MAPPING THE POTENTIAL ACIDIC DEPOSITION IN SOUTHWESTERN CALIFORNIA USING AMBIENT AIR CONCENTRATIONS OF ACID PRECURSORS

by

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MAPPING THE POTENTIAL ACIDIC DEPOSITION IN SOUTHWESTERN CALIFORNIA USING AMBIENT AIR CONCENTRATIONS OF ACID PRECURSORS

ABSTRACT: Attempts to map the distribution of acidic deposition have been inadequate, particularly in areas of seasonal or limited rainfall. Ambient air concentrations of acid precursors may be used to monitor and map the distribution of potential acidic deposition. A network of stations in California currently monitor these ambient air concentrations. Maps were produced from these data showing the distribution of acid precursors in southwestern California in 1979. Graphs were prepared which describe the monthly and annual variations in the ambient air concentrations of acid precursors. The greatest potential for acidic deposition is in the Los Angeles and Bakersfield areas. Oxides of nitrogen dominate the ambient air concentrations of acid precursors with nitric oxide having the most influence on trends. The heaviest potential fallout of acid precursors occurs during the winter months. No increase in the presence of acid precursors in the ambient air was noticeable in the 1970s. Provisions should be made to increase the number of locations of monitoring stations, so that accurate maps may be created and more efficient monitoring may take place.

INTRODUCTION

Chemical compounds suspended in the atmosphere may be acidic or have the potential to become acidic. These compounds, precipitated in many forms, occur naturally and from human activity. The major compounds precursory to the formation of dilute acids are oxides of nitrogen and sulfur. In 1852, Angus Smith first recognized this phenomenon.[1] Only recently has acid precipitation become a popular subject of scientific research.[2] Attempts to describe the historical trends, to show the distribution, and to measure the deposition of these compounds and the acids they become are not adequate.[3] Federal and state regulations are being designed to reduce the occurrence of this little understood phenomenon.[4]

The Phenomenon of Acid Precipitation

Acids defined. Acids are water soluble compounds that have an excess of positively charged hydrogen ions (cations). As the concentration of these hydrogen ions increases, the acidity of a solution intensifies. The acidity of any solution is measured on a potential hydrogen (pH) scale. The pH scale is logarithmic and extends from an index of zero to fourteen. Any value along this continuum below seven identifies an acidic solution and above seven, a basic solution.

Acid rain and acidic deposition. The theoretical pH value

of pure rainwater is 5.6. Rain reacts with atmospheric carbon dioxide to form a slightly acidic solution of carbonic acid. Precipitation which has a pH value less than 5.6 is popularly referred to as acid rain. However, acid rain is only one way in which acid or acid forming compounds suspended in the atmosphere enter the surface environment. Acid and precursor deposition occurs in wet or dry forms such as precipitated rain, snow, hail, fog, particulates, and gases. For the sake of simplicity, acidic deposition will be used to refer to all forms of materials that are acids or acid precursors which are precipitated out of the atmosphere.

Sources. Acidic deposition has always taken place, although fluctuations in intensity most likely have occurred.[5] Volcanic eruptions, forest fires, lightning, and other natural events contribute to acidic deposition.[6] Mankind's greatest contribution to this phenomenon is the combustion of fossil fuels. Although the exact impact of the combustion of fossil fuels cannot be precisely determined, abundant claims exist that promote the belief that human activities are the primary source of materials that produce acidic deposition.[7]

Precursors. Nitric and sulfuric acids are the major components of acidic deposition. These acids are formed when oxides of nitrogen and sulfur are converted into compounds, which then react with moisture in the atmosphere. These reactions may occur along several pathways which

include photochemical, heavy metal catalysis, and heterogeneous mechanisms. Photochemical reactions occur with energy received from the sun. Heavy metal catalysis results from metal ion dust particles increasing the rate of reactions. Heterogeneous chemistry refers to a reaction of components in different phases. The formation of nitric acid is thought to result from heterogeneous chemistry and photochemical mechanisms in both gas and liquid phases. The formation of sulfuric acid is thought to result from heavy metal catalysis and photochemical mechanisms in both gas and liquid phases.[8]

The Measurement of Acidic Deposition

Research emphasis. Although acidic deposition was recognized in the 1850s, it was not considered to be a significant problem until the 1970s. A great majority of the research involving acidic deposition relates to its effect upon the environment after it has precipitated out of the atmosphere. Very little is known or understood about what goes on while these compounds are suspended in the atmosphere. Much of the effort to measure, map distributions of, and identify trends has been based upon sparse, piecemeal, and limited data covering only a few years. Studies have primarily been centered in the northeast quadrant of the United States.[9]

The variable pH of rainwater. The pH of rainwater will vary depending on when in a storm the measurement is taken.

Lower pH values have been associated with the early stages of storms and with lower precipitation rates. The highest acid content in rainwater has been recorded during cold fronts and squall lines. Warm fronts generally produce precipitation with relatively higher pH values. Thunderstorms create a large amount of acidic deposition in relation to the amount of rain that falls. The greatest total deposition of acidic material occurs in the summer when total rainfall is least. In comparison to the eastern half of the United States, storms moving on to the west coast produce rain with minor concentrations of acid.[10]

Measurement problems. There are problems in attempting to measure the acidity of rainwater. It has been shown that the methods of measuring pH are prone to error, and that sampling methods, sample integrity, and other factors affect the results.[11] This monitoring of the pH of rain has only been going on for a few years, and the network of stations collecting these data is far from complete. Rainfall does not occur continuously and, in some cases, it occurs only seasonally if at all. The question of how to come up with a representative measurement from rain pH values that accurately describes the situation has not been answered.[12]

The measurement of dry acidic deposition also has problems. A common method is to place huge soup pots (similar to what is used to catch radioactive fallout) out in the open and then attempt to measure what has fallen inside.

Miscellaneous debris often pollute the results, and the interaction of gases with soil and vegetation is completely ignored (due to the inability of these pots to catch the gases). This type of monitoring has been going on for less time than the monitoring of the pH of rain, and the network of stations collecting the dry acidic deposition data is even less complete.[13]

Recent Approaches to Acidic Deposition

Legislation. On February 23, 1982, a bill was introduced by the Assembly Select Committee on Acid Rain in the State of California called the Acid Deposition Act of 1982. This bill established a State Agency Working Group and a Scientific Advisory Committee on Acid Deposition, which will be chaired by the Air Resources Board. The Act calls for the defining of acid deposition and acid deposition precursor for purposes of state air pollution laws, and for the preparation of a comprehensive research and monitoring program.[14] Other state and federal actions are also taking into account the acidic deposition situation. A treaty that deals with acid rain is being considered by the United States and Canada.

The geography of California. California is a unique case when considering acidic deposition for several reasons. Due to geographical conditions, the acidic deposition that occurs in the state as a result of human activity or natural events is produced entirely within the state. In contrast,

interstate transportation of acid precursors and acidic materials in the northeastern quadrant of the United States is an important issue. Whereas oxides of sulfur are the major components in other areas of the United States, oxides of nitrogen predominate in the acidic deposition phenomenon in California. Rainfall is very seasonal over most of the state with the rainy season occurring between the months of November and April. Precipitation in some areas is quite limited. California experiences very stable conditions conducive to the transportation of materials during the summer, while during the winter months transportation is less likely to happen. It is believed that as much as 90% of the acidic deposition is in dry form in California.[15]

The need for alternative monitoring procedures. A procedure to monitor the acidic deposition that would circumvent the previously mentioned pitfalls is needed, particularly in areas such as California. A method which provides the relative distribution and changes in the potential acidic deposition but would not give actual measurements would be valuable. This is the case since it is not known how to interpret actual measurements at the present time.

Monitoring emissions. One alternative method would be to examine the distribution of emissions of precursors to acidic deposition. Two major problems hinder this procedure. First, the current ability to model and predict the distribution of emissions and subsequent fallout is poor.[16] Second, the data needed to accomplish such an alternative

are generally not available. The first year the state of California compiled an accurate and complete inventory of emissions was 1979. The next inventory will not be compiled until 1985. As of early 1982, the 1979 inventory had not been published.[17]

Monitoring ambient air concentrations. Another alternative would be to examine the surface level ambient air concentrations of acidic deposition precursors as the potential for fallout. Acid precursors may become acids after fallout in the presence of water. This procedure has two major advantages. First, by studying the surface level conditions, the need to predict the transportation of these materials is avoided. Second, these data have been collected since late 1968 in a fairly extensive network in California. Levels are taken continuously and published quarterly in the form of daily maximum hourly concentrations. This method could also take into account the gases available for interaction with the surface as well as suspended materials.

The ambient air concentrations of acid precursors therefore appear to be a feasible and desirable alternative to the present methods of monitoring the acidic deposition situation in California. This procedure would allow for year round monitoring and would not be dependent on rain. It would allow for essentially simultaneous readings to be taken across the network providing a more accurate method of collecting data. Although not a direct measurement of acidic deposition, this procedure would allow administrators

and regulators to observe the relative distribution of materials at ground level that could interact with the surface or fallout and the relative trends both seasonally and yearly. Although caution must be used when evaluating trends with only a few years of data, this information has been available for a longer period of time and the network is established and functional. Therefore, this procedure has a jump on the other alternatives.

Study Objectives and Expectations

Objectives. Maps will be created showing the distribution of the potential acidic deposition as described by ambient air concentrations recorded by air monitoring stations in southwestern California. Monthly and annual variations will be noted by graphically displaying the appropriate data. Graph comparison and map interpretation will be used to look for variations between geographical locations such as the San Francisco and Los Angeles areas.

Expectations. The lowest recorded pH values of rain were observed in the Los Angeles and San Jose areas, and the primary sources of pollutants that contribute to acidic deposition have been identified as automobiles, industrial activities, and utilities.[18] If the proposed alternative monitoring method is consistent with the above, the highest ambient air concentrations will be shown to be in the South Coast and Bay Area Air Basins and the lowest in areas of low density population and low industrial activity such as

the central coast. The concentrations of the oxides of sulfur should be much less than the concentrations of the oxides of nitrogen. The summer months should show lower levels of both components with the peak concentrations occurring between November and April. The emission of these materials has either decreased in the last decade or stayed nearly the same.[19] Therefore, no major increase in the concentrations of acid precursors should be shown. The relative concentrations of these materials should be higher in the south, but no other difference is expected between the northern and southern areas.

MAPPING METHOD

The State of California monitors the ambient air concentrations of a number of pollutants including those precursory to the formation of dilute nitric and sulfuric acids (nitric oxide (NO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) which also represents the oxides of sulfur (SO_x)). The data from these stations are published in the form of daily hourly maximums and thus may be considered to be better than worst case but worse than best case situations. The distribution of these precursors in 1979 was mapped for a study area in southwestern California, and graphs were prepared showing the change in monthly and annual concentrations.

Air monitoring stations. Since late 1968, the California

Air Resources Board (CARB) has published California Air Quality Data quarterly with annual summaries:[20]

> (The data that are published are) obtained from air monitoring stations operated by governmental agencies (such as local air pollution control districts and the California Air Resources Board) and, in some cases, by private firms. In general, these stations are located to measure community wide air quality and are operated over a period of years . . . The local air pollution control districts and the Air Resources Board operate more than 240 air monitoring stations in California.

The state is divided into fourteen air basins for administrative and statistical purposes (Fig. 1).

Precursor measurement. The concentrations of NO, NO_2, and NO_x ($NO+NO_2$) are measured continuously using the chemiluminescence nitric oxide-ozone method. A measure of NO is taken directly in this fashion. NO_x is determined by passing the sample through a catalytic converter which breaks down NO_2 into NO and then taking the measurement. NO_2 is indirectly derived by subtracting the NO value from the NO_x value. There are several methods used to determine SO_2. These include the coulometric method, the flame photometric method (with and without gas chromatography), and the fluorescence method. All of these provide continuous measurement.[21]

Data terminology. As mentioned, nitrogen oxides (NO_x) and SO_2 are continuously monitored. The maximum level

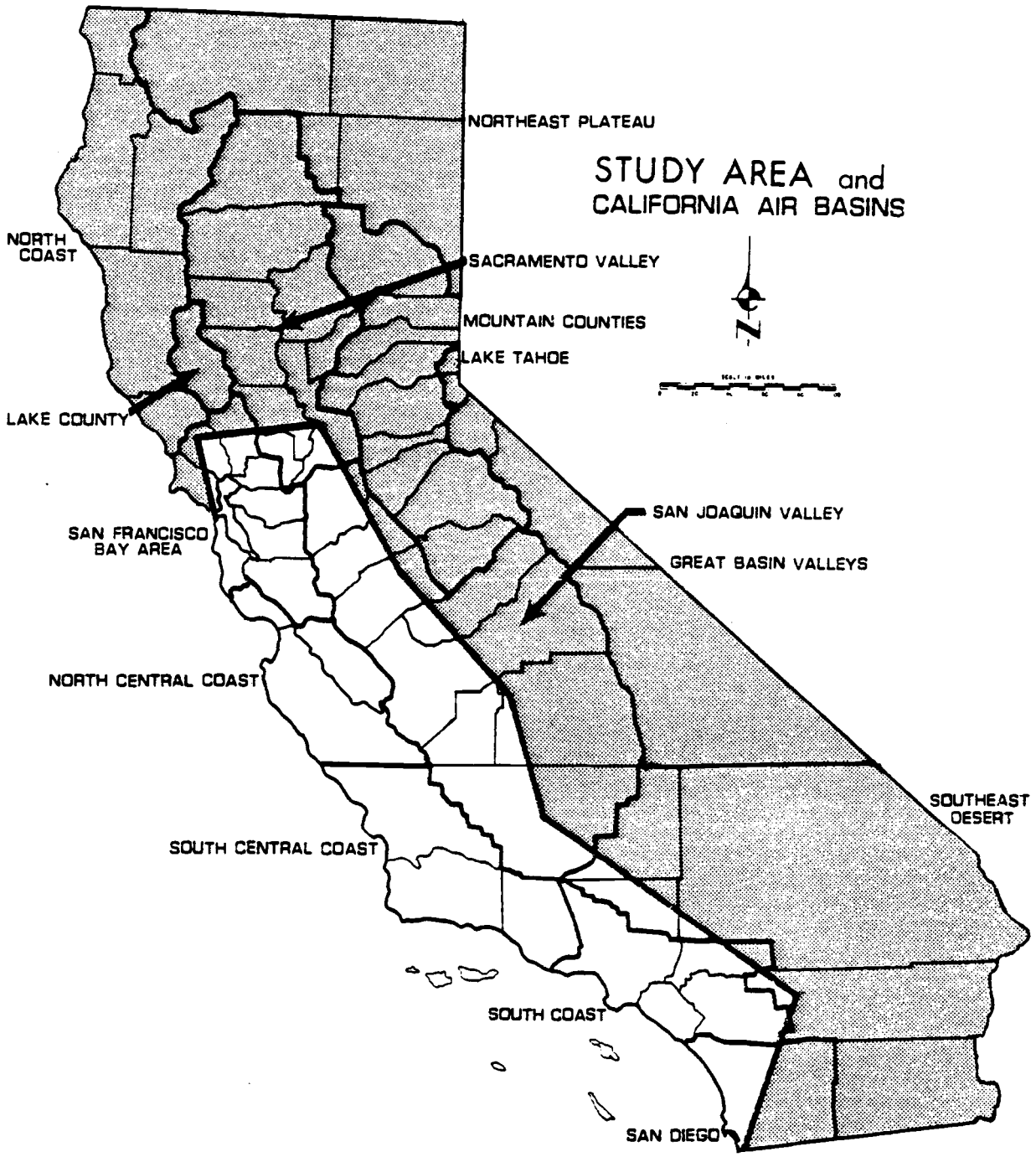
STUDY AREA and
CALIFORNIA AIR BASINS
NORTHEAST PLATEAU
NORTH COAST
SACRAMENTO VALLEY
MOUNTAIN COUNTIES
LAKE TAHOE
LAKE COUNTY
SAN JOAQUIN VALLEY
SAN FRANCISCO BAY AREA
GREAT BASIN VALLEYS
NORTH CENTRAL COAST
SOUTHEAST DESERT
SOUTH CENTRAL COAST
SOUTH COAST
SAN DIEGO

Figure 1

reached each hour is recorded (the hourly maximum), and the largest of these is published for each day (the daily hourly maximums). The average of these is then computed and published for every month (the mean monthly daily hourly maximum). At the end of each year, the average of all the daily hourly maximums is determined and published (the mean annual daily hourly maximum).

Study area. The study area was determined through visual inspection of the distribution of the appropriate data points (Fig. 1 and 2). The Pacific Ocean was treated as the western edge of the study area from San Diego to San Francisco, and then along a line from San Francisco to Santa Rosa. A line drawn between Santa Rosa and Sacramento comprised the northern boundary. Merced, Fresno, Visalia, Bakersfield, Lancaster, Palm Springs, El Cahon, and Chula Vista were along the perimeter of the eastern edge. Less than 10% of the appropriate data points fell outside of the study area due to the scarcity of points in eastern and northern California. However, all appropriate data points were used in the computation of contours (Fig. 2).

The maps. Six contour maps were created using a computer mapping program called SYMAP. These maps show the relative distribution of NO (Fig. 3), NO_2 (Fig. 4), NO_x (Fig. 5), SO_2 (Fig. 6), all the acid precursors (Fig. 7), and the relative ratio between the nitrogen based and sulfur based precursors (Fig. 8) in the study area. The 1979 mean annual daily hourly maximum ambient air concentrations for each

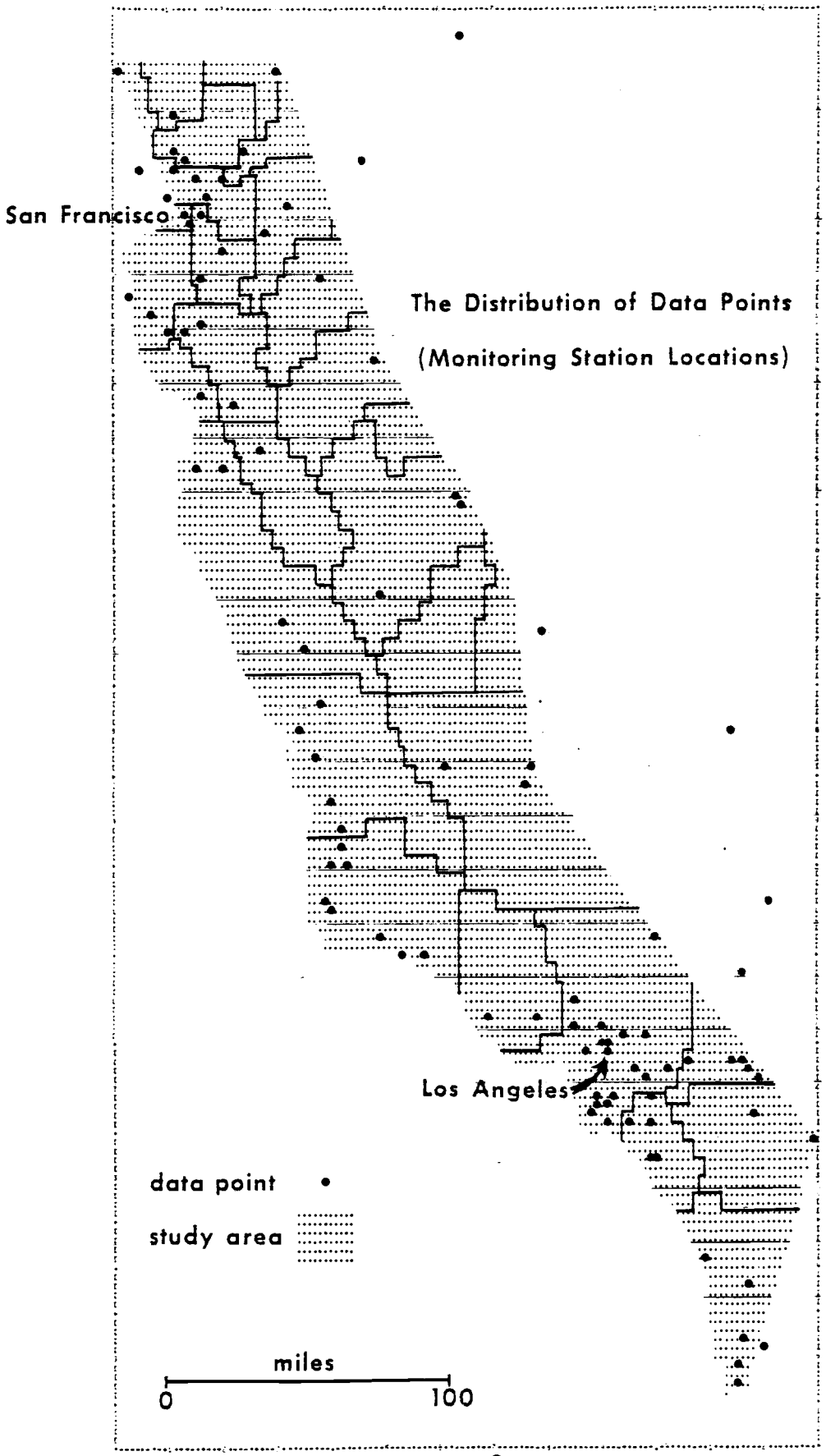
San Francisco
The Distribution of Data Points
(Monitoring Station Locations)
Los Angeles
data point
study area
miles
0
100

Figure 2

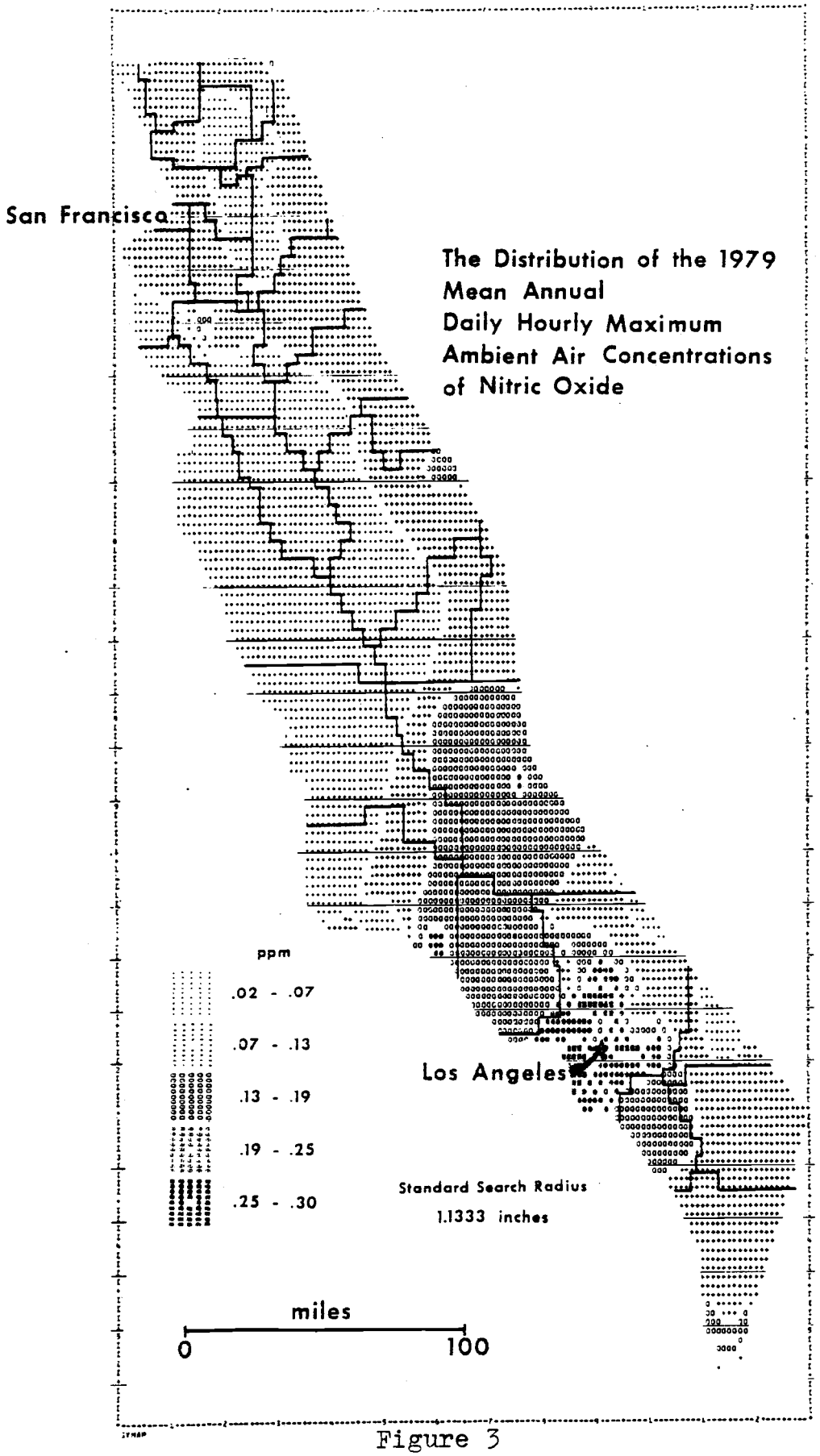
San Francisco
The Distribution of the 1979
Mean Annual
Daily Hourly Maximum
Ambient Air Concentrations
of Nitric Oxide
ppm
.02 - .07
.07 - .13
.13 - .19
.19 - .25
.25 - .30
Los Angeles
Standard Search Radius
1.1333 inches
miles
0
100

Figure 3

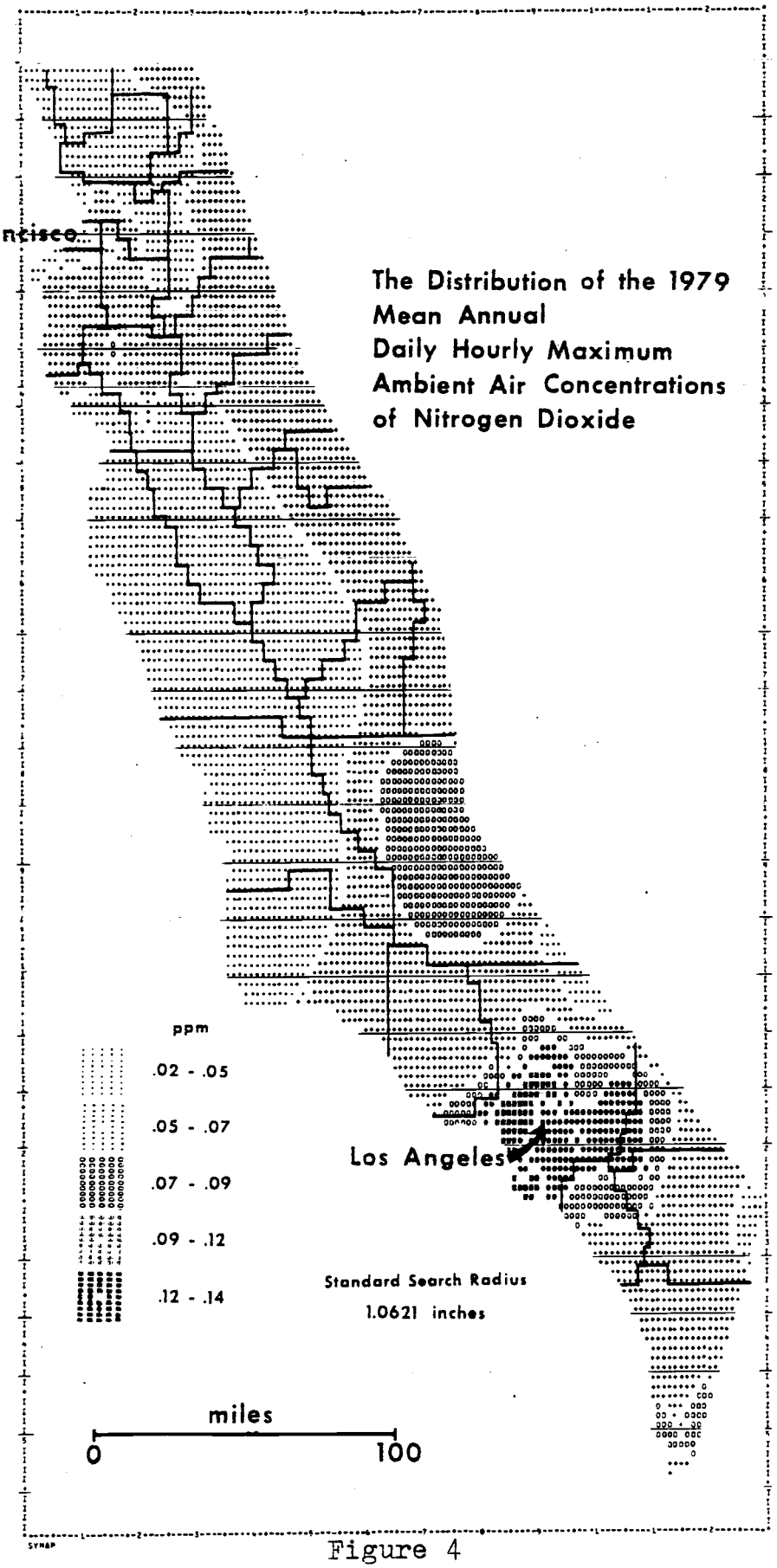
San Francisco
The Distribution of the 1979
Mean Annual
Daily Hourly Maximum
Ambient Air Concentrations
of Nitrogen Dioxide
ppm
.02 - .05
.05 - .07
.07 - .09
.09 - .12
.12 - .14
Los Angeles
Standard Search Radius
1.0621 inches
miles
0
100
SYMAP

Figure 4

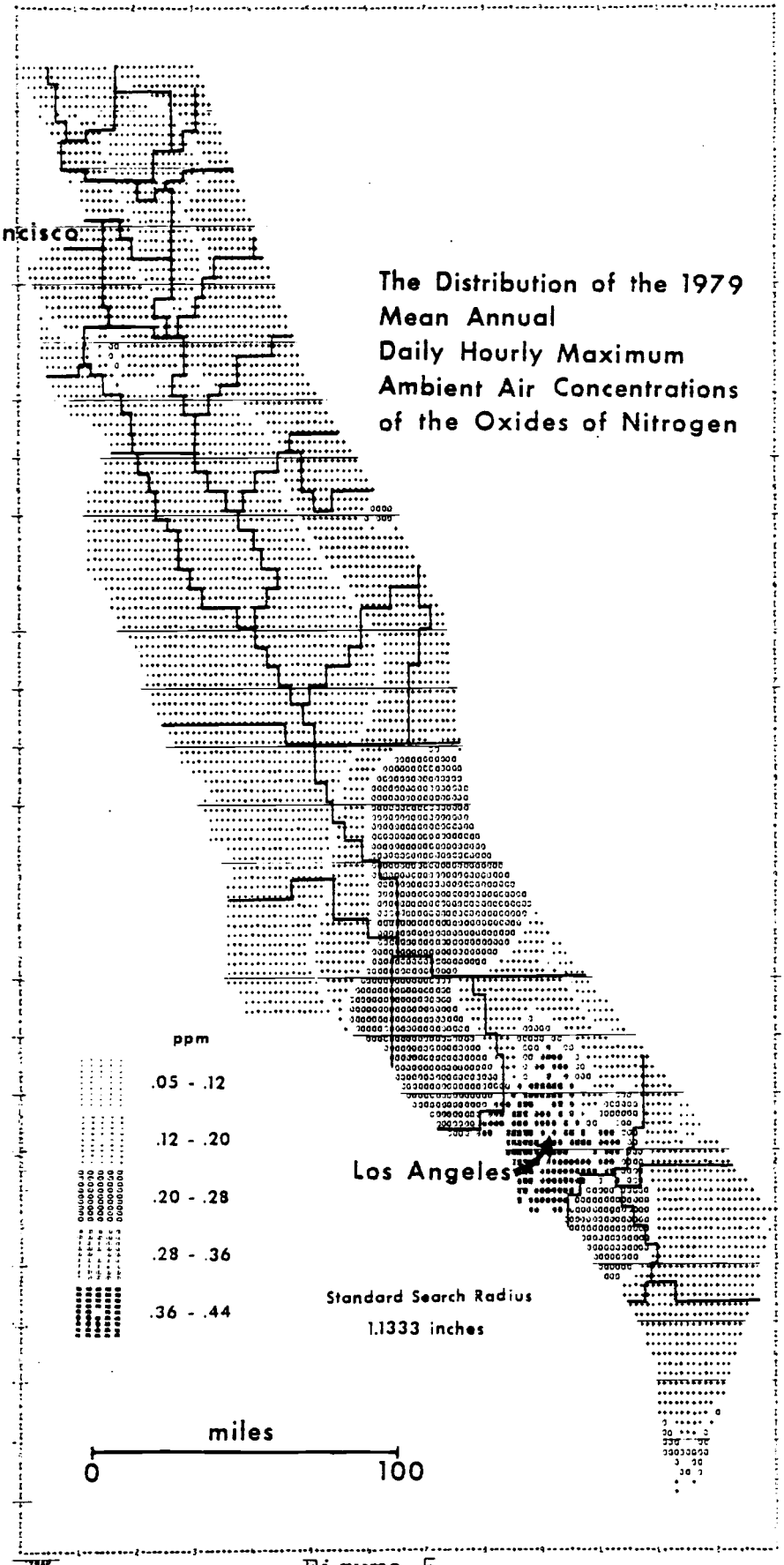
San Francisco
The Distribution of the 1979
Mean Annual
Daily Hourly Maximum
Ambient Air Concentrations
of the Oxides of Nitrogen
ppm
.05 - .12
.12 - .20
.20 - .28
.28 - .36
.36 - .44
Los Angeles
Standard Search Radius
1.1333 inches
miles
0
100

Figure 5

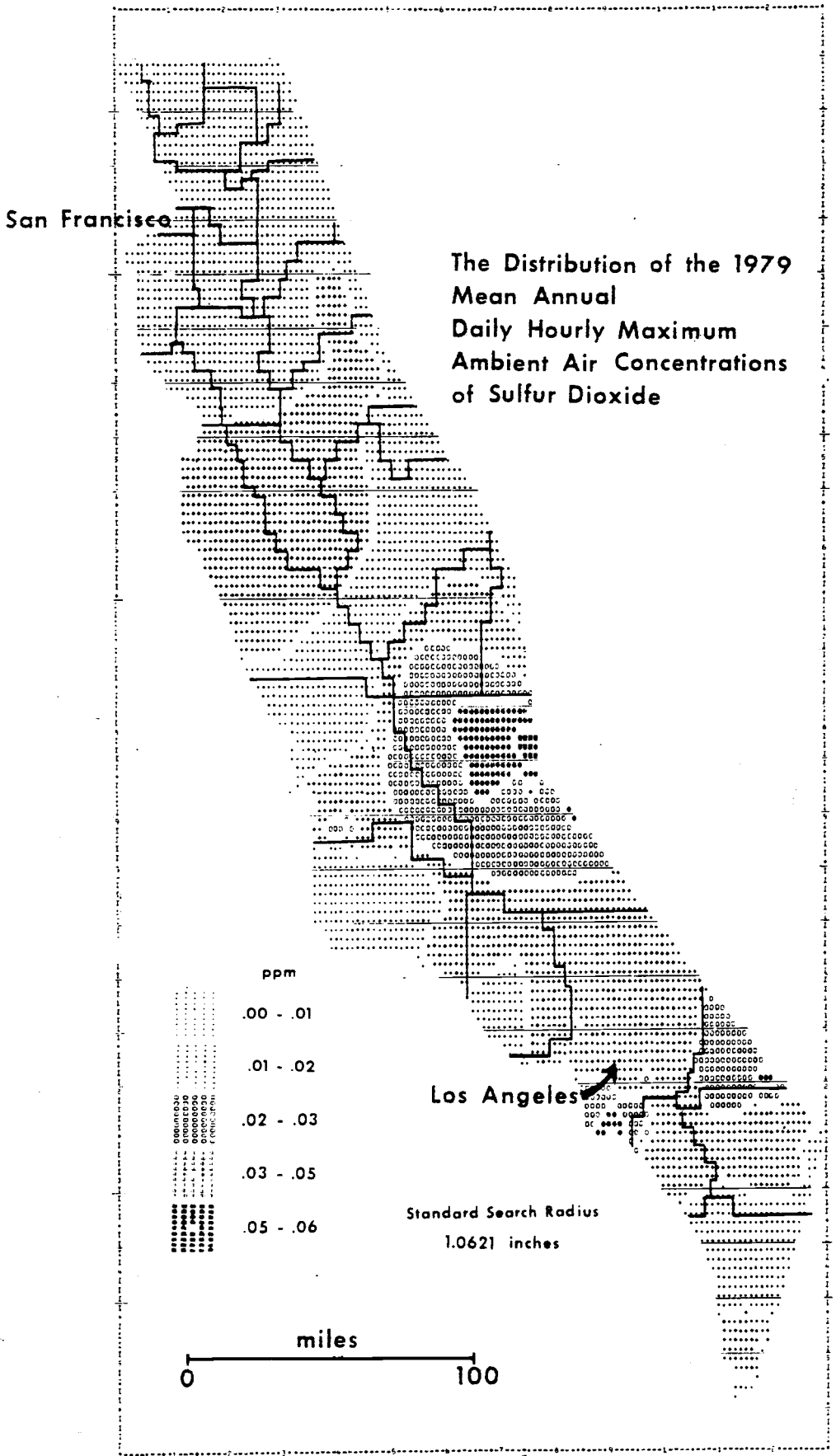
San Francisco
The Distribution of the 1979
Mean Annual
Daily Hourly Maximum
Ambient Air Concentrations
of Sulfur Dioxide
ppm
.00 - .01
.01 - .02
.02 - .03
.03 - .05
.05 - .06
Los Angeles
Standard Search Radius
1.0621 inches
miles
0
100

Figure 6

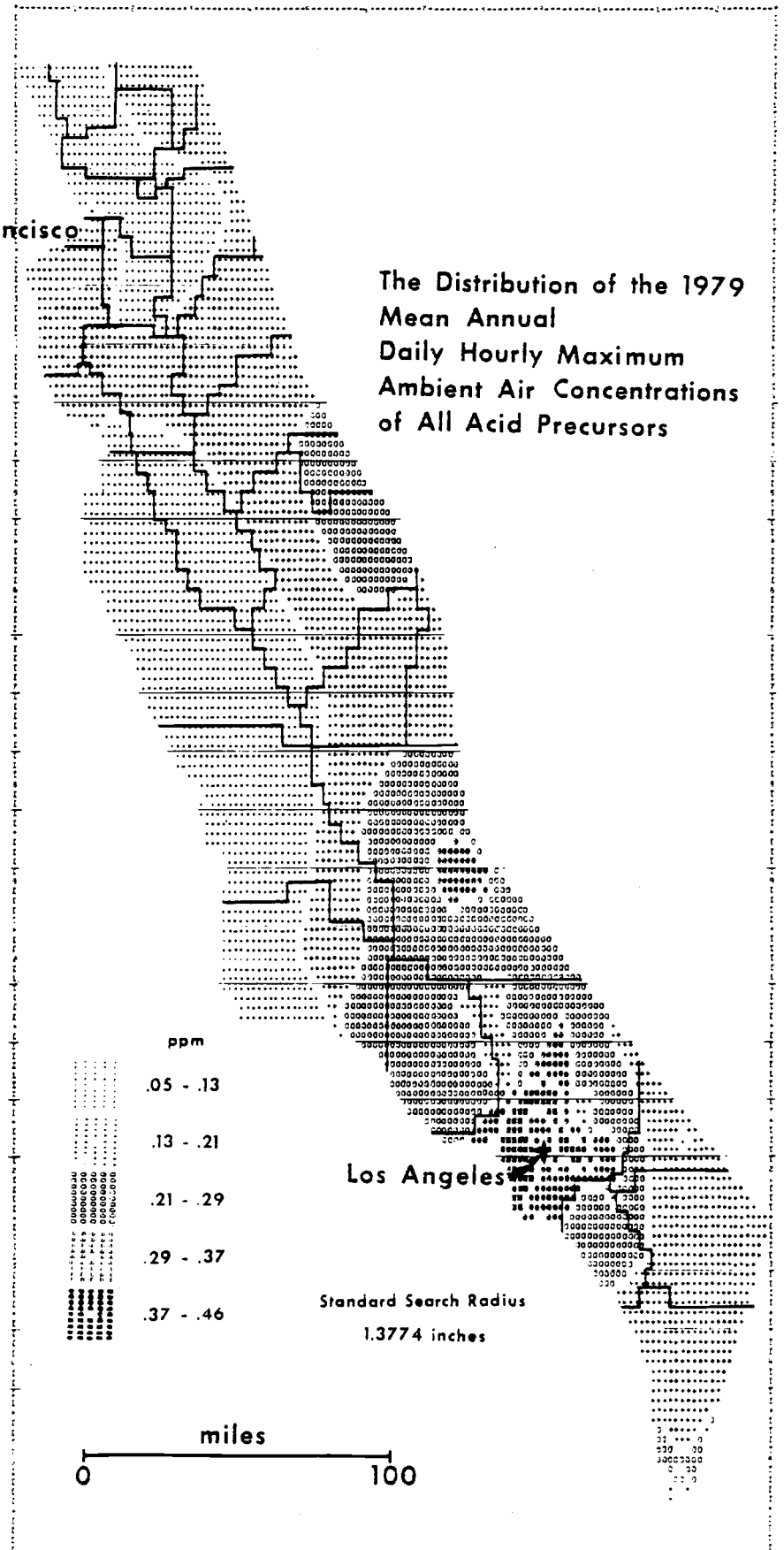
San Francisco
The Distribution of the 1979
Mean Annual
Daily Hourly Maximum
Ambient Air Concentrations
of All Acid Precursors
ppm
.05 - .13
.13 - .21
.21 - .29
.29 - .37
.37 - .46
Los Angeles
Standard Search Radius
1.3774 inches
miles
0
100

Figure 7

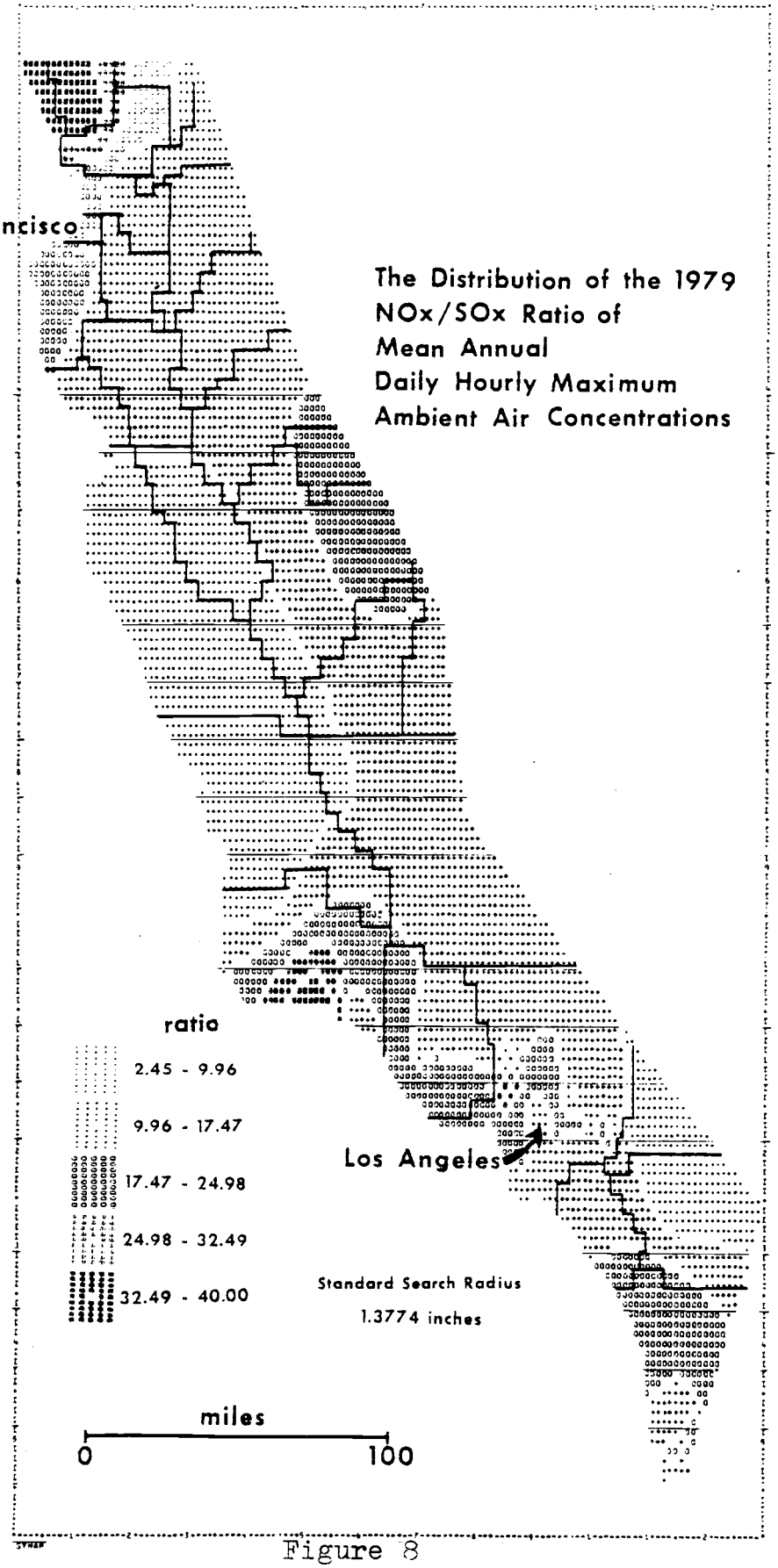
San Francisco
The Distribution of the 1979
NOx/SOx Ratio of
Mean Annual
Daily Hourly Maximum
Ambient Air Concentrations
ratio
2.45 - 9.96
9.96 - 17.47
17.47 - 24.98
24.98 - 32.49
32.49 - 40.00
Los Angeles
Standard Search Radius
1.3774 inches
miles
0
100

Figure 8

data point (monitoring station location) were used in the creation of these maps in order that they would correspond with any study using the 1979 emissions inventory once it is published. Not all of the 105 data points used had appropriate values for the three primary acid precursors.

SYMAP. SYMAP was created by Howard T. Fisher in the Fall of 1963 at Northwestern University's Technological Institute. The purpose of SYMAP is to "display spatial data graphically with variable darkness and texture . . . and . . . provide a method of interpolating irregularly spaced data values."[22] In order to create maps displaying the relative distribution of the appropriate acid precursors, the SYMAP program was provided with three sets of data:

1) the coordinates of the study area;
2) the coordinates of the data points; and
3) the values assigned to each data point.

The SYMAP program then interpolates between an average of seven data points in assigning every print location value. Circles created by the computer are expanded from a given data point until the minimum number of data points required for interpolation fall within. The standard search radius used in interpolation is given on each map at the scale shown. The data point values were divided into five equally spaced classes between the lowest and highest values, and a shaded contour map was output on a line printer. Figures 3 through 8 are shown at approximately 35% of the original size. The data points that fell outside of the study area

were used in the interpolating process. The SYMAP program also allows for missing data to be accommodated by a flag - a unique and unreasonable number - in the data, which excludes that point from being used for interpolation.

The graphs. Two graphs were prepared that show the mean monthly daily hourly maximum ambient air concentrations of NO, NO_2, and SO_2, and the total of these three precursors. The South Coast Air Basin (Fig. 9 and 10) and the Bay Area Air Basin (Fig. 11 and 12) were chosen for these graphs for several reasons:

1) these areas have a relatively large number of monitoring stations reporting the appropriate data;
2) almost all of the area in each air basin is within the study area; and
3) these areas are at opposite ends of the study area.

The concentrations from all the stations reporting in the air basin in a particular month were combined and averaged. This was repeated for the years 1978, 1979, and 1980. A three year average was computed for each month and plotted. This was done in order to reduce the effect of a fluctuation in any particular year.

Two graphs were prepared that show the mean annual daily hourly maximum ambient air concentrations of NO, NO_2, SO_2, and the total of these three precursors. The Los Angeles downtown station in the South Coast Air Basin (Fig. 13) and the Richmond 13th Street station in the Bay Area Air Basin (Fig. 14) were chosen for these graphs for several reasons:

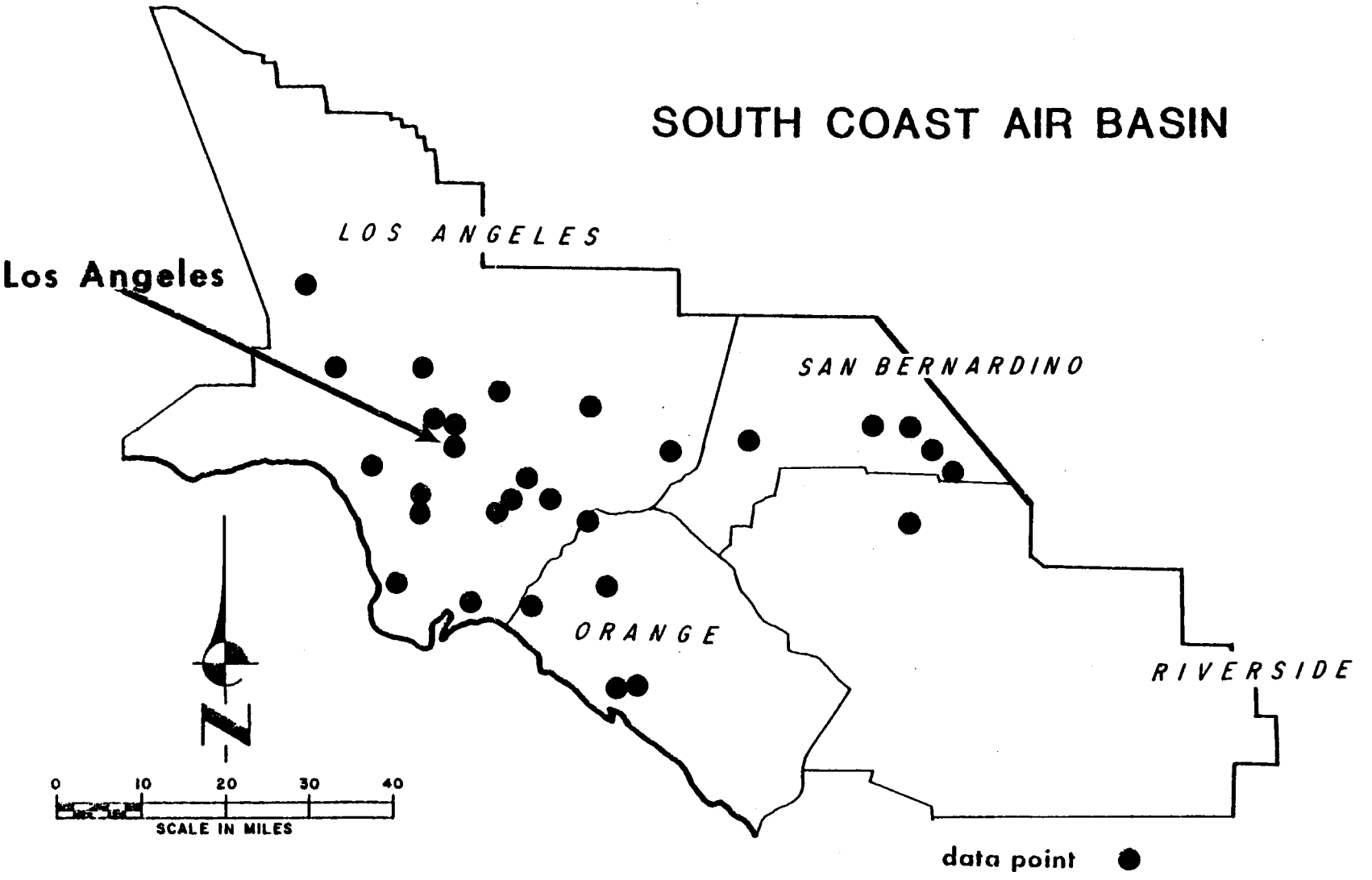
SOUTH COAST AIR BASIN
LOS ANGELES
Los Angeles
SAN BERNARDINO
ORANGE
RIVERSIDE
N
0 10 20 30 40
SCALE IN MILES
data point

Figure 9

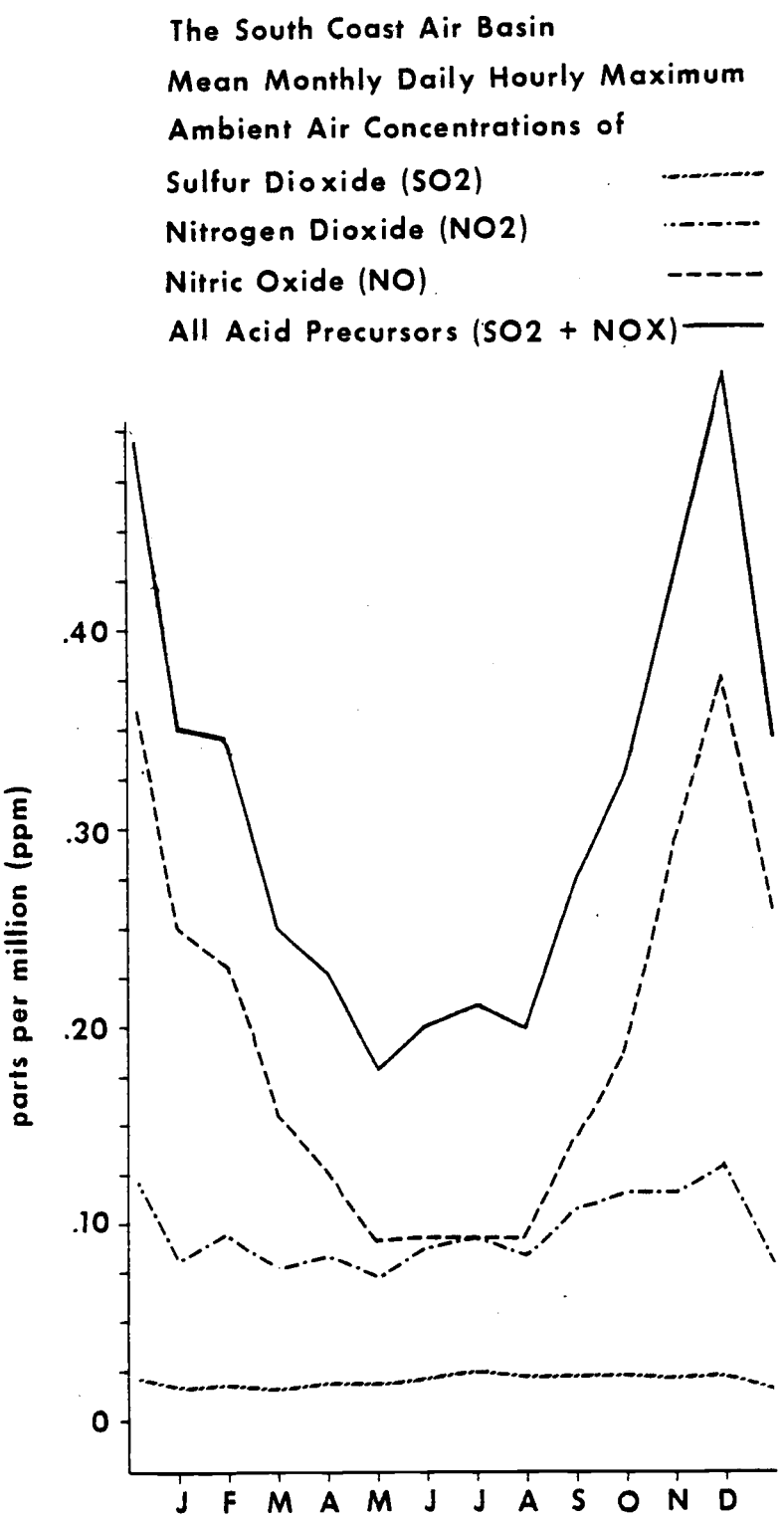
The South Coast Air Basin
Mean Monthly Daily Hourly Maximum
Ambient Air Concentrations of
Sulfur Dioxide (SO2)
Nitrogen Dioxide (NO2)
Nitric Oxide (NO)
All Acid Precursors (SO2 + NOX)
parts per million (ppm)
.40
.30
.20
.10
0
J F M A M J J A S O N D

Figure 10

SAN FRANCISCO BAY AREA AIR BASIN

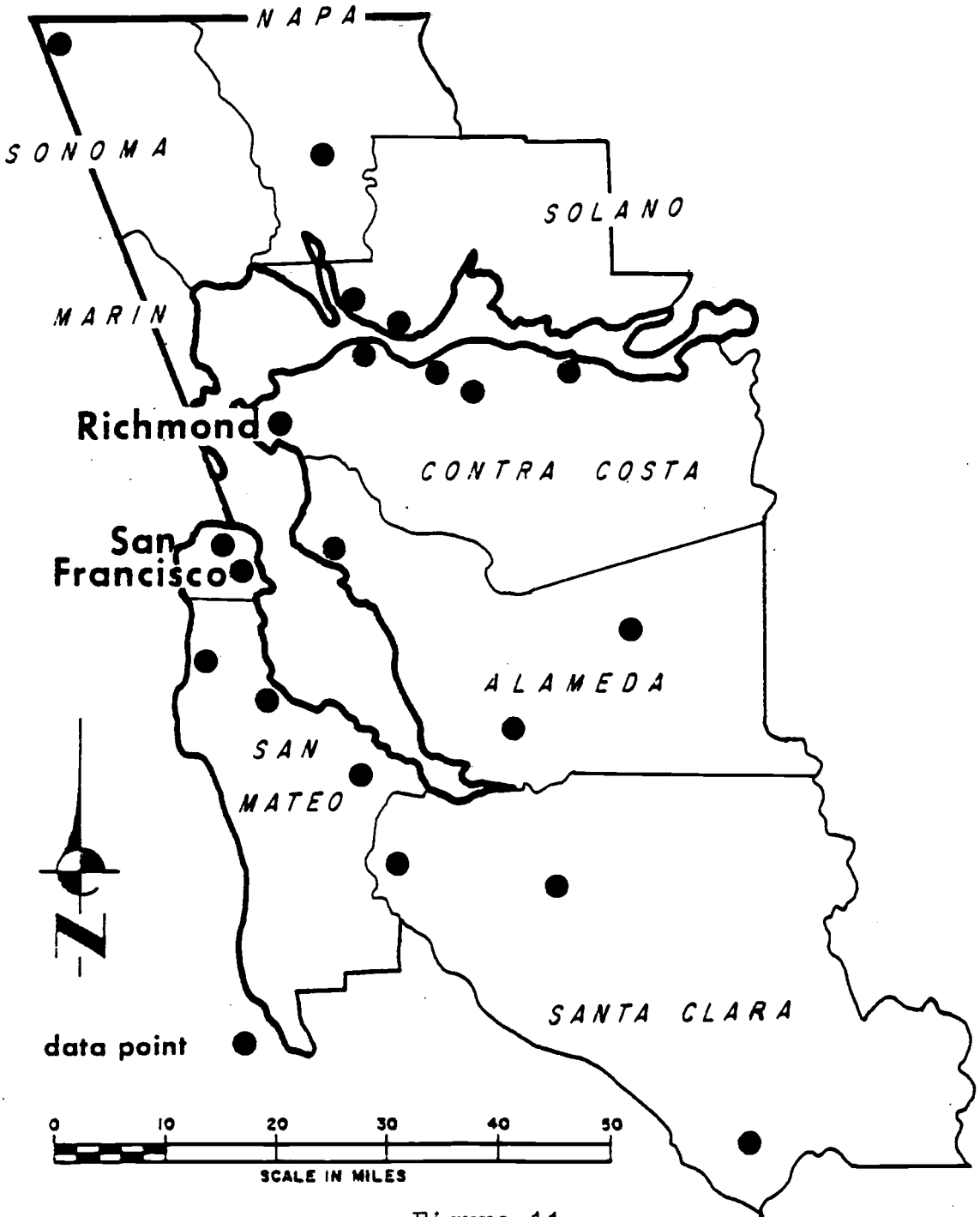

Figure 11

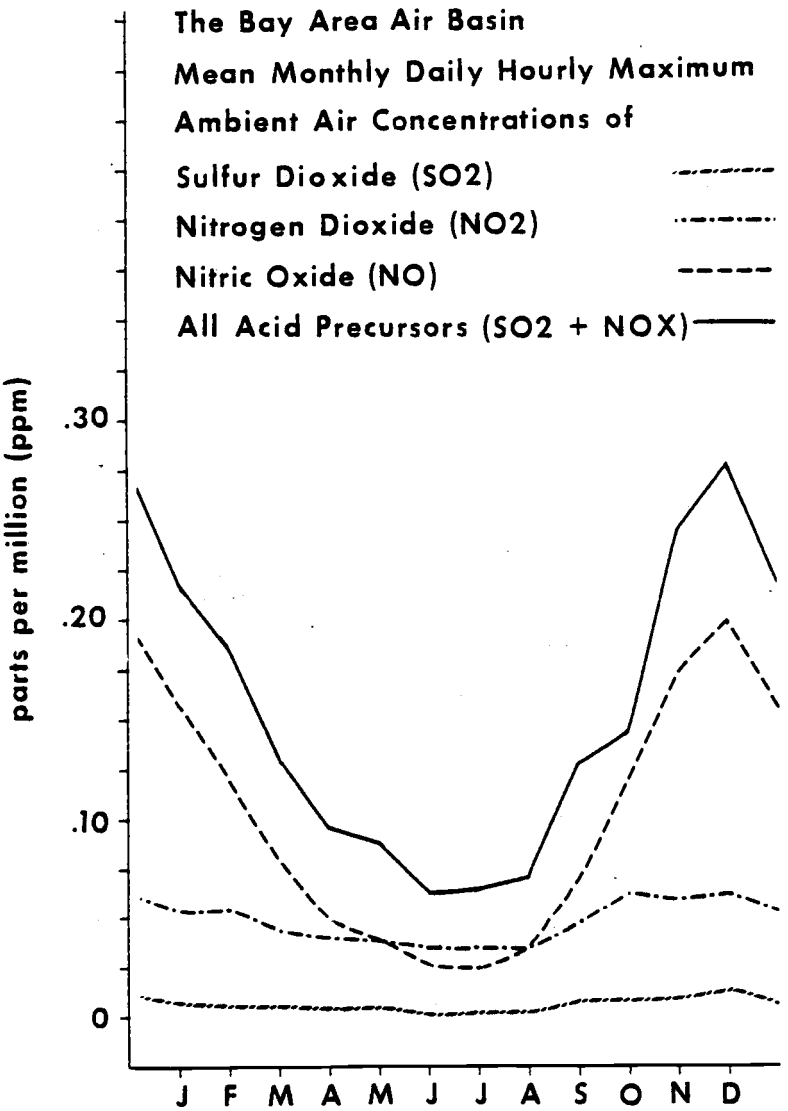
The Bay Area Air Basin
Mean Monthly Daily Hourly Maximum
Ambient Air Concentrations of
Sulfur Dioxide (SO2)
Nitrogen Dioxide (NO2)
Nitric Oxide (NO)
All Acid Precursors (SO2 + NOX)
parts per million (ppm)
.30
.20
.10
0
J F M A M J J A S O N D

Figure 12

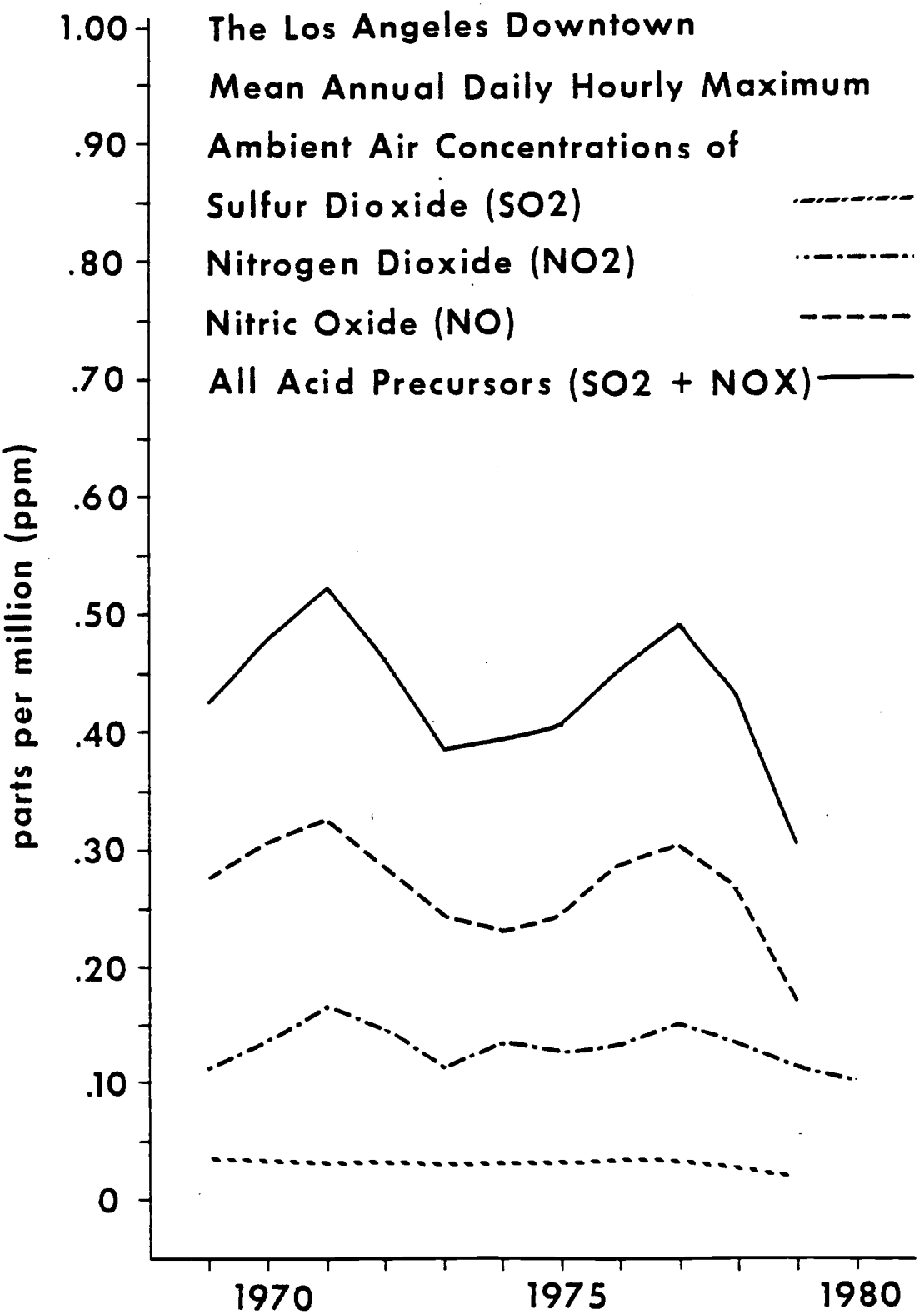
The Los Angeles Downtown
Mean Annual Daily Hourly Maximum
Ambient Air Concentrations of
Sulfur Dioxide (SO2)
Nitrogen Dioxide (NO2)
Nitric Oxide (NO)
All Acid Precursors (SO2 + NOX)
parts per million (ppm)
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
1970
1975
1980

Figure 13

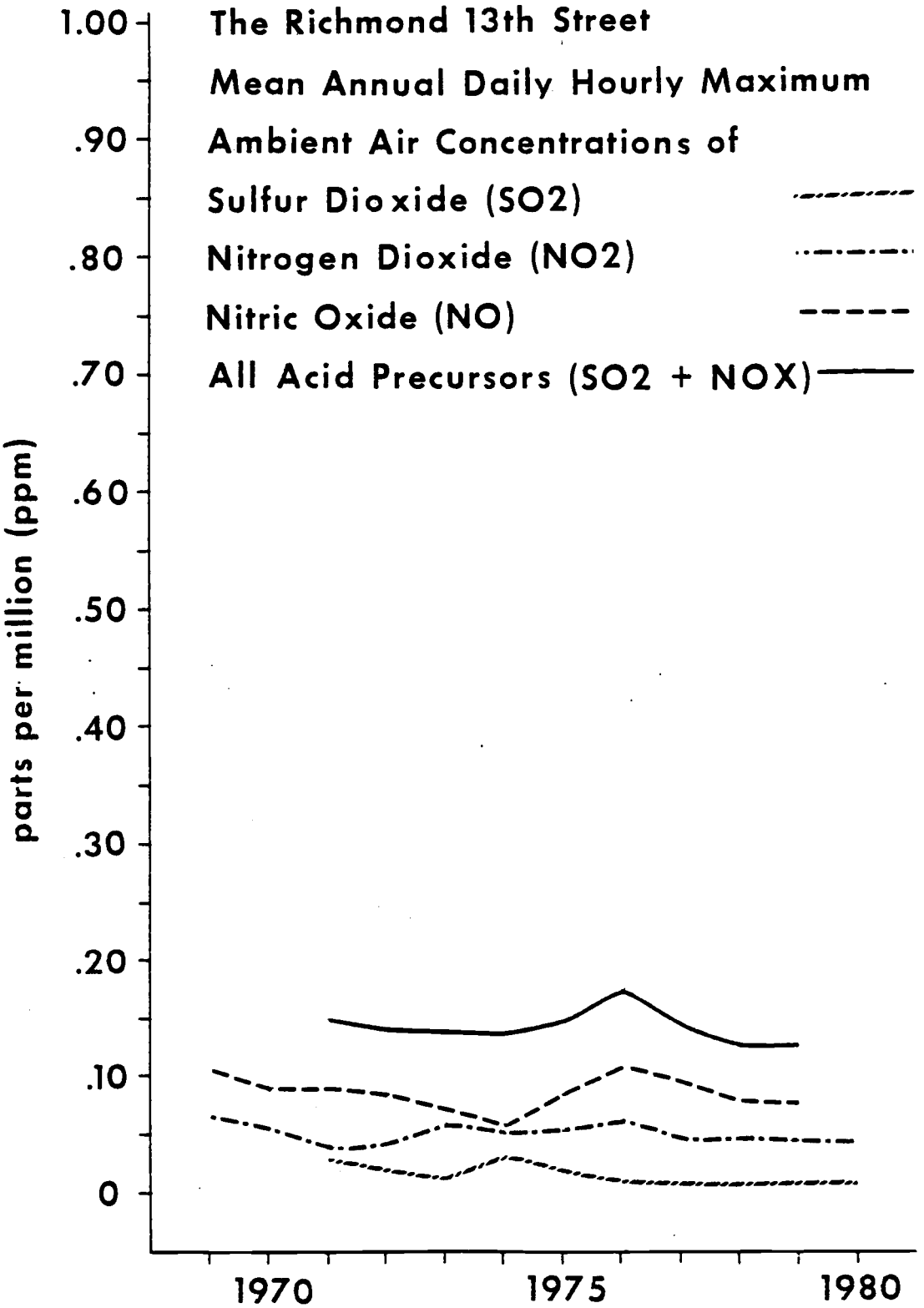
The Richmond 13th Street
Mean Annual Daily Hourly Maximum
Ambient Air Concentrations of
Sulfur Dioxide (SO2)
Nitrogen Dioxide (NO2)
Nitric Oxide (NO)
All Acid Precursors (SO2 + NOX)
parts per million (ppm)
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
1970
1975
1980

Figure 14

1) these stations reported the appropriate data throughout most of the 1970s;
2) these stations are in the air basins used for figures 9 and 11; and
3) the same reasons stated in 2) and 3) above.

When not provided, the yearly average was computed as the mean of the monthly averages for each year.

Interpretation. Visual inspection was used to analyze the maps and charts described above. Figures 3 through 8 were overlayed and areas of high and low concentrations were identified and compared as well as areas where the NO_x/SO_2 ratio was great or small. Trends in seasonal and annual variations were observed in figures 9, 11, 13, and 14 for individual and combined precursors.

RESULTS

The study area is divided into sections of high, moderate, and low relative concentrations. These areas are very similar for each acid precursor. The level of concentration for each component is quite distinct. The ratio of NO_x/SO_2 displays a more unique pattern for high values, but it is very similar in the lower values. Seasonal patterns are very apparent for the nitrogen based precursors and vague for sulfur dioxide. Yearly values show fluctuations but no trend is obvious.

In the northern portion of the study area between Oakland

and Stockton, from northern Solano County to southern San Joaquin County is an area that experiences relatively low ambient air concentrations of NO, NO_2, and NO_x. The NO_2 and NO_x areas of low concentrations extend farther to the northwest with NO_2 also extending farther west. Another low concentration area of nitrogen based precursors stretches from San Mateo County to Kings County to Santa Barbara County along the central coast. Isolated pockets of low potential fallout occur near Lancaster and San Bernardino for NO and NO_x, and Palm Springs for NO_2 and NO_x. The highest area of nitrogen based acid precursor ambient air concentrations is the Los Angeles area. Santa Barbara and Bakersfield experience additional high concentrations of NO.

Areas of low SO_2 concentrations occur from Santa Clara County north, from San Luis Obispo to Fresno, all but eastern Santa Barbara County, southwestern Ventura County, and northern San Diego County. The highest SO_2 concentrations are found in the Bakersfield area. Smaller areas of high ambient air concentrations of SO_2 occur near Long Beach and San Bernardino.

The areas that experience the lowest concentrations of all the acid precursors include everywhere in the study area northwest of Gilroy to Stockton, the central coast area previously mentioned, and the San Bernardino area. The Los Angeles and Bakersfield areas experience the highest total concentrations.

The low NO_x/SO_x ratios occur along the central coast, in

San Bernardino and Riverside Counties, and at Newhall. The highest ratios occur in Napa and Sonoma Counties, southern Santa Barbara County, and near Reseda. In all cases, the NO_x concentrations exceeded the SO_2 concentrations (Fig. 15).

The monthly concentrations of NO and the sum of NO_x and SO_2 show distinct seasonal patterns. NO dominates during the winter months constituting over 70% of the NO_x concentration (Fig. 16). NO_x also dominates SO_2 at all times constituting over 88% of the total concentration. NO makes up from 39 to 75% of the total values. A slight seasonal pattern of NO_2 concentrations may exist, but this is not clear. No SO_2 trend is obvious. The overall view shows distinct winter highs and summer lows, but only NO clearly demonstrates this pattern.

The concentrations of NO, NO_2, and SO_2 fluctuated during the 1970s, but no clear trend can be determined. It would be safe to say, however, that no clear increase can be observed.

DISCUSSION

The results. The results described above were close to what was expected. Los Angeles was shown to be the center of the highest concentrations and the central coast the predominate low value area. The Bay Area, on the other hand, proved to have lower concentrations than were expected. The industrial activity near Bakersfield also showed up clearly,

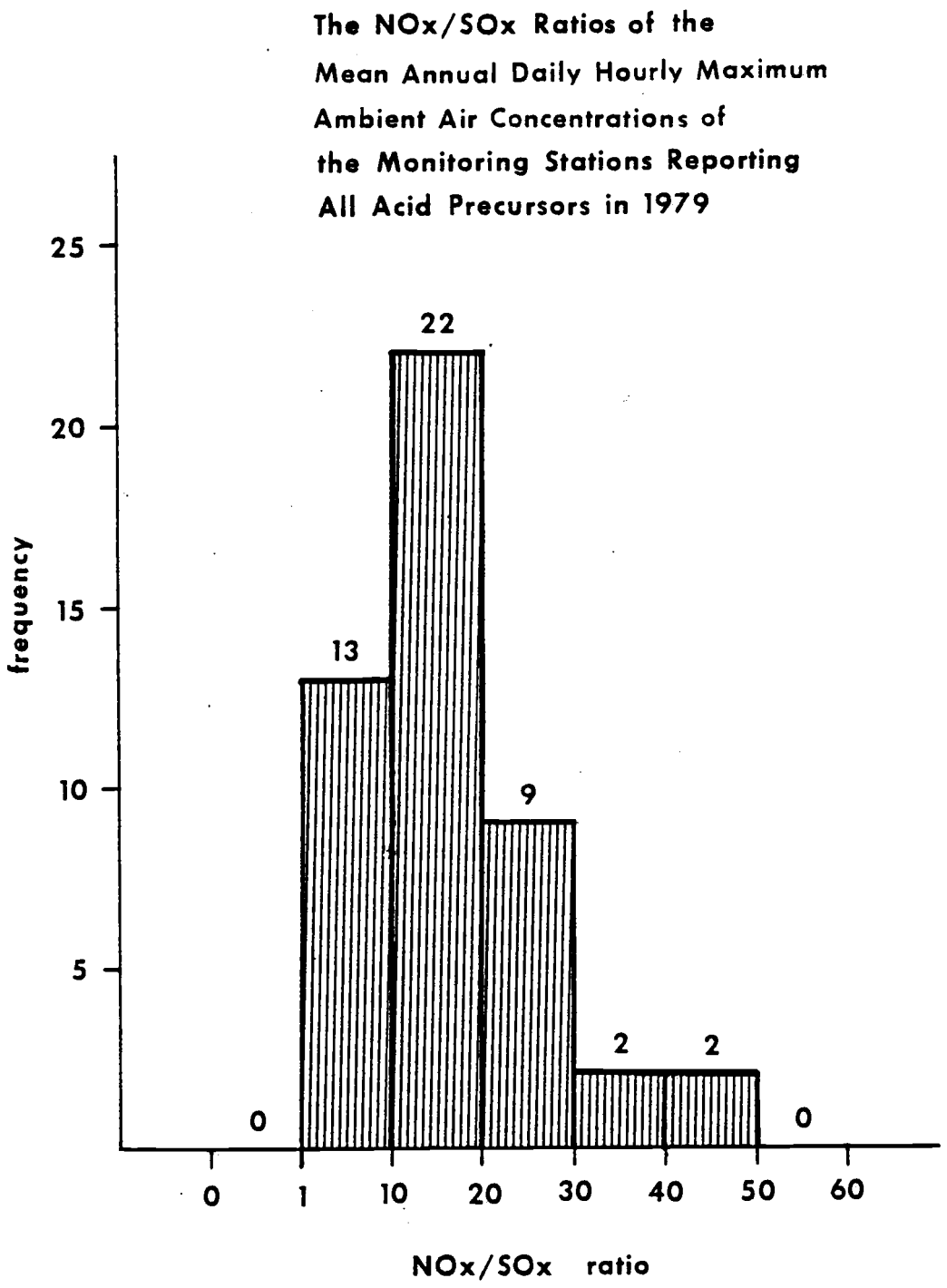
The NOx/SOx Ratios of the
Mean Annual Daily Hourly Maximum
Ambient Air Concentrations of
the Monitoring Stations Reporting
All Acid Precursors in 1979
frequency
25
20
15
10
5
22
13
9
2
2
0
0
0
1
10
20
30
40
50
60
NOx/SOx ratio

Figure 15

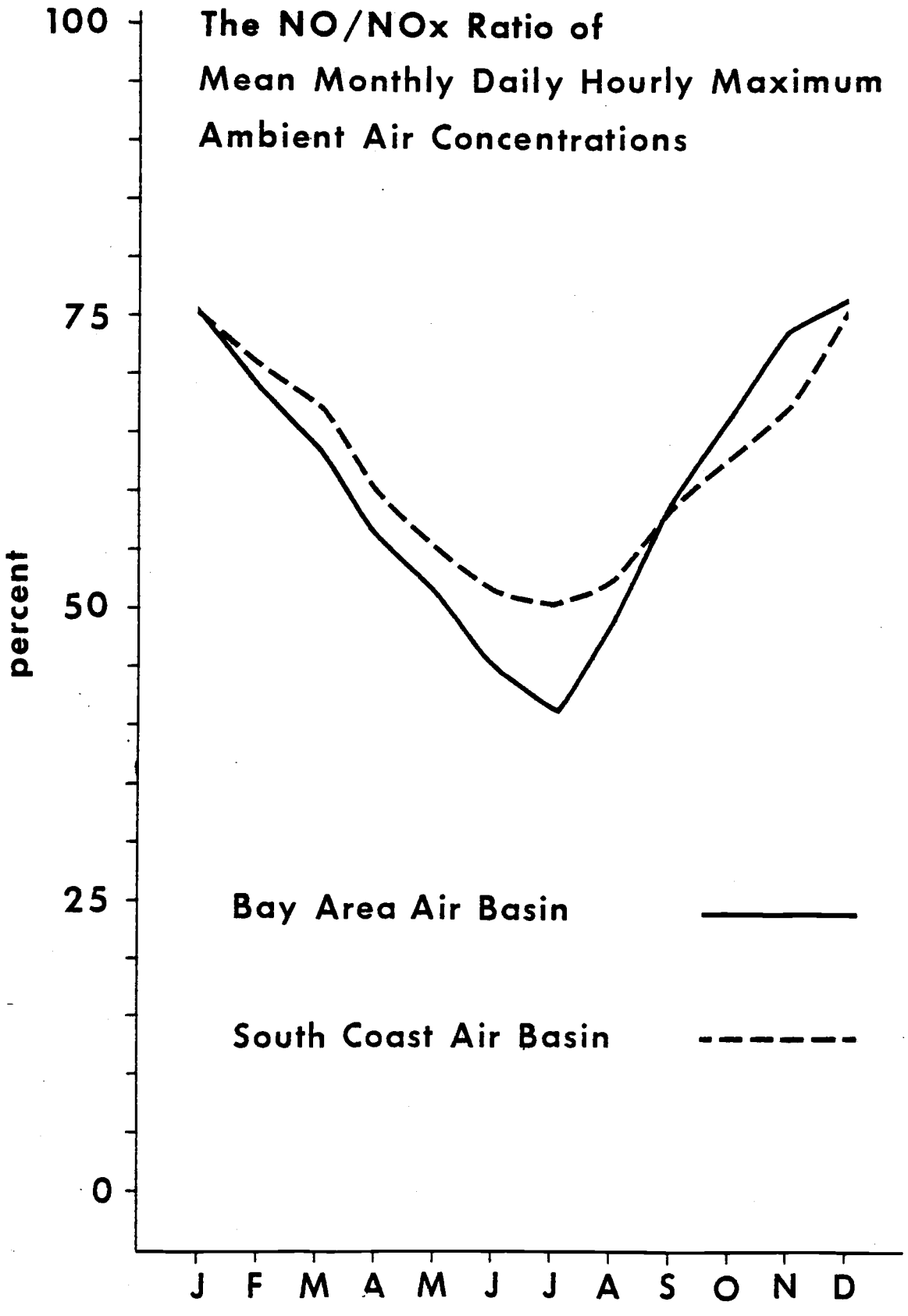
The NO/NOx Ratio of
Mean Monthly Daily Hourly Maximum
Ambient Air Concentrations
100
75
50
25
0
percent
Bay Area Air Basin
South Coast Air Basin
J F M A M J J A S O N D

Figure 16

although it was not anticipated. The ratio value patterns were not predicted, and an explanation for them will not be offered here. The reasons most likely may be found in the sources of these pollutants in the relative areas. The strength of these values was anticipated. However, the winter high and summer low that were expected were also shown, but the domination of NO in this pattern was not predicted. The nonincreasing trend of these precursors was also expected, as were the elevated levels in the south.

Map reliability. From visual inspection, it is obvious that the location of the data points is more clustered than random. The SYMAP program confirms this statistically by the point distribution coefficient, R. This coefficient is determined by dividing the mean point distances of the observed (actual) distribution (D_o) by the mean point distances of the expected (random) distribution (D_e). D_e is computed by taking one half of the square root of the area of the study area divided by the number of data points. D_o is computed by summing the distances from a point to its nearest neighbor and dividing that by the number of data points. The result may then be interpreted as follows:

1) R = 0.00 - 0.90 means a clustered to random distribution;

2) R = 0.90 - 1.25 means a random distribution; and

3) R = 1.25 - 2.15 means a random to uniform distribution.

If all of the data points are clustered in one location, the value of R would be 0. If all of the data points are distributed such that the greatest spacing between each was

achieved, the value of R would be 2.15. The point distribution coefficient for all of the above maps is below 0.90 (Table 1).[23]

When air monitoring stations were first established in California, the concern was with community air quality. The concern with air pollution now transcends community, state, and even national boundaries. As noted above, the result of previous efforts to monitor pollutants in the air is a clustering of stations around a few locations. The results of any mapping must be treated with caution in such a case. New stations should be established in areas without significant population or industry in order to fill in the holes of the existing network. The areas to the north and east of the study area are examples, but even within the study area there is a need for expansion. Such areas include north of Lompoc and Newhall to Bakersfield, from Bakersfield to Fresno, and Fresno, Coalinga, and San Ardo to Monterey, Salinas, and Merced. Cooperation between agencies might be another solution in times of budget cutting. National Weather Service, U. S. Forest Service, California Air Resources Board, local agencies, universities, and private concerns could combine their facilities to benefit all and reduce duplication of effort that is so typical in this country.

The above method of mapping acidic deposition has other problems as well as many advantages. A major disadvantage is that this is a qualitative approach in many regards. The question "What does this mean?" cannot be easily and

THE MAP POINT DISTRIBUTION COEFFICIENTS (R)

Map	The Number of Data Points Used in Determining Contours	The Point Distribution Coefficient (R)
Nitric Oxide	64	0.61
Nitrogen Dioxide	72	0.66
Oxides of Nitrogen	64	0.61
Sulfur Dioxide	74	0.52
All Acid Precursors	45	0.56
NO_x/SO_x Ratio	45	0.56

Table 1

precisely answered. However, even if fallout could be measured and values be given in micrograms per square meter, the question "What does this mean?" still could not be easily and precisely answered. Advantages of this procedure include that measurements are taken continuously and simultaneously across the network in a standardized way, the problem of estimating the transportation of materials is avoided, the need to try and catch gases that have fallen out is eliminated, and data can be collected without regard to the weather.

Future studies. Most of the research dealing with acidic deposition has approached only small portions of the phenomenon. Certain aspects are still in the black box stage. Many volumes are being produced that deal with emissions and environmental impacts of acidic deposition, particularly acid rain. Relatively few studies have dealt with the chemistry, atmospheric interactions, and environmental breakdown of acidic materials. The former points to the situation saying "Here it is. See what it does." These aspects must be known, but unless how the phenomenon occurs and how the environment deals with it are understood, nothing can be accomplished to alter where it occurs and what it does. Acid rain is a very popular subject of propaganda. Claims being made regarding historical trends and the transportation of materials lack substantial proof. On the other hand, there are those who would like everyone to believe that acidic deposition does

not occur or is nothing to be concerned about.

There are many factors of acidic deposition that need to be studied more thoroughly:

1) how the ambient air concentrations of acid precursors in gas form interact with surface materials;
2) what the distribution of ambient air concentrations of acid precursors in particulate form (suspended sulfates and nitrates) is and how these interact with surface materials or fallout;
3) the emissions of acid precursors;
4) the pH of rainwater; and
5) the influence of meteorological conditions, terrain, other chemical compounds, and environmental factors.

Perhaps the ultimate goal of acidic deposition research should be to create a model that can be used to predict the fallout of acidic materials at any given point and the impact of that deposition so that actions could be taken to modify emissions in order to accomplish desired economic and environmental conditions.

FOOTNOTES

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