating the tropopause), the total contribution towards the mass flux from the stratosphere to the troposphere from meso- and small-scale eddy processes most likely lies near 1 percent of the mass equivalent to one hemispheric stratosphere.

2. Implications on Ozone Transport from the Stratosphere

From the foregoing discussion the annual mass budget of the stratosphere of the northern hemisphere appears as follows:

Seasonal adjustments of tropopause level	10%
Mean meridional circulation	43%
Stratospheric exchange between hemispheres	16%
Large-scale eddies	20%
Small-scale eddies	negligible
Total:	89%

These transport processes would act on an atmospheric tracer that has been introduced into the northern hemisphere stratosphere and disperses from there into the northern hemisphere troposphere and into the southern hemisphere stratosphere. A typical tracer of this sort is ^{90}Sr, injected in large quantities into the northern hemisphere lower and middle stratosphere during the US and USSR atmospheric tests before the Test Ban Treaty went into effect in 1963. Figure 2 illustrates a typical ^{90}Sr distribution in the stratosphere.

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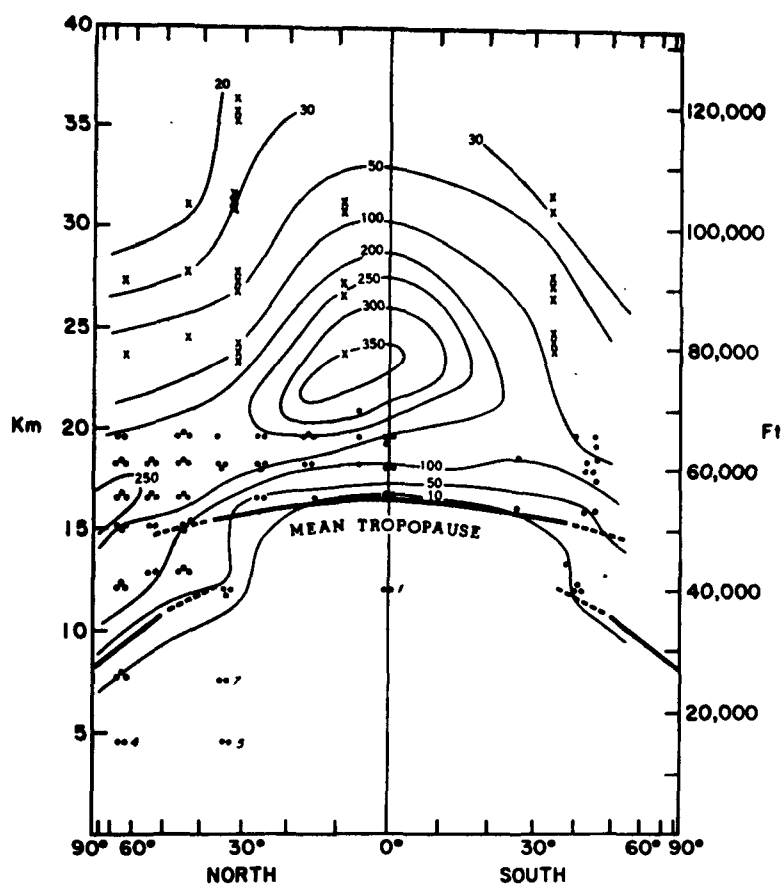
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FIGURE 2 ^{90}Sr CONCENTRATIONS DURING MARCH-MAY 1965 IN UNITS
OF DISINTEGRATIONS PER MINUTE PER 1000 STANDARD FT^3

Decay corrected to time of sampling.   Dots show location of mean
aircraft data; crosses indicate mean balloon samples.   (From *List
and Telegadas*, 1969)

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Figure 3 shows the northern and southern hemispheric burdens of ^{90}Sr, as well as the total stratospheric burden, as functions of time. The e-folding residence time of ^{90}Sr in the northern hemisphere appears to be 14 months (before the effects of the French and Chinese tests). If we assume that concentrations of radioactive debris, N , diminish according to

$$\frac{\Delta N}{\Delta t} = - \frac{1}{T} N \qquad (3)$$

where T is the e-folding residence time, N is taken to be 100 percent, ΔN is 89 percent and Δt is one year, we arrive at T = 1.12 years or 13.4 months.

According to Figure 3, the e-folding residence time in the southern hemisphere stratosphere appears to be of the order of 21 months. Assuming that the mean meridional and eddy exchange processes between stratosphere and troposphere are as effective in the southern as in the northern hemisphere, we have to blame the discrepancy in e-folding residence times between the two hemispheres on the following fact: interhemispheric exchange processes within the stratosphere tend to reduce the radioactive burden of the northern hemisphere where the original source was located. At the same time this transport process increases the southern hemisphere burden. Therefore, in approximation we can write

$$\frac{\Delta N}{\Delta t} = -\frac{1}{T} N + S \qquad (4)$$

where S (= 16 percent, the stratospheric mass exchange between hemispheres) is the "source" of stratospheric debris for the southern hemisphere in the form of transport from the northern hemisphere. This 16 percent contribution towards the mass budget of the stratosphere now appears as a "source" of debris and has to be removed from the "sink" effects of the mass budget. Therefore, for the southern hemisphere, we
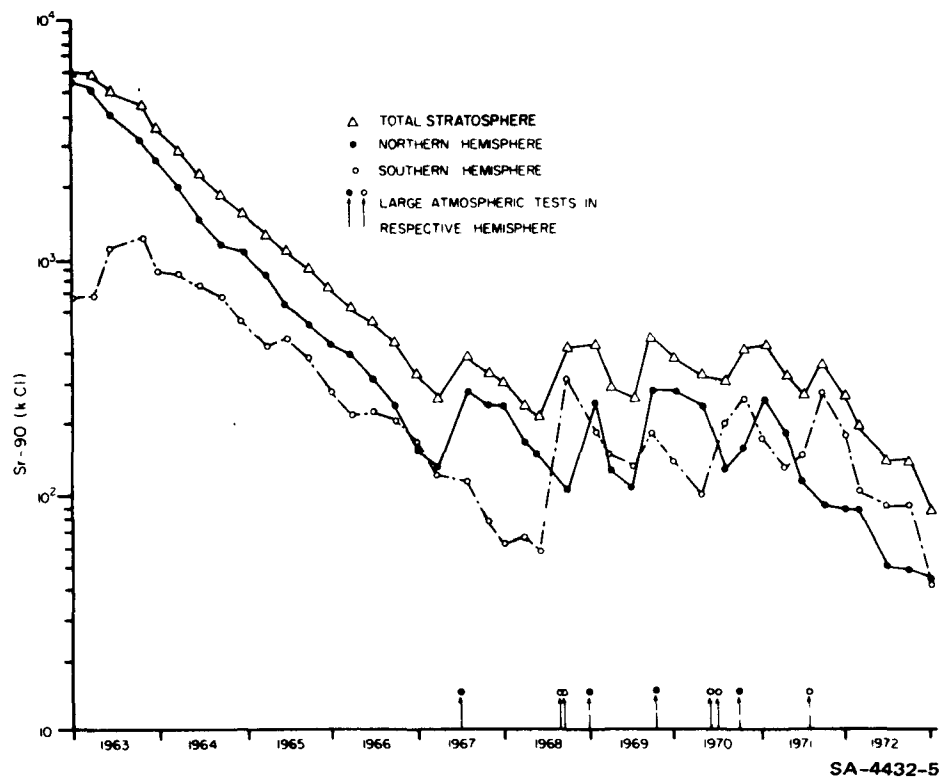
FIGURE 3   STRATOSPHERIC INVENTORY OF ^{90}Sr   (From *Krey et al*, 1974)

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have to assume a value of 73 percent for ΔN (89% - 16%). For $N = 100$ percent and $\Delta t = 1$ year , we thus arrive at $T = 1.75$ years or 21 months, which is exactly what Figure 3 indicates.

E-folding residence times for other radioactive tracers introduced into the lower and middle stratosphere under similar conditions yield similar residence times (for references see Reiter, 1975b).

The above discussion leads us to the following preliminary conclusions:

- The estimate of an annual exchange of 16 percent of the mass equivalent to one hemispheric stratosphere appears to be accurate when applied to tracers in the lower and middle stratosphere.

- The total effects of other transport processes listed above have been estimated with similar reliability.

The mixing ratios of ozone, as reported by Newell (1964) (see Figure 4), show a distribution with respect to latitude and height that is similar to that for ^{90}Sr. The axis of maximum ozone mixing ratios dips downward from the equator to high latitudes, similar to the axis of maximum ^{90}Sr concentrations (see Figure 5 for similar evidence from additional other tracers).

Since the photochemical life-time of O_3 is relatively long at levels below 25 km (for references see Reiter, 1971 and Reiter et al., 1975) we can regard it almost as an inert tracer when comparing it, for instance, with ^{90}Sr. However, the following exception applies: in contrast to ^{90}Sr, O_3 is produced in both hemispheres. Interhemispheric transport processes within the stratosphere, therefore, will have no profound effect on the mean residence time of O_3. To calculate the mass budget of one hemisphere, as it applies to ozone, we thus use Equation (3), with a value $\Delta N = 73$ that includes all effects except the one from interhemispheric exchange. The e-folding residence time of O_3 in the
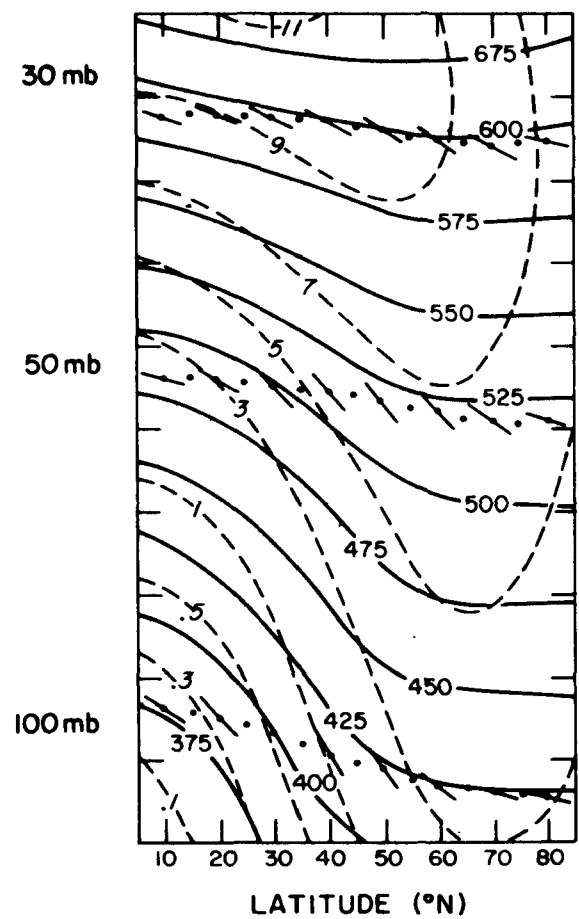
FIGURE 4   SLOPES OF SURFACES OF PREFERRED MIXING
            (SHORT LINE SEGMENTS) FOR WINTER SEASON
            AS DERIVED FROM HEAT FLUX DATA

Solid lines represent mean potential temperature (°A)
and dashed lines mean ozone mixing ratio (μgm/gm)
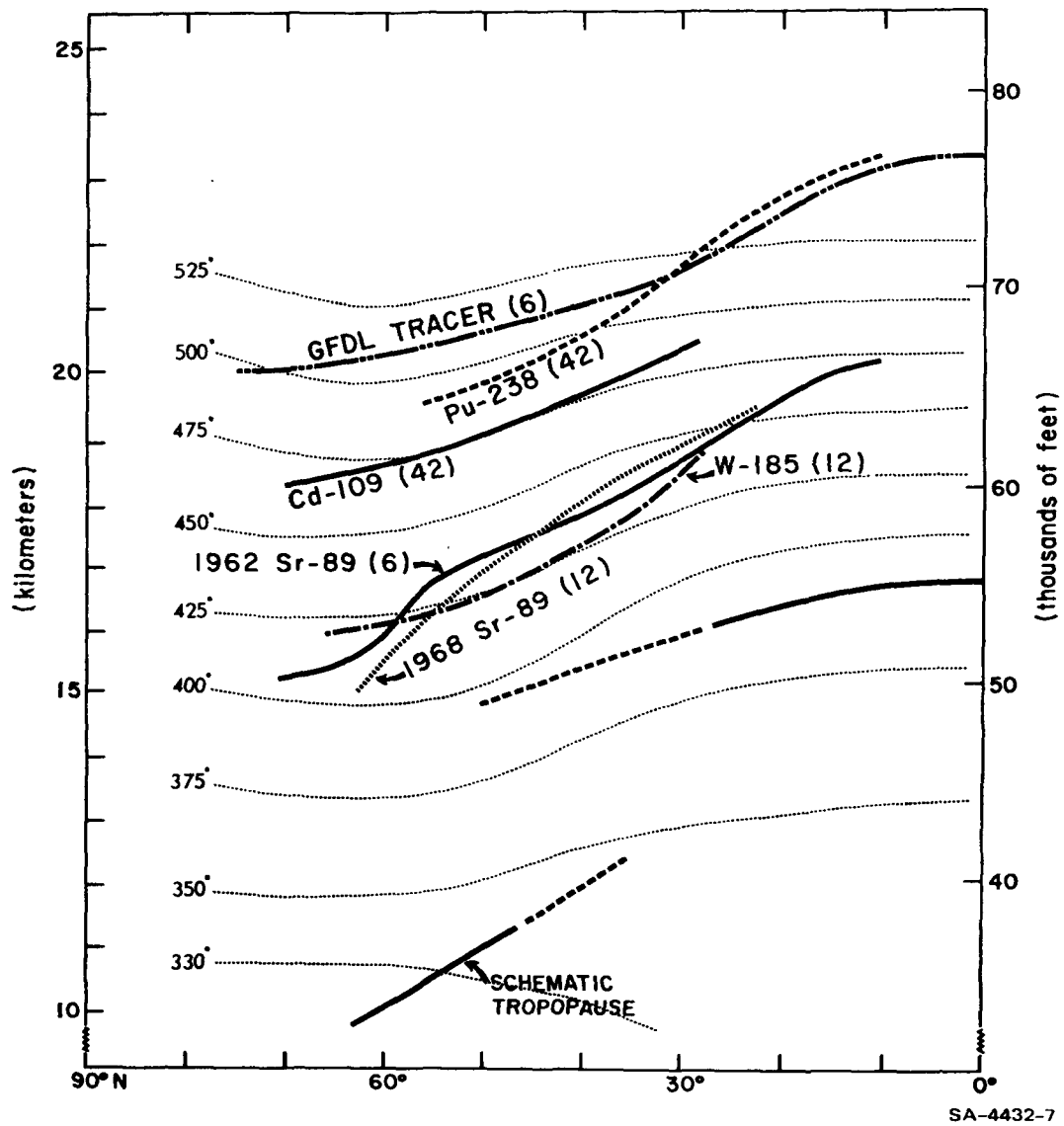after Newell (1964). (From *Reed and German*, 1965)

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FIGURE 5   OBSERVED LEVELS OF MAXIMUM CONCENTRATION AND MEAN ANNUAL
ISENTROPES

Numbers in parentheses are months from injection into the stratosphere to
observation (From *Machta et al.*, 1970)

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lower and middle stratosphere, therefore, should be of the order of 1.4 years or approximately 16 months (similar to the e-folding residence time of ^{90}Sr in the total stratosphere as shown in Figure 3).

It is not surprising that estimates of the O_3 residence time in the stratosphere made from the phase lag between the maximum in total O_3 and that in surface O_3 concentrations are much larger than this estimate of 16 months. Junge (1962, 1963) and Fabian and Junge (1970) arrive at a stratospheric residence time of three to five years, a tropospheric residence time of 3.3 months, and a tropospheric vertical flux of approximately 0.5×10^{-7} g/m^2/sec (equivalent to 0.804×10^9 tons of O_3 per year over the entire globe). A vertical flux of 1.3×10^9 tons of O_3 per year over the globe was estimated by Regener and Aldaz (1969). Since O_3 is continuously generated photochemically in the stratosphere, Equation (3) is inapplicable, even for a crude estimate of residence time. Influx of O_3 from higher levels and from lower latitudes also provides a source for the atmospheric "box" that comprises the northern hemisphere stratosphere between the tropopause and approximately 30 km.

From satellite data, Lovill (1972) estimates the average global value of total ozone to be 303.3 Dobson units (or milli-atmospheric-centimeters, i.e., the height of the layer in units of 10^{-3} cm if all ozone were compressed to normal temperature and pressure). To convert these units into mass of ozone we apply the gas law

$$p = \frac{R^*}{m} \rho T \, , \qquad (5)$$

where $p = 1013.25 \times 10^3$ dynes/cm^2, the universal gas constant $R^* = 8.31436 \times 10^7$ erg mole^{-1} deg K^{-1}, the molecular weight of ozone, $m = 47.998$, $T = 273.16$ deg K. We arrive at a density for ozone of $\rho = 2.14138 \times 10^{-3}$ g/cm^3, at normal temperature and pressure. The weight of the average ozone column, therefore, is 6.4948×10^{-4} g/cm^2.

On a hemispheric basis (area = 2.55×10^8 km^2) this amounts to 1.6565×10^{15} g, or 1.6565×10^9 tons.

The annual downward flux in one hemisphere (0.402×10^9 tons) thus corresponds to approximately one-quarter of the total atmospheric burden. Dividing the latter by the former to arrive at a crude measure of residence time (Ehhalt, 1973) one obtains a value of about four years, which falls within the range given by Junge.

Since the average tropospheric ozone mixing ratio of the troposphere is $\ll 0.1$ μg/g, the tropospheric ozone burden in one hemisphere is much less than 1.3×10^3 tons. Therefore, we can ascribe 1.65×10^9 tons of ozone to the hemispheric stratosphere.

According to estimates described earlier, in one year approximately 73 percent of the stratospheric air containing this amount of ozone should be transported into the troposphere by various mechanisms. This would correspond to an annual hemispheric ozone flux of 1.2×10^9 tons, a value that is almost twice as high as the estimates by Regener and Aldaz and higher yet than those made by Junge. Eddy transport mechanisms in the jet-stream region should account for a flux of 20 percent of 1.65×10^9 tons, i.e., for 0.33×10^9 tons, which is not far from the value estimated by Junge from the phase lag between the maximum in total ozone and that in surface ozone. Since the latter--similar to the spring maximum of radioactive fallout--can be ascribed to the enhanced eddy activity in the jet-stream region during that season, Junge's estimates are comparable with effects that can be expected from these large-scale eddy exchange processes.

Even though the eddy exchange processes in the jet-stream region account for only a fraction of the total mass exchange between stratosphere and troposphere, they constitute the only mechanism which transports stratospheric air rapidly and relatively undilutedly towards the

ground. In the further investigation of the impact of stratospheric
ozone concentrations on ground-level ozone concentrations, we will there-
fore concentrate our attention almost exclusively on this transport
mechanism.

C.   Natural Sources and Sinks of Ozone in the Troposphere

In the 1950s (Leighton, 1961; Wayne, 1962), it was shown that ozone
synthesis was possible in polluted atmospheres. In 44 out of 251 cases,
Hering and Borden (1967) found ozone concentration below 5 km to be
greater than above 5 km. In seven of these cases, the O_3 concentration
was greater at or below 2.5 km than at the tropopause. As argued by
Kroening and Nye (1962), tropospheric layers of O_3 concentration near
the tropopause can be explained by stratospheric intrusion, but high
values near the ground can be more easily explained in terms of in-situ
synthesis than in terms of subsidence, through half the troposphere, of
a layer of high O_3 content.

As previously mentioned in Section I-A, Went (1960) suggested a
photochemical mechanism for tropospheric ozone synthesis using natural
terpenes and NO_2. Ripperton et al. (1971) tested this hypothesis under
controlled conditions and confirmed that this process can result in
ozone formation similar to that occurring in polluted atmospheres.
Rasmussen and Went (1965) found an average of 1 pphm (maximum of 5 pphm)
of atmospheric terpenoid compounds in the Appalachian and Ozark Mountains.
Lodge and Pate (1963) measured an average of 0.09 pphm NO_2 (maximum of
0.5 pphm) in Panama, and Worth et al., (1967) measured an average of
0.4 pphm NO_2 (maximum of 2.6 pphm) in the southern Appalachians. Thus
it is clear that both natural terpenes and natural NO_2 are emitted in
quantities significant enough to influence O_3 behavior.

Crutzen (1973) pointed out that the methane oxidation chain, which
ultimately leads to the production of CO, represents a large source of

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ozone. Chemides and Walker (1973) presented a photochemical theory of tropospheric ozone synthesis from the methane oxidation chain. Calculations indicate that this mechanism can support an ozone production rate of 5×10^6 cm^3/s. Their calculations yield a photochemical lifetime of O_3 ranging from about one day at 5 km to about 10 days at 10 km. Since the mixing time due to the presence of eddies in the troposphere is about 30 days (Junge, 1962), this result suggests that O_3 is in photochemical equilibrium in the troposphere, contradicting the usual view of O_3 as a relatively inert constituent of tropospheric air.

The model of Chemides and Walker (1973) was found to satisfactorily explain the general variation of O_3 with season as well as its dependence on altitude. Indeed there is agreement that earlier assumptions that ozone is destroyed on heterogeneous surfaces only were incorrect and that gas phase ozone destruction is an effective sink for ozone (Ripperton and Vukovich, 1971). Lightning from thunderstorms may also cause local increases in ozone, but by itself this mechanism constitutes an insignificant ozone source in remote areas (Shalanta and Moore, 1972).

D. Long-Range Transport and the Nonurban Oxidant Problem

Most of the nonurban data taken before the mid-1960s consistently reports low ozone values all over the world. McKee (1961) reports a maximum ozone concentration of 0.013 ppm based on his measurements in Greenland. Junge (1963) summarizes a number of observations prior to 1961, with most of the concentrations being below 0.045 ppm (see Table 2). Only one location reports O_3 values as high as 0.06 ppm. In the Antarctic region, the mean surface ozone values ranged from 0.01 to 0.034 ppm, based on data from April 1957 to May 1958. At the Admundsen Scott Station located at the geographical South Pole monthly average mean values of 0.01 to 0.04 were obtained (Aldaz, 1967). During other studies conducted by the University of North Carolina during 1964 and

OBSERVER	LOCATION, TIME AND RESULTS	ALTITUDE (Meters)	OZONE CONCENTRATION $\mu g/m^3$ [c]	
			RANGE APPROXIMATE	AVERAGE APPROXIMATE
Gotz & Volz (1951)	Arosa, Switzerland, 1950-51, high valley, daily maxima value	1860 m above sea level	19-90 daily maximum values	50
Ehmert (1952)	Weissenau, Bodensee, Germany, 1952	20 m above ground	0-90 all values	35[a]
Kay (1953)	Farnborough, England, 1952-53	0-12000 m above ground	26-50 a few aircraft soundings	38[b]
Regener (1954)	Mt. Capillo and Albuquerque, New Mexico, USA, 1951-52	3100 and 1600 m above sea level	3-120 . all data	36[a]
Regener (1954)	O'Neil, Nebraska, USA, 1953	12 m above ground	0-90 all data	35[a]
Teichert (1955)	Lindenberg Observ., Germany, 1953-54	80 m above ground	0-50 all data	30[a]
Brewer (1955)	Tromso, Norway, 1954	0-10000 m above ground	60-70 a few aircraft soundings	65
Teichert & Warmbt (1956)	Fichtelberg, Central Germany, 1954-55	1215 m above sea level	20-67 monthly average values of hourly observations	40
	Brocken, Central Germany, 1955	1152 m above sea level	26-52 monthly average values	40
	Kaltennordheim, Central Germany, 1955	494 m above sea level	15-25 monthly average values	20[a]
	Wahnsdorf, near Dresden, East Germany, 1954-55	257 m above sea level	2-26 monthly average values of hourly observations	12[a]
Price & Pales (1959, 1961)	Mauna Loa, Hawaii, 1958	3000 m above sea level	20-80 daily maximum values	50
Wexler et al. (1960)	Little America Antarctica, 1958	50 m above sea level, near the ground	10-70 all values	50
Ramanathan et al. (1961)	Srinagar, North India, 1957-1960	1700 m above sea level	26-59 monthly average values of daily maxima	50
Dave (1961)	Ahmedebad, 1954-55	50 m above sea level, near the ground	24-50 monthly average values of daily maxima	40

[a] Influence of ozone destruction near the ground not eliminated in these average values. To some extent this applies also to other sets of data, except for those which refer to daily maximum values.

[b] Values likely too low due to ozone destruction in the intake tube.

[c] To convert $\mu g/m^3$ to pphm, divide by 20.

1967 in rural North Carolina, high ozone values were not observed (RTI, 1975).

However, as mentioned earlier, a study sponsored by EPA in 1970 in a rural area of western Maryland and eastern West Virginia, oxidant values well in excess of the NAAQS (0.08 ppm) were frequently measured (EPA, 1970; Richter, 1970), which led to a number of studies on the rural oxidant problem. In the summer of 1972, the EPA sponsored a special study for ozone measurements in Garret County, Maryland, and Preston County, West Virginia (EPA, 1972). Approximately 11 percent of the 1043 hourly measurements measured by the gas-phase chemiluminescent method exceeded 0.08 ppm. The maximum O_3 value during the study period (4 August to 25 September 1972) was 0.12 ppm. Simultaneous measurements of NO_x and nonmethane hydrocarbons (NMHC) concentrations yielded values that were at or near geochemical levels. Neither natural nor anthropogenic sources in the study area appeared capable of producing the required precursor species (HC and NO_x) in sufficient quantities for synthesis of ozone at the levels observed.

A more extensive study was conducted in the summer of 1973, when ground-level ozone was measured at McHenry, Maryland, Kane, Pennsylvania, Coshocton, Ohio, and Lewisburgh, West Virginia between 26 June and 30 September 1973. The measurement period at Kane extended through October. A C-45 aircraft equipped with a solid-phase chemiluminescent ozone meter was used to measure O_3 aloft. Hourly O_3 concentrations exceeded the NAAQS for oxidants 37, 30, 20 and 15 percent of the hours for which data were available at McHenry, Kane, Coshocton, and Lewisburgh, respectively. The aircraft data further indicated that the source of high O_z was located at the surface, because vertical O_z profiles showed a distinct concentration decrease with altitude. Maximum hourly ozone concentrations were 0.16 ppm at McHenry, 0.14 ppm at Kane, 0.17 ppm at Coshocton, and 0.13 ppm at Lewisburgh.

Miller et al. (1972) measured ozone at several rural and urban locations near Fresno, California during the period 17-27 August 1970, and found the NAAQS was widely exceeded. In the rural locations the 11-day average for each of the hours between 11 a.m. and 6 p.m. was in excess of 0.08 ppm, with the lowest hourly average about 0.05 ppm. High O_3 concentrations in rural areas were attributed to transport from the Fresno urban area; however, the authors were unable to explain why the O_3 concentration remained high when the prevailing wind was not from the direction of the city.

Since 1973, a great deal of emphasis has been placed on the non-urban problem. The oxidant conditions that had been typically observed in California were found to be quite widespread. Based on limited 1973 oxidant data in New York state, Stasiuk and Coffey (1974) concluded that, since average daily rural ozone concentrations at widely separated sites correlated well with the daily maximum urban ozone concentrations, a common source was implied. They discounted transport as the primary source of high nonurban oxidant values.

In another study, Cleveland et al. (1975) conducted an analysis of data from the New Jersey/Pennsylvania area and concluded that the oxidant problem in rural Ancora was caused by regional oxidant transport from the Philadelphia-Camden urban complex. These authors also observed that Sundays, with typically lower emissions, were overrepresented among the days that exceeded the NAAQS in New Jersey.

Wolff (1974), in a preliminary investigation of the tri-state (New York-New Jersey-Connecticut) photochemical oxidant problem, concluded that the NAAQS is widely exceeded in the tri-state region and suggested that this may be due to precursor transport from the Philadelphia-Camden area, especially with west or southwest winds. No correlation was found between the early morning (6 to 9 a.m.) hydrocarbons and the afternoon

ozone at any given station. High afternoon temperatures ($> 86^{O}F$) and a mixing depth of less than 500 m resulted in high O_3 concentrations. Wolff also observed high O_3 concentrations associated with the sea-breeze cycle, and proposed a hypothesis similar to the one suggested by Lyons and Cole (1974).

Lyons and Cole observed very high oxidant values in 1973 in southern Wisconsin rural areas and along the shoreline of Lake Michigan. Rural hourly ozone values as high as 0.2-0.3 ppm were measured several times. The results of this study indicated that significant mesoscale and even synoptic-scale transport of ozone into this particular area might occur.

Several other studies conducted in California (Cavanagh and Smith, 1973; Blumenthal et al., 1974) confirmed large-scale transport of ozone and ozone precursors. In Los Angeles, it was found that the urban plume may extend as much as 70 to 100 miles downwind of the city. Studies at Houston and Phoenix (Rasmussen et al., 1974) and Philadelphia (Cleveland, 1975) confirmed that transport from urban centers as far as 30-50 miles downwind is quite widespread.

Extensive oxidant monitoring in rural areas was conducted in 1974. Perhaps the most comprehensive single study to date on urban/nonurban oxidant interrelationships was conducted in the Ohio Valley in the summer of 1974. It was concluded that oxidant values in the rural areas clearly exceeded the NAAQS. After about 30 to 50 miles, a single urban plume was found to lose its identity (RTI, 1975). It was also found that a distinct and nearly identical diurnal ozone variation at widely separated locations indicated that area-wide mixing processes were important. Specific air trajectories could not be consistently associated with the arrival of air containing high or low oxidant values. It was found that high oxidant values persisted with the incoming movement of high pressure systems. Martinez (1975), in reviewing the relation of

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oxidant values with meteorological features, found that high rural oxidant values appear to be related to the influence of high pressure cells, maximum temperatures above 60°F, abundant sunshine, low wind velocities, and low-level atmospheric instability.

On the basis of the Ohio studies, Ripperton et al. (1974) support the surface origin of high oxidant values and discount the possibility of significant stratospheric transport. Rasmussen and Robinson (1975) present a qualitative surface ozone model which describes the approximate oxidant contributions to be expected in rural and urban locations from both natural and anthropogenic sources.

Other studies in the New York-New Jersey-Connecticut area have attempted to relate the high east coast rural oxidant values to various meteorological factors (Graedel et al., 1974). Bruntz et al. (1974) have attempted to obtain an empirical correlation between O_3, solar radiation, wind speed, and air temperature by using statistical curve-fitting methods. Cleveland et al. (1975) explain that the high night-time ozone values in Massachusetts are indicative of transport from the New York-Connecticut area. Coffey and Stasiuk (1975) propose that the high nonurban ozone concentrations would result in a reverse transport to urban areas, making any urban oxidant controls ineffective. Rubino et al. (1975) report high urban and nonurban O_3 values in Connecticut, and attribute this to transport from New York City.

In the Houston area, the Goober III study (Fowler et al. 1975) confirmed that oxidant was transported from Houston to a nonurban site in Prairie View (40 miles northwest of Houston). However, during the Yellow Pine study conducted during April-June 1974 in eastern Texas, no evidence of transport could be found. The measured ozone concentrations showed a diurnal profile, with peak O_3 concentrations in the early afternoon. The NAAQS was exceeded only twice during the monitoring period.

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Becker (1974) analyzed data from the Wisconsin area, where O_3 was monitored at seven urban and four nonurban locations. The rural sites in southern Wisconsin were found to experience more hours of alert levels (400 ppb) than the four urban Milwaukee sites.

Based on his ozone measurements in Miami, Florida, Nagler (1974) confirmed the high O_3 levels on an area-wide basis, with indications of long-range transport from the Chicago-Pittsburgh urban complex (Fankhauser, 1975).

In Beulah, North Dakota, a relatively remote location, it was found that 23 percent of all one-hourly average concentrations exceeded the NAAQS, based on a brief sampling study in July 1974. Values as high as 0.12 ppm were measured and no evidence of transport was found. It was suggested that scarcity of foliage in the area with which O_3 might react could account in part for the high ozone values (Browning, 1975).

In a modeling study based on measurements from the Ohio Valley and Los Angeles, Johnson and Singh (1975) examined the significance of O_3 in the upper inversion layer in terms of its effects on concentrations at the surface level. They found that high night time ozone values and the "weekend effect" could be explained by ozone layers aloft dispersing downwards during turbulent conditions. This phenomenon is expected to be significant in both urban and rural locations. It may be especially significant in nonurban areas because of the lack of primary ozone-destroying precursors.

Among the locations that showed low oxidant values were monitoring sites in Wyoming and Montana. At the Powder River Plant in northwest Wyoming, ozone data taken from 1 January to 30 June 1974 yielded values that were typically between 0.03 and 0.05 ppm (Ancell, 1975). The maximum hourly concentration measured was 0.071 ppm. At McRae, Montana (Tsao, 1974), O_3 was monitored from December 1973 to June 1974 with a

total of 3820 hourly values obtained over a period of 184 days. At no time did the maximum O_3 value exceed the NAAQS. A vast majority of the data was below 0.06 ppm.

It is obvious, therefore, that effective control strategies cannot be formulated until there is general agreement on some of the basic questions. Altshuller (1975) has attempted to delineate some of the important questions that must be answered. He concludes that the effects of downwind transport and the growth of suburban cities must be isolated. He also points to a scenario that may apply on the east coast area, in which urban plumes constantly intermix with naturally emitted precursors as well as with other plumes.

The question of what is a natural ozone background is also a confusing one, since recent data seem inconsistent with measurements made a few years ago. While it is not possible to completely define the accuracy of data taken before the mid-1960s, it is difficult to make a strong argument that the earlier data are wrong (RTI, 1975). However, even today there is considerable controversy about ozone measurement methods, and the possibility that all EPA measurements are 22 percent too high (Demore et al., 1975) would imply that the nonurban problem is probably less serious than hitherto believed.

Vertical ozone profiles showing a characteristic decline with height have been used as the primary argument in favor of the surface origin of ozone in rural areas (RTI, 1975). However, high concentra-tions of ozone aloft at these same rural areas are found trapped within inversion layers (Johnson and Singh, 1975).

As more data become available it should be possible to develop a consensus on what is a typical background ozone level, what is the nature and extent of urban transport, and what strategies must be used to control the oxidant problem. If trajectory analyses cannot define

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consistent source-receptor relationships, and if area-wide effects are shown to be prevelant, regional strategies will have to be developed.

E.   Summary of Significant Scientific Findings

As has been discussed in this section, a number of intensive studies have been made on the urban/nonurban oxidant relationship, and a wealth of data are at hand. In addition, a number of monitoring stations over the continental United States have helped generate an extensive data base for both urban and nonurban locations. Although considerable disagreement still persists on various points, a number of findings have been generally confirmed by these efforts, and are summarized below:

- Urban oxidants are directly attributable to precursor emissions and their relationships (HC, NO_x, HC/NO_x) in urban areas.

- Oxidant levels are generally higher in those suburban areas that are located directly downwind from central urban locations.

- In the absence of NO, the sinks for oxidant such as NO_2, olefins, particulate matter, and surface features scavenge ozone slowly. However, urban plumes can affect oxidant levels at a range exceeding 50 miles.

- Oxidant aloft may be effectively isolated from destructive precursors and can be entrapped within stable inversion layers. This oxidant can diffuse downward either during the following day or at night if turbulent conditions persist. The persistence of oxidant in layers aloft and its downward diffusion occurs in nonurban as well as urban locations.

- While short-range horizontal transport of oxidant and oxidant precursors has been generally invoked as the cause of high oxidant levels, recent investigations indicate mesoscale and even synoptic-scale transport of oxidant over the United States. Distances of travel, persistence of oxidant and oxidant precursors, and the contributions of large and small sources superimposed on large-scale transport have prevented the identification of clear cut source-receptor relationships by

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trajectory analysis. An analysis of nonurban hydro-
carbon data, even though limited, suggests that
nonurban hydrocarbons are composed of the same
complex mixtures that characterize urban areas.
Similar oxidant diurnal variations are also observed
in both urban and nonurban areas.

- Lightning from thunderstorms may cause brief local
  increases in ozone but by itself constitutes an
  insignificant source of ozone.

- Ozone contributions from natural precursors and
  stratospheric ozone injections are likely to be
  between 0.04 and 0.05 ppm. Ozone from natural hydro-
  carbons may increase the ambient ozone by 0.02 to
  0.05 ppm, however the atmospheric conditions that
  are conducive to ozone production from photochemical
  processes are usually different from conditions that
  favor transport from the stratosphere.

- Typically, high temperatures ($> 60^\circ F$), abundant solar
  flux, low wind speeds, high pressure cells and low-
  level instability present favorable conditions for
  elevated oxidant levels. A fairly good statistical
  correlation exists between oxidant levels and tempera-
  ture, relative humidity, and inverse mixing height.

- Synoptic-scale weather patterns with migratory anti-
  cyclones achieve a widespread mass of air contamination.

- High pressure cells often have the highest oxidant
  concentrations near the center of the cell in an area
  of about 100 to 200 miles in diameter, where conditions
  are apparently conducive to high oxidant formation.

- More recent results favor the area-wide mixing hypothesis,
  in which natural precursors constantly intermix with
  urban plumes. So far, trajectory analysis has not been
  useful to relate high or low rural oxidant concentra-
  tions to any specific sources. A significant possi-
  bility is the transport of hydrocarbon precursors of
  lower reactivities from urban locations over long
  distances, which then intermix with NO_x from both
  natural and anthropogenic sources to form high oxidant
  concentrations in rural areas.

- For a long time the belief has been that oxidants were
  formed from reactive hydrocarbons such as olefins, some
  aromatics and aldehydes only, and nonreactive hydrocarbons

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which were a significant portion of the hydrocarbons emitted, did not contribute to oxidant formation. It has now become clear that all hydrocarbons (even methane) are capable of forming oxidants and the only real difference is the relative time of irradiation. Thus very low reactivity hydrocarbons (say alkanes) will eventually lead to ozone formation but the chemical processes may take several days. Such occurrences will lead to a higher background of ozone, and long-range transport of hydrocarbons and thereby of oxidants.

III   DESCRIPTION OF SELECTED RESEARCH STUDIES

In this section we present brief summaries of the results of a selected number of research studies that are judged to be significant in terms of the relation of oxidant levels to meteorological features. Both theoretical studies and observational studies that contain analyses of data are included. With regard to observational studies, the emphasis in this review has been placed on the results of analyses of oxidant or ozone data collected in the United States east of a line from the western border of the Dakotas southward to El Paso, Texas. However, a few studies elsewhere that contain results of apparent general significance have also been included. The summaries are presented in alphabetical order, by author.

(1) **Flux Measurements of Atmospheric Ozone over Land and Water**
     (Aldaz, 1969)

Based on experimental measurements, it is estimated that ozone destruction rates are 0.60 cm s^{-1} (cm^3 cm^{-2} s^{-1}) over land, 0.04 cm/s over fresh water, and 0.02 cm/s over the ocean. Assuming a destruction rate of ozone by tropical vegetation that may vary from 0.06 cm/s to 3.0 cm/s, it is estimated that global sinks for ozone vary from 5.4 to 8.6 x 10^{29} molecules s^{-1} (or 1.3 to 2.1 x 10^9 tons of ozone per year). Because of the land-sea distributions of the northern and southern hemisphere, the southern hemisphere is estimated to account for 1.5 to 3.1 x 10^{29} molecules s^{-1}. The ozone density is taken to vary from 35 to 55 μg/m^3, depending on latitude.

(2) Evaluation of Oxidant Results at CAMP sites in the United States (Altshuller, 1975)

Oxidant measurements available between 1964 and 1973 at six CAMP sites (Chicago, Cincinnati, Denver, Philadelphia, St. Louis, and Washington, D.C.) were evaluated. Elevated oxidant concentrations were characterized by season, hour of the day, Sundays compared to weekdays, sampling site, and long-term trend. With the exception of Chicago, downward oxidant trends are reported at all CAMP sites. These and other studies indicate that proportional declines in suburban locations have not been achieved. It is concluded that effects of downwind urban transport cannot be isolated from the growth of suburban cities. The paper points to the significance of urban plumes that extend 50 to 100 miles downwind, constantly intermixing with natural emissions as well as with other urban plumes. If long-range transport is indeed important, regional scale strategies will be required. It has been generally observed at CAMP sites that a general downwind shift in HC/NO_x ratios is occurring. This could also explain the greater linear decrease in oxidants, compared with the nonmethane hydrocarbons.

(3) Mesoscale Flows and Ozone Levels in a Rural California
     Coastal Valley (Baboolal, 1975)

The mesoscale flow over a rural California coastal valley is
characterized using year-long data collected by a network of field sites
made up of surface winds, acoustic radar, sigma meter, and temperature
soundings. With the additional support of the historical meteorological
data the air pollution is defined. The presence of well-developed
drainage flows with noticeable turbulence appears on the acoustic radar
record; this is supported by the sigma meter turbulence measurements.
Three times daily, temperature profiles, taken at increasingly greater
distances from the Pacific Coast, were used to characterize the
inversion climatology of the marine layer. Simultaneous ozone soundings
reveal unusually high levels aloft, suggesting the rural valley itself
to be the unlikely source. This suggestion is supported by the results
of a limited modeling effort.

(4) Three-Dimensional Pollutant Gradient Study--1972-1973 Program (Blumenthal et al., 1974)

Two years of data on the 3-D distribution and transport of aerosols and gaseous pollutants in the South Coast (Los Angeles), San Joaquin Valley, and San Francisco Bay air basins were obtained and analyzed. Two hundred forty sampling flights on 59 different days were made by two aircraft in conjunction with ground-level sampling. Extensive meteorological data were obtained along with the scattering coefficient, condensation nuclei, O_3, NO_x, CO, turbulence, temperature, and humidity data obtained by the aircraft.

The data present a detailed picture of the mixing layer structure and ventilation processes in the Los Angeles Basin and point out the modifications to the normal mixing and ventilation processes that lead to episode conditions. The air pollution problem in Los Angeles and other air basins is shown to be a regional problem exemplified by the accumulation of pollutants in a stagnant air mass and subsequent transport to downwind areas. Various statistical and other analyses were performed on the data, which demonstrated the changes in the aerosol and gaseous pollutants as they aged and indicated certain factors contributing to aerosol formation and growth.

Other special studies were performed, which documented in some detail the structure of a few point source plumes and demonstrated the possible buoyant effect of roadways. A 24-hour sampling program in the eastern Los Angeles Basin documented the overnight stability of ozone at high concentrations in aged polluted air.

(5) Some Large-Scale Features of the Vertical Distribution of Atmospheric Ozone Associated with the Thermal Structure of the Atmosphere (Breiland, 1968)

Ten-case running means of the vertical distributions of hydrostatic stability and of the vertical fractional gradient of the partial pressure of ozone computed from ozone and temperature soundings arranged according to tropopause height are presented for four stations located in different latitudes. It is shown that the characteristic large-scale features of the vertical distributions of the vertical ozone gradient correspond closely to similar characteristic large-scale features of the thermal structure of the atmosphere depicted by the vertical distributions of the hydrostatic stability. The layer structure of the ozone gradient and of the hydrostatic stability both show characteristic features that vary significantly with latitude and with the height of the tropopause.

(6) The Dependence of Ambient Ozone on Solar Radiation, Wind
     Temperature, and Mixing Heigh (Bruntz et al., 1974)

Based on physical theory and "weathervane plots" of data collected
from New York metropolitan area, the authors conclude that O_3 concentra-
tions are statistically related to wind speed, solar radiations, and air
temperature. They obtain the following equation using statistical curve-
fitting methods, and claim a correlation coefficient of 0.84 between the
observations and the predicted values:

$$O_t = 3.29\ (\pm 0.70) + 0.21\ (\pm 0.04)\ \log_{10} S - 0.61\ (\pm 0.11)\ \log_{10} V$$
$$+ 2.65\ (\pm 0.36)\ \log_{10} T$$

where

$O_t = \log_{10}\ [O_3 (ppb) + 5]$

S = solar radiation (Langleys)

V = wind speed (mi hr^{-1})

T = air temperature (deg F)

(7) The Transport of Photochemical Air Pollution From the
     Camden-Philadelphia Urban Complex (Cleveland and Kleiner, 1975)

This paper reports the results of an analysis of ground-level
hourly chemiluminescent ozone measurements obtained from 1 May 1973
to 30 September 1973 and from 1 May 1974 to 13 September 1974 from
four stations surrounding the Philadelphia-Camden urban complex.
With the aid of a graphical-statistical technique, it is shown that at
each of four sites in New Jersey and Pennsylvania, ranging from 27 km
to 49 km away from the center of the Camden-Philadelphia urban area,
ozone concentrations are higher when the air is flowing from the urban
area to the site. It is judged by the authors that this accounts for
some of the ozone previously observed in the nonindustrial, low-traffic-
density area of Ancora, New Jersey, where concentrations of primary
pollutants are low, but where ozone daily maxima frequently exceed the
federal standard. It is thus concluded that photochemical air pollution
in this area is a regional rather than a local phenomenon, and ozone
resulting from emissions from the urban area is widespread and not
confined to the urban area itself.

(8) <u>The Analysis of Ground-Level Ozone Data from New Jersey, New York,</u>
<u>Connecticut, and Massachusetts: Data Quality Assessment and</u>
<u>Temporal and Geographical Properties (Cleveland et al., 1975)</u>

Hourly ground-level ozone measurements from 41 sites in eastern

New York, northern New Jersey, Connecticut, and Massachusetts from

1 May 1974 to 30 September 1974 were analyzed. Various techniques for

assessing data quality and uniform calibrations show the data to be of

high reliability for yielding information on the ozone problem in the

region. Nighttime concentrations, relative to those during the day, are

highest in Massachusetts; more specifically, the ratio of the upper

quartile of hourly average ozone concentrations at 1500 hours EST to

the upper quartile at 0100 hours EST decreases with increasing distance

from New York City, which is in the center of the tri-state urban

complex (northern New Jersey, southwestern Connecticut and New York

City). The site distributions of daily maximum concentrations are high-

est in the Stamford-Greenwich region of Connecticut and next highest in

a region to the east and northeast of Stamford-Greenwich. The lowest

O_3 concentrations were found in Boston, Waltham, Springfield, Newark

and Elizabeth; however, all five stations were located next to automobile

emission sources and the NO emissions could account for the low oxidant

levels measured at these poorly located sites.

(9) **Long-Range Transport of Photochemical Ozone in Northwestern**
    Europe (Cox et al., 1975)

Measurements of the concentrations of ozone and trichlorofluoromethane
in the atmosphere were obtained in 1973 at three locations in the
southern British Isles. The U.S. Air Quality Standard for photochemical
oxidants was exceeded on a number of days at all three sampling sites,
including one situated in southern Ireland. The authors conclude that
in suitable meteorological conditions, measurable amounts of photochemical
pollution of anthropogenic origin are transported over distances up to at
least 1,000 km in northwestern Europe, and that occasionally continental
emissions provide a major contribution to photochemical pollution in the
United Kingdom. During such periods photochemical pollution is essentially
a regional rather than a local problem, with uniformly elevated concentra-
tions of photochemical ozone being observed simultaneously over different
parts of the United Kingdom. It follows that, should controls on the
emission of the pollutant precursors (hydrocarbons and nitrogen oxides)
be considered necessary to reduce future levels of photochemical oxidants
in the United Kingdom, then such controls are unlikely to be effective in
the absence of similar controls elsewhere in Europe.

(10)   Vertical Distribution of Photochemical Smog in Los Angeles
       Basin (Edinger, 1973)

Aircraft soundings of oxidant concentration and temperature in
the vertical section from the Santa Monica coastline inland to the
San Bernardino area were analyzed. In addition to the polluted layer
confined beneath the temperature inversion, laminae of pollution were
detected within the inversion layer with concentrations of oxidant as
high as those observed in the ground-based smog layer. It is hypoth-
esized that the upper layers of pollution are formed when a portion of
the smog moving up the heated mountain slopes that bound the basin on
the north moves out horizontally from the slopes at elevations between
the top and bottom of the inversion.

(11)   Penetration and Duration of Oxidant Air Pollution in the
       South Coast Air Basin of California (Edinger et al., 1972)

On June 18, 19, and 20, 1970, two aircraft, a rawinsonde, two
pibal stations, and four ground stations provided simultaneous samples
of total oxidant, temperature, and winds up to 8000 ft in an area extend-
ing from Santa Monica, Calif., east to Redlands and north across the
San Bernardino Mountains. It was shown that photochemical oxidant
formed in the marine layer is vented up the slopes and over the crest
of the San Bernardino Mountains during the day. Layers of high oxidant
concentrations were detected above the inversion base, suggesting that
some pollution is vented up the slopes and subsequently advected back
to the south. The diurnal changes in the temperature inversion also
contribute to the high concentration found above the inversion base.
These processes result in multi-layers of pollution. The study suggests
that oxidant air pollution is transported up to 80 mi to forested
mountains, where severe damage to conifer species has been documented.

(12)   Control of Photochemical Oxidants--Technical Basis and Implications
        of Recent Findings (EPA, 1975)

To insure the technical accuracy of the oxidant control strategy
and to refine that strategy where necessary, EPA has conducted a continuing
program of research studies and data analysis. New findings based on
laboratory and field studies accomplished over the last several years
generally support the control measures currently being taken and further
indicate that additional measures may be necessary to meet the oxidant
standard nationwide. These recent studies have documented frequent
violations of the oxidant standard in both urban and rural areas although,
in some urban areas, both the maximum concentrations of oxidants and the
frequency of violations have decreased over the past several years. At
rural locations, the number of violations of the standard and the maximum
concentrations are sometimes as high and even higher than in nearby urban
areas. It is thus apparent that oxidants are a rural as well as an urban
problem.

The recent studies show that: (1) man-made emissions are the
predominant source of high levels of oxidants, even in remote rural areas;
(2) the contribution of natural sources of oxidants is usually not more
than 0.05 ppm, compared with the oxidant standard of 0.08 ppm; and (3)
transport of oxidants and their precursor compounds has been demonstrated
to about 50 miles downwind of urban areas and it is likely that transport
over longer distances occurs. It also has been shown that the highest
oxidant concentrations in the Midwest in both rural and urban areas occur
during periods of stagnant conditions associated with high pressure
weather systems.

In both urban areas and in many nonurban areas, there appear to
be sufficient emissions of man-made precursors to account for the high
oxidant levels observed. While transport of oxidants and their precursors
may occur, most urban areas probably are responsible for their own

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oxidant problem. The high oxidant levels in nonurban areas appear to be the result of both locally produced precursors and precursors transported from urban and other nonurban sources. As a result, control strategies for nonurban areas will need to be directed at measures which reduce emissions from both nonurban sources as well as urban sources and which meet the specific needs of each of these areas.

The following implications of the new findings are suggested:

- Because of the high precursor emission densities and the large numbers of people exposed to oxidants, continued emphasis on intensive control measures within cities will be necessary to meet the oxidant standard in major urban areas.

- It may be necessary to extend some measures under present state implementation plans to include nonurban areas as well as cities.

- Although mobile source controls (including transportation control plans) will continue to be a major part of the oxidant control program, there is a need for more stringent control of precursor emissions from stationary sources.

- Both under conditions of transport and under persistence of stagnant air masses there can be sufficient time for less reactive hydrocarbons to contribute to oxidant formation. This indicates the importance of controlling all organic compounds that can form oxidants.

- Nitrogen oxides emissions may be transported into rural areas and contribute to oxidant formation by reaction with locally emitted organic compounds. It may eventually become necessary to consider control of nitrogen oxides, coordinated with the control of hydrocarbons, as a part of the oxidant control strategy.

- Oxidant concentrations that can be attributed to natural sources are usually less than 0.55 parts per million compared with the oxidant standard of 0.08 parts per million. Because of emissions from natural sources, more stringent reductions of man-made emissions may be necessary in some areas.

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(13)   A Theoretical Investigation of Tropospheric Ozone and Stratospheric-Tropospheric Exchange Processess (Fabian, 1973)

Based on the global distribution of various surface types the mean tropospheric residence time of ozone is estimated as a function of latitude. Due to the land-sea distribution t varies from 50 days in the northern hemisphere to 190 days in the southern hemisphere. For the stratospheric-tropospheric exchange a sinusoidal variation with season is assumed. The annual variation of tropospheric ozone thus gets a sine function from mean, amplitude, and phase from which the injection function for the particular latitude can be determined. Ozone and strontium-90 fallout data show similar behavior between 25° south and 65° north latitudes.

(14)   Ozonesonde Observations over North America, Vols. 1-4 (Hering and Borden, 1964a, 1964b, 1965b, 1967)

An experimental program for the measurement of the vertical ozone distribution was established by the Air Force Cambridge Research Laboratories (AFCRL) in Janyary 1963. Observations from eleven network stations spread throughout North America have been published in this series of four reports. Ozonagrams for individual ozonesonde ascents made during the period January 1963 to January 1966 are included.

The fourth volume also presents a statistical summary of the ozonesonde data for the three-year period ending December 1965. Seasonal mean ozone profiles and the standard deviations from the average distributions are given for each station. Correlations of the ozone concentration at specific levels with temperatrue, pressure, and total ozone are also summarized.

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(15)   Mean Distribution of Ozone Density over North America, 1963-1964
        (Hering and Borden, 1965)

        An interim summary of the ozone climate over North America was pre-

pared from AFCRL ozonesonde network observations made during 1963 and

1964. Mean bimonthly distributions of ozone density computed for individual

network stations depict the average ozone structure as a function of

altitude and season for the first two years of network operation. Data

are also presented on the standard deviation of ozone density and the

mean seasonal distributions along a meridional cross section extending

from the Canal Zone to Greenland. A brief statistical analysis indicates

that approximately 35 to 50 percent of the variance in the total ozone

amount at middle and high latitudes is given by the fluctuations in ozone

density in the 11- to 13-km or 13- to 15-km layers.

(16)   Photochemical Oxidants in the New York-New Jersey Metropolitan
        Area (Jacobson and Salottola, 1975)

Atmospheric oxidant concentrations measured at seven locations
during the years 1970-1972 were compared to explore the nature of the
photochemical oxidant problem in the New York-New Jersey metropolitan
area. The results indicate that oxidants occurred in highest concentrations
during the months of May-September; a diurnal pattern existed during the
spring and summer seasons with concentrations usually rising to a maximum
between 12:00 and 17:00h Eastern Standard Time; the federal ambient air
quality standard of 0.08 ppm was exceeded each year with a frequency
varying with location; maximum hourly average concentrations for the region
were in the range of 0.2-0.3 ppm; sites located in heavily trafficked
areas generally reported lower oxidant concentrations than sites in sub-
urban areas.

Comparisons between oxidants at Yonkers, a suburban location north
of the metropolitan area, and meteorological measurements indicated that
elevated concentrations occurred more frequently with wind directions
from the southeast through southwest sectors, wind speeds between 6 and
11 miles h^{-1}, solar radiation intensities above 400 Langleys, temperatures
greater than $75^{\circ}F$, and with early morning mixing depths less than 1000 m.
Concentrations of oxidants in Yonkers rarely exceeded 0.05 ppm during the
winter or on days with low solar radiation.

It is concluded that during the spring and summer in the metropolitan
area oxidant concentrations exceed federal standards more frequently than
any other pollutant, that oxidants are formed largely by photochemical
reactions as polluted air is transported from urban to suburban areas,
that elevated oxidant concentrations occur more frequently at less urbanized
locations downwind of major sources of emissions, and that concentrations
which reach or exceed the ambient air quality standard arise mainly from

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pollutant emissions occurring in the heavily urbanized portion of the metropolitan area while natural sources of oxidants and their precursors make less significant contributions to the photochemical oxidant problem in this region.

The oxidant measurement methods employed either colorometric (Beckman or Technicon) or coulometric (Mast) analyzers. The standard calibration method (neutral buffered KI) was used throughout. At the Yonkers station during the summer of 1973, chemiluminescent measurements of ozone and coulometric oxidant measurements gave comparable results.

(17)   <u>Surface Ozone in the Arctic Atmosphere (Kelly, 1973)</u>

Near-surface atmospheric ozone measurements were carried out at Barrow, Alaska (71° 19'N, 156°W), from January 1965 to September 1967. Ozone was continuously monitored by microcoulombmetric analysis at a level 2 m above the ground. Daily ozone concentrations near the ground varied from 7 to less than 1 pphm by volume. Highest concentrations occurred in the spring and showed sharp increases lasting from several hours to a few days. These sudden rises in ozone concentration correlated with storm front passages. The concentration of surface ozone from late spring through the summer and fall showed less variability from day to day than in the spring. The lowest ozone concentrations occurred from late May to early June.

(18)   <u>The Vertical Distribution of Ozone Over the San Francisco</u>
<u>Bay Area (Lovill and Miller, 1968)</u>

Observations of the vertical distribution of ozone were made during February 1967 in the San Francisco Bay Area with the carbon-iodine (Komhyr) ozonesonde. Horizontal and vertical velocity components were obtained by simultaneous tracking with an M33 radar. In the lower troposphere, two peaks of ozone were found near 1 and 1.5 km within the west coast sub-sidence inversion; the lower maximum coincides in position with a wind jet. In the middle and upper troposphere there are significant time variations of ozone, believed to be caused by intrusions of stratospheric air. Undulations in the ozone, temperature, and wind profiles in the stratosphere suggest laminas of air masses. The mean profile of ozone suggests that there are several distinct zones that are related to ozone production and vertical mixing.

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(19)   The Use of Monitoring Network and ERTS-1 Data to Study Interregional
Pollution Transport of Ozone in the Gary-Chicago-Milwaukee Corridor
(Lyons and Cole, 1974)

Limited ozone monitoring conducted by EPA in Milwaukee during the
summer of 1971 revealed surprisingly high values (5 episode alert levels
in 99 days). In the summer of 1973, the Wisconsin Department of Natural
Resources began installation of nine air quality monitoring stations in
southeast Wisconsin, and one in rural Poynette (32 km north of Madison).
The southeastern sites again revealed high values, two or more sites
exceeding 8 pphm on 27 days over a 47-day period, with alert levels (40 pphm)
being reached 9 times. Peak values between 20-30 pphm were recorded several
times, especially at Racine, Wisconsin. Poynette also frequently
exceeded 8 pphm.

An analysis of the data revealed several interesting facts. The
winds were from the southwest through east-southeast fully 92 percent
of the days during which the primary oxidant standard was exceeded. The
data show that O_3 levels are comparatively low within 1 km of the shore-
line and reach their highest values 1-4 km inland. This is confirmed by
extensive bioindicator monitoring conducted in Milwaukee in 1972. A
mechanism is proposed that illustrates how the complex wind and thermal
structures in lake breezes could lead to continuous fumigation of stored
oxidants to the surface in a narrow band parallel to the shore. Simply
stated, oxidants are conserved over the lake area (in the absence of NO
fluxes) and returned to the shore during the lake-breeze cycle in the
morning.

In addition, the unexpectedly high values found both along the
shoreline and at rural Poynette suggest that oxidants can be subjected
to significant mesoscale and even synoptic scale transport. An ERTS
image of the Lake Michigan area strongly supports a theory that much of
the oxidants and/or its predecessor HC and NO_x originates in the Chicago-
Gary area and is funneled northwards in the lake-breeze convergence zone.

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It even seems conceivable that the high Poynette readings are the result
of transport from such areas as St. Louis, Kansas City, Dallas, etc.
The low level nocturnal jet stream of the Great Plains is suggested as a
plausible mechanism.

(20)   <u>Temporal-Spatial Variations of Nonurban Ozone Concentrations and
        Related Meteorological Factors (Martinez, 1975)</u>

This paper provides a history of the nonurban ozone problem and
summarizes the results of various studies that have been conducted since
1970. The primary information for the paper came from EPA-sponsored
studies the eastern U.S. in 1972-1973 (Figure 6) and the summer of 1974
(Figure 7). These studies have revealed considerable temporal and spatial
variations in ozone concentrations, with levels sometimes exceeding the
national one-hour average ambient standard of 160 $\mu g/m^3$ (0.08 ppm).

Both local and synoptic scale meteorological factors, including
the role of transport from urban areas, have been examined and apparent
relationships with ozone concentrations are described. A consistent
statistical correlation was found between air temperatures in excess of
$60^\circ F$ and ozone concentrations in excess of the NAAQS. Trajectory analyses
were inconclusive and showed no direct urban/nonurban pathway pattern.
However, high O_3 values were associated with slower air movement.
Further, synoptic weather features were found to correlate with ozone
variations. Some high-pressure cells have maximum ozone concentrations
at the center of the high. A slow-moving high pressure system is expected
to be particularly conducive to high ozone values.

SCALE

| | | | | | | | | |
|0|1|2|3|4|5|6|7|8|

(km X 100)

Station No.	Town	County
1	McHenry	Garrett
2	Kane	McKean
3	Coshocton	Coshocton
4	Lewisburg	Greenbrier
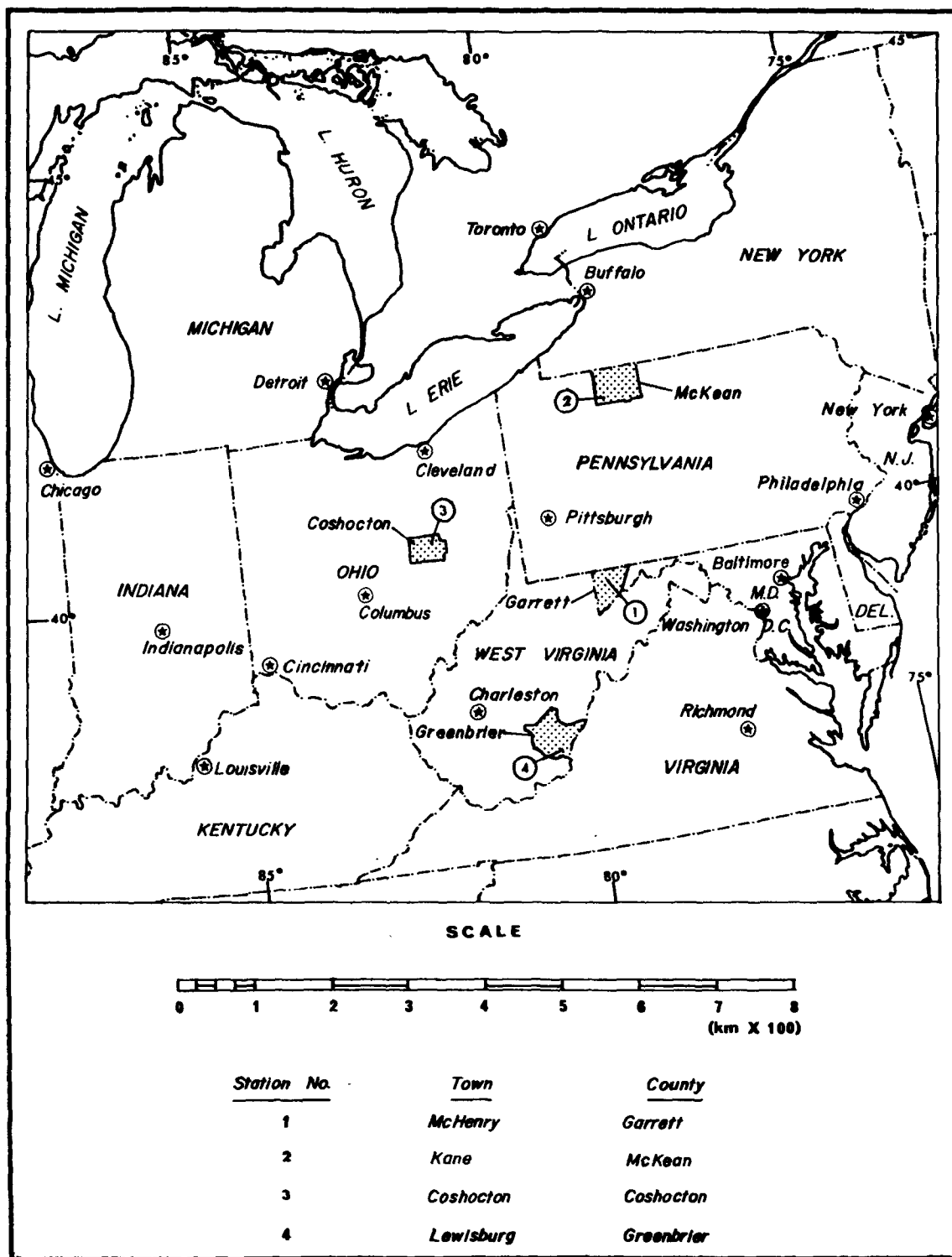
SA-4432-8

FIGURE 6   NONURBAN OZONE GROUND SAMPLING STATIONS, 1972-73 EPA-SPONSORED
STUDIES (McHENRY ONLY 1972 SITE)

56

Lake Erie

Toledo

Cleveland

(Wooster) ▧ Canton

(DuBois) ▧

Columbus ◉ ▧ Pittsburgh ◉

Dayton ◉ (McConnelsville) ▧

Indianapolis ○

■ (Wilmington)

▧ (McHenry)

Cincinnati ◉

Louisville ○

Charleston △

| City Stations ● (6) |
| Rural Sites ▧ (5) |
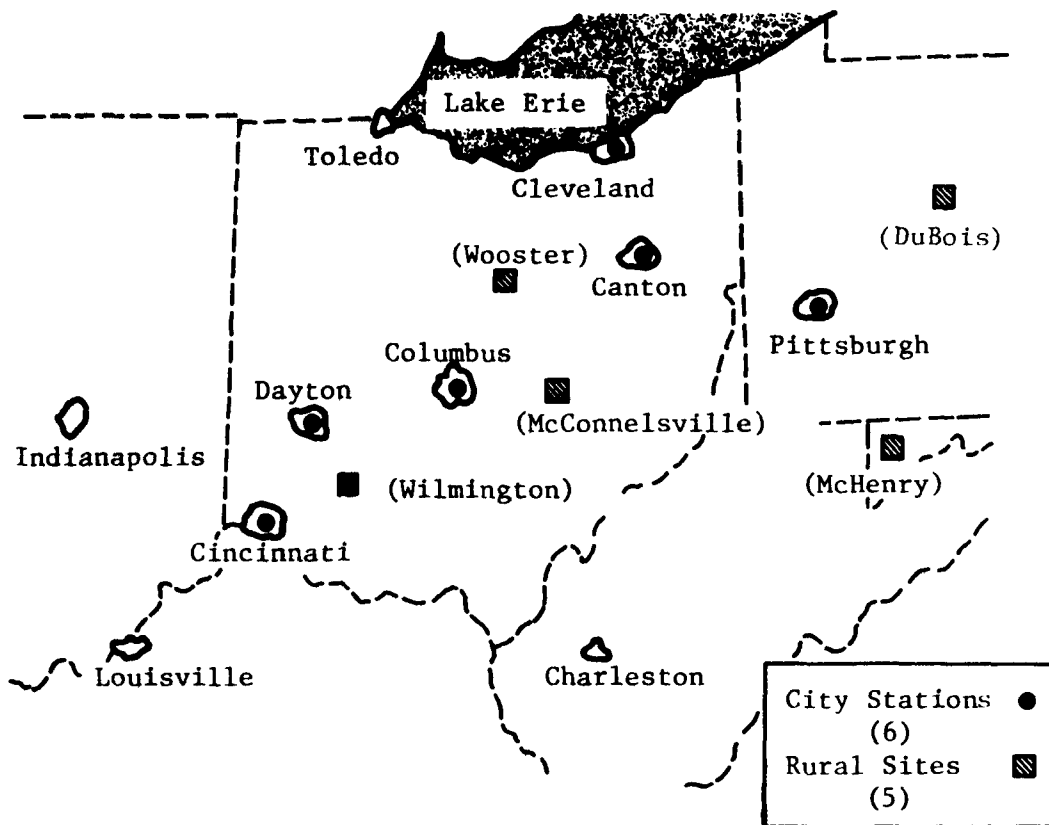
SA-4432-9

FIGURE 7   OZONE GROUND SAMPLING STATIONS, 1974 EPA-SPONSORED STUDY

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(21)   Ozone Within and Below the West Coast Temperature Inversion
       (Miller and Ahrens, 1970)

The oxidant concentration in the air over the San Francisco Bay
Area and the Pacific Ocean was measured up to an altitude of 2500 m and
the observed distribution in the vertical and horizontal has been related
to the characteristics and behavior of the west coast temperature inversion.
Vertical time sections at fixed points and vertical cross sections were
constructed of oxidant concentration, temperature, humidity, and winds
measured from aircraft and radar.

The oxidant concentration in polluted air is strongly dependent
on the destruction rate. The mean destruction rate within the surface
layer depends directly on the intensity of eddy mixing and inversely on
the square of the depth of the vertical mixing. Thus, the existence of
a temperature inversion does not necessarily lead to a high concentration
of oxidants, since the destruction rate may be high in a shallow mixing
layer. The highest oxidant concentration was observed almost invariably
at the edges of the west coast marine inversion, where pollutants are
available for ozone production and the mixing layer is deep. Explanations
are offered for the maxima of ozone that often occur above the inversion
base. Distribution patterns of oxidants clearly depict the waving of
the inversion layer.

(22) Oxidant Air Pollution in the Central Valley, Sierra Nevada Foothills, and Mineral King Valley of California (Miller et al., 1972)

Total oxidant air pollution, temperature, and winds were measured in the Central Valley, the Sierra Nevada foothills, and Mineral King Valley from 17-28 August 1970. Vertical profiles of total oxidant and temperature were determined by aircraft (at Fresno, Visalia, Three Rivers and Mineral King) several times daily during a 2-day period. Evidence was recorded of the transport of photochemical smog from the Central Valley to Mineral King. In situ formation of oxidant and diurnal changes in the temperature profile in Mineral King Valley were observed.

(23)   The Average Tropospheric Ozone Content and Its Variation with
Season and Latitude as a Result of the Global Ozone Circulation
(Pruchniewicz, 1973)

Evaluations of radiosonde soundings over North America and Europe,
measurements aboard commercial airlines, and permanent ozone registrations
at nineteen ground-based stations between Tromso, Norway, and Hermanus,
South Africa, yield three belts of higher ozone intrusion from the strato-
sphere and maximum values of the annual means at about 30°N, and between
$40^{\circ}-45^{\circ}$N and at about 60°N. A marked decrease of the annual mean values
of the tropospheric ozone is detected towards the equator and the pole,
respectively.

In the northern hemisphere the maximum of the annual cycle of the
tropospheric ozone concentration occurs in spring at high latitudes and
in summer at mid-latitudes.

For the tropical region from 30°S to 30°N a strong asymmetry of
the northern and southern hemisphere occurs. This fact is discussed in
detail. The higher troposphere of the tropics seems to be a well-mixed
reservoir and mainly supplied with ozone from the tropopause gap region
in the northern hemisphere. The ozone distribution in the lower tropo-
sphere of the whole tropics seems to be controlled by the up and down move-
ments of the Hadley cell. The features of large-scale and seasonal
variation of tropospheric ozone are discussed in connection with the
ozone circulation in the stratosphere, the dynamic processes near the
tropopause and the destruction rate at the earth's surface.

(24) The Role of Trace Atmospheric Constituents in a Surface Ozone Model
      (Rasmussen and Robinson, 1975)

The authors present a description of a qualitative model of ground
level ozone concentrations obtained by the chemiluminescent methods during
several field studies conducted during 1973 and 1974. The model considers
a typical rural site upwind and downwind of an urban site. The following
features characterize model:

- Stratospheric ozone transport contributes about 30 to 50 ppb to
  the ozone concentration at ground level.

- Natural photochemical reactions (between terpenes and biogenic
  NO) contribute about 20 ppb to the natural background.

- Out of this total of 50 to 70 ppb of natural ozone, at least
  10 ppb is lost due to reactions involving surface O_3 background
  level is about 40 to 60 ppb.

- As this air enters an urban location, the O_3 value quickly
  approaches zero because of reactions with urban NO and aerosols.
  The urban precursors (HC and NO_x) can photolyze to produce as
  much as 50 ppb of photochemical ozone.

- Urban ozone is then advected to downwind rural sites, while
  slow dispersive and destructive processes reduce this ozone
  level to near background concentrations.

The authors believe that the high rural ozone levels are primarily due to
the transport of pollutants from a number of closely located urban sources,
which cannot always be clearly identified.

(25)   Stratospheric-Tropospheric Exchange Processes (Reiter, 1975a)

Qualitative descriptions and quantitative estimates are presented of various transport processes between stratosphere and troposphere. The seasonal changes of tropopause heights account for a flux of about 10 percent of the mass of the stratosphere in one hemisphere during the course of 1 year. This flux is balanced approximately by the seasonal shift of stratospheric air masses between the northern and southern hemispheres. Vertical transport through the Hadley cell transfers approximately 38 percent of the mass equivalent to one hemispheric stratosphere through the tropopause per year. This appears to be the most effective of all transport mechanisms. Large-scale eddies of the scale of cyclones and anticyclones transfer about 20 percent of stratospheric air through the tropopause per year. Small-scale and mesoscale diffusion processes at tropopause level probably account for the transfer of only 1 percent of stratospheric air. These mass flux estimates are in reasonable agreement with observed residence times of stratospheric pollutants.

(26) **High Ozone Concentrations in Nonurban Atmospheres (Ripperton et al., 1974)**

In the summer of 1973, ozone concentrations were measured at several rural locations in West Virginia, Pennsylvania, and Ohio. Chemiluminescent techniques were used and calibrations were performed using the standard method (neutral buffered KI). A C-45 aircraft was used to make O_3 measurements aloft, between and over the fixed field stations. Mean wind data at 900 mb from NOAA were used for trajectory analysis. Some of the results from the field program are as follows (see Figure 6 for station locations):

Station Location	No. of Hours of Data	Percentage of Hours Exceeding O_3 Standard	Highest One-Hour O_3 Concentration (ppm)
McHenry, Md.	1652	37	0.16
Kane, Pa.	2131	30	0.14
Coshocton, Ohio	1785	20	0.17
Lewisburgh, W.V.	1663	15	0.13

The aircraft data, some of which show lower concentrations aloft than at ground level, are used to exclude the possibility of significant stratospheric air intrusions. Collection of air samples in outdoor smog chambers indicates that local air is sufficiently contaminated to permit significant local ozone synthesis. It is contended that ozone in nonurban areas is not due to any given urban source but is a result of area-wide mixing. The interdispersed urban sources add to an air mix that already has natural as well as anthropogenic precursors, thereby making it impossible to identify precursor sources by trajectory analysis. The authors agree with the now well-accepted notion that ozone can be generated in a "spent photochemical system." They conclude that rural ozone is of surface origin.

(27)   Investigation of Rural Oxidant Levels as Related to Urban Hydrocarbon
Control Strategies (RTI, 1975)

A network of ground stations was established to document the occur-
rence of high ozone values in the rural areas of the eastern United States
and their interrelationships with urban contaminants. A total of 11
stations (6 urban and 5 rural) were operational during the study period
of 14 June to 31 August, 1974. Aircraft measurements were taken to obtain
vertical ozone profiles and to determine the extent of urban plumes. In
addition to meteorological parameters, THC, CH_4, O_3, NO_2, and selected
hydrocarbons were measured.

It was found that the NAAQS for photochemical oxidants was exceeded
twice as frequently at rural as at urban stations. Area-wide contamination
of air masses was observed. It was not possible to track an urban plume
for more than 30-50 miles downwind of Columbus, Ohio. High ozone concen-
trations were observed when a synoptic high pressure system moved over a
given station, and high ozone levels persisted as long as the high pressure
system remained in the vicinity.

Although no specific air trajectory terminating at the nonurban
stations could be consistently associated with either high or low ozone
concentrations, the results of the field measurement program still provide
support for transport of ozone precursors from urban areas to rural stations
under appropriate meteorological conditions. These results also imply
that the control of hydrocarbon in any individual city will not necessarily
prevent the occurrence of high rural ozone concentrations in excess of the
NAAQS at any given nonurban site. The implication is that the release
of hydrocarbons and oxides of nitrogen from anthropogenic or biogenic
sources, located in either an urbanor rural area, all combine to generate
appreciable quantities of ozone over wide areas.

(28) <u>Rural and Urban Ozone Relationships in New York State (Stasiuk</u>
      <u>and Coffey, 1974)</u>

Ozone data from a number of air monitoring stations in New York
State were analyzed. The rural monitoring stations were set up in Delaware
(Mt. Utsayantha--elevation 3200 ft) and in the Northern Adirondacks
(White Face Mountain--elevation 4980 ft). The urban sites were at Welfare
Island (New York City); Kingston, Renesslaer, and Glen Falls in the
Hudson River Valley; Syracuse in mid-state; and Buffalo in western New York.
All O_3 data were measured using gas phase chemiluminescent analyzers and
the federal calibration method.

High O_3 concentrations, often in excess of the NAAQS, were measured
both at urban and nonurban locations. Average daily O_3 concentrations in
rural areas--typically 30 to 100 ppb--were found to correlate well with
the daily maximum ozone concentrations in the urban locations. The authors
state that because of the high correlation between O_3 levels at widely
separated urban and rural sites a common source for O_3 is suggested.
Additionally, rough calculations of atmospheric O_3 overburden within the
mixing layer show that the flux of O_3 into New York state can be an
order of magnitude greater than that which might be generated by complete
photochemical reactions of hydrocarbons emissions from New York state.
On the basis of these rough estimates the authors question the likely
effectiveness of oxidant abatement strategies.

IV SUMMARY OF AVAILABLE SOURCES OF OXIDANT/OZONE DATA

In this section descriptions are presented of sources of oxidant (or ozone) data believed to be suitable for studying the relation of oxidant levels to meteorological features. In searching for these data, we have carefully surveyed the EPA National Aerometric Data Bank (NADB), and have obtained information and data from various EPA central and regional offices, various state agencies, and a number of private organizations who have conducted or sponsored routine oxidant monitoring or special research studies.

Since the nonurban oxidant problem and its relation to meteorological processes is currently of considerable interest, we have excluded all urban and near-urban data. Hence this listing includes only those data that are believed to be relatively free from short-range urban contamination.

Particular efforts have been made to identify and include here sources of nonurban data in the eastern United States since this is a geographical region of much interest at the present time. Accordingly, data from the far western states have not been included in this compilation.

The two-year period 1973-1974 has been selected as optimum for the purposes of our later data analysis, and thus our review of the data has been restricted to this period. Any stations reporting less than 300 hours of data during this period have been excluded from this compilation.

The locations of the selected stations are shown in Figure 8. Following this, the data source descriptions are presented in alphabetical order by station name.
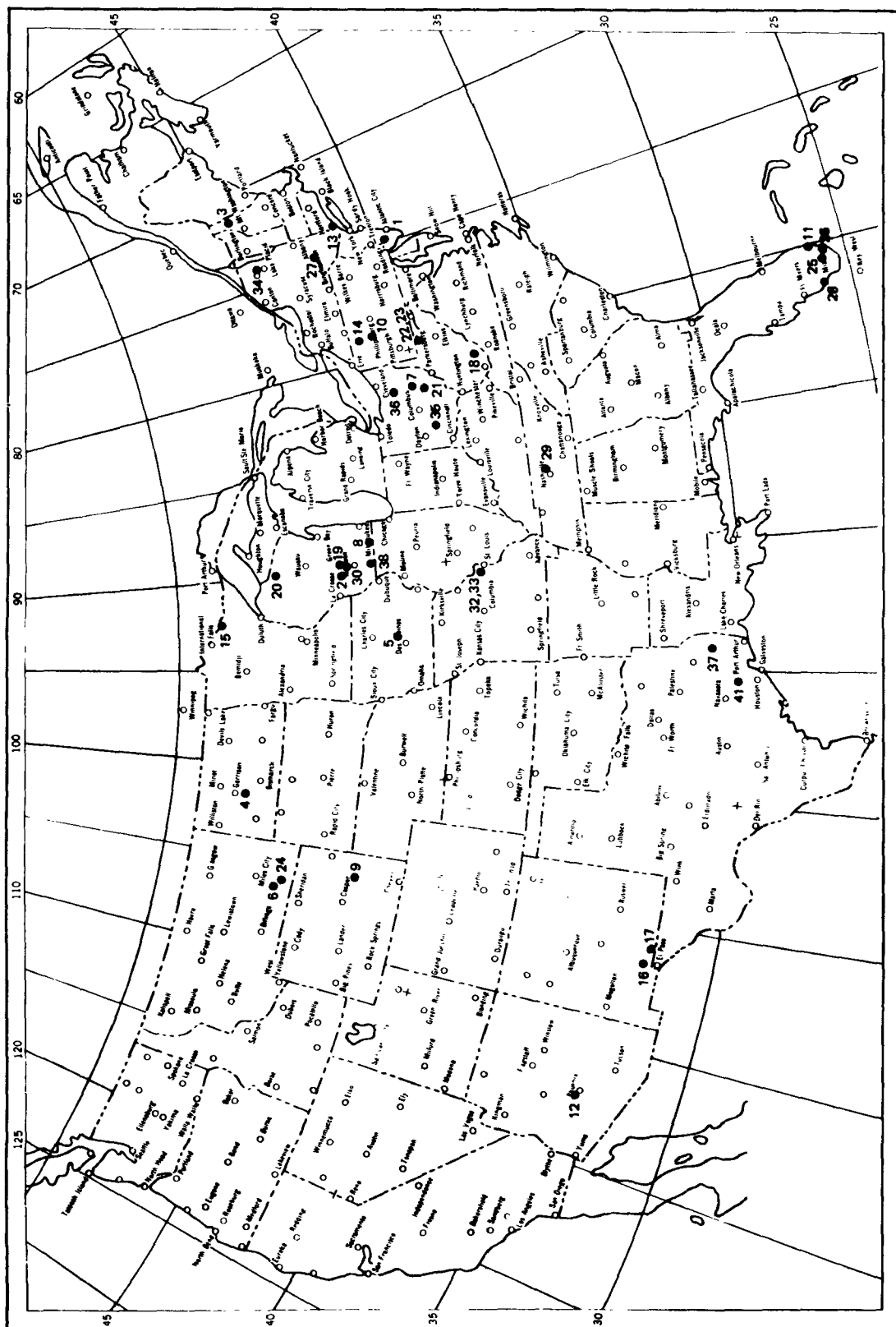
FIGURE 8   LOCATION OF SELECTED NONURBAN STATIONS (NUMBERS REFER TO DATA SOURCE DESCRIPTIONS INCLUDED IN THIS SECTION)

SA-4432-10

Data Source Number: _____1_____

Station Name: __Ancora_____(SAROAD Code 310740001F01)_____

Location: ___Camden County, New Jersey (39° 41' N, 74° 51' 45" W)_____

Responsible Organization: _New Jersey Bureau of Air Pollution Control_____

Cognizant Individual/Organization: _EPA Region II_____

_____

Telephone: _212-264-2525_____

Type of Site: _Rural-Agricultural_____

Type of Pollutant Measured: _O$_3$_____

Measurement Technique: ___Chemiluminescence_____

Period of Record Examined: __1973-1974_____

Frequency of Observations: __Hourly_____

Physical Form of Data Record: _Cards, tape, or printout_____

Remarks: ___3,368 observations reported during 1973-1974_____

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Data Source Number: ___2___

Station Name: Badger (SAROAD Code 513160999F05)

Location: Sauk County, Wisconsin

Responsible Organization: Wis. Dept. of Nat. Resources, Air Pollution Control Section

Cognizant Individual/Organization: EPA Region V

Telephone: 302-353-5250

Type of Site: Rural - Agricultural

Type of Pollutant Measured: O_3

Measurement Technique: Chemiluminescence

Period of Record Examined: 1973-1974

Frequency of Observations: Hourly

Physical Form of Data Record: Cards, tape, or printout

Remarks: 827 observations reported during 1973-1974.

Data Source Number: _____3_____

Station Name: ___Berlin___(SAROAD_Code_300040007F01)_____

Location: _____Coos County, New Hampshire___(44° 27' N, 71° 11' 05" W)_____

Responsible Organization: ___New Hampshire Air Poll. Control Agency_____

Cognizant Individual/Organization: ___New Hampshire Air Poll. Control Agency___

_____

Telephone: _____

Type of Site: ___Suburban - industrial_____

Type of Pollutant Measured: ___O$_3$_____

Measurement Technique: ___Chemiluminsescence_____

Period of Record Examined: ___1973-1974_____

Frequency of Observations: ___Hourly_____

Physical Form of Data Record: ___Cards, tape, or printout_____

Remarks: ___4,547 observations reported during this period._____

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Data Source Number: _____4_____

Station Name: _Beulah_____

Location: __7 miles north of Beulah, North Dakota (47° 22' N, 101° 49' W)___

Responsible Organization: _American Natural Gas Service Company, Detroit, Michigan_

Cognizant Individual/Organization: _Albert Browning_____

_____

Telephone: _313-965-1616_____

Type of Site: _Rural-nonurban_____

Type of Pollutant Measured: _____O_3_____

Measurement Technique: ___Chemiluminescence (Bendix 8002)_____

Period of Record Examined: _(Bendix Model 8002 Ozone Monitor)_
_15 June - 31 July 1974_____

Frequency of Observations: _Hourly_____

Physical Form of Data Record: _Printout_____

Remarks: __Approximately 23% of all 1-hour average concentrations exceeded 0.08 ppm._

Values as high as 0.12 ppm were measured. The ozone values could not be attributed

to transport from urban sources. Lack of foliage, which would otherwise destroy

_O_3, was postulated as one reason for the high O_3 values._____

_____

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_____

Data Source Number: _____5_____

Station Name: _____Bondurant_____(SAROAD Code 163120024G02)_____

Location: _____Polk County, Iowa_____(41° 41' 59" N, 93° 28' 00" W)_____

Responsible Organization: _____Des Moines-Polk Co. Health Dept._____

Cognizant Individual/Organization: ____EPA Region VII_____

_____

Telephone: __816-374-5493_____

Type of Site:.__Rural - Agricultural_____

Type of Pollutant Measured: ____O$_3$_____

Measurement Technique: _____Chemiluminescence_____

Period of Record Examined: ___1973-1974_____

Frequency of Observations: ___Hourly_____

Physical Form of Data Record: __Cards, tape, or printout_____

Remarks: ___2,324 observations reported during 1973-1974._____

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Data Source Number: ____6____

Station Name: ___Colstrip_____

Location: ___Rosebud County, Montana____(45° 55'N, 106° 38' W)_____

Responsible Organization: ___Department of Natural Resources & Conservations,___
_____Helena, Montana
Cognizant Individual/Organization: _____James Gelhaus_____

_____

Telephone: __406-449-3454_____

Type of Site: __Remote_____

Type of Pollutant Measured: _O_3_____

Measurement Technique: ___Chemiluminescence_____

Period of Record Examined: ___December 1973 - May 1975_____

Frequency of Observations: ___Hourly_____

Physical Form of Data Record: ___Printout_____

Remarks: ___Data are missing for August and September 1974. Excellent remote location

with very low O_3 values (< 0.06 ppm) and a virtual absence of diurnal variations.

At no time did the O_3 level exceed 0.08 ppm, although a number of observations

were above 0.06 ppm._____

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_____

Data Source Number: _____7_____

Station Name: __Coschocton_____

Location: ___Coschocton, Ohio (40° 15' N, 81° 54' W)_____

Responsible Organization: __Research Triangle Institute_____

Cognizant Individual/Organization: __J.J. Bufalini (EPA/ESRL)_____

_____

Telephone: __919-549-8411_____

Type of Site: __Rural_____

Type of Pollutant Measured: __O$_3$_____

Measurement Technique: ___Chemiluminescence (Bendix #8002)_____

Period of Record Examined: __26 June - 30 September 1973_____

Frequency of Observations: __Hourly_____

Physical Form of Data Record: 'Printout_____

Remarks: __High O$_3$ concentrations were recorded. Limited O$_3$ data aloft were__

also obtained._____

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Data Source Number: ___8___

Station Name: Darien (SAROAD Code 513680099F05)

Location: Walworth County, Wisconsin (42° 38' N, 88° 40' W)

Responsible Organization: Wisconsin Department of Natural Resources

Cognizant Individual/Organization: Ronald W. Becker

Telephone: 608-266-7588

Type of Site: Rural - Agricultural

Type of Pollutant Measured: O_3

Measurement Technique: Chemiluminescence (REM) and/or ultraviolet

Period of Record Examined: June-September 1974

Frequency of Observations: Hourly

Physical Form of Data Record: Cards, tape, or printout

Remarks: 1,545 observations reported during this period. Monitoring in this area is continuing in 1975.

Data Source Number: _____9_____

Station Name: _Douglas_____

Location: _Converse County, near Douglas, Wyoming (42° 55' N, 105° 18' W)_

Responsible Organization: _Panhandle Eastern Pipeline Company_____

Cognizant Individual/Organization: _Kenneth L. Ancell_____

Telephone: _____

Type of Site: _Rural-remote_____

Type of Pollutant Measured: _O_3_____

Measurement Technique: _Chemiluminescence (Bendix 8002)_____

Period of Record Examined: _January - June 1974_____

Frequency of Observations: _Hourly_____

Physical Form of Data Record: _Printout_____

Remarks: _All O_3 data recorded during this period were generally below 0.06 ppm._

A maximum of 0.076 ppm was measured on 21 June 1974

Data Source Number: _____10_____

Station Name: __DuBois_____

Location: ___DuBois, Pennsylvania (41° 10' N, 78° 44' W)_____

Responsible Organization: __Research Triangle Institute_____

Cognizant Individual/Organization: __J.J. Bufalini (EPA/ESRL)_____

_____

Telephone: __919-549-8411_____

Type of Site: __Rural_____

Type of Pollutant Measured: __O_3_____

Measurement Technique: ___Chemiluminescence (Bendix 8002)_____

Period of Record Examined: __14 June - 31 August 1974_____

Frequency of Observations: __Hourly_____

Physical Form of Data Record: __Printout_____

Remarks: ___In addition to O_3, other species such as hydrocarbons, NO_x, etc., were
measured. Some aircraft data on vertical O_3 distributions were also obtained.___

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Data Source Number: ____11____

Station Name: __Ft. Lauderdale (SAROAD Code 101260100G03)__

Location: __Ft. Lauderdale, Florida (26° 07'N, 80° 09' W)__

Responsible Organization: __EPA Region IV__

Cognizant Individual/Organization: __Louis Nagler__

_____

Telephone: __305-621-0561__

Type of Site: __Nonurban__

Type of Pollutant Measured: __O$_3$__

Measurement Technique: __Chemiluminescence (Bendix 8002)__

Period of Record Examined: __January - June 1973__

Frequency of Observations: __Hourly__

Physical Form of Data Record: __Printout__

Remarks: _____

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Data Source Number: _____12_____

Station Name: __Glendale (SAROAD Code 030320001G01)_____

Location: _____Glendale, Arizona   (33° 33' 45", 112° 11' 15" W)_____

Responsible Organization: __Maricopa County Health Dept._____

Cognizant Individual/Organization: __EPA Region IX_____

_____

Telephone: __415-556-2320_____

Type of Site: __Rural - near urban_____

Type of Pollutant Measured: __O_3_____

Measurement Technique: ___Dasibi Ultraviolet_____

Period of Record Examined: __1973-1974_____

Frequency of Observations: __Hourly_____

Physical Form of Data Record: __Cards, Tape, or Printout_____

Remarks: __1,808 observations reported during 1973-1974_____

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Data Source Number: _____13_____

Station Name: _Greenwich (SAROAD Code 070330004F01)_____

Location: _____Greenwich, Connecticut (41° 4' 37" N, 73° 41' 56" W_____

Responsible Organization: _Conn. Dept. Envir. Protection_____

Cognizant Individual/Organization: _EPA Region I_____

_____

Telephone: _617-223-7210_____

Type of Site: _Remote_____

Type of Pollutant Measured: _O_3_____

Measurement Technique: ____Chemiluminescence_____

Period of Record Examined: __1973-1974_____

Frequency of Observations: __Hourly_____

Physical Form of Data Record: _Cards, tape, or printout_____

Remarks: ___5315 observations reported during 1973-1974_____

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Data Source Number: ___14___

Station Name: ___Kane___

Location: ___Kane, Pennsylvania (41° 40' N, 78° 47' W)___

Responsible Organization: ___Research Triangle Institute___

Cognizant Individual/Organization: ___J.J. Bufalini (EPA/ESRL)___

___

Telephone: ___919-549-8411___

Type of Site: ___Rural___

Type of Pollutant Measured: ___O_3___

Measurement Technique: ___Chemiluminescence (Bendix #8002)___

Period of Record Examined: ___26 June - 30 October 1973___

Frequency of Observations: ___Hourly___

Physical Form of Data Record: ___Printout___

Remarks: ___High O_3 concentrations were recorded. Limited O_3 data aloft were___

___also obtained.___

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Data Source Number: _____15_____

Station Name: __Lake Kabetogema__

Location: __Lake Kabetogema, Minnesota (48° 27' N, 93° 02' W)__

Responsible Organization: __---__

Cognizant Individual/Organization: __Ned Meyers (EPA/OAQPS)__

_____

Telephone: __919-688-8146__

Type of Site: __Rural-Near Urban__

Type of Pollutant Measured: __O_3__

Measurement Technique: __Chemiluminescence (MEC 1100)__

Period of Record Examined: __18 July - 21 August 1974__

Frequency of Observations: __Hourly__

Physical Form of Data Record: __Printout__

Remarks: __The measurements yielded low ozone values, with an hourly maximum__
__of 0.055 ppm.__

Data Source Number: _____16_____

Station Name: __Las Cruces_____ (SAROAD Code 320340010F01)_____

Location: __Dona Ana County, New Mexico (32° 20' 20" N, 106° 49' 00" W)___

Responsible Organization: _State of New Mexico Envir. Improvement Agency_____

Cognizant Individual/Organization: _EPA Region VI_____

_____

Telephone: _214-749-1962_____

Type of Site: _Rural-agricultural_____

Type of Pollutant Measured: ___O_3_____

Measurement Technique: ___Chemiluminescence_____

Period of Record Examined: ___1973-1974_____

Frequency of Observations: ___Hourly_____

Physical Form of Data Record: __Cards, tape, or printout_____

Remarks: __3,755 observations reported during 1973-1974_____

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Data Source Number: _____17_____

Station Name: La Union _____(SAROAD Code 320340008F02)_____

Location: _____Dona Ana County, New Mexico (31° 55' 50" N, 106° 37' 50" W)_____

Responsible Organization: _____State of New Mexico Envir. Improvement Agency_____

Cognizant Individual/Organization: _____EPA Region VI_____

Telephone: _____214-749-1962_____

Type of Site: _____Rural-agricultural_____

Type of Pollutant Measured: _____O_3_____

Measurement Technique: _____Chemiluminescence_____

Period of Record Examined: _____1973-1974_____

Frequency of Observations: _____Hourly_____

Physical Form of Data Record: _____Cards, tape, or printout_____

Remarks: _____7,616 observations reported during 1973-1974_____

Data Source Number: ___18___

Station Name: ___Lewisburg___

Location: ___Lewisburg, West Virginia (37° 50' N, 80° 22' W)___

Responsible Organization: ___Research Triangle Institute___

Cognizant Individual/Organization: ___J.J. Bufalini (EPA/ESRL)___

Telephone: ___919-549-8411___

Type of Site: ___Rural___

Type of Pollutant Measured: ___O_3___

Measurement Technique: ___Chemiluminescence (Bendix #8002)___

Period of Record Examined: ___26 June - 30 September 1973___

Frequency of Observations: ___Hourly___

Physical Form of Data Record: ___Printout___

Remarks: ___High near-ground O_3 concentrations were recorded. Limited O_3___

___data aloft were also obtained.___

Data Source Number: _____19_____

Station Name: __MacKenzie Environmental Center   (SAROAD Code 510600001F03)__

Location: __Columbia County, Wisconsin__

Responsible Organization: __Wisconsin Department of Natural Resources, Air Pollution__
                              Control Section
Cognizant Individual/Organization: __EPA Region V__

Telephone: __302-353-5250__

Type of Site: __Rural-industrial__

Type of Pollutant Measured: __O_3__

Measurement Technique: __Chemiluminescence__

Period of Record Examined: __1973-1974__

Frequency of Observations: __Hourly__

Physical Form of Data Record: __Cards, tape, or printout__

Remarks: __12,665 observations reported during 1973-1974__

Data Source Number: _____20_____

Station Name: __Manitowish Waters__

Location: __Vilas County, Wisconsin (46° N, 89° 54' W)__
                   (6 miles south of Manitowish Waters on County K)

Responsible Organization: __Wisconsin Dept. of Natural Resources__

Cognizant Individual/Organization: __Ronald W. Becker__

Telephone: __608-266-7588__

Type of Site: __Rural__

Type of Pollutant Measured: __O_3__

Measurement Technique: __Chemiluminescence (REM) and/or Dasibi Ultraviolet__

Period of Record Examined: __June - September 1974__

Frequency of Observations: __Hourly__

Physical Form of Data Record: __Cards, tape, or printout__

Remarks: __Monitoring in this area is continuing in 1975.__

Data Source Number: ____21____

Station Name: ____McConnelsville____

Location: ____McConnelsville, Ohio $(39^{\circ}$ 57' N, 82° 02' W)____

Responsible Organization: ____Research Triangle Institute____

Cognizant Individual/Organization: ____J.J. Bufalini (EPA/ESRL)____

____

Telephone: ____919-549-8411____

Type of Site: ____Rural____

Type of Pollutant Measured: ____O_3____

Measurement Technique: ____Chemiluminescence (Bendix 8002)____

Period of Record Examined: ____14 June - 31 August 1974____

Frequency of Observations: ____Hourly____

Physical Form of Data Record: ____Printout____

Remarks: ____In addition to O_3, other species such as hydrocarbons, NO_x, etc.____

____were also measured. Some aircraft data on vertical O_3 distributions were____

____also obtained.____

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Data Source Number: _____22_____

Station Name: __McHenry__

Location: __McHenry, Maryland (39° 36'N, 79° 16' W)__

Responsible Organization: __Research Triangle Institute__

Cognizant Individual/Organization: __J. J. Bufaline (EPA/ESRL)__

Telephone: __919-549-8411__

Type of Site: __Rural__

Type of Pollutant Measured: __O_3__

Measurement Technique: __Chemiluminescence (Bendix 8002)__

Period of Record Examined: __26 June - 30 September 1973__

Frequency of Observations: __Hourly__

Physical Form of Data Record: __Printout__

Remarks: __High near-ground O_3 concentrations were recorded. Limited O_3__

__data aloft were also obtained.__

Data Source Number: _____23_____

Station Name: __McHenry_____

Location: _____McHenry, Maryland (39° 36' N, 79° 16' W)_____

Responsible Organization: ____Research Triangle Institute_____

Cognizant Individual/Organization: __J.J. Bufalini (EPA/ESRL)_____

_____

Telephone: __919-549-8411_____

Type of Site: ___Rural_____

Type of Pollutant Measured: ___O_3_____

Measurement Technique: _____Chemiluminescence (Bendix 8002)_____

Period of Record Examined: ___14 June - 31 August 1974_____

Frequency of Observations: ___Hourly_____

Physical Form of Data Record: _Printout_____

Remarks: __In addition to O_3, other species such as hydrocarbons, NO_x, etc. were__

measured. Some aircraft data on vertical O_3 distributions were also obtained.

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Data Source Number: _____24_____

Station Name: ___McRae_____(SAROAD Code 271360028F03)_____

Location: _____Rosebud County, Montana (45° 45' 47" N, 106° 23' 09" W)_____

Responsible Organization: __Montana State Air Quality Bureau_____

Cognizant Individual/Organization: __EPA Region VIII_____

_____

Telephone: _303-837-3895_____

Type of Site: ___Rural - Agricultural_____

Type of Pollutant Measured: O_3_____

Measurement Technique: ___Chemiluminescence_____

Period of Record Examined: __1973-1974_____

Frequency of Observations: __Hourly_____

Physical Form of Data Record: ___ᐟ___Cards, tape, or printout_____

Remarks: _____3570 observations reported during 1973-1974._____

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Data Source Number: _____25_____

Station Name: __Miami Jetport   (SAROAD Code 100860008P02)_____

Location: ____Dade County, Florida (25° 51' 50" N, 80° 52' 10" W)_____

Responsible Organization: __EPA Region IV_____

Cognizant Individual/Organization: __EPA Region IV_____

_____

Telephone: __404-526-5727_____

Type of Site: __Remote_____

Type of Pollutant Measured: __O$_3$_____

Measurement Technique: __Chemiluminescence_____

Period of Record Examined: __1973-1974_____

Frequency of Observations: __Hourly_____

Physical Form of Data Record: __Cards, tape, or printout_____

Remarks: __4,187 observations reported during 1973-1974._____

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Data Source Number: _____26_____

Station ·Name: __Miami West   (SAROAD Code 10270009P05)_____

Location: _____Miami. Florida (25° 50' 06" N. 80° 14' 09" W)_____
              (AT&T transmission station Hwy. 27 east of Tamiami Trial)
Responsible Organization: _____EPA Region IV_____

Cognizant Individual/Organization: __Louis Nagler/EPA Region IV_____

_____

Telephone: _305-621-0561_____

Type of Site: ____Rural - Near Urban_____

Type of Pollutant Measured: ____O_3_____

Measurement Technique: ____Chemiluminescence   (Bendix 8002)_____

Period of Record Examined: ___1973-1974_____

Frequency of Observations: ___Hourly_____

Physical Form of Data Record: _Cards, tape, or ptintout_____

Remarks: __3,176 Observations reported during 1973-1974._____

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Data Source Number: _____27_____

Station Name: ___Mt. Utsayantha_____

Location: _____Mt. Utsayantha, New York (74° 37' W, 42° 24' N)_____

Responsible Organization: __N.Y. State Dept. of Env. Conservation_____

Cognizant Individual/Organization: __William N. Stasiuk_____

_____

Telephone: __518-457-5276_____

Type of Site: _____Remote_____

Type of Pollutant Measured: _____0$_3$_____

Measurement Technique: ____Chemiluminescence_____

Period of Record Examined: ____1 August - 17 August 1973_____

Frequency of Observations: ____Hourly_____

Physical Form of Data Record: __Printout_____

Remarks: __High altitude location (3200 ft MSL)_____

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Data Source Number: _____28_____

Station Name: __Naples (SAROAD Code 102880001P05)__

Location: __Naples, Florida (26° 01' 31"N, 81° 43' 50" W)   (on Rookery Bay)__

Responsible Organization: __EPA Region IV__

Cognizant Individual/Organization: __Louis Nagler__

_____

Telephone: __305-621-0561__

Type of Site: __Rural - Near Urban__

Type of Pollutant Measured: __O_3__

Measurement Technique: __Chemiluminescence (Bendix 8002)__

Period of Record Examined: __1973-1974__

Frequency of Observations: __Hourly__

Physical Form of Data Record: __Cards, tape, or printout__

Remarks: __3342 observations reported during 1973-1974.__

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Data Source Number: _____29_____

Station Name: _____Old Hickory_____ (SAROAD Code 443320007F01)_____

Location: _____Sumner County, Tennessee (36° 17' 53" N, 86° 39' 11"W)_____
_____(10 miles northeast of Nashville)_____

Responsible Organization: _____Tenn. Dept. of Public Health, Div. of Air Pollution_____
_____Control_____

Cognizant Individual/Organization: _____EPA Region IV_____

_____

Telephone: _404-526-5727_____

Type of Site: _____Rural-Industrial_____

Type of Pollutant Measured: __O_3_____

Measurement Technique: _____Chemiluminescence_____

Period of Record Examined: __1973-1974_____

Frequency of Observations: __Hourly_____

Physical Form of Data Record: __Cards, tape, or printout_____

Remarks: ___13,104 observations reported during 1973-1974._____

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Data Source Number: _____30_____

Station Name: _____Poynette_____

Location: _____Columbia County, Wisconsin (43° 24' N, 89° 28' W)_____

Responsible Organization: _____Wisconsin Dept. of Natural Resources_____

Cognizant Individual/Organization: _Ronald W. Becker_____

_____

Telephone: _608-266-7588_____

Type of Site: _____Rural_____

Type of Pollutant Measured: __O_3_____

Measurement Technique: _____Chemiluminescence (REM) and/or Dasibi Ultraviolet

Period of Record Examined: __June - September 1974_____

Frequency of Observations: _____Hourly_____

Physical Form of Data Record: _Cards, tape, or printout_____

Remarks: _Monitoring in this area is continuing in 1975._____

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Data Source Number: _____31_____

Station Name: ___Prairie View_____

Location: ___Prairie View, Texas (30° 18' N, 95° 26' W)_____

Responsible Organization: ___Texas Air Quality Control Board_____

Cognizant Individual/Organization: ___Duane J. Johnson_____

_____

Telephone: ___512-451-5711_____

Type of Site: ___Suburban - Rural_____

Type of Pollutant Measured: ___O_3_____

Measurement Technique: ___Chemiluminexcence (MEC #1100)_____

Period of Record Examined: ___1 May - 1 September 1974_____

Frequency of Observations: ___Hourly_____

Physical Form of Data Record: ___Printout_____

Remarks: ___This site is located 40 miles north of Houston, Texas. Transport____

___from Houston was believed responsible for the high ozone values observed____

___at Prairie View. These measurements were part of the Goober III Study.____

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Data Source Number: _____32_____

Station Name: ____Queeny (Oxidant) (SAROAD Code 264300006G01)_____

Location: _____St. Louis County, Missouri (38° 59' 58" N, 91° 45' 46" W)_____

Responsible Organization: ____St. Louis Co. Health Dept., Air Pollution Control Div.

Cognizant Individual/Organization: ____EPA Region VII_____

_____

Telephone: ____816-374-5493_____

Type of Site: _____Rural - Near Urban_____

Type of Pollutant Measured: ____O_x_____

Measurement Technique: ____Neutral KI_____

Period of Record Examined: ____1973-1974_____

Frequency of Observations: ____Hourly_____

Physical Form of Data Record: ____Cards, tape, or printout_____

Remarks: ____14,683 observations reported during 1973-1974._____

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Data Source Number: _____33_____

Station Name: ___Queeny__(Ozone)___(SAROAD Code 264300006G01)_____

Location: ____St. Louis County, Missouri__(38° 59' 58" N, 91° 45' 46" W)___

Responsible Organization: ___St. Louis Co. Health Dept, APCD_____

Cognizant Individual/Organization: ___EPA Region VII_____

_____

Telephone: ___816-374-5493_____

Type of Site: ____Rural - Near Urban_____

Type of Pollutant Measured: ____O$_3$_____

Measurement Technique: ____Chemiluminescence_____

Period of Record Examined: ____1973-1974_____

Frequency of Observations: ____Hourly_____

Physical Form of Data Record: ____Cards, tape, or printout_____

Remarks: ___1,823 observations reported during 1973-1974._____

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Data Source Number: _____34_____

Station Name: _____White Face Mountain_____

Location: _____White Face Mountain, New York   (44° 20' N, 74° 05' W)_____

Responsible Organization: _____N.Y. State Dept. of Env. Conservation_____

Cognizant Individual/Organization: _____William N. Stasiuk_____

_____

Telephone: _____518-457-5276_____

Type of Site: _____Remote_____

Type of Pollutant Measured: _____O_3_____

Measurement Technique: _____Chemiluminescence_____

Period of Record Examined: _____1 August - 17 August 1973_____

Frequency of Observations: _____Hourly_____

Physical Form of Data Record: _____Printout_____

Remarks: _____Additional data have been obtained and will be made available shortly._____

_____This is a high altitude location (4980 ft MSL)._____

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Data Source Number: 35

Station Name: Wilmington

Location: Wilmington Industrial Air Park, Ohio (39° 20' N, 83° 48' W)

Responsible Organization: Research Triangle Institute

Cognizant Individual/Organization: J. J. Bufalini   (EPA/ESRL)

Telephone: 919-549-8411

Type of Site: Rural

Type of Pollutant Measured: O_3

Measurement Technique: Chemiluminescence (Bendix 8002)

Period of Record Examined: 14 June - 31 August 1974

Frequency of Observations: Hourly

Physical Form of Data Record: Printout

Remarks: In addition to O_3, other species such as hydrocarbons, NO_x, etc.,
were measured. Some aircraft data on vertical O_3 distributions were also
obtained.

Data Source Number: ___36___

Station Name: ___Wooster___

Location: ___Wooster, Ohio (40° 50' N, 81° 56' W)___

Responsible Organization: ___Research Triangle Institute___

Cognizant Individual/Organization: ___J. J. Bufalini (EPA/ESRL)___

_____

Telephone: ___919-549-8411___

Type of Site: ___Rural___

Type of Pollutant Measured: ___O_3___

Measurement Technique: ___Chemiluminescence (Bendix 8002)___

Period of Record Examined: ___14 June - 31 August 1974___

Frequency of Observations: ___Hourly___

Physical Form of Data Record: ___Printout___

Remarks: ___In addition to O_3, other species such as hydrocarbons, NO_x, etc.,___ ___were measured. Some aircraft data on vertical O_3 distributions were also___ ___obtained.___

Data Source Number: _____37_____

Station Name: _____Yellow Pine_____

Location: _____Sabine National Forest, Texas (31° 20' N, 94° 00' W)_____

Responsible Organization: ____Texas Air Quality Control Board_____

Cognizant Individual/Organization: ____Duane J. Johnson_____

_____

Telephone: _512-451-5711_____

Type of Site: _____Rural - Remote_____

Type of Pollutant Measured: ____O_3_____

Measurement Technique: ____Chemiluminescence (MEC #1100)_____

Period of Record Examined: ____April - June 1974_____

Frequency of Observations: ____Hourly_____

Physical Form of Data Record: __Printout_____

Remarks: ____This location is 85 miles north of Beaumont and 135 miles northeast_

____of Houston. O_3 values exceeded 0.08 ppm only twice during this period._

____Transport from urban sources was not responsible for high O_3 values._

____Local synthesis was predominant._____

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Data Source Number: 38

Station Name: Yellowstone Lake (SAROAD Code 511720001F05)

Location: Lafayette County, Wisconsin   (42° 46' N, 89° 54' W)

Responsible Organization: Wisconsin Dept. of Natural Resources

Cognizant Individual/Organization: Ronald W. Becker

Telephone: 608-266-7588

Type of Site: Rural

Type of Pollutant Measured: O_3

Measurement Technique: Chemiluminescence (REM) and/or Dasibi Ultraviolet

Period of Record Examined: June - September 1974

Frequency of Observations: Hourly

Physical Form of Data Record: Cards, tapes, or printout

Remarks: 3,205 observations were reported during this period. Monitoring in this area is continuing in 1975.

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16. ABSTRACT

This report was originally published as an Interim Report in November 1975. Literature available at that time was reviewed and a summary was prepared describing the processes affecting ozone concentrations in remote areas. The topics discussed include ozone of stratospheric origin, natural tropospheric sources and sinks, and long range transport in the troposphere. Selected research studies are abstracted and 38 sources of ozone or oxidant data taken at remote locations are discussed. A bibliography is included.

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