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A CLIMATOLOGICAL/ AIR QUALITY PROFILE

CALIFORNIA SOUTH COAST AIR BASIN

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An
Air Programs Division
Report

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COVER PHOTO

View from Belmont Shores
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For four decades continuing progress has been made in understanding the climatology of the Greater Los Angeles area and the role of weather in determining the air quality of the region. Credit for this progress is attributed to many individuals and research organizations. The foundation for and the direction given to this effort is the pioneering work of Dr. Morris Neiburger, Professor Emeritus, Department of Meteorology, University of California at Los Angeles.

ABSTRACT

The climate of the populous California South Coast Air Basin combined with atmospheric effluents of a highly mobile and industrialized society have produced a long-standing air pollution problem in the area. Representatives of business, industry, and public agencies, engineers, and consulting scientists in the fields of meteorology and air quality have a continuous need for climatological data in relating planning and air pollution control to Basin air quality. This report furnishes data to meet the basic requirements of many of those users. Additionally, the role of climatological elements in limiting atmospheric dispersion and in providing an ideal environment for photochemical reactions is discussed. Finally, intra-and inter-Basin contaminant transport is outlined.

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SUMMARY

The general climatology and geography of the South Coast Air Basin are outlined in this report. More specifically, data (averages and extremes) are presented for several climatological elements: temperature, humidity, rainfall, solar radiation, wind, and inversions. The over-all effects of these elements on the air quality of the Basin are discussed. These effects are shown by relating specific meteorological conditions to ambient concentrations of ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide, and sulfates.

Transport of contaminants from source areas to receptor areas in the Basin and between air basins in Southern California follow predictable patterns. Specific examples substantiate the existence of those transport routes.

Although this profile is, in itself, a summation of facts concerning the Basin climatology and its effects on air quality, the following are conclusions drawn from this study:

- Yearly average temperatures in the Basin show little variance among non-mountain locations, $61^{o}F$ to $65^{o}F$.

- The monthly and annual spreads between maximum and minimum temperatures are greatest inland and smallest at the coast because of the moderating marine influence that decreases with distance from the ocean.

- Temperature has an important influence on Basin wind flow, dispersion along mountain ridges, vertical mixing, and photochemistry.

- The annual mean relative humidity is 71 percent at the coast and 59 percent in the eastern portion of the Basin.

- Basin precipitation patterns show a strong orographic influence. The annual rainfall is 11 to 15 inches in the coastal plain and inland valleys, up to 21 inches in the foothills, and greater than 50 inches in the mountains.

- Fifty-eight percent of the potential extraterrestial radiation reaches the surface of the Basin.

- About three-quarters of possible sunshine is received in the Basin; this abundant radiation (the ultraviolet portion) is the key factor in photochemical reactions.

- The typical daily wind regime is a daytime onshore sea breeze and a night-time offshore drainage wind.

- Strong foehn winds, locally termed "Santa Anas," are experienced five to ten times each year. These gusty, northeasterly winds blow from a few hours to several days and ususally are accompanied by high temperatures.

- On 80 percent of the days during the summer smog season, the average morning wind speed in Downtown Los Angeles is less than five miles-per-hour. This is a measure of daily stagnation in a major pollution source area.

- During January, a surface inversion exists on 70 percent of the mornings.

- During July, the 50 percentile inversion base height is 1,200 feet.

- The 50 percentile mixed layer height is 3,800 feet in January and 2,600 feet in July.

- Pollution is introduced into the inversion layer by the undercutting sea breeze, by the return flow from mountain ridges, and by emissions into the layer from tall stacks.

- There is a high correlation between the number of surface inversions and average carbon monoxide concentrations during the winter.

- A similar correlation exists between the number of "Rule 444" days (days with low wind speeds, low inversions, and restricted vertical mixing) and ozone concentrations during the summer.

- Since 1950, the area of the Basin with the greatest number of low-visibility days per year has shifted from central Los Angeles to the sub-basin east of the Chino Hills.

- High-ozone days require: adequate sunshine; early morning stagnation in source areas; high surface temperatures; strong, low, morning inversions; greatly restricted vertical mixing during the day; and daytime subsidence that strengthens the inversion layer.

- High-nitrogen dioxide days usually occur during the autumn or winter, but with summer weather conditions. Low inversions, limited daytime mixing, and stagnant windflow conditions are requirements. Days are clear and hazy and photochemical reactions usually are not complete. Highest concentrations occur near high-density traffic sources.

- High carbon monoxide days occur during the winter with strong surface inversions and light winds. Highest concentrations are achieved near the coast or in the immediate inland valleys. These concentrations are associated with either the early morning or late afternoon traffic peaks.

- Highest sulfur dioxide concentrations are attained immediately downwind of sources usually in a looping plume or under fumigation conditions.

- A marine layer, topped by a strong inversion, is ideal for the conversion of sulfur dioxide to sulfate.

- The most frequent ozone transport route is from source areas in coastal areas to receptors along the base of the San Gabriel and San Bernardino Mountains.

- With offshore flows, ozone transport is more limited, and highest concentrations are attained in the western portion of the Basin.

- A third ozone transport path results from an early morning northerly flow. In this case, pollutants are pushed into Orange County and through Santa Ana Canyon.

- Nitrogen dioxide transport on high-concentration days during the summer is limited, highest concentrations being attained near source areas of nitric oxide.

- Nitrogen dioxide transport on similar days during the winter is usually confined to the western third of the Basin. Pollution is pushed seaward during early morning with offshore winds, and returns a short distance inland on light sea breezes.

- Carbon monoxide transport is extremely limited, and highest concentrations are associated with areas of highest traffic density.

- Sulfur dioxide transport is direct from source to receptor with concentrations varying with distance and local diffusion.

- Highest sulfate concentrations are achieved with meandering transport patterns. This sloshing effect distributes sulfates fairly evenly in the Basin, although maximum values are usually found inland as a result of a net onshore flow each day.

- Transport of pollutants to Ventura County from the Basin is fairly infrequent but can occur via water over Santa Monica Bay, westward through the San Fernando Valley, or northward over the Santa Monica Mountains.

- Transport to the Basin from Ventura County can be from the Oxnard Plain over the ocean to the Santa Monica Bay coast, or with the sea breeze to the Newhall area and the San Fernando Valley.

- Transport from the Southeast Desert Air Basin to the South Coast Air Basin is principally through Newhall and Cajon Passes. Advected pollutants are dust with Santa Ana flows or contaminants from infrequent forest fires.

- Transport to the Southeast Desert Air Basin is directionally opposite from the paths through the mountain passes, mentioned above. In addition, a westerly flow through Beaumont Pass at the eastern limit of the Basin is common. Also, there is northward transport over the San Gabriel and San Bernardino mountains.

- Transport from San Diego County occurs with southerly or southeasterly wind flows. These flows are associated with deep marine layers and the resulting pollution advection is relatively unimportant.

- Transport from the Basin to San Diego County occurs with light east or northeasterly flows from the Basin. In these cases, pollution is blown out of the Basin to the immediate ocean area and thence to San Diego County on north or northwest winds. High ozone concentrations in northern San Diego County are attributed to this transport.

I INTRODUCTION

The climate of a region is modified by local geographical features, but is determined principally by its location within a large-scale climatic zone with distinct atmospheric patterns. Several areas in the world are situated under a subtropical high on the western shore of a continent. Thus, the South Coast Air Basin climate is not unique. What is singular about the Basin is that it is a highly populated, highly industrialized, and highly mobile metropolis with a climate that severely restricts dispersion of atmospheric pollution generated by its society.

Southern California lies in the semi-permanent high pressure zone of the eastern Pacific. Typical of coastal strips along the western shores of continents at lower latitudes, the region is characterized by sparse rainfall, most of it occurring in the winter season, and hot summers tempered by cooling seabreezes. During spring and summer, the predominant wind flow in coastal waters is from the northwest. The ocean flow resulting from this wind pattern is a drift of warm surface water seaward to the southwest. This surface water is then replaced by cold water from below, a process called "upwelling."

The cold ocean surface caused by upwelling underlies warm, descending air on the eastern side of the high pressure system and produces, by cooling and turbulent mixing, a persistent layer of marine air based at the ocean surface. The top of this marine layer defines the base of the temperature inversion above which the air is warm and dry. The presence of a cool, marine layer of air at the surface, capped by a temperature inversion, is the root cause of the air pollution problem in coastal Southern California. Contaminants emitted into the atmosphere are trapped near the surface because of limited vertical disperision in the air below the base of the marine inversion. (See Section on "Inversions and Mixing Heights.")

Geographically, a major portion of coastal Southern California is the South Coast Air Basin. See Figure 1. This basin consists of the metropolitan areas of Los Angeles, Orange, San Bernardino, and Riverside Counties. It is bounded on the northwest by Ventura County and on the south by San Diego County. The northern boundary runs roughly along the Angeles National Forest line north of the crest of the San Gabriel and San Bernardino Mountains. The eastern border runs north-south through the San Bernardino and San Jacinto mountains, although the Banning Pass area is excluded. The final boundary line is the entire shoreline of Los Angeles and Orange Counties.

Inside the rim of high mountains that rise to an altitude greater than 11,000 feet, the Basin is a coastal plain with connecting broad valleys and low hills. See Figure 2. On most days, the net wind flow is from west to east. This produces the effect of having source areas near the coast impacting receptor areas inland to the east, and this source-receptor relationship is compounded by the population distribution in the Basin. The highest population, the greatest population density, and the majority of industries, commerce, and streets and freeways are located in the principal source areas in the western portion of the Basin. Table I shows the population and total area of each of the four counties in the Basin. The Southeast Desert Air Basin portions of Los Angeles, San Bernardino and Riverside Counties are not included in the statistics.

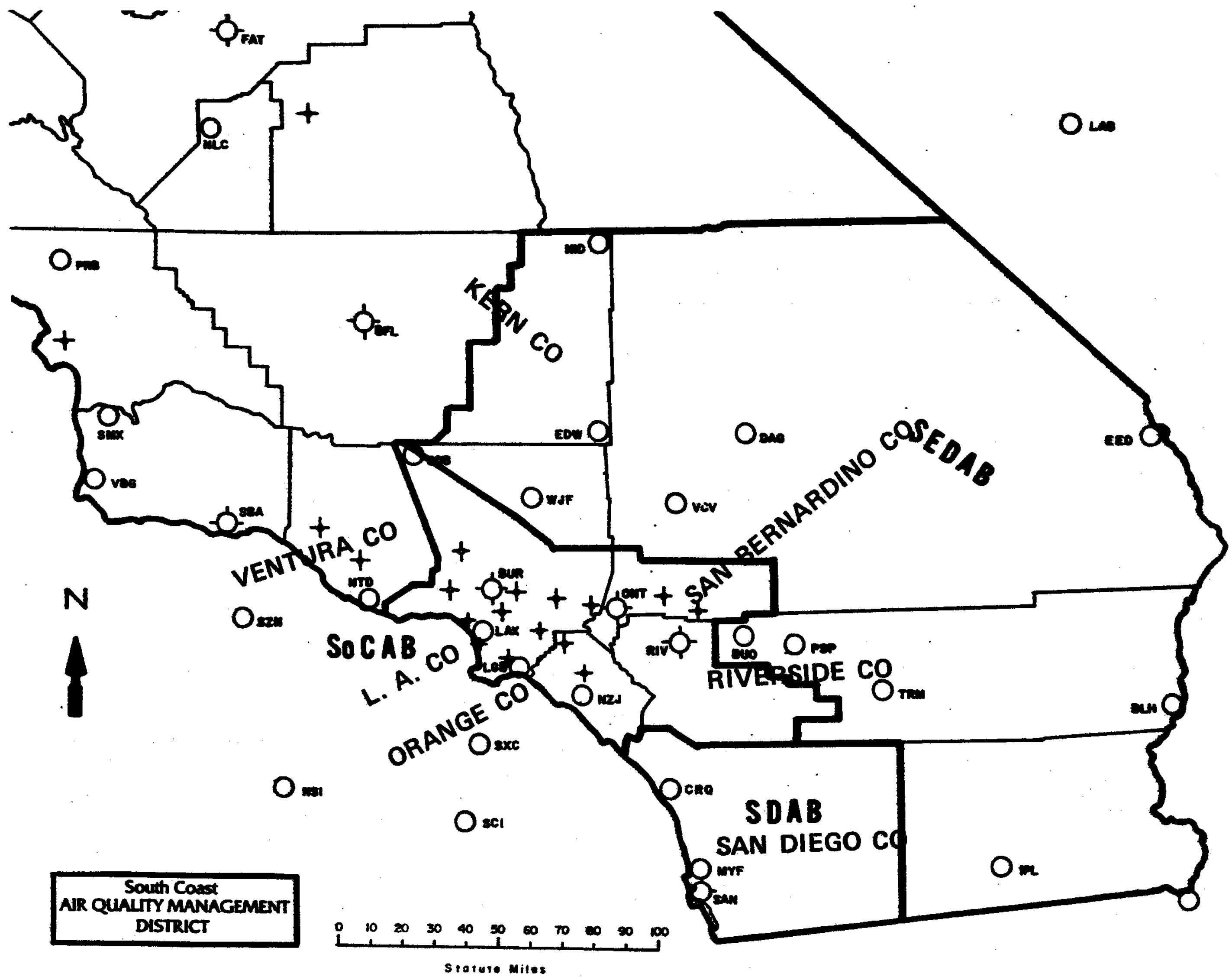

Figure 1 is a map of Southern California showing the boundaries of the South Coast Air Basin and the Southeast Desert Air Basin.

Figure 2 is a map of the South Coast Air Basin showing major geographical features and city locations.

TABLE I

POPULATION AND AREA OF THE SOUTH COAST AIR BASIN BY COUNTY

County	Basin Population		Basin Area In Square Miles		Density Per Square Mile
Los Angeles	6,890,000	73%	2,440	37%	2,824
Orange	1,565,200	17%	782	12%	2,002
San Bernardino	587,800	6%	1,600	24%	367
Riverside	364,900	4%	1,758	27%	208
Total	9,407,900		6,580		-
Average	-		-		1,430

Data in Table I are from the CARB "Supplement to the Implementation Plan, South Coast Air Basin, revised December 11, 1973, and are based on 1970 census figures.

Individual climatic elements in the Basin and the relationships between meteorological factors and contaminant concentrations are examined in the discussion that follows.

(NO TEXT, THIS PAGE)

II CLIMATIC ELEMENTS

TEMPERATURE

Southern California frequently is referred to as an area without seasons and a place where it is possible to ski in the morning in the mountains and swim in the ocean during the afternoon of the same day. This reputation is partially merited. The montly mean maximum temperatures along the coast are but 12°F higher during August than in January, and there are periods of warm days in all seasons throughout the Basin. It also is true that local mountains ordinarily have heavy snowfalls during the winter. On the other hand, ocean temperatures are cool all year and swimmers in January do not cavort in tropical waters.

Ocean Temperatures

To show the conservative nature of sea temperatures along the coast, eastern Pacific mean sea surface temperatures during January and August [32] are depicted in Figures 3 and 4. In the first figure, the water temperature in Santa Monica Bay is shown to be 15.5°C or 59°F. In Figure 4, the same type data are shown for August 1978; here the local sea surface temperature averages 18.3°C or 65°F. The January, 1978 temperature was about normal for that month while the August temperature was about 2°F cooler than the long-term average.

Figure 4 also shows the interesting and important effect of upwelling along the coast. By August, the area of peak upwelling is found to be displaced northward beyond San Francisco Bay with the coldest temperature 11.8°C or 53°F in that area.

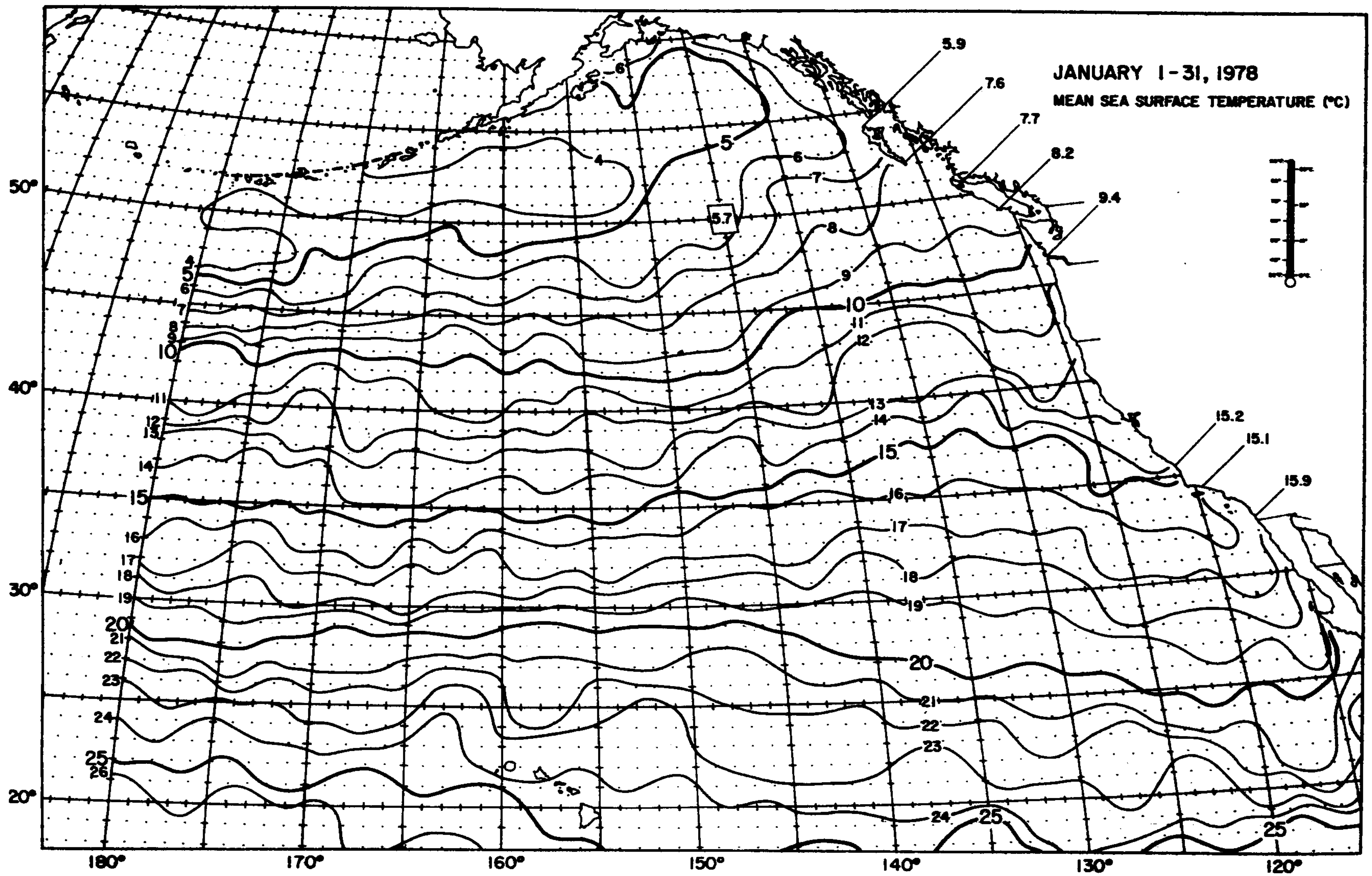

Figure 3 is a chart of the eastern Pacific Ocean with plot of mean sea surface temperatures during January 1978.

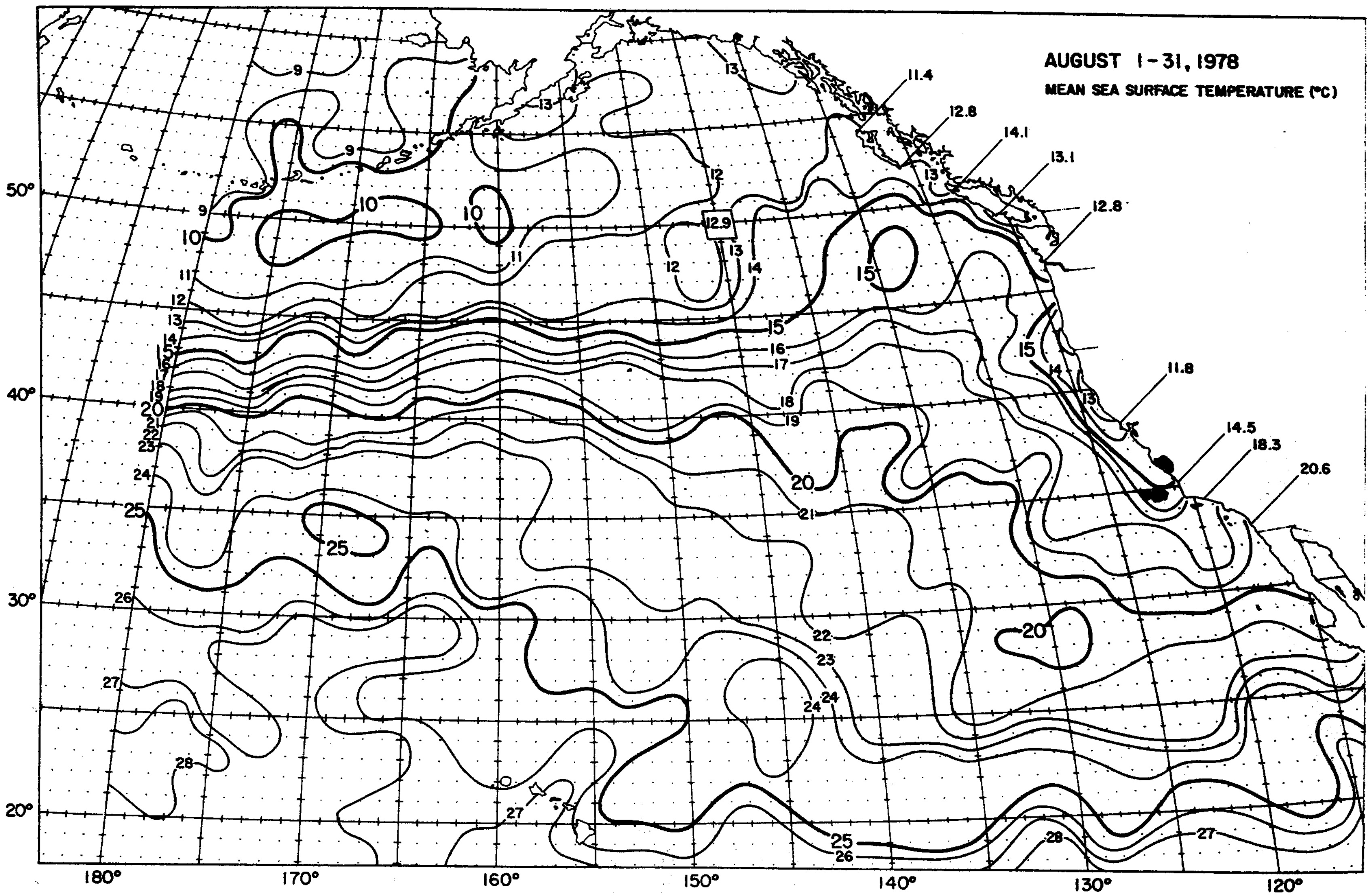

Figure 4 is a chart of the eastern Pacific Ocean with plot of mean sea surface temperatures during August 1978.

During the same August, the sea surface temperature along the coast of Japan (at the same latitude) was 75°F, twenty-two degrees warmer than San Francisco. This is an example of the substantially lower sea surface temperatures in areas of upwelling and cold ocean currents. It also illustrates the difference between California coastal water temperatures and water temperatures along the east coasts of continents that have warm offshore ocean currents and where significant upwelling does not occur. The widely disparate climates of east coastal and west coastal areas at similar latitudes throughout the world point to the significant influence of offshore sea surface temperatures.

As a result of a fairly narrow spread between the warmest and coldest monthly mean sea surface temperatures in Southern California coastal waters, the climate in the Basin is modified by the relatively warm ocean in winter and cooling seabreezes in summer. The effect is most noticeable along the coast and decreases in importance with distance inland.

Figures 5 and 6 show the marked ocean influence on Basin temperatures. The maps plot the average January minimum temperatures in the Basin and the average August maximum temperatures. During January, the warmest minimum temperatures are along the coast and the area immediately inland. The coldest area is in western Riverside County. In contrast, during August along the coast, the daily mean maximum temperature is a relatively cool 75°F while western Riverside County averages slightly under 100°F.

Continental Influences

Reversals from the moderation of the climate by coastal waters occur with the intrusion of continental air. Winter outbreaks of artic air moving from the north can drop air temperatures in the Basin far below the temperature of coastal ocean water. At other times, weak offshore flows of cool air masses in the winter, in combination with nighttime radiational cooling, can produce sub-freezing temperatures throughout the Basin. Ordinarily, extremely low temperatures occur during January.

The continental influence also accounts for the highest temperatures of the year. Occasionally, continental air moves into Southern California during summer or early fall producing weak offshore flows of warm air that negate the seabreeze and its cooling effect; during those periods, temperatures well in excess of 100°F are experienced even at the immediate coast. Maximum temperatures of the year usually are recorded during September.

Figure 5 is a plot of the average daily minimum temperatures in degrees Fahrenheit during January in the South Coast Air Basin.

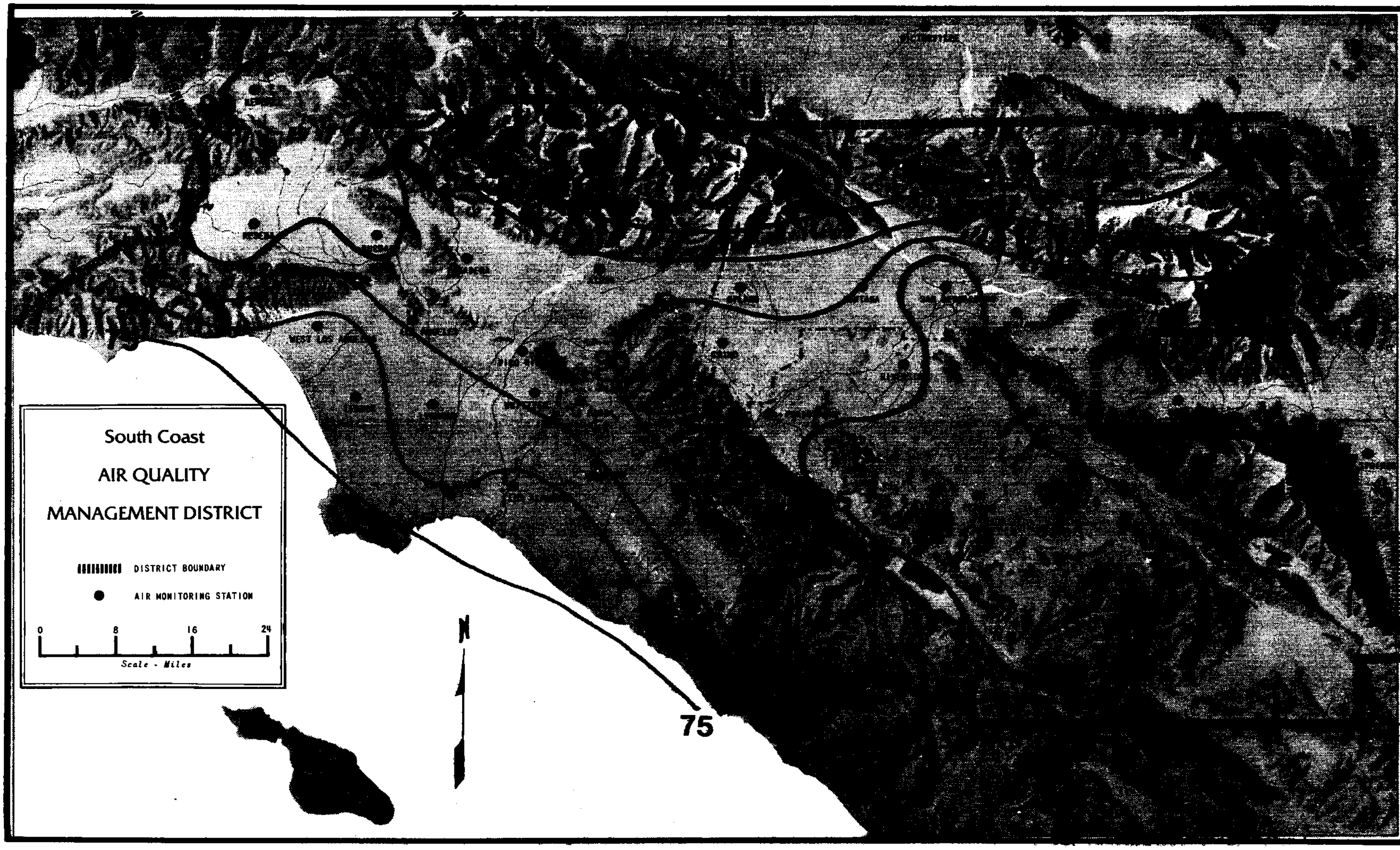

Figure 6 is a plot of the average daily maximum temperatures in degrees Fahrenheit during August in the South Coast Air Basin.

Climatological Temperature Data

To the general population in the Basin, the most manifest climatic element is temperature. Not only does temperature affect living comfort, but it is an important economic factor because of the cost of heating and cooling homes and public, industrial, and commercial buildings. Other temperature-dependent enterprises include agriculture, power plants, and fuel suppliers. Finally, a knowledge of temperature distribution and fluctuations in the Basin is needed to define properly the air pollution problem since temperature is one of the basic meteorological parameters employed to correlate emissions with air quality.

Real-time and historical temperature data are necessary to satisfy a variety of public needs. Many of the temperature observation stations in the Basin were initiated as a service to citrus growers. Other temperature recording stations were established at airports to assist that industry. Data concerning temperature extremes and averages at specific locations are used to plan for solar and conventional heating and cooling units. Power plant usage peaks with high temperatures because of air conditioning demands, and natural gas usage rises with the attainment of cold temperatures. Although more detailed temperature data may be required for some purposes, Tables II and III provide general climatological temperature data for thirty-five locations in the Basin. Table II lists locations and altitudes above mean sea level of stations for which data are presented; Table III tabulates long-term averages and extremes for the four-county area. (8, 9.)

For the greater part, stations listed in these tables have extended periods of record, a factor that adds to the validity of the listed values. It may be found, however, that other published data for some stations do not agree exactly with data in this report if different periods of record were used for the tabulations; in such cases, record maximum and minimum temperatures most likely would show the greatest deviations. Additionally, records for reporting stations, although close to one another geographically, may vary because of different altitudes or dissimilar instrument exposures or type of sensing devices.

Excluding data from the three mountain stations, Table III shows that annual average temperatures vary little throughout the area, 61°F to 65°F. Because oceanic influence gives way at times to effects of continental air masses, wide temperature ranges that do not appear in annual averages are experienced in all parts of the Basin, especially in the inland valleys. Annual mean minimum temperatures vary between 45°F and 55°F, while the spread of annual mean maximum

TABLE II

STATIONS FOR WHICH TEMPERATURE DATA ARE AVAILABLE IN THIS REPORT

County	Station Location	Station Altitude Above Mean Sea Level	
Los Angeles	Burbank	775 feet	236 meters
	Culver City	75 "	23 "
	Long Beach	58 "	18 "
	Los Angeles (Civic Center)	270 "	82 "
	Los Angeles (International Airport)	109 "	33 "
	Mount Wilson	5709 "	1740 "
	North Hollywood	619 "	189 "
	Pasadena	864 "	263 "
	Pomona (Claremont College)	1196 "	365 "
	Sandberg (Top of Bald Mountain)	4517 "	1377 "
	San Fernando	965 "	294 "
	San Gabriel	450 "	137 "
	San Pedro	10 "	3 "
	Santa Monica	63 "	19 "
	Sunland	1460 "	445 "
	Torrance	95 "	29 "
	UCLA (Westwood)	430 "	131 "
	Van Nuys	799 "	244 "
Orange	El Toro	383 "	117 "
	Laguna Beach	35 "	11 "
	Los Alamitos	35 "	11 "
	Newport Beach	8 "	2 "
	Santa Ana	53 "	16 "
	Tustin	118 "	36 "
	Yorba Linda	405 "	123 "
San Bernardino	Arrowhead (Lake Arrowhead)	5205 "	1586 "
	Fontana	1090 "	332 "
	Ontario	952 "	290 "
	Redlands	1318 "	402 "
	San Bernardino	1125 "	343 "
	San Bernardino (Norton AFB)	1156 "	352 "
	Upland	1840 "	561 "
Riverside	Elsinore	1285 "	392 "
	Riverside	820 "	250 "
	Riverside (March AFB)	1532 "	467 "
	San Jacinto	1561 "	476 "

TABLE III

SOUTH COAST AIR BASIN
CLIMATOLOGICAL TEMPERATURE DATA

Average Temperature In Degrees F. By Month		Location: Los Angeles County											
		Burbank	Culver City	Long Beach	Los Angeles	LAX	Mount Wilson a)	No Hollywood	Pasadena	Pomona	Sandberg a)	San Fernando	San Gabriel
Years of Record		30	25	30	30	30	19	21	53	55	30	42	21
Jan.	Max	65	66	65	67	64	40	65	65	64	46	64	67
	Min	42	43	43	47	45	34	38	40	38	34	42	40
Feb.	Max	66	66	66	68	64	50	67	66	65	49	66	68
	Min	44	45	45	49	47	34	40	42	40	35	42	42
Mar.	Max	69	67	68	69	64	52	69	69	68	52	70	71
	Min	47	47	47	50	49	35	43	44	42	36	44	44
Apr.	Max	72	69	71	71	66	59	73	72	73	58	75	74
	Min	51	50	51	53	52	41	47	47	45	40	46	48
May	Max	75	71	74	73	68	64	76	75	77	66	79	77
	Min	54	53	54	56	55	46	50	51	49	46	49	52
June	Max	79	73	77	77	70	73	79	81	84	75	85	82
	Min	57	57	58	60	59	54	53	54	53	53	52	55
July	Max	86	77	83	83	75	80	88	88	91	85	93	89
	Min	61	60	62	64	62	64	57	58	57	63	56	59
Aug.	Max	87	78	84	84	76	79	88	88	91	84	92	89
	Min	62	61	63	64	63	62	57	58	57	62	55	59
Sept.	Max	86	78	83	83	76	77	88	86	89	79	89	88
	Min	60	59	60	63	62	59	55	56	55	59	54	57
Oct.	Max	79	75	78	78	73	67	80	79	81	68	81	81
	Min	54	54	56	59	58	49	49	51	50	50	50	52
Nov.	Max	74	73	73	73	70	58	75	74	74	55	74	76
	Min	47	48	48	52	51	42	41	45	43	41	48	45
Dec.	Max	68	69	67	68	67	53	69	67	66	48	66	70
	Min	44	45	45	48	47	38	41	42	39	36	46	42
Annual	Max	75	72	74	74	69	63	76	76	77	64	78	78
	Min	52	52	53	55	54	47	48	49	47	46	49	50
	Average	64	62	63	65	62	55	62	63	62	55	64	64
Record	Max	106	111	111	110	110	98	112	113	114	102	113	111
Record	Min	32	24	25	28	23	10	18	21	19	3	23	22

a) mountain location

(Continued)

TABLE III (Continued)

SOUTH COAST AIR BASIN
CLIMATOLOGICAL TEMPERATURE DATA

Average Temperature In Degrees F. By Month		Location												
		Los Angeles County						Orange County						
		San Pedro	Santa Monica	Sunland	Torrance	U.C.L.A.	Van Nuys	El Toro	Laguna Beach	Los Alamitos	Newport Beach	Santa Ana	Tustin	Yorba Linda
Years of Record		41	20	11	26	27	10	14	27	12	29	43	46	44
Jan.	Max	63	64	65	65	64	62	63	64	64	63	68	66	66
	Min	47	47	41	42	47	39	44	44	42	45	39	40	41
Feb.	Max	63	64	68	65	65	64	65	65	65	63	68	67	68
	Min	48	48	43	44	48	41	45	45	44	47	42	42	42
Mar.	Max	64	65	70	67	63	70	67	66	66	65	71	70	71
	Min	50	49	43	45	49	44	46	46	46	49	44	43	43
Apr.	Max	66	67	74	69	68	75	69	68	68	66	73	72	73
	Min	52	52	47	49	51	48	50	50	50	52	48	47	47
May	Max	68	69	78	71	70	75	72	71	70	68	76	75	77
	Min	55	54	49	52	54	50	53	53	53	55	51	51	50
June	Max	71	72	86	73	73	83	76	73	73	70	79	80	82
	Min	58	57	53	56	56	53	56	56	57	58	55	55	54
July	Max	75	75	95	77	78	89	81	76	79	74	84	84	88
	Min	61	60	59	59	60	57	61	60	61	61	59	58	58
Aug.	Max	75	75	94	77	78	91	81	77	79	74	85	85	88
	Min	62	61	58	60	60	55	60	60	61	62	59	58	58
Sept.	Max	76	75	93	77	78	86	81	77	80	74	84	84	87
	Min	60	60	58	58	59	53	59	58	59	60	56	58	55
Oct.	Max	71	72	84	75	75	77	76	73	75	71	79	79	80
	Min	57	56	52	54	56	49	55	54	54	56	51	50	51
Nov.	Max	69	69	77	73	72	71	72	70	71	68	75	75	75
	Min	53	51	48	47	53	43	50	48	47	50	44	43	47
Dec.	Max	65	66	70	68	67	65	66	66	67	65	69	68	69
	Min	49	49	44	44	50	39	46	45	43	46	41	40	43
Annual	Max	69	69	80	71	71	76	72	70	71	68	76	75	77
	Min	54	54	50	51	54	48	52	52	51	53	49	49	49
Average		62	62	65	61	63	62	62	61	61	61	63	62	63
Record	Max	104	105	116	111	109	111	107	106	108	106	112	111	114
Record	Min	28	33	22	24	25	22	25	21	28	29	22	18	23

(Continued)

TABLE III (Continued)

SOUTH COAST AIR BASIN
CLIMATOLOGICAL TEMPERATURE DATA

Average Temperature In Degrees F. By Month		Location										
		San Bernardino County							Riverside County			
		Arrowhead[a)]	Fontana	Ontario	Redlands	San Bernardino	Norton AFB	Upland	Elsinore	Riverside	March AFB	San Jacinto
Years of Record		19	9	4	56	64	12	21	59	12	64	56
Jan.	Max	47	65	66	63	66	63	62	65	62	66	64
	Min	28	43	39	38	37	39	40	35	40	38	35
Feb.	Max	50	68	64	65	68	67	64	67	65	67	67
	Min	28	44	41	40	40	41	41	38	42	40	37
Mar.	Max	54	70	66	68	71	70	65	70	67	71	70
	Min	31	45	43	43	42	43	43	40	43	41	40
Apr.	Max	61	74	72	73	75	74	71	76	72	75	75
	Min	36	48	44	47	45	48	46	44	47	46	44
May	Max	67	80	77	77	80	78	74	81	76	79	81
	Min	41	52	49	50	49	51	48	49	51	49	48
June	Max	75	87	80	84	88	87	81	90	85	87	90
	Min	47	55	51	54	53	56	52	53	56	53	52
July	Max	82	95	89	94	97	95	90	98	93	94	98
	Min	56	62	55	60	57	62	58	59	63	57	57
Aug.	Max	81	93	92	93	96	93	89	98	91	94	97
	Min	55	60	57	59	57	61	58	59	61	57	57
Sept.	Max	79	93	90	89	93	90	88	94	89	91	93
	Min	51	60	56	57	54	57	57	55	59	54	53
Oct.	Max	68	82	80	80	83	81	78	84	80	83	83
	Min	42	54	50	50	48	51	51	48	52	48	46
Nov.	Max	56	74	73	72	76	71	70	75	71	75	75
	Min	34	48	43	43	41	43	45	40	45	42	39
Dec.	Max	49	68	67	65	68	66	64	68	66	68	67
	Min	30	45	40	39	38	39	41	36	41	38	35
Annual	Max	64	79	76	77	80	78	75	81	76	79	80
	Min	40	51	47	48	47	49	48	46	50	47	45
	Average	52	65	62	63	64	64	62	64	63	63	63
Record	Max	101	117	110	115	116	113	111	118	110	118	120
Record	Min	5	28	21	18	17	25	22	17	25	19	7

a) mountain location

temperatures is from 68°F to 81°F. All-time extreme temperatures recorded in the Basin show a much greater variance--7° to 120°F, both measured at San Jacinto, a town located at the base of the San Jacinto Mountains.

The time of the daily maximum temperature in the Basin during the summer smog season varies more or less with distance from the ocean. At the coast, the maximum most often occurs during the late morning, about noon in Downtown Los Angeles, and mid-afternoon in the inland valleys. High afternoon temperatures at the coast are precluded by the continuous advection of cool air, the seabreeze. The timing of the daily maximum temperature in the coastal plain is dependent upon the characteristics of the inversion and the duration of the morning off-shore flow. The abrupt reversal of this flow precedes the advent of the sea breeze and allows temperatures to rise until the ocean air intrudes. With a late-occurring or absent seabreeze, such as happens with weak Santa Ana winds, the time of the daily maximum temperature in the coastal strip is mid-afternoon, similar to the inland areas.

Except during periods of strong winds or storm conditions, the daily minimum temperature usually occurs during the hour before sunrise in all parts of the Basin. For daily sunrise times, see the sunrise and sunset table provided later in the text as part of the discussion of solar radiation and cloudiness.

Temperature and Air Quality

In assessing the relationship between air quality and climatology in the South Coast Air Basin, temperature is important beyond causing the existence of the persistent marine layer that is produced by the cool surface waters of the Pacific. Large-scale synoptic systems control the wind flow of an area; but in the Basin, local sea breezes and land breezes are superimposed upon the general wind pattern. Essentially, these local winds are the product of temperature differentials between the ocean air temperature, constant in the short term, and the uneven heating and cooling that takes place in the Basin over widely varying topography. At night, air in the hills and mountains, cooled by radiation from the surface, flows into the valleys and eventually meanders to the coast. Conversely, when the air is heated by the warm ground during the morning, an onshore flow is initiated throughout the Basin. This reversal of direction of the wind is followed later by the sea breeze "front," the daily intrusion of sea air.

A second phenomenon associated with temperature is the "chimney effect" along the mountain borders of the Basin during late mornings and afternoons in the summer smog season. When the mountain slopes are heated by solar radiation, upward drafts are created that carry some of the polluted air from the Basin to high altitudes, while a portion of the polluted air flows over the ridge line into the desert. With the proper wind flow in the inversion layer, some of the pollution carried aloft returns to the Basin in layers above the inversion base. Thus, the chimney effect produces a wind flow that acts as a vehicle to transport contaminants out of the Basin preventing carry-over of pollution from day to day. On the other hand, a return flow, also the result of the chimney effect, can trap polluted air in the inversion. These contaminants remain in the Basin over night and can be mixed downward to the surface the following day as a result of surface heating. Figure 7 is a simplified diagram showing the chimney effect over a mountain.

Another important role that temperature plays in the daily Basin air quality is its control of the extent of vertical mixing. This mixing or upward diffusion dilutes the concentration of contaminants in the surface layer of air. As each day progresses, the land surface is heated by the sun, creating updrafts or "thermals" that mix the air between the surface and the base of the inversion. This process mixes relatively clean air downward as the inversion base rises incrementally. With surface temperatures continuing to rise, vertical mixing is accomplished over greater heights, terminating in what is designated as the "daily maximum mixing height." This is the greatest vertical mixing of the day and occurs at the time of the attainment of the daily maximum surface temperature for a given location. With sufficient surface heating the inversion may be broken with resultant virtually unlimited vertical dispersion.

Another aspect of the importance of temperature is its influence on contaminant characteristics in the ambient air of the Basin. This is mentioned to point out the complexity of meteorological-air quality relationships and the presence of many unresolved problems in the area. Knowledge of the effect of temperature on atmospheric chemical and photochemical reactions is, at best, incomplete and probably will remain so until more is learned about the chemical reations themselves.

However, research is on-going in this field. Pitts (31) has found that: "Substantial effects were seen (on ozone formation) for increasing temperature or constant light intensity. Approximately a 20% increase in final ozone concentration occurs for a 10°F increase in temperature and a 30 percent increase occurs for an increase in light intensity from 70 percent to 100 percent of maximum."

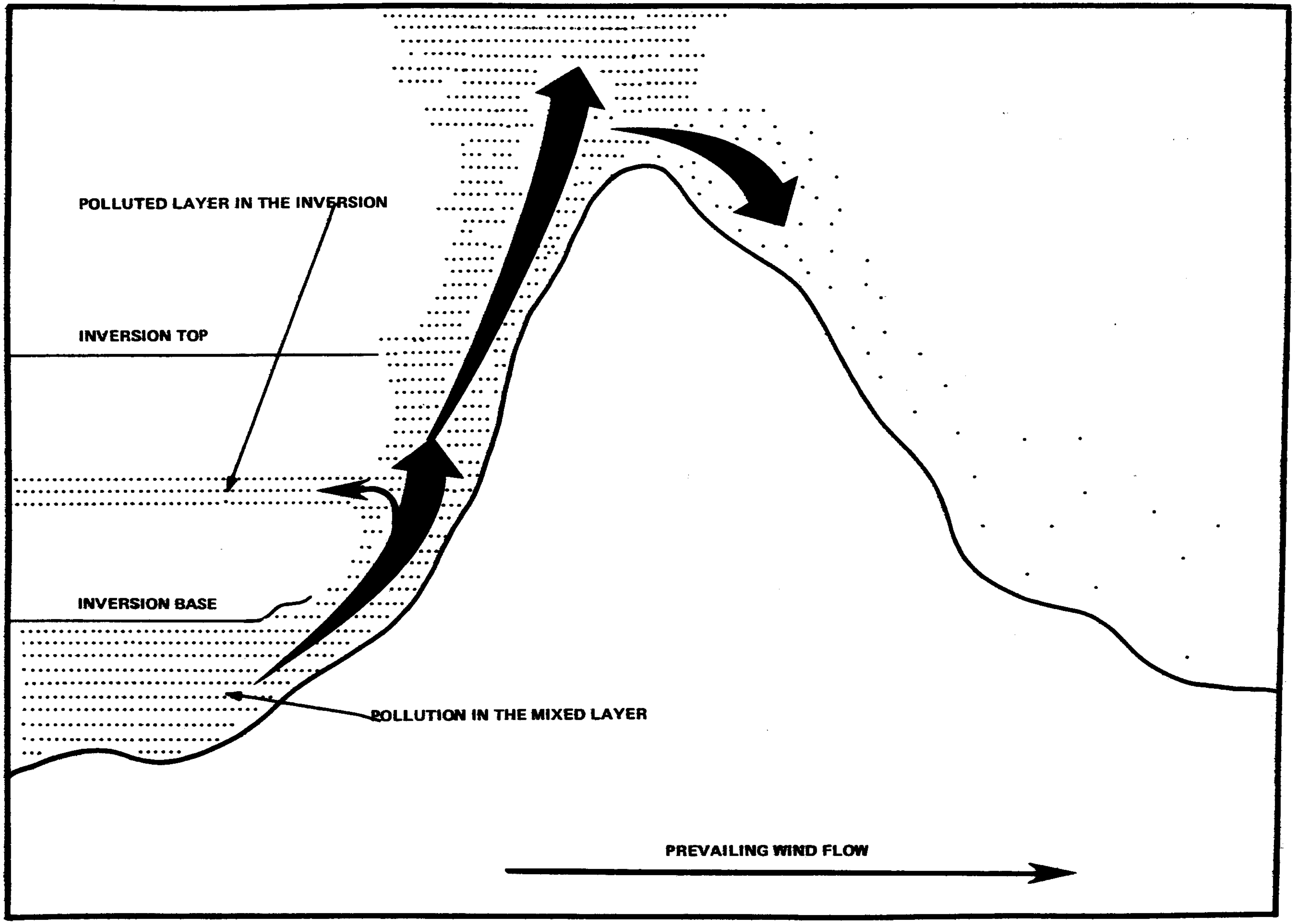

Figure 7 diagrams the "chimney effect" on the windward side of a mountain. Solar heating of the mountain slope causes updrafts that disperse pollution aloft. Frequently, with this condition, a reverse flow traps pollution in the inversion layer, itself.

Just as temperature influences the chemistry of contaminants, the polluted layer beneath the inversion affects temperature. Whereas a limited amount of solar radiation is absorbed by pure air, aerosols in the atmosphere do absorb an appreciable portion of incoming radiation and thereby modify the heat balance of the polluted layer. Additionally, a significant portion of solar radiation is reflected from the top of the layer. The result of these two processes is that sunshine received at the earth's surface is reduced, restricting vertical mixing among other effects.

Although there is a positive correlation between high temperatures and elevated ozone concentrations in the Basin, the relationship may be misleading if the conclusion is drawn that the high temperatures per se account for the high ozone values. Meteorological conditions favorable to the production and accumulation of maximum ozone concentrations include the presence of a low, intense inversion and strong solar radiation. Both conditions are accompanied by high temperatures at the surface and aloft, masking the role of temperature in the photochemical process.

Temperature, as the key factor in the climatology of Southern California, is inter-related with several other elements such as relative humidity, wind flow in three dimensions, and stability. These relationships are discussed in the sections that follow.

(NO TEXT, THIS PAGE)

HUMIDITY

Although the climate of the South Coast Air Basin is semi-arid, the air near the surface is quite moist on most days because of the presence of the marine layer. This shallow layer of sea air is a most important modifier of the Basin climate. The marine layer is moist because, in the off-coast area where it is formed and perpetuated, evaporation from the ocean surface takes place constantly. With this evaporative process, there is continuous horizontal and vertical turbulent mixing by wind and wave action that makes the entire layer fairly homogeneous from the standpoint of moisture content. This mixing is capped at the inversion base above which the air is dry and stable.

Over the ocean, the marine layer is characterized by fog or stratus clouds most of the time. Typically, the stratus deck recedes seaward during the morning and afternoon and moves onshore during the late afternoon and evening. But even in cloud-free areas, the humidity is high beneath the inversion although the air may not be saturated. The moisture content of air is a measure of the amount of gaseous water present, not of suspended, minute cloud droplets or larger water particles that make up drizzle or rain and fall through the air. Atmospheric humidity, then, is not concerned with visible clouds or precipitation but simply with the amount of water vapor in the air; this can be expressed in several ways. Relative humidity is a term frequently used.

Relative Humidity

Relative humidity is a percentage reflecting the ratio between the amount of water existing in the air and the total water vapor the air could hold at a given temperature (and pressure). For example, if the air temperature were 80°F and the relative humidity were fifty percent, the moisture content of the air would be half of what it would be at saturation at that temperature. In the Basin, with changing daytime temperatures, the relative humidity can fluctuate considerably, although the actual moisture content of the air at the surface remains nearly constant.

Dew Point Temperature

Another measure of the water content in air is the "dew point." This is the temperature to which air must be cooled (considering no change in pressure and water vapor content) in order for saturation to occur. Dew point is considered conservative or unchanging whereas relative humidity is temperature dependent. On many days in the Basin, the dew points throughout the area are approximately equal while the relative humidities near the coast are high and those in the hot interior are very low.

Humidity and Air Quality

Relative humidity and dew point are quite different measurements of the moisture content of the air, but each has important applications in defining the climate of the Basin and each can be an aid in correlating air quality and the weather of the region. Relative humidity data are used to determine the attainment or violation of the State air quality standard for visibility at several observation stations in the Basin. This standard is based upon the daily minimum visibility which must be ten miles or greater to meet the standard. However, individual observations are considered only for those hours when the relative humidity is less than seventy percent. Above that percentage, the presence of water droplets in the air restricts visibility and the relative contribution of contaminants and naturally occurring aerosols cannot be determined by the observer. Conversely, at relative humidities less than seventy percent, the predominant restriction to visibility is considered to be contaminants produced by human activities. When the relative humidity remains at or above seventy percent all day, compliance with or violation of the State visibility standard is not determined regardless of the minimum visibility.

Another important relationship between humidity and Basin air quality concerns sulfates in the atmosphere. Although sulfur dioxide emissions are relatively low, the State sulfate air quality standard is violated a significant number of days each year. This situation occurs because the conversion of sulfur dioxide to sulfates is heightened in air with high relative humidity, and the marine layer is an excellent environment for that conversion process, especially during spring and summer months.(6)

The dew point temperature can be used to trace the progress of marine air as it intrudes into inland valleys with the daily onshore breezes. With this flow, dew points will remain constant if no significant amount of dry air is mixed downward by vertical eddies produced by surface heating. However, if this heating erodes the inversion base and dry air moves to the surface from aloft, then dew point temperatures will decrease as the marine air moves inland.

Climatological Humidity Data

To compare dew point temperatures and relative humidities in the Basin on a monthly and annual basis, three tables are presented.(29) Table IV lists the monthly and annual mean dew point temperatures for several stations and shows that average dew points decrease with distance from the ocean as continental effects become more noticeable. For comparison, data for the Mojave Desert station, Palmdale, are included. The Upper and Lower Deserts are affected less by marine air than is the Basin because of the intervening mountain barriers. Additionally, the sea air usually is modified considerbly by the time it reaches those remote areas.

The data in Table IV show that dew point temperatures along the coast vary very little from station to station on a monthly basis and are identical on an annual basis. In the inland valleys, the dew point temperatures are several degrees less than those temperatures along the coast, monthly and annually. Mean dew points in the High Desert are about one-third less than dew points at the coast. A final observation is that dew point temperatures are highest during July and August and lowest during December and January. These periods correspond respectively to the months with the least and the greatest influence of continental air on the Basin.

Table V presents the monthly and annual mean relative humidities for eleven stations in the Basin including a mountain location, Sandberg. Highest annual mean relative humidities are found at the coast (72%) and the lowest at the eastern end of the Basin (58%). This shows the decreasing ocean influence with distance inland. Sandberg, above the marine inversion most of the time, has an even lower annual relative humidity, forty-nine percent. Average relative humidities are fairly constant in the Basin, month to month, but peak slightly during the spring when the marine layer is deepest and most persistent.

TABLE IV

MONTHLY AND ANNUAL MEAN DEW POINT TEMPERATURES
SOUTH COAST AIR BASIN

Station	Mean Dew Point Temperatures in Degrees F.												
	Month												Annual
	J	F	M	A	M	J	J	A	S	O	N	D	
Los Angeles Intl Airport	42	43	46	49	51	56	60	60	59	54	45	41	51
Long Beach Mun. Airport	43	43	46	49	51	56	60	60	59	54	45	42	51
Santa Ana	42	45	47	49	52	55	59	61	58	54	46	45	51
Los Alamitos	43	43	46	50	52	56	60	61	59	54	46	43	51
El Toro	42	42	45	49	51	55	60	60	58	53	44	41	50
Burbank	37	37	40	46	48	54	57	57	54	49	39	35	46
Van Nuys	34	40	41	45	47	52	55	54	53	48	36	36	45
Ontario	37	40	42	45	48	52	56	56	54	51	38	39	47
San Bernardino	36	38	40	45	48	52	56	57	53	45	37	35	45
Riverside	34	35	38	44	46	51	54	54	51	44	35	31	43
Palmdale[a)]	29	28	30	37	36	39	43	40	38	33	30	27	34

a) Mojave Desert Station

TABLE V

MONTHLY AND ANNUAL MEAN RELATIVE HUMIDITIES
SOUTH COAST AIR BASIN

Station	Mean Relative Humidities in Percent												
	Month												Annual
	J	F	M	A	M	J	J	A	S	O	N	D	
Los Angeles Intl. Airport	63	67	69	70	74	77	76	77	75	71	67	64	71
Long Beach Mun. Airport	63	65	65	65	68	69	68	67	68	66	66	66	66
Santa Ana	73	77	77	77	74	75	77	77	76	76	71	76	76
Los Alamitos	76	72	74	74	73	76	76	77	76	75	70	72	74
El Toro	69	67	70	73	71	73	73	75	72	71	62	63	70
Burbank	59	60	60	63	64	66	62	62	60	62	55	54	61
Van Nuys	60	70	66	64	65	68	64	60	61	64	53	61	63
Ontario	64	70	70	68	66	67	66	61	61	69	58	64	65
San Bernardino	65	62	63	64	63	59	54	56	55	55	56	59	59
Riverside	62	60	62	64	62	58	51	54	53	56	52	53	59
Sandberg[a)]	54	57	59	59	53	45	34	36	41	47	51	58	49

a) Mountain Station

Table VI is presented to show the large diurnal variation in relative humidities at all stations. Being temperature dependent, the daily relative humidities follow the diurnal temperature curves with high relative humidity corresponding to the daily minimum temperature and low relative humidity occurring during the afternoon, the time of the daily temperature maximum inland. At Los Angeles International Airport, the minimum relative humidty (in this listing) occurs at 1000 PST; this is related to the noon maximum temperature.

TABLE VI

MONTHLY AND ANNUAL MEAN RELATIVE HUMIDITIES
BY SELECTED HOURS OF THE DAY, SOUTH COAST AIR BASIN

Station	Hour Pacific Standard Time	Mean Relative Humidities in Percent												
		Month												Annual
		J	F	M	A	M	J	J	A	S	O	N	D	
Los Angeles Intl. Airport	0400	69	74	78	80	83	86	86	86	84	80	75	71	79
	1000	54	58	60	60	66	70	68	69	67	60	57	55	62
	1600	59	62	65	63	66	68	68	69	68	65	63	61	65
	2200	69	72	74	76	80	83	83	83	81	78	73	70	77
	Average	63	67	69	70	74	77	76	77	75	71	67	64	71
Long Beach Mun. Airport	0400	73	77	77	79	80	81	81	80	81	80	77	76	78
	1000	57	60	59	57	61	64	61	60	61	58	58	60	60
	1600	50	52	53	50	55	56	53	53	54	52	54	53	53
	2200	71	72	72	72	75	76	75	75	76	75	74	73	74
	Average	63	65	65	65	68	69	68	67	68	66	66	66	66
Downtown Los Angeles	0400	63	71	74	78	81	85	84	84	78	76	61	62	75
	1000	51	54	52	53	56	59	54	56	52	55	45	45	53
	1600	50	52	52	54	55	56	53	55	54	56	49	50	53
	2200	67	70	72	74	75	78	79	79	76	74	62	62	72
	Average	58	62	63	65	67	70	68	69	65	65	54	55	63
Burbank	0400	70	74	75	79	80	84	82	80	76	77	67	67	76
	1000	53	51	49	53	54	57	51	51	48	50	45	45	51
	1600	46	47	46	47	49	49	41	42	42	49	45	45	46
	2200	66	66	68	72	73	75	75	75	72	70	61	60	69
	Average	59	60	60	63	64	66	62	62	60	62	55	54	61
Sandberg[a)]	0400	51	56	65	67	64	58	42	45	47	55	57	62	56
	1000	56	57	57	52	46	36	26	27	30	39	47	54	44
	1600	52	51	51	51	45	37	29	30	36	42	48	55	44
	2200	55	57	62	64	58	50	39	43	49	51	53	59	53
	Average	54	57	59	59	53	45	34	36	41	47	51	58	49

a) Mountain Station

(NO TEXT, THIS PAGE)

PRECIPITATION

Rainfall in the South Coast Air Basin is characterized by an overlying variability, annually and seasonally. Notwithstanding this changeable pattern, the rainy and dry seasons are fairly constant, the former extending from November through April. During this period, more than ninety percent of the annual rainfall occurs. Over the years, zero precipitation has been recorded in all months; and, in contrast, a rain total greater than the annual average can fall in a single month.

Rainfall Climatology

With the Basin located in the southern portion of the temperate zone, its winter season is punctuated by periods when the storm track that ordinarily follows the strong westerlies in mid-latitudes moves southward into the area. A common weather pattern during late fall and early spring is a series of rapidly moving cold fronts passing through Southern California; these produce widespread shower activity of relatively short duration.

Heavy, steady rain occurs during winter when low pressure systems move southward and stagnate off the coast, producing continuous precipitation until the storm moves through the area. The most intense and prolonged rain systems occur in conjunction with southwesterly flows from the tropics that feed moist, unstable air into Southern California. When established, these storms can persist for several days and produce widespread flooding.

Despite frequent years with heavy rain (and considerable precipitation in the mountains nearly every winter) the climate of the Basin is dry and there are few rainy days each year compared with coastal and mountain areas in Northern California. A rainy day can be defined in several ways, one of which is a day when one-tenth of an inch falls. With that definition, Crescent City along the northern coast records ninety-two days annually; San Francisco, thirty-nine; Big Sur, forty-seven. On the dry end of the scale, the Los Angeles area has twenty days and Indio, located in a true desert, four days.

Table VII shows the frequency of rainy days at various locations with monthly and annual means for precipitation equal or greater than 0.01 inches, and 0.10 inches. Annual averages are listed for the number of days with substantial rainfall--one-half inch or greater. As expected, the frequency of rainy days follows the annual rainfall curve closely with mid-winter maximums and summer minimums. The table shows also that, aside from the Big Bear location, there are about the same number of rainy days (twenty days at one-tenth of an inch or greater) throughout the Basin except for northern San Bernardino County. The additional days in the latter area are due to the greater frequency of summertime thunderstorms than in other sections of the Basin and to the proximity of the mountains. In general, two rainy days can be expected in the dry season, May through October.

The average number of days on which more than one-half inch of precipitation falls is six days at Anza and Elsinore, fifteen at Fontana, and seventeen at Big Bear. Even at the last location, days with heavy rain (or snow) occur less than five percent of the time.

Data were available for several stations in Los Angeles County listing days when more than a trace of rain was recorded. Even with this liberalized definition of a rainy day, including days with measurable drizzle, ninety percent of the days each year are rain-free, an important statistic from the standpoint of solar radiation and photochemical smog.

Precipitation Patterns

Thunderstorms are not uncommon during winter storms and are produced when a cold, unstable air mass moves across the relatively warm ocean surface into the Basin. Also, frontal and air mass thunderstorms sometimes accompany these storms.

At any time during the rainy season, the precipitation pattern can be broken by high pressure systems that build in the Great Basin of Nevada and Utah. These anticyclones last from a few days to several weeks and bring either Santa Ana

TABLE VII

RAINFALL FREQUENCY - SOUTH COAST AIR BASIN

Location By County	Number of Days Precipitation ≥ Specified Amounts by Month and Year																											
	0.01 inches														0.10 inches														0.50 inches
	PR[a]	J	F	M	A	M	J	J	A	S	O	N	D	AN[b]	PR	J	F	M	A	M	J	J	A	S	O	N	D	AN	AN
Los Angeles																													
Burbank	34	6	6	6	4	2	1	*	1	1	2	3	6	38	7	6	4	3	3	1	0	0	0	*	1	2	2	22	9
Long Beach	34	5	5	5	3	1	*	*	*	1	2	3	5	31	7	5	3	2	3	1	0	0	0	*	1	2	2	19	9
Los Angeles (Downtown)	38	6	5	6	4	1	1	*	1	1	2	3	5	35	7	5	4	3	3	1	0	0	*	0	1	2	2	21	7
Los Angeles (LAX)	43	6	6	5	3	1	1	1	*	1	2	3	5	35	7	6	3	3	3	1	0	0	0	0	1	2	2	21	8
Sandberg	42	6	6	6	4	2	*	*	1	1	2	4	6	40	7	5	3	2	3	1	0	0	0	1	1	2	2	20	7
Orange																													
Brea															7	5	4	3	3	1	*	0	*	*	1	2	2	21	7
Fullerton															7	5	4	3	3	1	*	0	*	*	1	2	2	21	8
Newport															7	5	4	3	2	2	*	*	0	*	*	2	2	19	8
Santa Ana															7	4	4	3	3	1	0	0	*	0	1	1	2	19	9
Yorba Linda															7	5	4	4	3	1	*	0	*	*	1	2	2	22	7
San Bernardino																													
Big Bear															7	7	6	4	4	2	*	2	2	1	1	3	3	35	17
Fontana															7	6	5	4	3	2	*	*	0	*	2	2	3	27	15
Redlands															7	5	4	3	3	2	*	*	0	*	1	2	2	22	8
San Bernardino															7	5	5	4	3	2	*	*	*	1	1	2	3	26	12
Upland															6	5	4	5	3	2	0	*	*	1	2	2	3	27	14
Riverside																													
Anza															7	4	4	2	3	1	0	1	1	1	1	2	2	22	6
Elsinore															7	5	4	3	2	1	0	*	*	0	1	2	2	20	6
Hemet															7	6	3	2	3	1	0	*	*	1	*	2	2	20	7
Riverside															7	5	4	3	2	2	*	*	*	*	1	1	9	19	7
San Jacinto															7	5	3	3	2	1	0	1	0	1	2	2	2	22	8

a) PR = Period of record in years

b) AN = Annual total

* = Average is less than one-half

wind conditions to the Basin or gentle, off-shore flows that produce summer-like weather and its attendant smog problems. In drought years, these high pressure systems effectively block Pacific storms that are shunted northward through Washington and Southern Canada.

Aside from rare outbreaks of polar air that bring steady, light rain, most of the Basin precipitation during the summer falls as showers or thundershowers. Two weather patterns associated with tropical air produce this dry-season shower activity. The more common is a southeasterly flow from the Gulf of Mexico that moves clockwise around a stationary high pressure system centered over Texas and New Mexico. This summer pattern produces half the annual precipitation in eastern Arizona, but with considerable loss of moisture over the Arizona and Sonora mountains, these easterly waves account for a considerably smaller portion of the annual precipitation in the Basin.

Infrequently, the southeast flow will push thunderstorms and fairly heavy cloud decks associated with the Gulf air to the coast. With this situation, the pollution pattern may be disrupted as the inversion is broken or subsidence stops, and contaminant values drop sharply. However, within one or two days, the usual summer inversion regime is reinstated. Most frequently in the summer, even with towering cumulus and cumulonimbus clouds over the mountains surrounding the Basin visible through the haze, the inversion remains strong and contaminant values high. With an easterly flow that produces a weak off-shore pressure gradient, some of the highest daily maximum ozone values are attained. During most of the summer period, the Pacific high pressure system dominates the weather in the Basin and blocks the westward movement of the Gulf of Mexico air.

The other summer rainfall weather type is the intrusion of moist, tropical air from the Pacific source region off the coast of Mexico.[36] From June to October, about thirty tropical cyclones are spawned in this area southwest of the Baja California Peninsula. Of these, about twelve reach hurricane intensity (64 knots, or 73 miles-per-hour). In early summer, most of these cyclones move seaward to the west; but by late summer, some recurve to hit the Mexican mainland or move northward, eventually affecting Southern California. Although somewhat rare, chuboscos, the Spanish name for these cyclones, can bring widespread, heavy rain to the Basin during late August and September.

The Mexican storms that affect Southern California follow either of two principal routes -up the Gulf of California or northward over the ocean immediately west of Baja California. A less common path is northeastward across the peninsula. When the cyclones move through the Gulf, channeled between the mountains of Baja California and the Mexican mainland, they intensify because of the added energy and moisture from the extremely warm sea surface in the Gulf. Storms that follow this route affect the eastern mountains bordering the Basin and the desert beyond.

While the summer sea surface temperature in the Gulf of California may be as high as 88°F (31°C), the ocean temperature on the tropical storm route over the Pacific is about 70°F (20°C). Here, the cool surface waters cause the cyclones to lose intensity quickly as the heat and moisture source is cut off. On an annual basis, the Basin rainfall associated with these storms is insignificant. For the greater part, the storms advect decks of middle and high clouds and high surface humidity with isolated showers occurring mostly over the mountains. However, in 1939, 5.67 inches of rain fell in Downtown Los Angeles during September, virtually all of it from a single tropical storm. Since that year, the greatest September rainfall was 2.82 inches, recorded in 1978.

Although the Basin total rainfall at any location varies considerably year to year, the annual distribution and the long-term annual mean pattern are predictable because they relate directly to topography. Figure 8 is a plot of the Basin annual average precipitation. As shown, about twelve inches fall along the coast and thirteen to fifteen inches through the inland valleys except western Riverside County. Here the Basin minimum is recorded--ten to twelve inches. The Riverside sub-basin lies east of the Santa Ana Mountains and storms moving across that range are affected by the terrain, since the precipitation is heavier on the windward side of a mountain barrier than on the leeward.

Precipitation over mountains increases upward to a maximum zone near the ridge line and then decreases. This model has a perfect application in the Basin since the annual mean maximum rainfall occurs in the San Gabriel and San Bernardino Mountains and proportionately lesser amounts in the foothills. Not only are these mountains very high, producing a marked orographic effect on storms, but lying east-west, the range is nearly perpendicular to the general wind flow in storm systems. Winds in storms that are effective rain producers in the Basin have southerly components. The wind flow in major winter storms begins with strong southeasterlies, then veers to the southwest as the storms move through the area to the east. With clearing, winds continue to veer to the west or north but the air mass no longer has a high moisture content. The lifting of moist air masses over the mountains thus accounts for the heavy rainfall along the northern border of the Basin and the same process accounts for the sparse rainfall in the Mojave Desert since descending air flows are relatively dry. Rainfall in these mountains is about double that

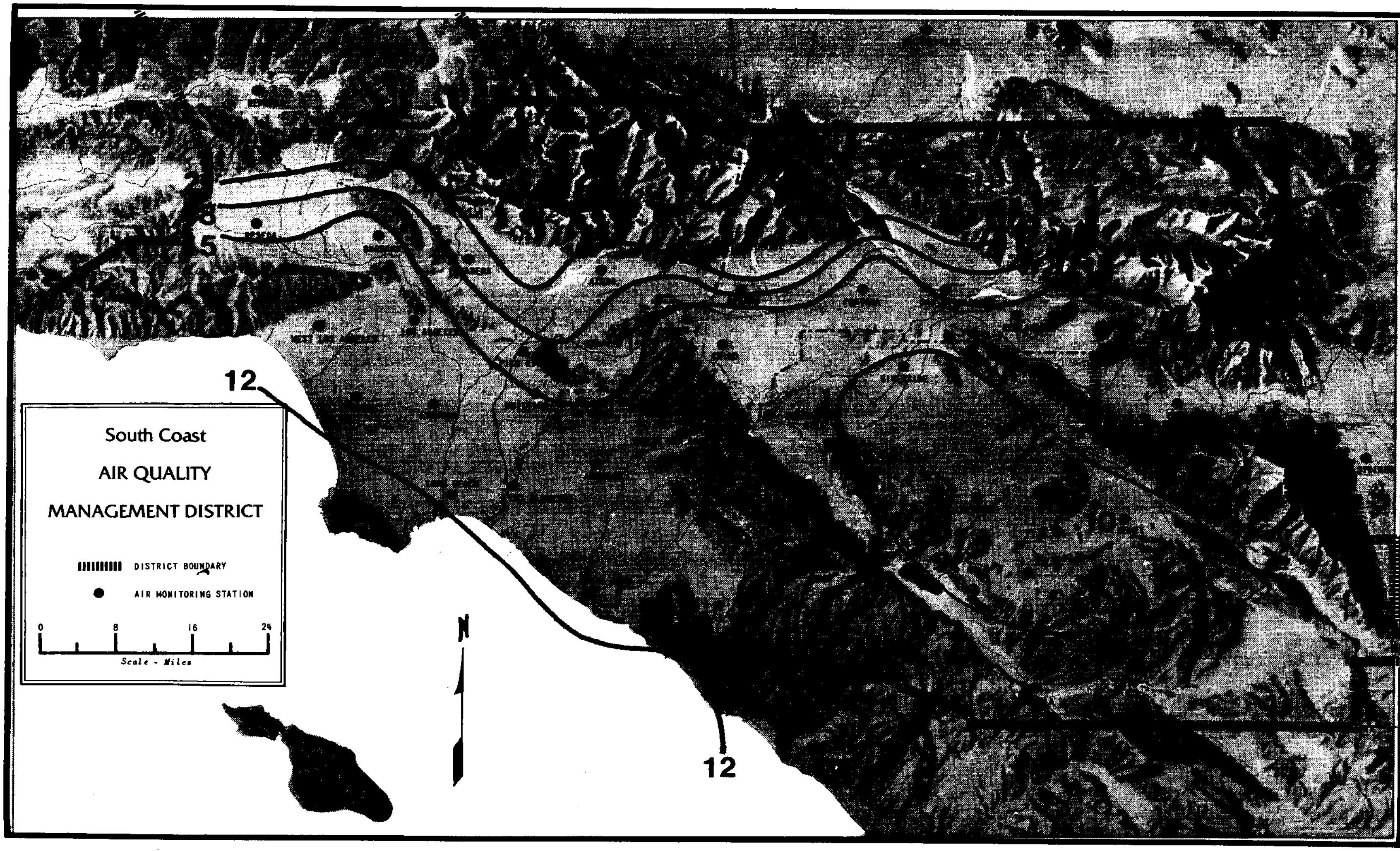

Figure 8 is a plot of the annual average precipitation (in inches) in the South Coast Air Basin.

recorded in the lower portions of the Basin; annual average rainfall at Mount Wilson is thirty-one inches, thirty-two inches at Mount Baldy, and thirty-six inches at Big Bear. By contrast, the Upper Desert receives about five inches per year.

Snowfall is a relatively unimportant aspect of the Basin climate. Below 2,000 feet, snow is recorded only with rare outbreaks of arctic air that move into the Basin from the north. Snowfalls are heavy in the mountains every winter, and 122 inches are recorded at Big Bear on an annual average basis.

Climatological Rainfall Data

Table VIII is a compilation of average rainfall statistics for thirty locations in the Basin. For comparison, similar data for the Southeast Desert Air Basin station at Indio are added. The mean rainfall in inches is listed for each month as well as the annual average. Finally, the record annual maximum and minimum rainfall totals are shown for the available periods of record for all locations. These record annual figures may vary from similar data published elsewhere if the latter listings are based on a July through June season, since Table VIII is based on calendar-year data. In addition, other compilations may be different from data presented to this table if averaging periods are dissimilar or the averaging periods are not for the entire period of record. For example, the National Weather Service ordinarily bases its statistical averages on the latest thirty-year period (recomputed every ten years) although available data may extend beyond the averaging period.

Data in Table VIII indicate that for the greater part of the Basin, July is the driest month with no rain, or at most a few hundredths of an inch, falling in that period. In western Riverside County and the San Bernardino Mountains, June is the driest month because summer thunderstorm activity begins in those areas in July.

January and February are the wettest months in the Basin with two-thirds of the locations reporting long-term average maximums during January and the balance in February. The range in rainfall averages for those winter months is from two inches at Hemet to seven inches at Big Bear.

The record highest and lowest annual rainfall statistics listed in the table do not reflect the entire period of record for all stations. Had that data been available, the deviations from normal probably would have been greater than shown. Nevertheless, the spread between the wettest and driest years at all locations shows a wide variability. Except for

TABLE VIII

AVERAGE RAINFALL - SOUTH COAST AIR BASIN

COUNTY AND STATION LOCATION	MONTHLY AND ANNUAL RAINFALL[a] IN INCHES															
	PR[b]	J	F	M	A	M	J	J	A	S	O	N	D	AV	MAX[c]	MIN[c]
Los Angeles																
Burbank	29	3.12	3.14	2.24	1.15	0.17	0.05	T[d]	0.05	0.27	0.48	1.05	2.69	14.41	37.52	3.52
Covina	30	3.47	3.54	2.69	1.48	0.23	0.08	T	0.05	0.22	0.75	1.34	3.52	17.37	26.80	6.51
Downey	30	2.98	3.23	2.21	1.22	0.18	0.04	0.01	0.05	0.23	0.44	1.12	2.81	14.52	23.44	5.00
Los Angeles (City)	83	3.06	3.10	2.59	1.09	0.34	0.06	0.01	0.03	0.19	0.56	1.15	2.67	14.85	31.28	4.08
Los Angeles (LAX)	25	2.51	2.99	1.95	1.02	0.09	0.01	0.01	T	0.19	0.39	1.03	2.27	12.46	24.58	3.12
Long Beach	40	2.44	2.75	1.78	1.06	0.22	0.05	T	0.03	0.16	0.40	0.99	2.36	12.24	21.47	5.11
North Hollywood	24	3.53	3.51	2.76	1.25	0.14	0.02	0.01	0.03	0.22	0.42	1.21	2.95	16.05	33.59	3.91
Pacoima	23	4.08	3.43	2.98	1.97	0.44	0.10	0.02	0.13	0.30	0.67	1.55	3.37	19.04	33.51	6.57
Pasadena	63	4.27	3.97	3.08	1.47	0.51	0.09	0.01	0.03	0.30	0.77	1.46	3.21	19.17	37.13	5.83
Pomona	15	3.27	2.38	1.95	1.18	0.57	0.10	0.01	0.02	0.14	0.58	1.39	2.82	14.41	24.44	8.47
Orange																
Brea	10	4.06	1.80	1.73	1.48	0.31	0.03	0.02	0.02	0.96	0.28	1.12	1.65	12.56	21.44	5.16
El Modena (Orange)	10	4.00	2.15	1.80	1.69	0.25	0.03	0.02	0.03	0.07	0.29	1.18	1.65	13.16	24.91	5.29
Fullerton	20	3.03	2.13	2.11	1.22	0.25	0.03	0.03	0.08	0.04	0.34	1.40	2.29	12.95	24.38	5.79
Laguna Beach	30	2.45	2.64	1.91	1.11	0.24	0.08	T	0.07	0.16	0.55	1.11	2.13	12.45	19.35	3.45
Newport	30	2.27	2.53	1.71	1.19	0.20	0.08	0.01	0.07	0.19	0.45	1.01	2.17	11.88	19.63	3.56
Santa Ana	53	2.49	2.83	2.31	1.08	0.35	0.03	0.01	0.05	0.17	0.58	1.06	2.67	13.67	25.35	4.83
Tustin	84	2.61	2.60	2.20	1.03	0.40	0.04	T	0.02	0.13	0.55	1.05	2.22	12.85	22.66	4.37
Yorba Linda	47	2.88	3.06	2.31	1.22	0.37	0.04	0.01	0.07	0.27	0.62	1.09	2.57	14.51	23.83	5.15

a) Annual Averages are Calendar Years
b) Period of Record
c) Reported Maximum and Minimums may not include entire period of record
d) Trace—less than 0.01 inches

(continued)

TABLE VIII (continued)

AVERAGE RAINFALL - SOUTH COAST AIR BASIN

COUNTY AND STATION LOCATION	PR (b)	MONTHLY AND ANNUAL a) RAINFALL IN INCHES														
		J	F	M	L	M	J	J	A	S	O	N	D	AV	MAXc)	MINc)
San Bernardino																
Big Bear	28	6.54	7.10	6.35	3.15	0.70	0.10	0.65	0.49	0.75	1.49	2.83	6.04	36.19	51.41	13.30
Fontana	10	4.50	1.84	2.01	1.39	0.44	0.07	0.01	0.03	0.07	0.36	1.30	1.96	13.98	23.72	6.25
Lytle Creek	8	4.32	2.67	1.74	1.35	0.54	0.04	0.01	0.03	0.17	0.48	1.18	1.26	13.79	19.92	9.42
Redlands	72	2.59	2.65	2.51	1.23	0.60	0.09	0.05	0.20	0.29	0.78	1.02	2.24	14.25	22.42	6.23
San Bernardino	91	5.32	5.25	4.11	2.41	0.44	0.08	0.03	0.08	0.38	1.18	2.18	4.94	16.57	21.69	7.36
Upland	49	4.42	4.00	4.14	1.55	0.70	0.12	0.03	0.08	0.28	0.99	1.52	3.57	21.40	27.85	8.60
Riverside																
Anza	14	2.63	1.58	1.37	1.69	0.38	0.00	0.54	0.30	0.35	0.39	1.01	0.78	11.91	16.80	5.21
Elsinore	63	2.65	2.50	2.19	0.80	0.28	0.02	0.05	0.12	0.23	0.56	0.89	2.17	12.46	17.74	3.00
Hemet	20	2.05	1.59	1.61	1.04	0.19	0.03	0.12	0.20	0.20	0.59	1.11	1.53	10.26	18.05	5.36
Perris	6	3.82	0.87	1.63	0.94	0.42	T d)	0.06	0.02	0.18	0.04	1.23	1.48	10.69	19.67	3.52
Prado	10	3.75	1.93	1.70	1.43	0.22	0.02	0.10	0.12	0.09	0.29	1.11	1.56	12.32	19.53	4.42
Riverside	81	2.09	2.09	1.99	0.88	0.37	0.04	0.03	0.15	0.16	0.57	0.76	1.81	10.94	17.12	4.70
San Jacinto	70	2.44	2.39	2.27	1.20	0.41	0.05	0.10	0.19	0.24	0.72	1.03	1.94	12.98	19.15	5.39
(Southeast Desert Air Basin)																
Indio	84	0.66	0.44	0.27	0.11	0.04	0.01	0.07	0.26	0.29	0.20	0.22	0.57	3.14	6.46	0.41

a) Annual averages, maximums and minimums are calendar years.
b) Period of record.
c) Reported maximums and minimums may not include entire period of record.
d) Trace - less than 0.01 inches.

mountain stations, the driest year of record was at Elsinore with a three-inch total rainfall and the wettest year in the Basin (excluding the mountains) was recorded at Burbank where 37.52 inches fell in a single calendar year.

Rainfall and Air Quality

The influence of rainfall on contaminant levels in the Basin is minimal. Although some wash-out of pollution would be expected with winter rains, air masses that bring precipitation of consequence are very unstable and provide excellent dispersion that masks any wash-out effects.

Summer thunderstorm activity affects pollution only to a limited degree. If the inversion is not broken by a major weather system, high contaminant levels can persist even in areas of light showers. On the other hand, heavy cloud shields associated with outbreaks of tropical air minimize ozone production because of inadequate sunshine.

An example of the limited influence of summer storms and precipitation have on air quality in the Basin was the unusual tropical storm of August, 1977. Beginning August 16, rain was recorded over three days as tropical air moved into the Basin from the south. The rain total was 2.26 inches with more than two inches of that falling on the second day, the seventeenth. The daily maximum one-hour average ozone level at the Azusa air monitoring station on the fifteenth was 0.29 ppm. With the advent of the storm, the ozone fell to 0.05 ppm on the following day and to 0.02 ppm on the seventeenth. On the eighteenth, the day the storm was moving out of the Basin, the inversion was reestablished and the ozone peaked at 0.19 ppm, one-hour average, and 0.26 ppm on the nineteenth, the day after the storm had passed. Thus, with the heaviest August rainfall in the Los Angeles County portion of the Basin in nearly a century of records, the summer smog regime was disrupted for only two days.

CLOUDINESS AND SOLAR RADIATION

Early records of solar radiation measurements in California were tied to the farming industry. Plant growth and evaporation are directly related to the amount of sunshine received and determine irrigation requirements. During the last few decades, solar radiation data have been applied to air pollution research, principally photochemistry. More recently, with emphasis on renewable energy sources, solar radiation has been measured and studied to further its application to solar energy systems. Although cloudiness and solar radiation records for the South Coast Air Basin are not as extensive as records for other climatological elements, they do include seasonal and annual data for several locations. (5)

Radiation

Radiation moves from the sun to the surface of the earth largely unimpaired; the loss in space is near zero while our atmosphere absorbs and scatters only about twenty percent of the total. Solar radiation can be measured in several ways. The number of clear and partly cloudy days provides a gross estimate; calculating the percentage of possible sunshine is more precise; the most accurate method is to measure the energy received. The common energy measurement unit for radiation is the langley, one gram-calorie per square centimeter.

The amount of radiation reaching the top of the atmosphere is termed the solar constant and is slightly less than two (1.940) langleys per minute. For the South Coast Air Basin, based on a latitude of thirty-four degrees north, the average extraterrestial radiation is 720 langleys per day; the range is from 414 in December to 980 langleys in June. Of this potential influx, about fifty-eight percent is received in the Basin. In contrast, the eastern desert area (SEDAB) receives about seventy percent.

Figure 9 illustrates the seasonal variation in langleys by showing the radiation received in Downtown Los Angeles on two clear days in December and June, 1967. On December 21, sixty-eight percent of the total radiation was received, and on June 27, the percentage was seventy-eight. However, only 280 langleys were measured on the December day, while 762 langleys were recorded on the June day. The effectiveness of a heavy cloud deck in preventing solar radiation from reaching the surface is apparent, since on a cloudy day in June of the same year, only 136 langleys, or fourteen percent of the total incoming radiation, was received.

Climatological Radiation Data

Table IX lists the average daily solar radiation in the Basin by month and year for nine locations. This table was extracted from data compiled by the California Department of Water Resources.[5] Caution should be exercised when using the table, since the years of record are not the same for all stations, and secondly, data from individual measuring instruments may vary. Pyranometers, the instruments used to measure radiation are subject to deterioration of the sensing elements with time, and the simple fact that failure to remove dust regularly from the glass covering the sensor will reduce the radiation recorded. The pyranometer measures the total radiation reaching the earth, direct and diffuse.

The table shows that Newhall and Riverside, locations subject to less fog and stratus than stations nearer the coast, received the highest solar radiation in the Basin. For comparison, El Centro data were included. The annual daily average langleys received in the desert was 512, sixteen percent above the Basin average of 428 langleys. The rainy northern California coast measures an average of about 300 langleys daily.

Cloudiness and Sunshine

Sunrise and sunset are defined as the times the upper edge of the sun's disk appears to be exactly on the horizon. Table X lists times of sunrise and sunset at Los Angeles for

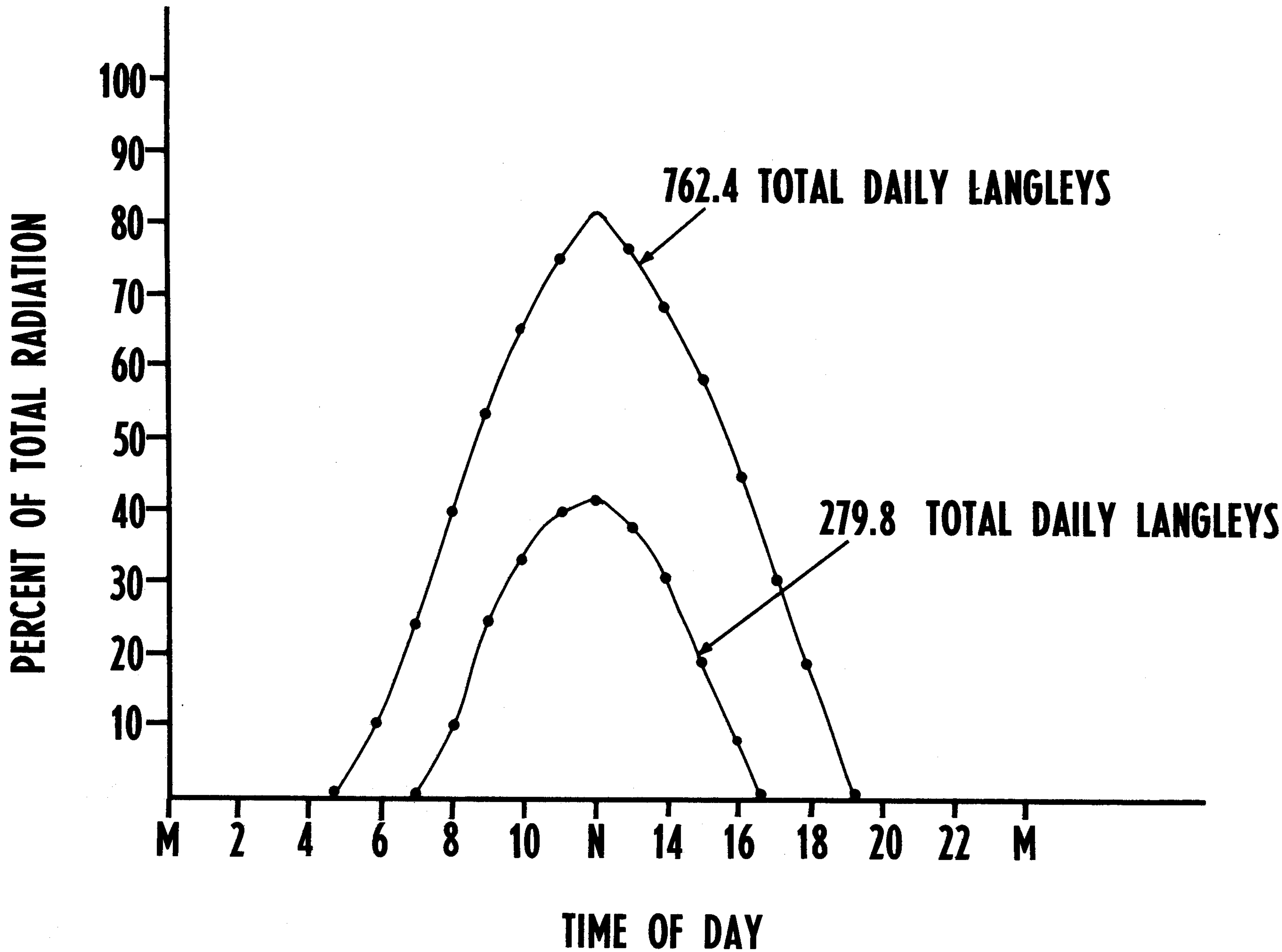

Figure 9 illustrates the difference in total langleys received in Los Angeles on clear days in January (lower curve) and June (upper curve).

TABLE IX

AVERAGE DAILY SOLAR RADIATION - SOUTH COAST AIR BASIN

LOCATION	YEARS OF RECORD	MONTHLY AVERAGE RADIATION[a] J	F	M	A	M	J	J	A	S	O	N	D	ANNUAL AVERAGE
El Segundo	2	304	307	484	536	508	650	515	544	354	373	306	269	429
Huntington Beach	2	298	305	467	525	529	628	515	600	342	381	307	269	431
(Laguna) Bell	2	317	325	493	482	509	631	551	584	313	346	280	242	423
Long Beach	7	238	282	378	466	477	496	505	453	347	281	238	196	363
Los Angeles (LAX)	26	254	343	455	540	579	581	644	584	484	368	282	238	446
Los Angeles (Downtown)	23	253	332	424	526	542	566	653	592	484	362	276	237	437
(Pardee) Newhall	2	306	305	479	516	604	688	638	600	377	391	307	281	458
Riverside	41	264	346	445	522	581	628	638	583	441	372	297	243	451
Walnut	2	283	272	428	476	500	631	554	575	323	355	287	253	411
El Centro (SEDAB)	7	311	388	495	629	694	710	644	617	549	470	346	290	512

a) Radiation in langleys - one langley is equal to one calorie per square centimeter.

TABLE X

SUNRISE AND SUNSET AT LOS ANGELES, CALIFORNIA
PACIFIC STANDARD TIME

DAY	JAN. Rise A.M.	JAN. Set P.M.	FEB. Rise A.M.	FEB. Set P.M.	MAR. Rise A.M.	MAR. Set P.M.	APR. Rise A.M.	APR. Set P.M.	MAY Rise A.M.	MAY Set P.M.	JUNE Rise A.M.	JUNE Set P.M.	JULY Rise A.M.	JULY Set P.M.	AUG. Rise A.M.	AUG. Set P.M.	SEPT. Rise A.M.	SEPT. Set P.M.	OCT. Rise A.M.	OCT. Set P.M.	NOV. Rise A.M.	NOV. Set P.M.	DEC. Rise A.M.	DEC. Set P.M.
1	6 59	4 55	6 50	5 23	6 22	5 49	5 41	6 14	5 04	6 37	4 43	6 59	4 45	7 08	5 04	6 54	5 26	6 19	5 47	5 38	6 12	5 00	6 40	4 44
2	6 59	4 55	6 50	5 24	6 21	5 50	5 39	6 14	5 03	6 37	4 42	7 00	4 45	7 08	5 05	6 53	5 27	6 18	5 48	5 36	6 13	4 59	6 41	4 44
3	6 59	4 56	6 49	5 25	6 20	5 51	5 38	6 15	5 02	6 38	4 42	7 00	4 46	7 08	5 05	6 52	5 28	6 16	5 49	5 35	6 14	4 59	6 42	4 43
4	6 59	4 57	6 48	5 26	6 18	5 52	5 37	6 16	5 01	6 39	4 42	7 01	4 46	7 08	5 06	6 51	5 28	6 15	5 49	5 33	6 15	4 58	6 43	4 43
5	6 59	4 58	6 47	5 27	6 17	5 52	5 35	6 17	5 00	6 40	4 42	7 01	4 47	7 08	5 07	6 50	5 29	6 14	5 50	5 32	6 16	4 57	6 44	4 43
6	6 59	4 59	6 46	5 28	6 16	5 53	5 34	6 17	4 59	6 40	4 41	7 02	4 47	7 08	5 08	6 49	5 30	6 12	5 51	5 31	6 17	4 56	6 44	4 43
7	6 59	4 59	6 46	5 29	6 14	5 54	5 33	6 18	4 58	6 41	4 41	7 02	4 48	7 07	5 08	6 48	5 30	6 11	5 52	5 29	6 18	4 55	6 45	4 44
8	6 59	5 00	6 45	5 30	6 13	5 55	5 31	6 19	4 57	6 42	4 41	7 03	4 48	7 07	5 09	6 47	5 31	6 10	5 52	5 28	6 19	4 54	6 46	4 44
9	6 59	5 01	6 44	5 31	6 12	5 56	5 30	6 20	4 56	6 43	4 41	7 03	4 49	7 07	5 10	6 46	5 32	6 08	5 53	5 27	6 20	4 54	6 47	4 44
10	6 59	5 02	6 43	5 32	6 11	5 57	5 29	6 20	4 55	6 44	4 41	7 04	4 49	7 07	5 10	6 45	5 32	6 07	5 54	5 25	6 21	4 53	6 48	4 44
11	6 59	5 03	6 42	5 33	6 09	5 57	5 27	6 21	4 55	6 44	4 41	7 04	4 50	7 06	5 11	6 44	5 33	6 05	5 55	5 24	6 22	4 52	6 48	4 44
12	6 59	5 04	6 41	5 34	6 08	5 58	5 26	6 22	4 54	6 45	4 41	7 05	4 51	7 06	5 12	6 43	5 34	6 04	5 55	5 23	6 23	4 51	6 49	4 44
13	6 59	5 05	6 40	5 35	6 07	5 59	5 25	6 23	4 53	6 46	4 41	7 05	4 51	7 06	5 13	6 42	5 35	6 03	5 56	5 22	6 23	4 51	6 50	4 45
14	6 59	5 06	6 39	5 36	6 05	6 00	5 24	6 23	4 52	6 47	4 41	7 05	4 52	7 05	5 13	6 41	5 35	6 01	5 57	5 20	6 24	4 50	6 50	4 45
15	6 58	5 07	6 38	5 37	6 04	6 01	5 22	6 24	4 52	6 47	4 41	7 06	4 52	7 05	5 14	6 40	5 36	6 00	5 58	5 19	6 25	4 49	6 51	4 45
16	6 58	5 08	6 37	5 38	6 02	6 01	5 21	6 25	4 51	6 48	4 41	7 06	4 53	7 04	5 15	6 39	5 37	5 58	5 59	5 18	6 26	4 49	6 52	4 45
17	6 58	5 09	6 36	5 39	6 01	6 02	5 20	6 26	4 50	6 49	4 41	7 06	4 54	7 04	5 16	6 38	5 37	5 57	5 59	5 17	6 27	4 48	6 52	4 46
18	6 58	5 10	6 35	5 39	6 00	6 03	5 19	6 26	4 49	6 50	4 41	7 07	4 54	7 04	5 16	6 37	5 38	5 56	6 00	5 15	6 28	4 48	6 53	4 46
19	6 57	5 10	6 34	5 40	5 58	6 04	5 17	6 27	4 49	6 50	4 41	7 07	4 55	7 03	5 17	6 35	5 39	5 54	6 01	5 14	6 29	4 47	6 53	4 47
20	6 57	5 11	6 33	5 41	5 57	6 04	5 16	6 28	4 48	6 51	4 42	7 07	4 56	7 02	5 18	6 34	5 39	5 53	6 02	5 13	6 30	4 47	6 54	4 47
21	6 57	5 12	6 32	5 42	5 56	6 05	5 15	6 29	4 48	6 52	4 42	7 07	4 56	7 02	5 18	6 33	5 40	5 51	6 03	5 12	6 31	4 46	6 55	4 48
22	6 56	5 13	6 30	5 43	5 54	6 06	5 14	6 30	4 47	6 52	4 42	7 08	4 57	7 01	5 19	6 32	5 41	5 50	6 04	5 11	6 32	4 46	6 55	4 48
23	6 56	5 14	6 29	5 44	5 53	6 07	5 13	6 30	4 46	6 53	4 42	7 08	4 58	7 01	5 20	6 31	5 41	5 49	6 04	5 10	6 33	4 46	6 56	4 49
24	6 55	5 15	6 28	5 45	5 52	6 07	5 12	6 31	4 46	6 54	4 42	7 08	4 58	7 00	5 21	6 29	5 42	5 47	6 05	5 09	6 34	4 45	6 56	4 49
25	6 55	5 16	6 27	5 46	5 50	6 08	5 10	6 32	4 45	6 55	4 43	7 08	4 59	6 59	5 21	6 28	5 43	5 46	6 06	5 07	6 35	4 45	6 56	4 50
26	6 54	5 17	6 26	5 47	5 49	6 09	5 09	6 33	4 45	6 55	4 43	7 08	5 00	6 59	5 22	6 27	5 44	5 44	6 07	5 06	6 36	4 45	6 57	4 50
27	6 54	5 18	6 24	5 47	5 47	6 10	5 08	6 33	4 44	6 56	4 43	7 08	5 00	6 58	5 23	6 26	5 44	5 43	6 08	5 05	6 37	4 44	6 57	4 51
28	6 53	5 19	6 23	5 48	5 46	6 11	5 07	6 34	4 44	6 56	4 44	7 08	5 01	6 57	5 23	6 24	5 45	5 42	6 09	5 04	6 37	4 44	6 58	4 52
29	6 52	5 20	6 23	5 49	5 45	6 11	5 06	6 35	4 44	6 57	4 44	7 08	5 02	6 56	5 24	6 23	5 46	5 40	6 10	5 03	6 38	4 44	6 58	4 52
30	6 52	5 21			5 43	6 12	5 05	6 36	4 43	6 58	4 45	7 08	5 03	6 56	5 25	6 22	5 46	5 39	6 11	5 02	6 39	4 44	6 58	4 53
31	6 51	5 22			5 42	6 13			4 43	6 58			5 03	6 55	5 26	6 20			6 11	5 01			6 58	4 54

each day of the year. Deviations of a few minutes, varying with distance from central city, will result when this table is applied to the entire Basin. The table shows that on the shortest day, there are about ten hours (9:53) of possible sunshine and about fourteen and one-half hours (14:26) on the longest day of the year.

Figure 10 shows the altitude of the sun above the horizon by hour of the day for the twenty-first day of each month at latitude 34°N. The sun angle, as well as duration of sunlight, determines seasonal radiation received at the surface of the earth. Both are important to photochemistry and to solar heating and cooling. Los Angeles receives seventy-three percent of possible sunshine. This is about midway between the fifty percent received in the rainy northwest coast of California and the ninety-one percent received in the desert at Yuma.

The percentage of cloud cover during daylight hours varies from forty-seven at Los Angeles International Airport to thirty-five percent at Sandberg, a mountain location. The number of clear days also increases with distance from the coast; 144 days at LAX and 187 days at Burbank. Finally, the data in Table XI reveal that during the first six months of the year, the Basin receives much less sunshine than during the remainder of the year. This is attributed to the greater frequency of deep marine layers and the subsequent increase in stratus clouds during the spring and to the fact that the rainy season begins late in the year, November, and continues through early spring.

Radiation and Air Quality

The abundance of sunshine in the Basin coupled with a persistent marine layer and light winds provide an ideal environment for photochemical smog. Photochemical reactions begin with absorption of radiation, visible or ultraviolet. The absorbed radiation causes dissociation of molecules into free radicals or atoms. These products then take part in secondary reactions and can lead to other reactions.[34]

The production of ozone in the lower atmosphere of the Basin is a paramount air pollution problem. Ultraviolet radiation is required for the photochemical reaction that produces ozone. Unfortunately, there is no extensive data bank of ultraviolet radiation measurements in the Basin, especially in the radiation band that affects the production of ozone. There is a gross relationship between visible sunshine and ultraviolet radiation in that a heavy cloud cover will retard the formation of ozone, even during the summer; and with clear skies during the winter, weak radiation limits ozone production.

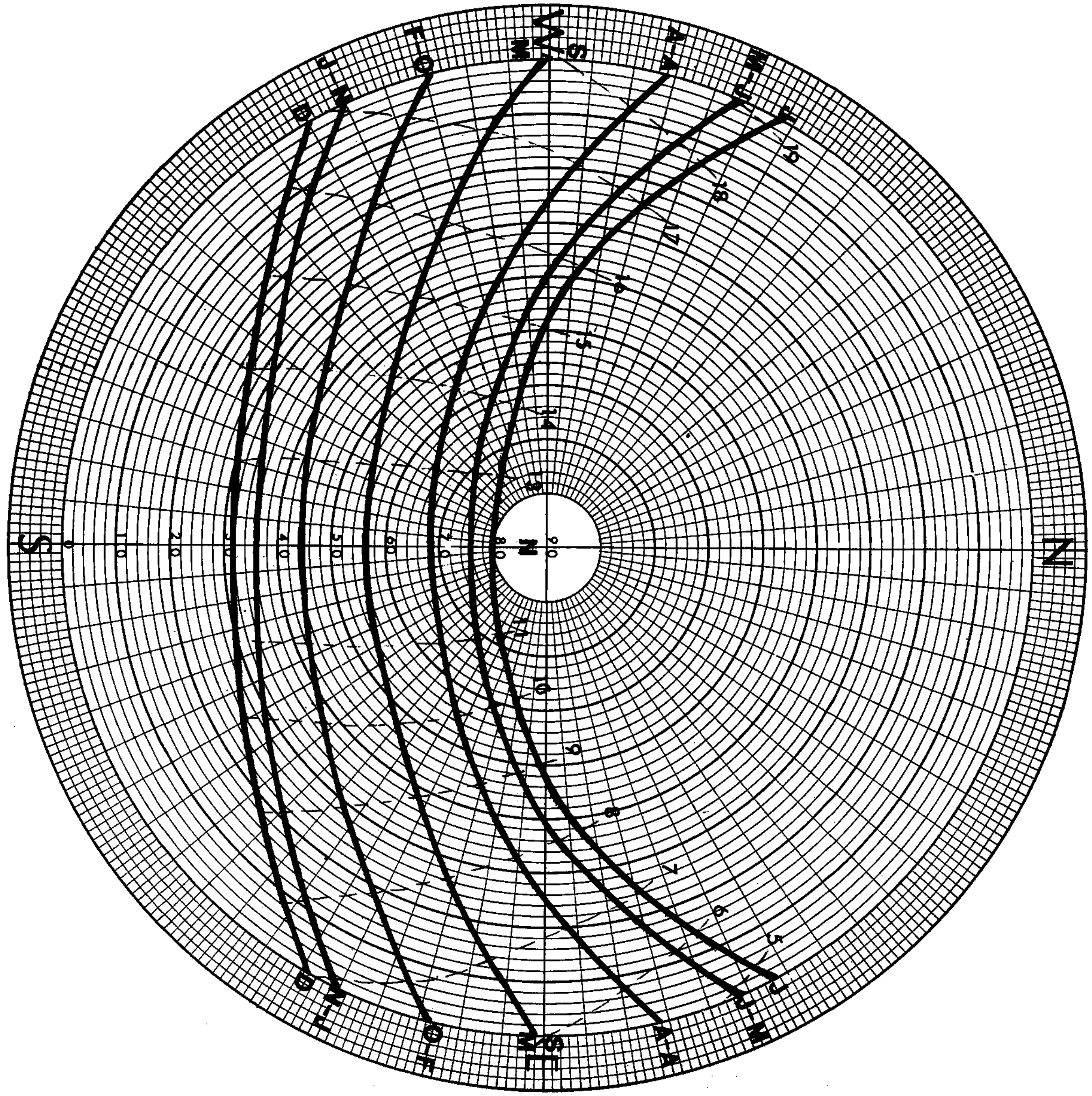

Figure 10 diagrams the altitude of the sun above the horizon in degrees by hour of the day for the twenty-first day of each month at Latitude 34 degrees North. Numbers shown are Pacific Standard Times.

TABLE XI

CLOUDINESS, SUNSHINE - SOUTH COAST AIR BASIN

Station	Yrs. of Record	Element	J	F	M	A	M	J	J	A	S	O	N	D	Annual Total/Average
Burbank	17	Clouds[a] %	51	47	50	51	46	38	23	25	26	37	41	44	40%
	34	Days - Clear[b]	14	12	13	12	13	15	21	21	19	17	16	14	187 Days
		Partly Cloudy[c]	8	7	8	9	11	10	9	8	9	8	8	7	102 Days
		Cloudy[d]	9	9	10	9	7	5	1	2	2	6	6	10	76 Days
Long Beach	21	Clouds %	52	53	53	44	50	47	33	32	40	45	48	49	45%
	21	Days - Clear	12	10	11	13	11	11	18	19	14	13	13	12	157 Days
		Partly Cloudy	8	7	10	10	12	13	11	10	11	12	8	9	121 Days
		Cloudy	11	11	10	7	8	6	2	2	5	6	9	10	87 Days
Los Angeles (DT)[e]	34	Clouds %	44	47	47	47	49	43	27	26	30	38	37	42	40%
	34	Days - Clear	14	12	13	12	11	14	21	22	18	16	17	15	185 Days
		Partly Cloudy	8	7	9	10	12	10	9	8	9	9	7	8	106 Days
		Cloudy	9	9	9	8	8	6	1	1	3	6	6	8	74 Days
	32	Sunshine %	69	72	73	70	66	65	82	83	79	73	74	71	73%
Los Angeles (LAX)	30	Clouds %	52	51	51	48	52	52	40	39	42	45	45	47	47%
	43	Days - Clear	12	12	12	11	10	9	12	13	13	13	14	13	144 Days
		Partly Cloudy	8	5	8	9	11	11	13	12	10	10	8	8	113 Days
		Cloudy	11	11	11	10	10	10	6	6	7	8	8	10	108 Days
Sandberg	27	Clouds %	51	52	52	44	35	18	15	14	17	29	42	51	35%

a) Sunrise to sunset
b) Zero to 0.3 of the sky obscured by clouds
c) 0.4 to 0.7 cloudiness
d) 0.8 to full cloud cover
e) Downtown Los Angeles

Pollutants in the air are affected by radiation and the reverse is also true. By increasing atmospheric turbidity, contaminants reduce the transparency of the air to radiation. In addition, ultraviolet radiation is absorbed by some contaminants; this absorption causes radiation to be reduced by as much as twenty percent in an intensely polluted layer. Oxygen molecules, ozone, nitrogen dioxide, sulfur dioxide and particulate matter absorb the upper ranges of ultraviolet light and visible light. Compounds such as hydrocarbons, carbon monoxide, nitric oxide, and water vapor do not. [28]

Apart from the photochemical aspect, radiation and contaminants act to produce other effects in the Basin atmosphere. The various colors of smog layers are produced by the scattering, reflection, and absorption of light. The brown cast is attributed to nitrogen dioxide. Haze, which usually is a combination of natural and man-made particles, subdues all colors and can give the air an opalescent appearance. Dry haze, or haze composed of very fine particles, will appear blue against a dark background and yellowish against a light background. When haze particles grow by the condensation of water on the tiny particles, the resultant visibility restrictor is termed "mist", and produces an overall gray color, as does fog. [18] A discussion of visibility in the Basin is found later in this text.

(NO TEXT, THIS PAGE)

WIND

During the late-autumn to early-spring rainy season, the South Coast Air Basin is subjected to wind flows associated with traveling storms moving through the area from the northwest. This period also brings a few days of strong Santa Ana winds each year. But during the dry season that coincides with the months of maximum photochemical smog concentrations, the wind flow is quite patterned, typified by a daytime sea breeze and a night-time land breeze. This daily reversing flow also predominates during the other seasons, although it is not as persistent, day-to-day, as during the summer.

Ordinarily, the sea breeze is about twice as strong as the return flow (the drainage land breeze) and lasts longer during the warm months. The land breeze begins along the mountain slopes shortly after sunset during the winter, while on most summer nights the onset is after midnight. The winter drainage wind is a well-organized flow as it moves to the ocean; the summer counterpart is light and tends to meander towards the coast.

Wind Patterns

Figures 11 through 14 show the most frequent Basin wind flows at 0100 PST and 1200 PST during January and July. Similar wind data for the entire year, a complete report of hourly wind flow patterns for each month are available in a South Coast Air Quality Management District publication.[22]

In Figure 11, a well-developed winter offshore pattern is evident. Winds are flowing southward from the San Gabriel and Santa Monica Mountains and seaward from the Santa Ana Mountains. The flow into the San Fernando Valley is from the surrounding mountains and thence eastward through the passes into the coastal plain. Wind speeds shown on the map are long-term averages for the depicted hour and direction and range from two to eight miles per hour.

Figure 12 shows the noon January sea breeze in the Basin blowing opposite in direction from the night-time flow. Speeds range from four to eight miles per hour and are slightly faster than the average land breeze shown on the previous figure. An interesting anomaly in the pattern is the strong northerly flow in the western half of the San Fernando Valley. During the winter months, a frequent daytime wind is a northerly flow through Newhall Pass into the western Valley. In January this flow predominates from 1100 to 1700 PST. The speeds, up to twelve miles per hour, are higher than average winds from other directions because they reflect the influence of Santa Ana winds that are strongest during those hours of the day and are in phase directionally.

Figure 13 illustrates the beginning of the drainage flow at 0100 PST during July. The sea breeze is still intact in the western part of the Basin, but the wind has begun to blow down the slopes of the mountains and hills in response to radiational cooling. Except at Malibu, the wind speeds are light--two to five miles per hour. Although this is the most frequent pattern, on many July days the onshore winds continue throughout the night.

Figure 14 shows the well-developed sea breeze at noon in July. The average speeds are up to twelve miles per hour, much stronger than the night-time land breeze. As the afternoon progresses, the flow increases in speed and becomes more westerly except over the Santa Monica Mountains and the San Fernando Valley, where a definite southerly component is retained.

Summer wind flows are created by the pressure differences between the relatively cold ocean and the unevenly heated and cooled land surfaces that modify the general northwesterly wind circulation over Southern California. In turn, the wind

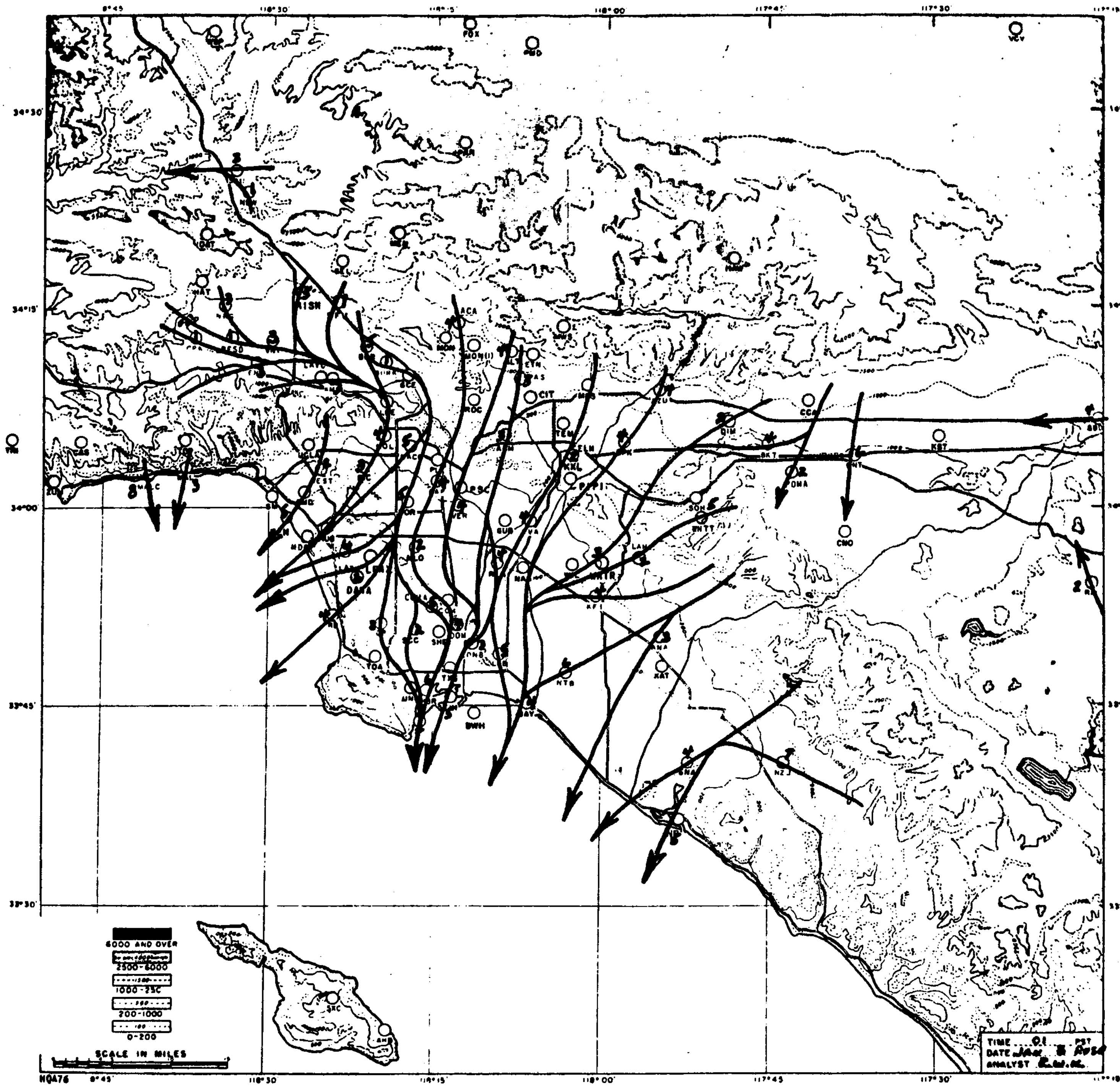

Figure 11 shows the most frequent Basin wind flow during January at 0100PST. Figures on the map are average wind speeds, in miles per hour, for given wind directions.

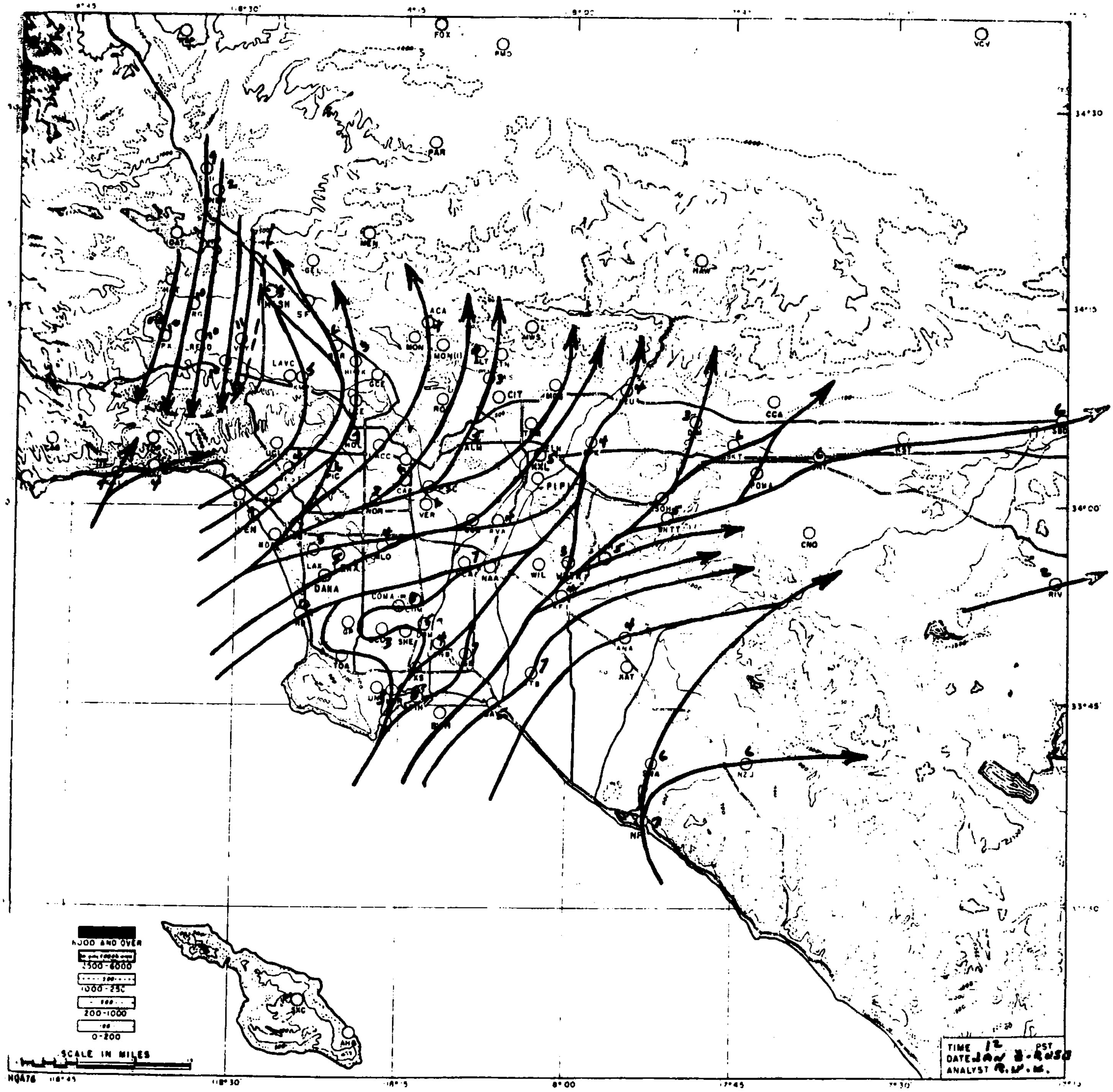

Figure 12 shows the most frequent Basin wind flow during January at 1200PST. Figures on the map are average wind speeds in miles per hour for given wind directions.

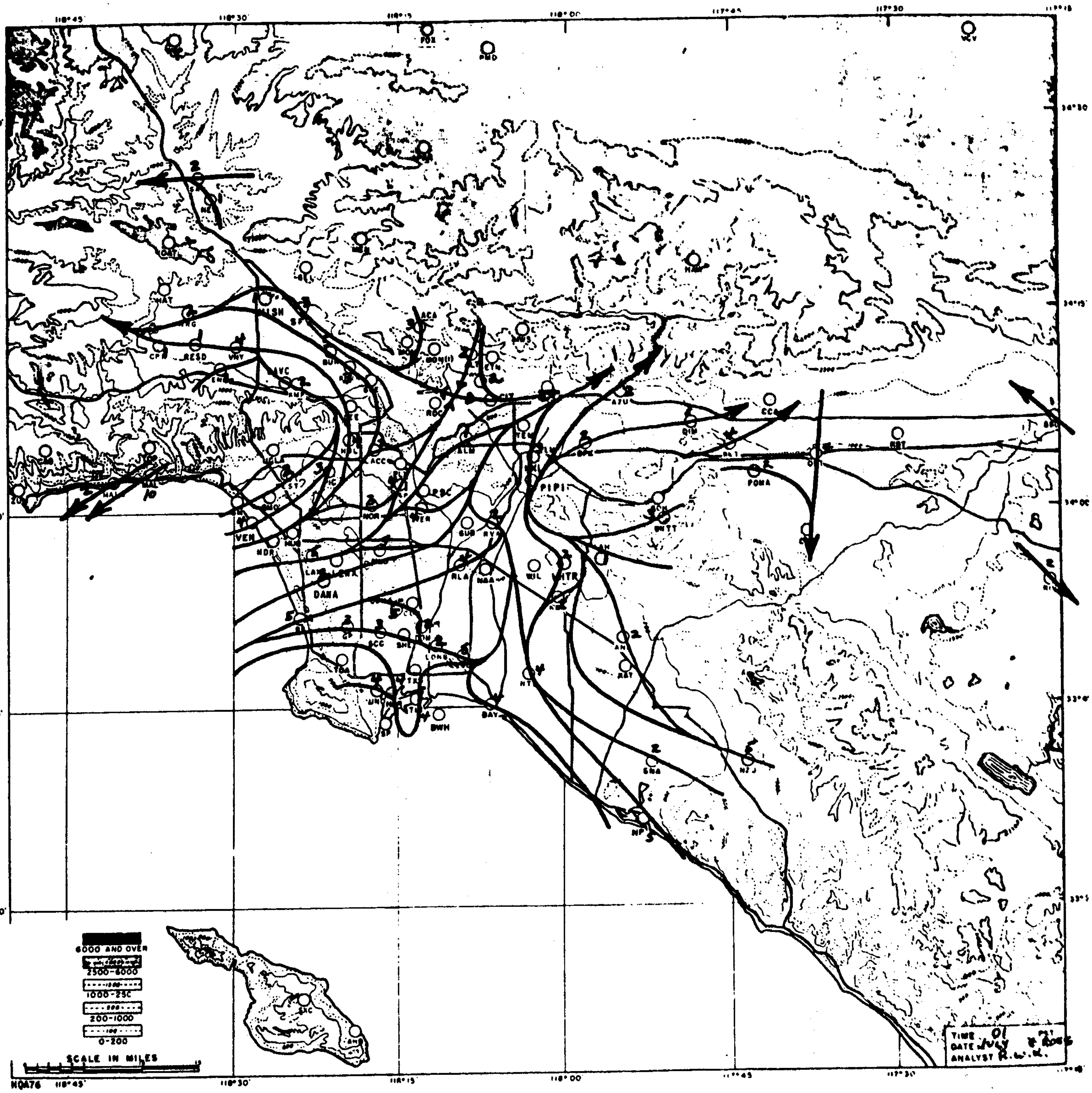

Figure 13 shows the most frequent Basin wind flow during July at 0100PST. Figures on the map are average wind speeds in miles per hour for given wind directions.

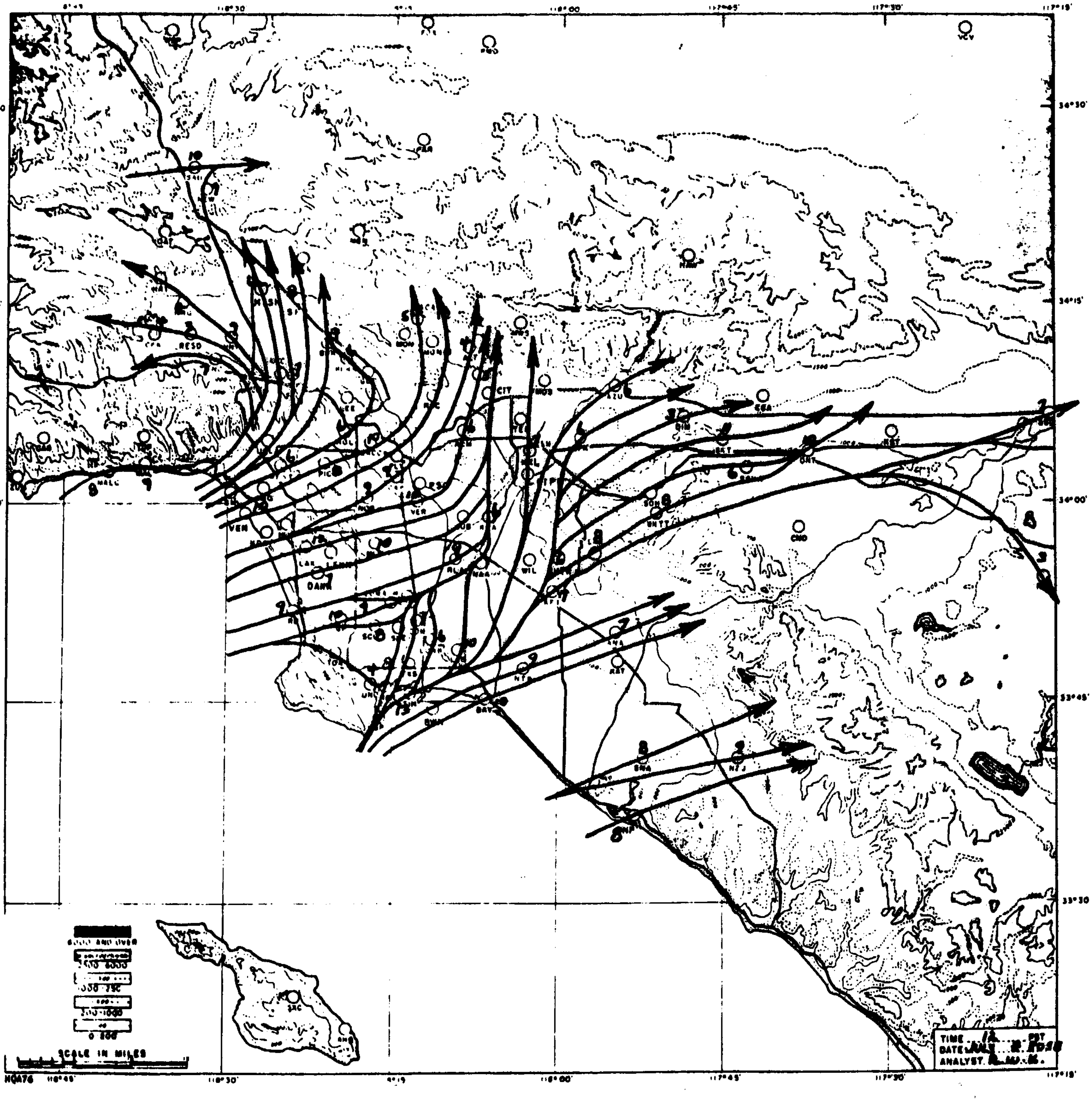

Figure 14 shows the most frequent Basin wind flow during July at 1200 PST. Figures on the map are average wind speeds in miles per hour for given wind directions.

field is affected by terrain. The mountains bordering the Basin act as barriers to the wind, while canyons and passes channel and accelerate the wind flow.

As shown by the figures above, night-time drainage begins with the radiational cooling of the mountain slopes; the heavy, cool air descends the slopes and goes through passes and canyons as it follows the lowering terrain toward the ocean. The process is analogous to a mountain water-shed effect. The stronger sea breeze is affected to a lesser degree by low rises, such as the Baldwin Hills, and blows over them with little deflection. But, unless the marine layer is very deep, the sea breeze is split around the hills on the Palos Verdes Peninsula. The San Gabriel Mountains partially deflect strong sea breezes, but there is also transport up and over the mountain slopes.

Another important terrain effect on air flow was discussed earlier: the chimney effect wherein mountains act to disperse polluted air masses. More effective vehicles for transporting pollution out of the Basin are the major passes. Newhall Pass, Cajon Pass, and Beaumont Pass (also referred to as San Gorgonio Pass or Banning Pass) are the main avenues through which air is funnelled out of the coastal plain. Lancaster, Victorville, and Palm Springs, respectively, are immediate receptor areas for pollution generated in the South Coast Air Basin and transported through the principal passes (mentioned above) during the summer smog season.

Convergence Zones

The presence of the Santa Monica Mountains, running east-west along the coast in the extreme westerly border of the Basin, creates still another variation in the sea breeze-land breeze regime: the San Fernando Valley convergence zone. (10, 12) During summer and fall, the normal morning onshore flow in the Valley is southeasterly; but in the afternoon, the westerly sea breeze from the Oxnard Plain penetrates the western portion of the Valley; the confrontation of these two flows creates a convergence zone where the air is pumped aloft. This north-south zone is found in different parts of the Valley on specific days, but there is a gradual eastward movement during each day, although the zone rarely moves to the eastern portion of the Valley. Canoga Park experiences a west flow eighty percent of the afternoons; Burbank, five percent. The zone is marked by a contrast in air masses with relatively clean air coming from the west and greater pollution and lower visibilities brought in by the southeast flow. With general, strong, easterly or southeasterly winds this convergence zone does not form.

A similar zone is found in western Riverside County where northwesterly flows from the Basin meet southerly and southeasterly flows to form the Elsinore convergence zone. The south wind originates in San Diego County and is essentially a modified sea breeze; the northwest flow is also ocean air that has moved through Santa Ana Canyon, then southward into the Elsinore area. This convergence zone is familiar to sailplane pilots who use it as a reliable source of lift.

Santa Ana Winds

Five to ten times a year, Southern California is subjected to strong foehn winds locally termed "Santa Anas." The duration of each occurrence can vary from a few hours to several days. Foehn winds, downslope flows that are warmed by compression as they descend a mountainside, are common to all major mountain ranges. Foehn winds are the result of a large-scale atmospheric circulation that is strong enough and deep enough to force air completely over a mountain range in a short period of time. South Coast Air Basin Santa Ana winds occur when a large high pressure system builds over the plateau (Great Basin) area of Nevada and Utah and spreads southward over the Mojave Desert. The clockwise wind circulation in the system produces a north or northeast flow as the air is pushed southward over the San Gabriel and San Bernardino Mountains and funnelled through the passes.

Because daily solar heating is strong in the plateau during the summer, strong persistent high pressure systems do not build in the Great Basin and Santa Ana winds are very rare during that season. The importance of these winds to air quality is that when they occur, during the spring or fall, they are often preceded or followed by periods of widespread stagnation. With very light winds throughout the Basin, horizontal dispersion is limited and contaminant concentrations rise. Additionally, when foehn winds not strong enough to be termed Santa Anas occur, the flushing effect of the daily sea breeze is dampened and restricted dispersion results.

Edinger [13] has defined a local foehn wind as a Santa Ana when specific conditions are met: an offshore pressure gradient from the Antelope Valley to the coast, cool temperatures in the upper desert, north winds in the San Fernando Valley ten miles per hour or greater, north winds in the Riverside-San Bernardino area thirty miles per hour or greater, and the relative humidity in Los Angeles thirty percent or less. While the definition shows the minimum wind speeds in a Santa Ana, the maximum winds are undefined--sustained winds of sixty miles per hour with higher gusts are not uncommon. Blowing dust and sand usually accompany these strong winds. Table XII lists extreme annual wind speeds at several Basin locations. (4, 15). Some of the strongest winds each year may be caused by winter storms, but the far greater number of occurrences is associated with Santa Anas.

Although each Santa Ana has individual characteristics, these strong winds generally conform to a pattern. Two mountain passes that expedite the movement of air out of the Basin with the sea breeze also channel Santa Ana winds into the Basin. In the west, strong northerly winds move through Newhall Pass into the San Fernando Valley, then follow the canyons through the Santa Monica Mountains to the sea. At the eastern part of the Basin, the northerlies pour through Cajon Pass then follow the Santa Ana River in a southwestward direction to the coast. Between the two strong flows are light winds in the (lee) wind shadow of the San Gabriel Mountains where ordinarily the Santa Anas do not surface. Often winds in this area are onshore, blowing in a direction opposite to the strong northeasterly winds at higher levels.

Santa Ana winds can persist from several hours to a few days. The highest speeds occur during the afternoon; this happens because of daytime thermal convection caused by surface heating. The convection brings about a downward transfer of momentum from stronger winds aloft.

<u>Catalina Eddy</u>

Another characteristic wind regime in the Basin and one that occurs much more frequently than the Santa Ana winds is the "Catalina Eddy", a low-level cyclonic flow centered over Santa Catalina Island. The orographic effect of the coastal mountain range that lies more or less on a west-east line from Point Conception to Santa Monica Bay is a deflection of the northerly winds around the point and a resultant counterclockwise flow over the ocean to the southeast.

On most spring and summer days, some indication of an eddy is apparent in coastal sections, especially during the morning hours when the seabreeze is southerly from San Pedro southeastward along the Orange County coast. However, the afternoon westerly sea breeze wipes out any indications of an eddy flow. A strong Catalina Eddy, on the other hand, persists much longer and can last for an entire day or several days. This eddy forms ahead of an approaching trough or weak cold front and causes Basin coastal winds to back to the southeast; this backing is seen as far south as San Diego, where the normal northwest sea breeze now blows from the south or southwest.

TABLE XII

EXTREME ANNUAL WIND SPEEDS - SOUTH COAST AIR BASIN

Station	Years of Record	Peak Gusts[a)]			Fastest Mile[b)]		
		Low	High	Average[c)]	Low	High	Average
El Toro	30	41	81	58			
Los Alamitos	21	40	62	49			
Los Angeles (LAX)	15	36	62	50			
Riverside (March)	19	36	56	45			
San Bernardino (Norton)	26	41	79	57			
Long Beach	18				18	44	34
Los Angeles (Downtown)	36				-	49	-
Los Angeles (LAX)	25				35	62	46
Sandberg[d)]	25				46	97	65

a) Miles Per Hour
b) The daily fastest speed, in miles per hour, of any "mile" of wind.
c) Average of highest gust each year for the period of record.
d) Mountain location

Due to the convergent flow associated with the Catalina Eddy, the effect on the persistent inversion in the Basin is a fairly rapid lifting. When a strong eddy flow is established in the western half of the Basin, the winds are southerly or southeasterly; and in the remainder of the Basin, in areas where the sea breeze is ordinarily westerly, the sea breeze acquires a southerly component. With the Catalina Eddy and the deepening marine layer, subsidence is at a minimum.

Climatological Wind Data

The importance of wind to air pollution concentrations is considerable. Just as the inversion base limits vertical dispersion of contaminants, the direction and speed of the wind determines horizontal dispersion and transport. Table XIII presents average annual wind data for several Basin stations, showing the percentage of time the wind blows from each of the sixteen cardinal compass points and the average speed for each direction.

More detailed wind rose information is available from District records in the form of wind rose printouts for more than fifty Basin stations. For example: Figure 15 is a wind rose for Station 13W, Los Angeles International Airport, for the month of August. The first portion of the figure lists the frequency of occurrence of winds from sixteen compass points for each hour of the day; the second lists the average speed in miles per hour for each direction. Annual as well as monthly wind roses are available. Wind roses are based upon the entire period of record for each location.

In general, coastal stations have higher average speeds than inland locations because of stronger sea breezes, with exceptions in the case of mountain passes and some mountain locations. Another exception is Ontario, in the extreme western portion of San Bernardino County, where the annual average wind speed is as strong as those at coastal sites. See Table XIII. One reason for this is the strong afternoon sea breeze caused by funnelling through the Pomona-Walnut Valley and convergence as the air mass is deflected to the east by the higher terrain of the foothills to the north.

The Los Angeles smog problem is aggravated by the absence of strong winds to ventilate the Basin on most days, particularly when combined with the strong, persistent temperature inversions of the warm seasons. Table XIV shows that the city of Los Angeles has the second lowest average wind speeds among major metropolitan area in the United States, only Phoenix being lower. (17) Because central Los Angeles, a source area for primary pollutants, has light winds on most days,

08/01--08/31 FOR 1955-1977 F=FREQUENCY P=PERCENT STATION 0134

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL	HR
35	6	7	11	35	22	24	39	49	40	49	140	181	55	41	26	760 F	00
4.6	.8	.9	1.4	4.6	2.9	3.2	5.1	6.4	5.3	6.4	18.4	23.8	7.2	5.4	3.4	100.0 P	
33	6	14	14	51	31	51	34	55	31	50	104	147	54	40	44	759 F	01
4.3	.8	1.8	1.8	6.7	4.1	6.7	4.5	7.2	4.1	6.6	13.7	19.4	7.1	5.3	5.8	100.0 P	
35	14	22	27	79	37	38	37	31	23	36	89	157	48	42	36	751 F	02
4.7	1.9	2.9	3.6	10.5	4.9	5.1	4.9	4.1	3.1	4.8	11.9	20.9	6.4	5.6	4.8	100.0 P	
39	23	22	32	99	41	34	23	37	22	19	74	152	44	47	45	753 F	03
5.2	3.1	2.9	4.2	13.1	5.4	4.5	3.1	4.9	2.9	2.5	9.8	20.2	5.8	6.2	6.0	100.0 P	
35	18	16	41	109	47	37	22	29	18	27	87	137	33	59	33	748 F	04
4.7	2.4	2.1	5.5	14.6	6.3	4.9	2.9	3.9	2.4	3.6	11.6	18.3	4.4	7.9	4.4	100.0 P	
37	13	27	59	108	64	46	19	33	21	27	52	126	44	42	26	744 F	05
5.0	1.7	3.6	7.9	14.5	8.6	6.2	2.6	4.4	2.8	3.6	7.0	16.9	5.9	5.6	3.5	100.0 P	
32	20	17	52	121	53	52	29	47	26	32	46	127	28	43	29	754 F	06
4.2	2.7	2.3	6.9	16.0	7.0	6.9	3.8	6.2	3.4	4.2	6.1	16.8	3.7	5.7	3.8	100.0 P	
35	21	25	38	90	67	67	35	54	36	32	75	90	37	41	20	763 F	07
4.6	2.8	3.3	5.0	11.8	8.8	8.8	4.6	7.1	4.7	4.2	9.8	11.8	4.8	5.4	2.6	100.0 P	
20	8	14	31	67	72	71	61	67	39	62	111	100	19	15	9	766 F	08
2.6	1.0	1.8	4.0	8.7	9.4	9.3	8.0	8.7	5.1	8.1	14.5	13.1	2.5	2.0	1.2	100.0 P	
8	4	2	14	28	52	59	46	59	27	70	188	168	22	13	3	763 F	09
1.0	.5	.3	1.8	3.7	6.8	7.7	6.0	7.7	3.5	9.2	24.6	22.0	2.9	1.7	.4	100.0 P	
2	3	1	4	8	17	24	19	25	23	96	305	219	21	3	1	771 F	10
.3	.4	.1	.5	1.0	2.2	3.1	2.5	3.2	3.0	12.5	39.6	28.4	2.7	.4	.1	100.0 P	
1	1	1		3	4	16	5	8	11	77	372	257	11		1	768 F	11
.1	.1	.1	ND	.4	.5	2.1	.7	1.0	1.4	10.0	48.4	33.5	1.4	ND	.1	100.0 P	
1		1		1	4	3	7	1	2	59	379	305	9	1		773 F	12
.1	ND	.1	ND	.1	.5	.4	.9	.1	.3	7.6	49.0	39.5	1.2	.1	ND	100.0 P	
			1	1	3	1		2	3	48	370	335	8			772 F	13
ND	ND	ND	.1	.1	.4	.1	ND	.3	.4	6.2	47.9	43.4	1.0	ND	ND	100.0 P	
					2	1	1			27	375	352	8	2	1	769 F	14
ND	ND	ND	ND	ND	.3	.1	.1	ND	ND	3.5	48.8	45.8	1.0	.3	.1	100.0 P	
						1	1		4	25	335	397	4			767 F	15
ND	ND	ND	ND	ND	ND	.1	.1	ND	.5	3.3	43.7	51.8	.5	ND	ND	100.0 P	
				1		1	1		2	16	327	418	3			769 F	16
ND	ND	ND	ND	.1	ND	.1	.1	ND	.3	2.1	42.5	54.4	.4	ND	ND	100.0 P	
				1		1	1	2	2	18	337	403	7			772 F	17
ND	ND	ND	ND	.1	ND	.1	.1	.3	.3	2.3	43.7	52.2	.9	ND	ND	100.0 P	
				1					1	28	340	390	10			770 F	18
ND	ND	ND	ND	.1	ND	ND	ND	ND	.1	3.6	44.2	50.6	1.3	ND	ND	100.0 P	
				1			1	5	8	48	312	378	14	1	2	770 F	19
ND	ND	ND	ND	.1	ND	ND	.1	.6	1.0	6.2	40.5	49.1	1.8	.1	.3	100.0 P	
1		1				1	6	14	16	70	316	304	33	6	4	772 F	20
.1	ND	.1	ND	ND	ND	.1	.8	1.8	2.1	9.1	40.9	39.4	4.3	.8	.5	100.0 P	
3	1			5	5	6	9	43	27	92	250	261	33	19	7	761 F	21
.4	.1	ND	ND	.7	.7	.8	1.2	5.7	3.5	12.1	32.9	34.3	4.3	2.5	.9	100.0 P	
11		3	1	14	10	12	18	52	46	73	202	230	35	28	19	754 F	22
1.5	ND	.4	.1	1.9	1.3	1.6	2.4	6.9	6.1	9.7	26.8	30.5	4.6	3.7	2.5	100.0 P	
17	7	7	7	14	25	20	27	57	36	57	158	189	60	37	24	742 F	23
2.3	.9	.9	.9	1.9	3.4	2.7	3.6	7.7	4.9	7.7	21.3	25.5	8.1	5.0	3.2	100.0 P	
345	145	180	332	837	556	566	441	670	464	1138	5344	5823	640	480	330	18291 F	
1.9	.8	1.0	1.8	4.6	3.0	3.1	2.4	3.7	2.5	6.2	29.2	31.8	3.5	2.6	1.8	100.0 P	

Figure 15 (Part 1) shows Los Angeles International Airport wind rose data for August; percent frequency of directions are listed by sixteen compass points by hour of the day.

1GRAM=GROSSA01 08/01--08/31 FOR 1955-1977 N=NUMBER (SPEED) M=MEAN SPEED STATION 013W

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	MSG	TOTAL		HR
35	6	7	11	35	22	24	39	49	40	49	140	181	55	41	26	14	774	N	00
3.8	3.5	3.7	5.3	4.9	6.2	4.7	4.4	4.3	5.7	5.2	5.6	6.0	6.0	4.2	4.5	1.0	5.2	M	
33	6	14	14	51	31	51	34	55	31	50	104	147	54	40	44	12	771	N	01
4.2	3.8	3.3	5.4	5.5	5.7	5.0	4.6	4.7	5.2	4.8	5.3	5.6	5.0	4.0	4.3	1.0	4.9	M	
35	14	22	27	79	37	38	37	31	23	36	89	157	48	42	36	22	773	N	02
3.8	4.0	3.9	4.2	5.6	5.9	5.2	4.1	4.1	4.3	4.5	4.9	5.4	4.8	4.4	3.8	1.0	4.7	M	
39	23	22	32	99	41	34	23	37	22	19	74	152	44	47	45	20	773	N	03
4.6	3.8	3.9	4.6	5.1	5.5	5.4	5.1	4.4	3.6	4.5	5.3	5.3	4.9	4.0	3.9	1.1	4.7	M	
35	18	16	41	109	47	37	22	29	18	27	87	137	33	59	33	25	773	N	04
3.6	4.9	4.2	4.7	4.8	6.0	5.8	4.2	3.8	4.8	3.6	5.3	5.1	5.2	3.8	3.4	1.0	4.6	M	
37	13	27	59	108	64	46	19	33	21	27	52	126	44	42	26	28	772	N	05
3.9	3.5	3.9	4.1	5.0	5.0	4.7	4.3	3.7	3.2	4.1	5.8	5.0	4.6	4.4	4.2	1.0	4.5	M	
32	20	17	52	121	52	52	29	47	26	32	46	127	28	43	29	20	773	N	06
3.4	4.8	4.7	4.7	4.9	4.8	5.1	4.5	3.7	4.2	3.8	5.3	5.3	5.3	4.1	3.5	1.0	4.6	M	
35	21	25	38	90	67	67	35	54	36	32	75	89	37	41	20	10	772	N	07
4.2	4.8	3.9	5.5	5.8	6.0	5.5	4.9	4.1	3.2	4.5	5.5	6.0	5.4	4.3	3.8	1.0	5.1	M	
20	8	14	31	67	72	71	61	67	39	62	111	100	19	15	9	5	771	N	08
4.2	5.4	3.9	4.3	5.5	5.9	5.6	4.8	4.3	4.2	5.3	6.7	6.3	4.8	4.7	4.2	1.0	5.4	M	
8	4	2	14	28	52	59	46	59	27	70	188	168	22	13	3	6	769	N	09
3.8	3.5	6.5	6.2	5.7	6.1	5.6	5.9	4.9	5.6	6.2	7.5	7.6	7.0	5.8	5.0	1.0	6.5	M	
2	3	1	4	8	17	24	19	25	23	96	305	219	21	3	1		771	N	10
6.0	4.3	5.0	5.8	4.8	6.4	7.2	6.2	6.6	6.8	8.0	8.9	8.9	7.0	5.0	8.0	ND	8.3	M	
1	1	1		3	4	16	5	8	11	77	372	257	11		1		768	N	11
7.0	3.0	6.0	ND	7.3	6.8	7.6	8.6	8.1	9.2	9.9	10.6	10.8	7.9	ND	3.0	ND	10.4	M	
1		1		1	4	3	7	1	2	59	379	305	9	1			773	N	12
6.0	ND	8.0	ND	8.0	6.5	9.0	7.1	7.0	10.0	11.4	11.8	12.1	10.7	12.0	ND	ND	11.7	M	
			1	1	3	1		2	3	48	370	335	8				772	N	13
ND	ND	ND	3.0	7.0	8.0	6.0	ND	14.0	9.0	12.7	12.6	13.1	12.8	ND	ND	ND	12.8	M	
					2	1	1			27	375	352	8	2	1		769	N	14
ND	ND	ND	ND	ND	8.0	10.0	12.0	ND	ND	12.6	13.3	14.0	13.8	11.5	9.0	ND	13.5	M	
						1	1		4	25	335	397	4			1	768	N	15
ND	ND	ND	ND	ND	ND	9.0	9.0	ND	7.8	14.0	13.5	14.1	9.8	ND	ND	1.0	13.8	M	
				1		1	1		2	16	327	418	3			1	770	N	16
ND	ND	ND	ND	12.0	ND	6.0	12.0	ND	9.0	12.6	13.1	13.8	5.7	ND	ND	1.0	13.4	M	
				1		1	1	2	2	18	337	403	7				772	N	17
ND	ND	ND	ND	8.0	ND	6.0	8.0	7.0	12.0	11.8	12.4	12.9	12.3	ND	ND	ND	12.6	M	
				1					1	28	340	390	10			1	771	N	18
ND	ND	ND	ND	12.0	ND	ND	ND	ND	10.0	10.0	11.2	11.8	9.6	ND	ND	1.0	11.4	M	
				1			1	5	8	48	312	378	14	1	2	1	771	N	19
ND	ND	ND	ND	7.0	ND	ND	5.0	6.0	7.5	8.2	9.9	10.3	8.9	6.0	7.5	1.0	9.9	M	
1		1				1	6	14	16	70	316	304	33	6	4	1	773	N	20
6.0	ND	8.0	ND	ND	ND	7.0	6.5	6.2	6.8	7.4	8.6	8.9	7.3	5.2	5.3	1.0	8.4	M	
3	1			5	5	6	9	43	27	92	249	261	33	19	7	7	767	N	21
3.3	2.0	ND	ND	6.0	6.2	5.5	6.0	6.1	6.0	6.7	7.6	7.9	6.4	5.4	3.6	1.0	7.2	M	
11		3	1	14	10	12	18	52	46	73	202	230	35	27	19	7	760	N	22
5.0	ND	3.7	2.0	5.4	4.4	6.4	5.1	5.6	5.8	6.4	6.7	7.1	5.7	4.5	4.3	1.0	6.3	M	
17	7	7	7	14	24	20	27	57	36	57	158	189	60	37	24	25	766	N	23
4.6	4.0	5.9	5.3	4.4	4.8	5.9	4.8	5.0	5.8	5.7	6.1	6.7	6.0	4.7	4.4	1.0	5.7	M	
345	145	180	332	837	554	566	441	670	464	1138	5343	5822	640	479	330	206	18492	N	
4.1	4.3	4.1	4.7	5.2	5.7	5.5	5.0	4.8	5.3	7.5	10.0	10.0	6.1	4.4	4.1	1.0	8.1	M	

Figure 15 (Part 2) shows Los Angeles International Airport wind rose data for August; average windspeeds in miles-per-hour are listed by sixteen compass points by hour of the day.

TABLE XIII

SOUTH COAST AIR BASIN
ANNUAL AVERAGE WIND SPEED AND PERCENTAGE OF DIRECTION

	Azusa		Burbank		Los Angeles		LAX		Terminal Is.		El Toro	
Dir	%	Av. Speed	%	Av. Speed	%	Av. Speed	%	Av. Speed	%	Av. Speed	%	Av. Speed
N	9.7	4.0	5.1	5.3	4.7	3.9	3.4	6.7	11.2	5.4	2.7	4.8
NNE	6.9	3.8	1.6	6.1	4.7	3.6	2.4	5.8	-	-	2.5	6.6
NE	6.8	3.1	1.5	5.5	14.8	3.9	3.8	5.7	8.8	4.5	6.8	7.3
ENE	3.8	3.2	2.0	4.3	1.6	4.0	5.0	5.7	-	-	5.3	6.7
E	4.1	2.7	6.2	5.0	6.2	3.7	9.7	5.9	4.6	5.2	9.8	5.5
ESE	2.5	2.8	10.5	6.3	1.7	4.4	5.6	5.9	-	-	5.6	5.9
SE	2.9	2.6	11.1	6.8	7.9	4.4	3.8	5.8	12.6	5.2	6.7	6.4
SSE	2.1	2.9	13.6	7.1	1.6	4.6	2.6	5.8	-	-	4.9	7.0
S	4.8	3.1	18.4	7.1	9.3	4.5	3.3	5.6	10.2	6.3	6.2	7.2
SSW	14.6	5.0	4.8	5.4	5.2	6.6	2.3	5.5	-	-	3.5	7.1
SW	18.9	4.6	2.7	4.0	26.3	6.9	5.7	6.4	25.7	8.7	3.8	6.7
WSW	9.4	4.9	2.4	4.4	3.2	7.7	21.3	7.9	-	-	5.5	7.7
W	6.2	4.1	3.9	4.9	8.1	6.5	23.3	9.9	4.6	9.7	19.9	7.6
WNW	2.3	3.1	4.5	5.2	0.3	5.9	3.3	10.3	-	-	10.0	6.4
NW	2.1	2.5	5.7	5.7	3.5	6.0	2.3	7.2	22.3	7.9	4.6	5.4
NNW	2.8	3.0	6.2	5.9	0.8	6.7	2.2	6.1	-	-	2.2	4.7
(AV)		4.0		6.0		5.3		7.9		6.9		6.2

	La Habra		Los Alamitos		Santa Ana		Ontario		Riverside		San Bernardino	
N	3.5	1.6	4.6	4.3	2.5	2.2	13.5	5.4	6.8	3.7	4.3	8.3
NNE	1.5	2.6	3.0	4.5	0.8	4.0	6.0	6.0	4.4	3.6	1.6	6.7
NE	9.6	1.9	5.6	4.8	6.2	4.9	4.7	7.7	5.3	2.9	3.4	4.0
ENE	4.7	2.3	4.4	6.4	5.2	3.6	4.0	7.9	4.3	3.5	3.2	3.8
E	16.5	1.8	6.6	5.0	13.5	2.6	3.3	5.7	5.5	3.2	15.1	2.7
ESE	2.8	2.1	3.3	4.6	3.2	2.9	1.6	4.6	3.8	2.7	5.5	2.5
SE	5.7	2.1	4.0	4.8	5.9	2.6	1.5	4.3	6.0	3.3	6.9	2.7
SSE	1.9	3.2	3.4	5.5	2.2	4.1	1.8	4.2	5.6	3.3	2.2	3.0
S	9.4	3.6	8.3	6.1	8.1	5.3	4.4	4.8	6.0	3.0	4.9	2.5
SSW	5.7	5.2	11.1	7.6	9.0	6.8	4.3	6.2	2.5	2.3	2.1	3.5
SW	17.2	5.1	16.8	8.6	18.9	5.6	7.7	7.7	2.4	2.3	11.9	4.2
WSW	7.3	5.6	7.5	8.5	8.8	5.9	16.3	9.5	2.2	2.8	15.6	6.6
W	11.2	4.1	6.0	7.3	10.6	5.0	19.4	9.5	7.9	4.3	15.8	5.9
WNW	0.9	3.8	5.4	7.0	1.5	3.1	5.3	7.6	11.8	6.2	2.9	5.7
NW	1.7	1.6	6.8	5.6	3.1	2.6	3.0	5.9	17.1	6.3	3.0	5.5
NNW	0.3	2.1	3.3	4.8	0.6	2.7	3.3	5.3	8.3	5.0	1.6	8.6
(AV)		3.4		5.2		4.5		7.1		3.5		4.0

TABLE XIV

AVERAGE YEARLY WIND SPEEDS
AT SELECTED METROPOLITAN AREAS

Rank	City	Location of Wind Record[a]	MPH	Years of Record	Month with Minimum Wind Speed	Minimum Monthly Speed (MPH)
1	Phoenix	A	5.0	12	December	3.9
2	Los Angeles[b]	C	5.3	21	January	4.5
3	Long Beach	A	6.4	21	December	5.0
4	San Diego	A	6.4	17	December	5.2
5	Washington D.C.	C	7.1	26	August	5.7
6	Cincinnati	C	7.4	36	August	5.4
7	New Orleans	C	7.7	87	July, Aug.	6.4
8	San Francisco	C	8.8	21	October	7.6
9	Philadelphia	A	9.6	17	August	7.8
10	Chicago	A	9.8	15	August	7.3
11	Baltimore	C	9.9	24	August	8.6
12	Detroit	C	10.0	24	August	7.8
13	Houston	C	10.1	19	July	8.3
14	Pittsburgh	A	10.3	5	August	8.0
15	Minneapolis	A	10.9	20	August	9.4
16	Cleveland	A	11.1	16	August	8.5
17	St. Louis	C	11.7	44	August	9.3
18	Boston	A	12.2	22	August	10.2
19	Miami	C	12.4	15	August	10.0
20	Milwaukee	A	12.4	17	July, Aug.	10.0
21	Buffalo	A	14.5	62	August	11.7
22	New York City	C	14.5	46	August	11.7

a) A = Airport; C = City Office

b) 434 So. San Pedro St.

sufficient time is provided for the buildup of these primary contaminants during the early to mid-morning hours. As the secondary pollutants develop, the onshore flow moves the polluted air inland to the north and east beginning late morning.

With sufficient stagnation, secondary pollutants, such as ozone, have additional hours to react to reach high concentrations before they move out of the Basin. Light winds during the morning over major sources, vehicular and stationary, are critical for attainment of high ozone levels; afternoon and early evening wind speeds affect ozone transport more than ozone dispersion. Stronger afternoon winds in the inland areas therefore are less important as ventilators since they merely act to draw pollutants in from source areas in the western portion of the Basin. It is not unusual to attain a daily maximum ozone concentration in the San Bernardino Valley with winds in the ten to fifteen miles-per-hour range.

Another measure of the frequency of near-stagnation conditions in source areas is the number of days with light winds during the morning hours in Downtown Los Angeles. On two-thirds of the days at that location between 0600 PST and noon, wind speeds average five miles per hour or less, and the frequency increases to eighty percent during the photochemical smog season.

<u>Winds Aloft</u>

Concern with wind flows and contaminants in the air over the Basin is restricted mainly to the layer from the surface to the base of the inverison where most of the pollution is found, rather than with winds and pollutants in the inversion layer. Historically, winds aloft data have been sparse in the Basin and computations of movement of polluted air masses have been based upon surface wind data.

Because of strong vertical mixing in the daytime sea breeze, surface winds are good indicators of the wind flow in the mixed layer. Angell [1] found there was very little difference during the day between trajectories estimated from surface winds and radar plots of tetroon (constant level, free balloon) trajectories in the Basin. Angell determined at night, however, surface wind flows can indicate drainage while tetroons, at altitudes of 600 to 1200 feet, may show stagnation, or wind flows different from the surface wind pattern. Additionally, surface winds at night may indicate stagnation while tetroons maintain their speed.

Under some conditions, pollution is trapped in the inversion layer itself. If the wind flow in the inversion is from the north or east, the pollution in the inversion is returned to the western or southern parts of the Basin and can be brought to the surface on subsequent days by the vertical mixing caused by surface heating. If the flow in the inversion is westerly or southerly, polluted layers in the inversion will be advected out of the Basin.

North or northeast flows above the inversion base frequently are indicators of subsidence that will lower and strengthen the inversion. These flows also may be indicators of foehn winds or the beginning of Santa Ana winds.

Compilations of wind flows above the surface in the Basin are found in some of the referenced papers listed at the end of this report. For instance: De Marrais [10] presents frequency distributions of winds aloft from the surface to 5,000 feet for four stations in the Basin. Average speeds for each one thousand foot level are also given. Data covers twice-daily listings for four seasons. It will also be found that three-dimensional air pollution and/or meteorological studies made in the Basin have included special winds aloft measurements. Finally, winds aloft data are available in District archives for individual days, plotted on daily coastal soundings charts. Other data are archived at the National Climatology Center, Asheville, North Carolina and at the California Air Resources Board in Sacramento, California.

A December, 1979 California Air Resources Board report, Summary of California Upper Air Meteorological Data, edited by Arndt Lorenzen, includes wind and temperature aloft data for several locations in the South Coast Air Basin in its statewide coverage of the subject.

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INVERSIONS AND MIXING HEIGHTS

The usual condition of the lower atmosphere (below the tropopause) is a constant decrease in temperature with altitude beginning at the surface, the warmest point. With that constantly falling temperature is a concurrent decrease in pressure and density of the air. A reversal of this state, an increase in temperature with altitude at any level, is termed an inversion.

Inversion Types

In the South Coast Air Basin, two inversion types occur: the surface inversion produced by offshore, descending air flows and nighttime radiational cooling and, second, the low-level inversion that caps the surface marine layer. These inversion types are illustrated in Figure 16. Note that the inversion base is the point on the vertical temperature profile where warming with height begins and is the coldest point. The inversion top is the warmest point on the profile and marks the resumption of cooling with altitude. Thus, the temperature inversion layer is a stratum of warm, dry air located immediately above a surface layer of cool, moist air. The situation is different with surface-based inversions.

With surface inversions, warming begins at the surface and thus, the inversion layer rests on the surface and is not superimposed upon a layer of ocean air. Surface temperatures with a surface inversion can be either very hot or very cold,

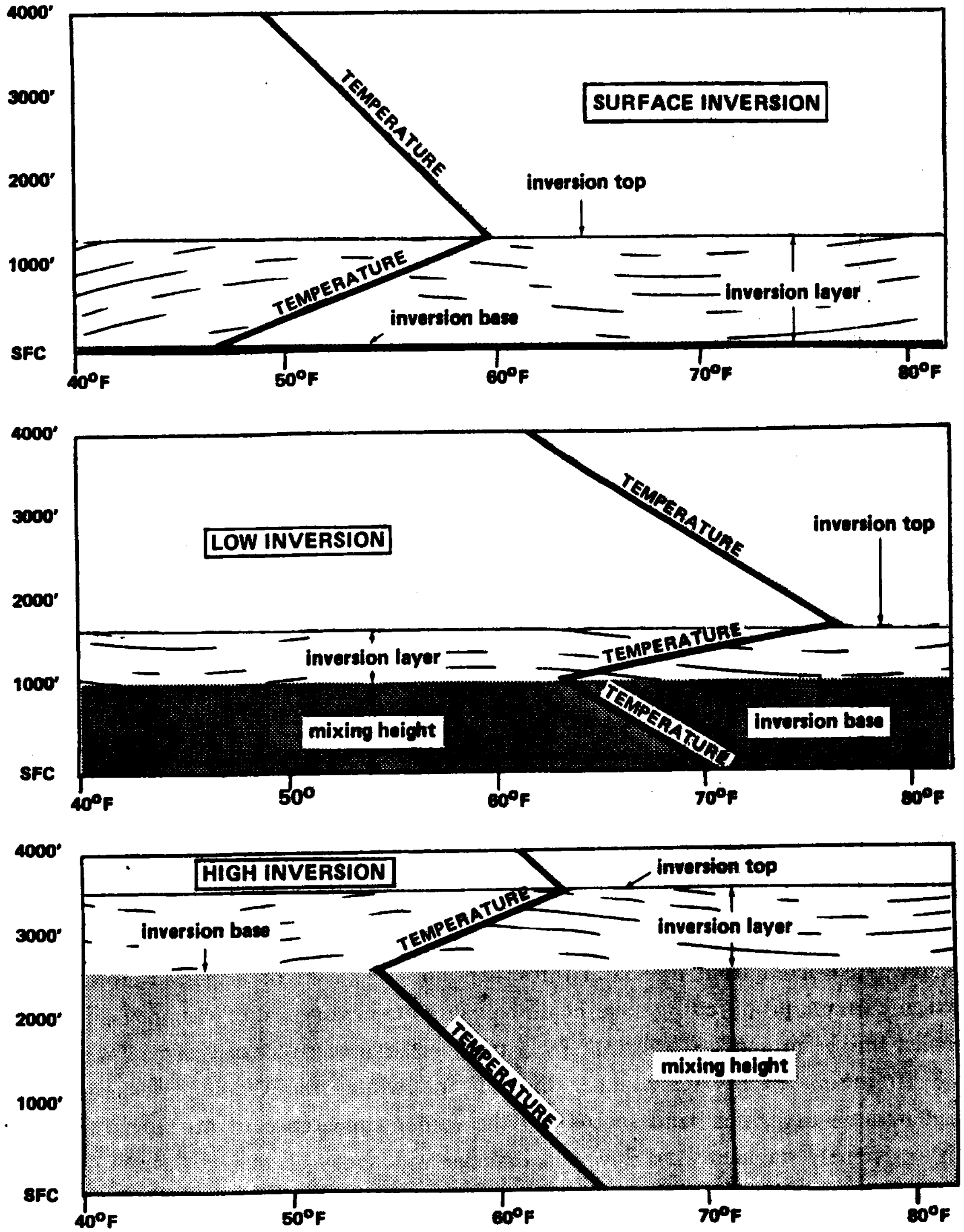

Figure 16 plots air temperature on the X axis versus altitude on the Y axis with diagrams of typical inversions: surface-based, low and high inversions. Most of the air pollutants are confined to the air volume below the base of any inversion, or in a very shallow layer near the ground in the case of a surface inversion.

depending upon the season and air mass involved. Some of the hottest days of the year occur during September with surface inversions; however, the excessively high temperatures occur with daytime heating after the surface inversion has been lifted or broken. But even during the coldest period of the day, the temperature at the base of the inversion (the surface) can be above 70°F. At the other extreme, during January, the lowest temperatures of the year occur with strong surface inversions and loss of surface heat through intense nocturnal radiational cooling. For the most part, surface inversions are dry because of the continental origin of the air masses involved, but fog regimes also exist with surface inversions. With high surface humidity there can be patchy late night and early morning fog, or widespread dense fog lasting through several days.

The Marine Layer

The marine layer under the inversion is fairly homogeneous in that moisture, particulate matter, and gaseous pollutants are well-mixed throughout the layer. Stratus clouds frequently form immediately under the inversion base and it is unusual not to find these stratus decks over the ocean and immediate coast during the night and early morning in spring and summer. With high and relatively strong inversions, the stratus clouds penetrate the inland valleys as far as the eastern boundary of the Basin.

The inversion base acts as a barrier to vertical mixing, not because it is a lid that cannot be penetrated by thermals or rising air currents, but because air that pushes through the inversion base is heavier than the air in the inversion and returns to equilibrium by sinking below the base.

Climatological Inversion Data

The frequency of occurrence of morning inversion base heights at Los Angeles International Airport is shown in Tables XV, XVI, and XVII for all months, all Januarys, and all Julys for the period 1950-1974. In the listings, "001" is the code for surface inversion. Days with inversions based at heights greater than 5,000 feet are lumped with days with no inversions and coded "999". In either case, the coding indicates days with mixing greater than 5,000 feet when vertical dispersion is not restricted to an important degree. Days with weak inversions of short duration are classified separately and coded "991"; on these days, vertical dispersion is limited only during early morning hours.

The listing for all days during the twenty-five years of record shows that on nearly nine out of ten days, an inversion exists in the Basin during the morning, and an inversion on

TABLE XV

FREQUENCY OF MORNING INVERSION BASE HEIGHTS

LOS ANGELES INTERNATIONAL AIRPORT 1950 - 1974, ALL MONTHS

CLASS LIMITS(a)	FREQ.	CUM FREQ.	REL. FREQ.	CUM REL FREQ.
001(b)	3209	3209	.354	.354
002	11	3220	.001	.355
003	40	3260	.004	.360
004	113	3373	.012	.372
005	107	3480	.012	.384
006	140	3620	.015	.399
007	131	3751	.014	.414
008	188	3939	.021	.435
009	129	4068	.014	.449
010	227	4295	.025	.474
011	127	4422	.014	.488
012	221	4643	.024	.512
013	160	4803	.018	.530
014	226	5029	.025	.555
015	170	5199	.019	.574
016	205	5404	.023	.596
017	171	5575	.019	.615
018	157	5732	.017	.633
019	168	5900	.019	.651
020	158	6058	.017	.669
021	112	6170	.012	.681
022	117	6287	.013	.694
023	114	6401	.013	.706
024	89	6490	.010	.716
025	80	6570	.009	.725

(a) Class limits in feet x 10^2 (mean sea level).
(b) Surface inversion.
(c) Class limits not appropriate.
(d) Insignificant surface inversion, broken by 0800 PST.
(e) No inversion, or inversion greater than 5,000 feet.

(continued)

TABLE XV (continued)

FREQUENCY OF MORNING INVERSION BASE HEIGHTS

LOS ANGELES INTERNATIONAL AIRPORT 1950 - 1974, ALL MONTHS

CLASS LIMITS(a)	FREQ.	CUM FREQ.	REL. FREQ.	CUM REL FREQ.
026	107	6677	.012	.737
027	82	6759	.009	.746
028	106	6865	.012	.758
029	71	6936	.008	.765
030	91	7027	.010	.775
031	51	7078	.006	.781
032	82	7160	.009	.790
033	65	7225	.007	.797
034	77	7302	.008	.806
035	73	7375	.008	.814
036	48	7423	.005	.819
037	60	7483	.007	.826
038	47	7530	.005	.831
039	37	7567	.004	.835
040	40	7607	.004	.839
041	25	7632	.003	.842
042	39	7671	.004	.847
043	37	7708	.004	.851
044	45	7753	.005	.856
045	36	7789	.004	.860
046	25	7814	.003	.862
047	25	7839	.003	.865
048	31	7870	.003	.868
049	36	7906	.004	.872
050	14	7920	.002	.874
051-990(c)	0	7920	.000	.874
991(d)	170	8090	.019	.893
992-998(c)	0	8090	.000	.893
999 (e)	972	9062	.107	1.000
MISSING	69	9131	.008	

(a) Class limits in feet x 10^2 (mean sea level).
(b) Surface inversion.
(c) Class limits not appropriate.
(d) Insignificant surface inversion, broken by 0800 PST.
(e) No inversion, or inversion greater than 5,000 feet.

TABLE XVI

FREQUENCY OF MORNING INVERSION BASE HEIGHTS

LOS ANGELES INTERNATIONAL AIRPORT 1950 - 1974 ALL JANUARYS

CLASS LIMITS(a)	FREQ.	CUM FREQ.	REL FREQ.	CUM REL FREQ.
001(b)	541	541	.705	.705
002	1	542	.001	.707
003	0	542	.000	.707
004	4	546	.005	.712
005	5	551	.007	.718
006	5	556	.007	.725
007	1	557	.001	.726
008	3	560	.004	.730
009	4	564	.005	.735
010	4	568	.005	.741
011	4	572	.005	.746
012	7	579	.009	.755
013	5	584	.007	.761
014	7	591	.009	.771
015	2	593	.003	.773
016	5	598	.007	.780
017	4	602	.005	.785
018	2	604	.003	.787
019	3	607	.004	.791
020	3	610	.004	.795
021	5	615	.007	.802
022	5	620	.007	.808
023	3	623	.004	.812
024	3	626	.004	.816
025	0	626	.000	.816

(a) Class limits in feet x 10^2 (mean sea level).
(b) Surface inversion
(c) Class limits not appropriate.
(d) Insignificant surface inversion, broken by 0800 PST.
(e) No inversion, or inversion greater than 5,000 feet.

(continued)

TABLE XVI (continued)

FREQUENCY OF MORNING INVERSION BASE HEIGHTS

LOS ANGELES INTERNATIONAL AIRPORT 1950 - 1974 ALL JANUARYS

CLASS LIMITS(a)	FREQ.	CUM FREQ.	REL FREQ.	CUM REL FREQ.
026	3	629	.004	.820
027	4	633	.005	.825
028	3	636	.004	.829
029	1	637	.001	.831
030	2	639	.003	.833
031	1	640	.001	.834
032	0	640	.000	.834
033	2	642	.003	.837
034	2	644	.003	.840
035	1	645	.001	.841
036	1	646	.001	.842
037	1	647	.001	.844
038	2	649	.003	.846
039	3	652	.004	.850
040	2	654	.003	.853
041	1	655	.001	.854
042	2	657	.003	.857
043	1	658	.001	.858
044	0	658	.000	.858
045	2	660	.003	.860
046	0	660	.000	.860
047	5	665	.007	.867
048	1	666	.001	.868
049	3	669	.004	.872
050	0	669	.000	.872
051-990(c)	0	669	.000	.872
991(d)	9	678	.012	.884
992-998(c)	0	678	.000	.884
999(e)	89	767	.116	1.000
MISSING	8	775	.010	

(a) Class limits in feet x 10^2 (mean sea level).
(b) Surface inversion
(c) Class limits not appropriate.
(d) Insignificant surface inversion, broken by 0800 PST.
(e) No inversion, or inversion greater than 5,000 feet.

TABLE XVII

FREQUENCY OF MORNING INVERSION BASE HEIGHTS

LOS ANGELES INTERNATIONAL AIRPORT 1950 - 1974, ALL JULYS

CLASS LIMITS(a)	FREQ	CUM FREQ	REL FREQ	CUM REL FREQ
001(b)	101	101	.131	.131
002	0	101	.000	.131
003	4	105	.005	.136
004	27	132	.035	.171
005	11	143	.014	.185
006	33	176	.043	.228
007	31	207	.040	.268
008	40	247	.052	.320
009	30	277	.039	.359
010	65	342	.084	.444
011	22	364	.029	.472
012	39	403	.051	.523
013	26	429	.034	.556
014	31	460	.040	.597
015	33	493	.043	.639
016	36	529	.047	.686
017	31	560	.040	.726
018	34	594	.044	.770
019	29	623	.038	.808
020	20	643	.026	.834
021	12	655	.016	.850
022	9	664	.012	.861
023	15	679	.019	.881
024	17	696	.022	.903
025	13	709	.017	.920

(a) Class limits in feet x 10^2 (mean sea level).
(b) Surface inversion.
(c) Class limits not appropriate.
(d) Insignificant surface inversion, broken by 0800 PST.
(e) No inversion, or inversion greater than 5,000 feet.

(continued)

TABLE XVII (continued)

FREQUENCY OF MORNING INVERSION BASE HEIGHTS

LOS ANGELES INTERNATIONAL AIRPORT 1950 - 1974, ALL JULYS

CLASS LIMITS(a)	FREQ	CUM FREQ	REL FREQ	CUM REL FREQ
026	12	721	.016	.935
027	4	725	.005	.940
028	10	735	.013	.953
029	4	739	.005	.958
030	3	742	.004	.962
031	4	746	.005	.968
032	3	749	.004	.971
033	3	752	.004	.975
034	3	755	.004	.979
035	0	755	.000	.979
036	2	757	.003	.982
037	3	760	.004	.986
038	0	760	.000	.986
039	2	762	.003	.988
040	0	762	.000	.988
041	2	764	.003	.991
042	0	764	.000	.991
043	2	766	.003	.994
044	1	767	.001	.995
045	0	767	.000	.995
046	2	769	.003	.997
047	0	769	.000	.997
048	0	769	.000	.997
049	0	769	.000	.997
050	0	769	.000	.997
051-990(c)	0	769	.000	.997
991(d)	0	769	.000	.997
992-998(c)	0	769	.000	.997
999(e)	2	771	.003	1.000
MISSING	4	775	.005	

(a) Class limits in feet x 10^2 (mean sea level).
(b) Surface inversion.
(c) Class limits not appropriate.
(d) Insignificant surface inversion, broken by 0800 PST.
(e) No inversion, or inversion greater than 5,000 feet.

the surface exists on one out of three days. The inversion class of 1200 feet is at the 50 percentile level.

The January frequency distribution shows seventy percent of the days with surface inversions; this reflects the preponderance of long winter nights with clear skies that allows maximum radiational cooling of the earth's surface. Similar to the annual listing, inversions in this month occur on about ninety percent of the days. However, the marine inversion develops on only five days per month, a reflection of storm conditions or the continental influence during the winter when very weak sea breezes are the rule and advection of ocean air to the land is limited.

During July, the middle of the photochemical smog season, inversions are present on virtually every day of the month. Half of the inversion bases are 1200 feet or less with surface inversions occurring only on four days. The inversion base is less than 2500 feet, a level that indicates limited potential for the dispersion of pollution, on ninety percent of the days.

During the winter with a typical morning surface inversion, lifting of the inversion base occurs with ground heating, and on most days the inversion is broken or substantial vertical mixing takes place. With the marine inversion in the summer smog season, the daily changes in the base of the inversion and the vertical mixing processes are more complex.

Diurnal Inversion Changes

A typical summer inversion base height at the coast line is in the 1200 to 1500-foot range during early morning. The divergent sea breeze flow causes the base to decrease at a rate of about 100 feet per hour from 0800 to noon PST. There is then litle change in the afternoon through 1600 PST as the sea breeze increases in strength to a maximum between 1500 and 1600 PST. (14). The change in the inversion base height (and consequent change in the height of vertical mixing) inland depends mainly upon distance from the coast. Irregular terrain and non-uniform surface heating also affect the height of the inversion base inland. For example, the inversion may break up over the slopes and crests of the mountains while inland valleys retain a strong inversion with a low base.

Away from the coast, morning surface heating causes vertical mixing, which in turn causes the inversion to rise at a rate of about 200 feet per hour until the last of the air with a land trajectory (air ahead of that day's sea breeze) has passed. To lift the marine inversion 1,000 feet, the ground must be heated seven degrees Celsius (about 13°F). Typically, the surface temperature increases about two degres Celsius (4°F) per hour. With the advent of the sea breeze, the inversion base lowers, the timing of this event being dependent upon distance inland and the strength of the sea breeze on the particular day.

The Mixed Layer

One key factor that determines maximum contaminant concentrations each day is the extent of vertical mixing (the highest level to which the inversion base is lifted) as pollution moves from source areas in the western portion of the Basin to receptor areas inland. This is in reference to summertime photochemical smog and marine layer inversions. Other weather situations also account for high pollution levels. During the winter, for example, high carbon monoxide concentrations are found with strong surface inversions along the coast and in the inland valleys of Los Angeles County. Another example is the weak offshore flow that pushes the smog cloud over Santa Monica Bay or ocean areas to the South. When this pollution returns to the Basin with the reestablishment of the sea breeze, coastal areas as well as inland valleys experience high ozone concentrations.

Maximum Mixing Heights

A method frequently used to monitor the highest vertical mixing achieved each day is the computation of the daily maximum mixing height. This mixing height marks the highest altitude to which the inversion base is lifted due to surface heating; it is computed using the morning inversion structure and the maximum temperature of the day. In the computation is the assumption that mixing will occur along the potential temperature line from the maximum temperature at the surface to the point where the dry adiabat intersects the inversion. See Figure 17. The figure also shows that with sufficient heating, the inversion can be broken; in this case, mixing extends upward beyond the original inversion top.

Although the maximum mixing height concept is useful, it can exaggerate the actual vertical mixing in some cases and prove less than helpful if elevated contaminant concentrations are achieved before good mixing occurs. Examples: with strong solar radiation, the surface layer of air is heated super-adiabatically and the surface temperature is higher than the potential temperature of the column of air from a few meters above the surface to the inversion base. Secondly, with strong surface inversions during the winter, there can be high concentrations of primary pollutants before daytime mixing provides good vertical mixing. Thirdly, a common summertime situation in the San Bernardino-Riverside Valley

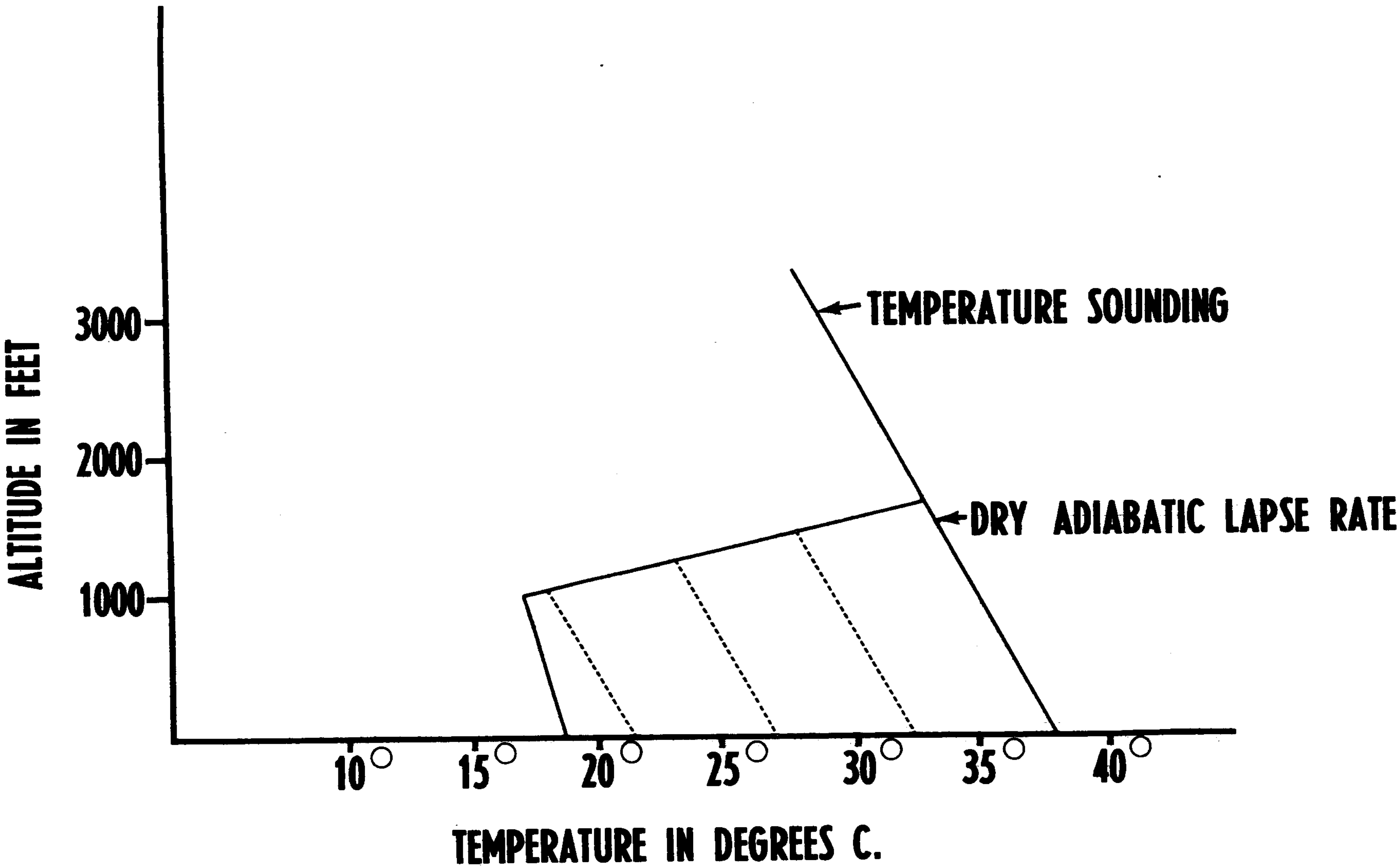

Figure 17 illustrates lifting of the inversion base height due to surface heating. The mixed layer continues to deepen until, at 38°C (100° F), the inversion is broken and vertical mixing is unlimited.

east of the Puente Hills is the achievement of excellent vertical mixing before the smog cloud from source areas near the coast is advected into the area during the early afternoon. With the advected pollution is a lower inversion with restricted dispersion. The relevant mixing height in that case is one computed at the time of the occurrence of the maximum ozone rather than one computed at the time of maximum temperature.

Despite these exceptions, the maximum mixing height is an excellent overall measure of vertical dispersion, but must be used carefully when applied to individual days or locations.

Coastal Southern California experiences the most restricted maximum mixing heights during the summer of any area in the United States. (17). Daily records of maximum mixing heights in the Basin are available from 1950 to the present.

Tables XVIII and XIX show the frequency distribution of these mixing heights for the months of January and July, 1950-1974. The heights were computed from morning coastal soundings and maximum temperatures in Downtown Los Angeles. Although these mixing heights are representative of a large portion of the western part of the Basin, to get a true mixing height for other areas or stations, individual daily station maximum temperatures must be used as well as station altitudes above sea level.

The January listing shows that good mixing (above 3,500 feet) is present on more than half of the days and unlimited mixing (above 5,000 feet) on more than one-fourth of the days. The few mixing heights below one thousand feet can be attributed to days with fog, rain, or heavy cloudiness when ground heating contributed little to vertical mixing. During July, nearly three-fourths of the days show mixing below 3,500 feet and half below 2,700 feet. On only one percent of the days is the mixing unlimited.

Pollution in the Inversion Layer

Although the inversion base limits vertical mixing, there are several mechanisms that function to trap pollutants in the inversion layer. During the summer, aged pollution in the inversion can add to ozone concentrations the following day if the contaminants are fumigated to the surface to mix with new emissions. Ozone, although highly reactive, is stable in the absence of reactors and can exist in layers aloft for extended periods of time.

Trapping of ozone or ozone precursors in the inversion occurs when the sea breeze undercuts a polluted layer, bringing with it an inversion at a lower level. Trapping also

TABLE XVIII

FREQUENCY OF DAILY MAXIMUM MIXING HEIGHTS

LOS ANGELES 1950 - 1974, ALL JANUARYS

CLASS LIMITS(a)	FREQ.	CUM FREQ.	REL FREQ.	CUM REL FREQ.
001(b)	1	1	.001	.001
002	0	1	.000	.001
003	0	1	.000	.001
004	2	3	.003	.004
005	2	5	.003	.007
006	0	5	.000	.007
007	1	6	.001	.008
008	1	7	.001	.009
009	2	9	.003	.012
010	3	12	.004	.016
011	1	13	.001	.017
012	2	15	.003	.020
013	4	19	.005	.025
014	2	21	.003	.027
015	4	25	.005	.033
016	14	39	.018	.051
017	9	48	.012	.063
018	14	62	.018	.081
019	14	76	.018	.099
020	16	92	.021	.120
021	9	101	.012	.132
022	18	119	.023	.155
023	12	131	.016	.171
024	14	145	.018	.189
025	17	162	.022	.211

(a) Class limits in feet x 10^2 (mean sea level).
(b) Surface.
(c) Class limits not appropriate.
(d) Mixing height greater than 5,000 feet.

(continued)

TABLE XVIII (continued)

FREQUENCY OF DAILY MAXIMUM MIXING HEIGHTS

LOS ANGELES 1950 - 1974, ALL JANUARYS

CLASS LIMITS(a)	FREQ.	CUM FREQ.	REL FREQ.	CUM REL FREQ.
026	21	183	.027	.239
027	18	201	.023	.262
028	9	210	.012	.274
029	15	225	.020	.293
030	28	253	.037	.330
031	15	268	.020	.349
032	18	286	.023	.373
033	16	302	.021	.394
034	21	323	.027	.421
035	20	343	.026	.447
036	13	356	.017	.464
037	10	366	.013	.477
038	14	380	.018	.495
039	18	398	.023	.519
040	20	418	.026	.545
041	15	433	.020	.565
042	11	444	.014	.579
043	17	461	.022	.601
044	18	479	.023	.625
045	16	495	.021	.645
046	21	516	.027	.673
047	15	531	.020	.692
048	17	548	.022	.714
049	11	559	.014	.729
050	10	569	.013	.742
051-990(c)	0	569	.000	.742
991(c)	0	569	.000	.742
992-998(c)	0	569	.000	.742
999(d)	198	767	.258	1.000
MISSING	8	775	.010	

(a) Class limits in feet x 10^2 (mean sea level).
(b) Surface.
(c) Class limits not appropriate.
(d) Mixing height greater than 5,000 feet.

TABLE XIX

FREQUENCY OF DAILY MAXIMUM MIXING HEIGHTS

LOS ANGELES 1950 - 1974, ALL JULYS

CLASS LIMITS(a)	FREQ.	CUM FREQ.	REL FREQ.	CUM REL FREQ.
001(b)	0	0	.000	.000
002	0	0	.000	.000
003	0	0	.000	.000
004	0	0	.000	.000
005	0	0	.000	.000
006	0	0	.000	.000
007	0	0	.000	.000
008	0	0	.000	.000
009	0	0	.000	.000
010	0	0	.000	.000
011	0	0	.000	.000
012	1	1	.001	.001
013	0	1	.000	.001
014	0	1	.000	.001
015	6	7	.008	.009
016	2	9	.003	.012
017	15	24	.019	.031
018	14	38	.018	.049
019	22	60	.029	.078
020	24	84	.031	.109
021	38	122	.049	.158
022	51	173	.066	.224
023	51	224	.066	.291
024	60	284	.078	.368
025	57	341	.074	.442

(a) Class limits in feet x 10^2 (mean sea level).
(b) Surface.
(c) Class limits not appropriate.
(d) Mixing height greater than 5,000 feet.

(continued)

TABLE XIX (continued)

FREQUENCY OF DAILY MAXIMUM MIXING HEIGHTS

LOS ANGELES 1950 - 1974, ALL JULYS

CLASS LIMITS(a)	FREQ.	CUM FREQ.	REL FREQ.	CUM REL FREQ.
026	43	384	.056	.498
027	49	433	.064	.562
028	46	479	.060	.621
029	40	519	.052	.673
030	34	553	.044	.717
031	36	589	.047	.764
032	26	615	.034	.798
033	20	635	.026	.824
034	24	659	.031	.855
035	17	676	.022	.877
036	15	691	.019	.896
037	15	706	.019	.916
038	11	717	.014	.930
039	12	729	.016	.946
040	6	735	.008	.953
041	3	738	.004	.957
042	3	741	.004	.961
043	2	743	.003	.964
044	7	750	.009	.973
045	3	753	.004	.977
046	2	755	.003	.979
047	4	759	.005	.984
048	4	763	.005	.990
049	0	763	.000	.990
050	0	763	.000	.990
051-990(c)	0	763	.000	.990
991(c)	0	763	.000	.990
992-998(c)	0	763	.000	.990
999(d)	8	771	.010	1.000
MISSING	4	775	.005	

(a) Class limits in feet x 10^2 (mean sea level).
(b) Surface.
(c) Class limits not appropriate.
(d) Mixing height greater than 5,000 feet.

occurs when the return flow from mountain ridges pours pollution into the air above the inversion base as the flow aloft moves from the mountains toward the Basin. A third method by which pollution enters the inversion is the penetration of the inversion base at a point source by buoyant effluents from elevated stacks. This is fairly common along the coast when a low inversion exists and power plant stacks emit directly into the inversion. The contaminants can later be brought to the surface as a result of ground heating, frequently after an over-water trajectory. A fourth method whereby pollution is trapped aloft is the formation of a surface inversion by radiational cooling of the land under an existing inversion. Unless winds aloft transport that pollution (trapped in the inversion layer) out of the Basin, it can surface the following day with sufficient vertical mixing.

The polluted layer is generally defined as the mixed layer extending from the surface to the base of the inversion. However, this is not so in the case of surface-based inversions. As previously shown, elevated sources inject contaminants into the inversion layer itself, and ground sources or very low stacks emit within a few feet of the surface. In the case of surface-based inversions, therefore, the pollution is stratified into layers aloft within the inversion proper as well as a layer at the surface.

When a surface inversion is present and is not subjected to ground heating, there is no vertical disperison aside from mechanical mixing at the surface boundary layer caused by wind. (Traffic along a major artery may provide limited local turbulence.) The effectual mixing by wind is limited by surface roughness, terrain and wind speed. For instance, strong surface inversions that accompany elevated carbon monoxide concentrations occur with very light wind speeds, and mixing (also the depth of the lowest polluted layer) may be restricted to less than one hundred feet. In addition, there can be polluted layers aloft from elevated stacks, the altitudes being dependent upon the effective stack heights of the sources, or additional layers may be present, the altitudes of which are determined by the specific processes that caused the pollution to be trapped in the inversion layer.

III. AIR QUALITY EFFECTS

AIR POLLUTION POTENTIAL

With light surface winds, frequent low inversions, and a long rainless summer season, the South Coast Air Basin has a potential for achieving high contaminant concentrations on many days each year. One measure of this potential is the frequency of "Rule 444 days".

Rule 444 Days

District Rule 444 (formerly Rule 57) prohibits open burning on days with poor atmospheric dispersion; the rule lists restricting parameters that designate days when burning is banned. The limiting factors of Rule 444, each of which must be met before burning is prohibited, are: the average morning windspeed in Downtown Los Angeles must be five miles per hour or less; the morning inversion base measured at a Los Angeles County coastal location must be less than 1,500 feet msl; the daily maximum mixing height, based on the maximum temperature at Downtown Los Angeles, must be 3,500 feet msl or less. Since low mixing heights limit upward dispersion and light windspeeds limit horizontal disperison, Rule 444 days qualify as indicators of days with poor dispersion.

Figure 18 is a plot of the number of Rule 444 days each year since 1950. Only two years in that period, 1962 and 1973, show major deviations from the long-term mean; the other years are within twenty percent of the average, 88 days. Based on the rule's criteria, the potential number of high pollution days is fairly constant from year to year.

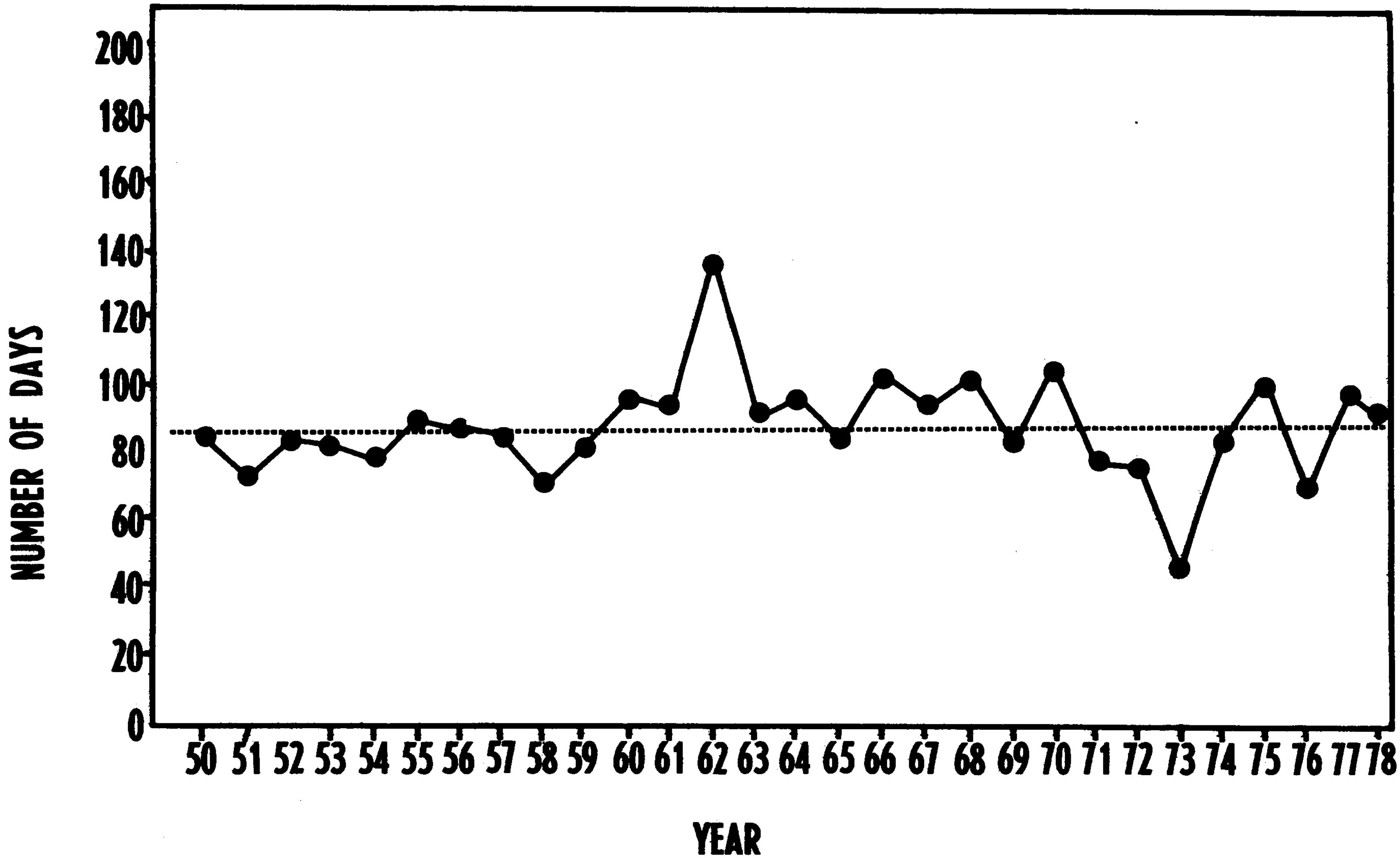

Figure 18 is a plot of the number of rule 444 (formerly Rule 57) days each year in the South Coast Air Basin with best-fit trend line.

Rule 444 Days and Air Quality

The rule applies primarily to the number of days conducive to elevated photochemical smog levels and correlates well with ozone concentrations. Figure 19 is a plot of the number of Rule 444 days each month during 1976 vs. the number of days the Stage 1 ozone episode level was attained at Azusa. The Stage 1 level is 0.20 ppm averaged over one hour. Nineteen hundred and seventy-six was a year with relatively few Rule 444 days--seventy.

In contrast, 1978 was a year with a slightly higher-than-average number of Rule 444 days. Figure 20 shows the plot of those days; a second curve shows the number of Stage 1 episode days at Azusa and a third curve, the number of days Stage 1 episode levels were attained at any station in the Basin. Both plots show excellent agreement between Rule 444 days and elevated ozone levels during the summer smog season. Note that from November through February, the correlation is poor because although limited disperison may be indicated on many winter days, the ultraviolet radiation during that season is limited by the shortness of the days and the low sun angle; this radiation is a necessary part of the photochemical reactions that produces ozone.

Surface Inversions and Air Quality

High levels of carbon monoxide, a primary pollutant, do not correlate well with Rule 444 days since the weather conditions required for those high concentrations are nighttime clear skies and strong surface inversions during the winter. A plot of the number of days with a coastal morning surface inversion against the number of days the State air quality standard for carbon monoxide (ten ppm averaged over twelve hours) was achieved or exceeded at Lennox during 1975 shows a good correlation between the two factors. Figure 21 presents this plot. The agreement is surprisingly good, considering the fact that a single meteorological parameter was used.

Inversion Strength and Height

A third set of meteorological parameters useful in measuring pollution potential involves inversion strength and height. These apply to ozone and sulfate concentrations. Zeldin (37) plotted the May-October 1973 daily concentrations of ozone and sulfates against daily inversion strength and height and determined that a definite stratification of the contaminant data existed. See Figure 22.

Ozone and sulfates are significant contaminants because air quality standards and episode criteria for both are exceeded on a substantial number of days in the Basin. There

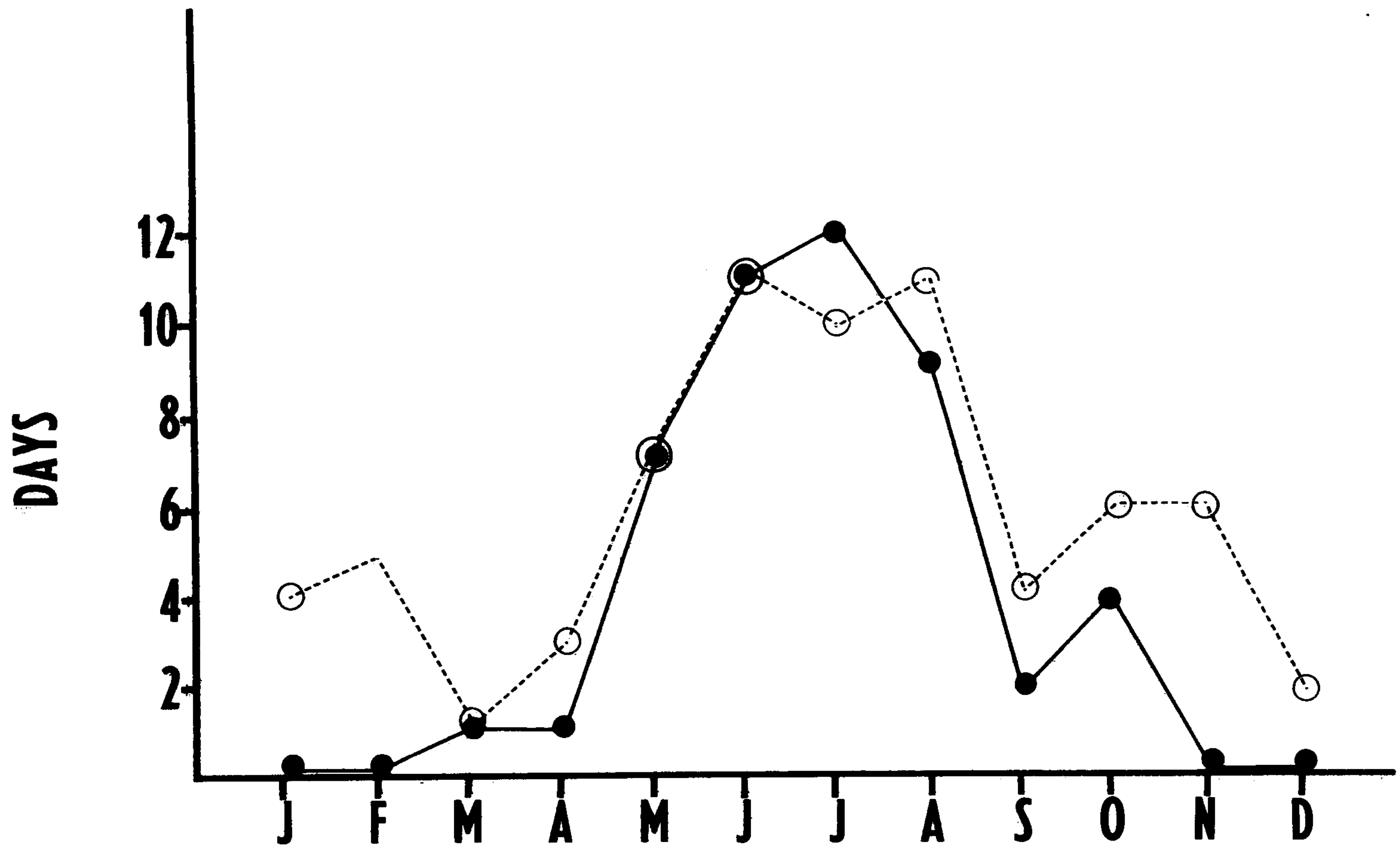

Figure 19 plots the number of Rule 444 days (dotted line) and the number of Stage 1 ozone episode days (0.20 ppm, one-hour average) at Azusa each month during 1976.

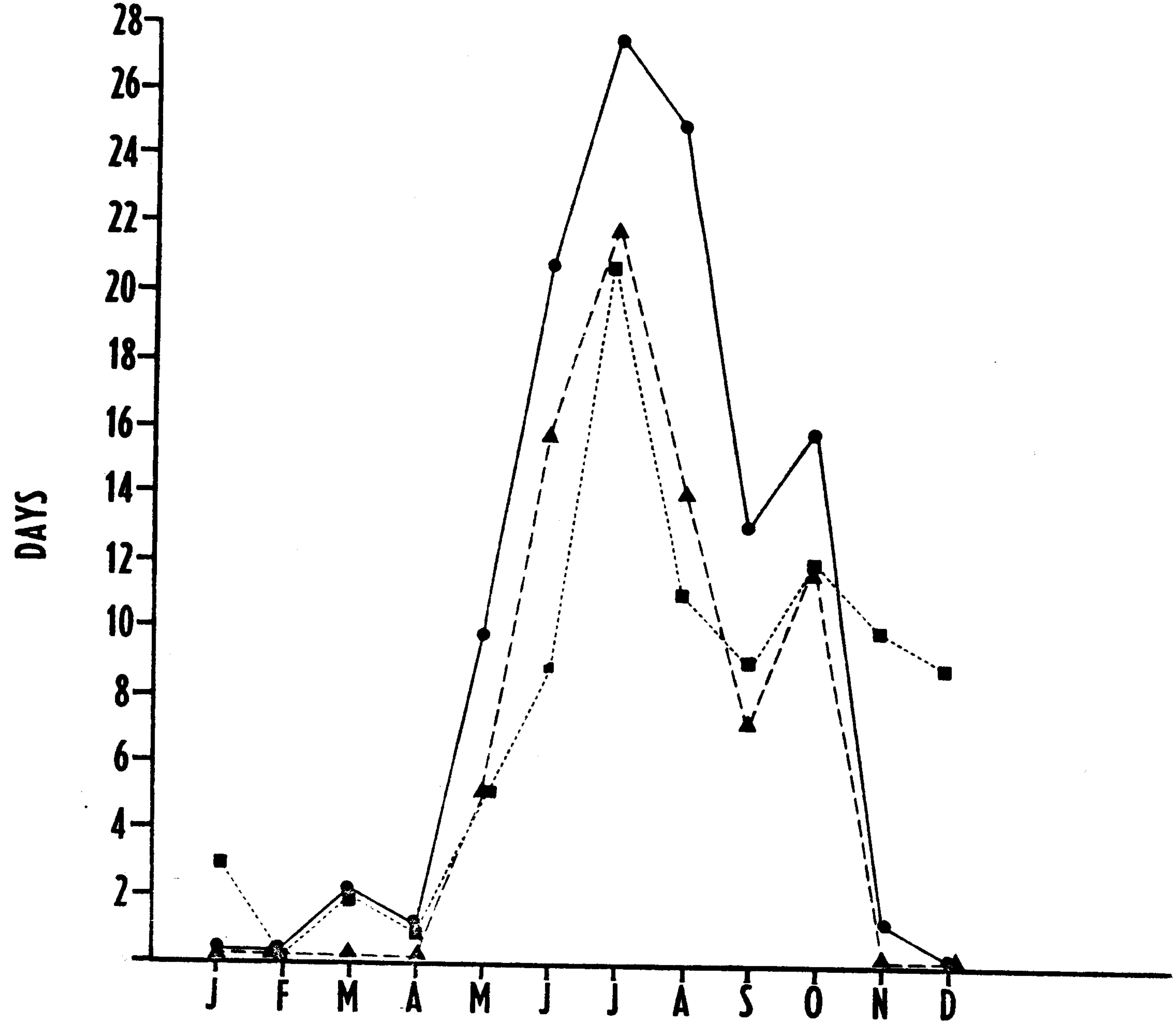

Figure 20 plots the number of Rule 444 days (squares) and the number of Stage 1 ozone episode days (0.20 ppm, one-hour average) attained Basin-wide (circles) and at Azusa (triangles) by month during 1978.

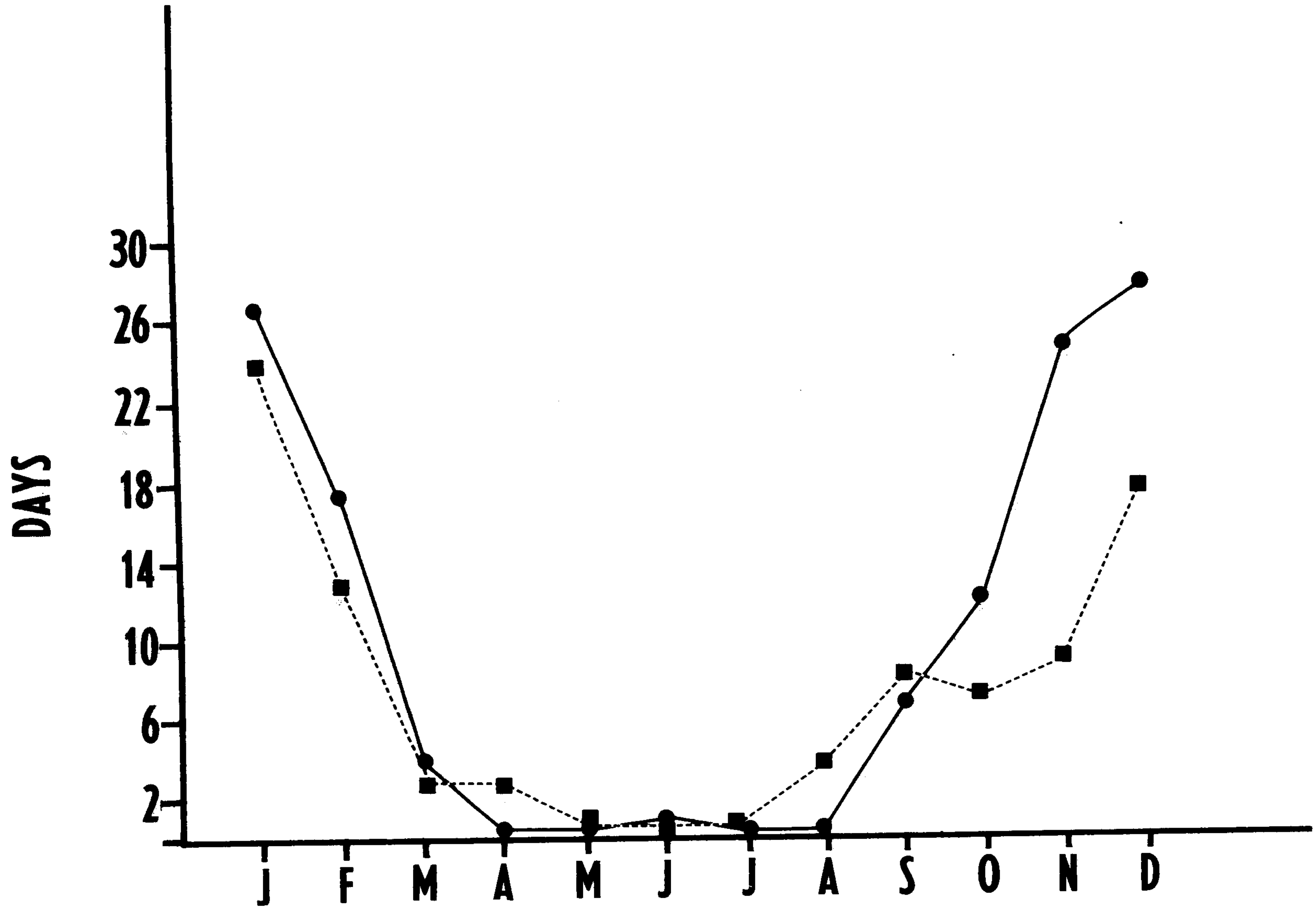

Figure 21 plots the number of surface-based coastal inversions (dotted line) and the number of days the State air quality standard for carbon monoxide (10 ppm, twelve-hour average) was violated at Lennox, by month, during 1975.

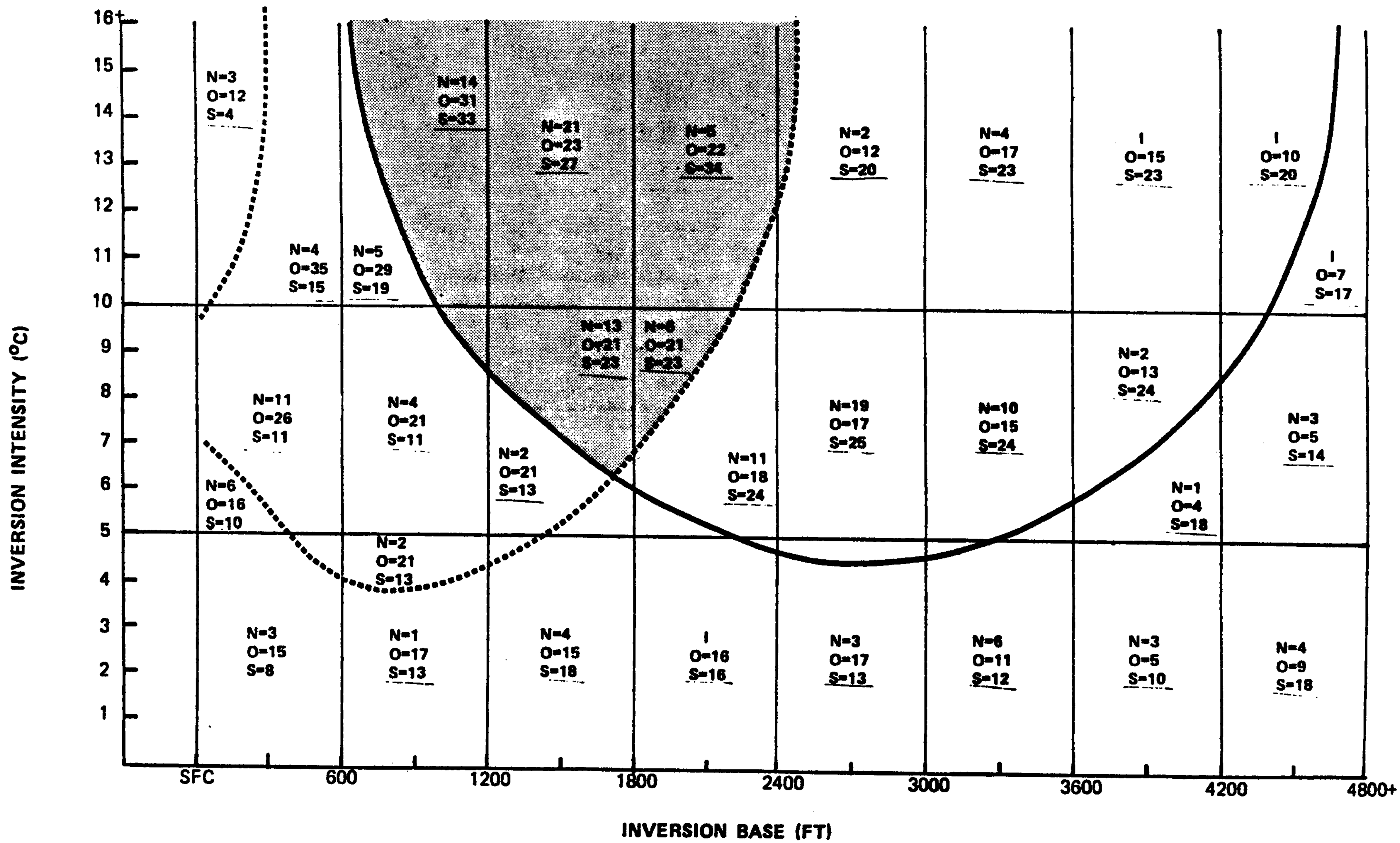

Figure 22. Distribution of ozone (pphm) at Azusa and sulfate (ug/m^3) at Glendora under specified inversion conditions. Areas of high sulfate values (solid curve) and high ozone (dashed curve) are given. For each interval, values represent average of observed data points where N=number of cases, O=observed ozone, S=observed sulfate, and I=interpolated values for ozone and sulfate where no data points exist. (After Zeldin, 1976).

are state air quality standards for each of the two contaminants and national standards for ozone. Also, emergency criteria have been established for ozone and for a combination of ozone and sulfates. See Table XX. The present District and its predecessor agencies have not set air quality standards, but since 1955 have established alert and health warning contaminant levels. (7)

Although different meteorological factors favor high concentrations of ozone as opposed to sulfates, Figure 22 indicates that with moderately low, strong inversions, elevated concentrations of both contaminants are found. High ozone values correlate well with low or moderately low, strong inversions, light winds, weak pressure gradients, and maximum sunshine but not humidity. Sulfates and humidity, on the other hand, correlate well and it follows that the marine layer over the Basin is an ideal climate for the conversion of sulfur dioxide to sulfates. When a marine layer exists under a strong inversion, vertical mixing is restricted and there is minimum mixing of the moist air in the marine layer with dry air from aloft. Under these conditions, sulfates can reach high concentrations.

There are days, as mentioned above, when meteorological conditions are favorable for the production of high concentrations of ozone and sulfates. Zeldin found that sixty-three percent of the study days were low sulfate and low ozone days. On thirty-seven percent of the days, one or the other but not both contaminants attained high concentrations, and on nine percent of the days, high values for both were measured. The latter days had inversion strengths equal to or greater than seven degrees Celsius with inversion bases between 800 and 2400 feet msl. (244 and 732 m.)

The typical high sulfate-high ozone day is a day with nighttime and early morning stratus clouds that enhance sulfate formation, followed by a sunny afternoon with sufficient radiation for the production of ozone by photochemical reactions. Strong subsidence aloft strengthens the inversion and limits vertical mixing all day. Low visibilities are found throughout the Basin on such a day because of the high concentration of particulates, especially sulfates, in the marine air.

The presence of a marine layer during winter months can lead to high sulfate levels, but the absence of factors, particularly radiation, that produce ozone, precludes the simultaneous occurrence of high concentrations of ozone and sulfates on virtually all days during the cold season. Although weather factors are a guide to days with high sulfate potential, the daily absolute concentrations of sulfates are also controlled by daily fluctuating tonnages of sulfur emissions and also by an apparent carry-over of sulfates in the atmosphere from day to day. For instance, with an established marine layer that has an inversion base and strength that does not change appreciably for several days, sulfate concentrations increase each day until the basic weather pattern changes. Emissions of ozone precursors, on the other hand, show less variability from day to day and those contaminants and ozone itself have a lesser tendency to accumulate in the Basin atmosphere over long periods.

TABLE XX

COMPARISONS OF AIR QUALITY STANDARDS AND EMERGENCY CRITERIA

Air Contaminant and Action Required	Air Quality Standards a)			Emergency Criteria						
	California	National b)		SCAQMD c) and California Episode			National Episode			
		Primary	Secondary	Stage 1 Health Advisory	Stage 2 Warning	Stage 3 Emergency	Alert Level	Warning Level	Emergency Action Level	Significant Harm To Health Level
Ozone O_3	0.10 ppm, 1-hr. avg.	0.12 ppm,* 1-hr avg.	0.12 ppm,* 1-hr. avg	0.20 ppm. 1-hr. avg	0.35 ppm, 1-hr avg.	0.50 ppm, 1-hr. avg.	0.10 ppm, 1-hr. avg.	0.40 ppm. 1-hr. avg.	0.50 ppm 1-hr. avg.	0.60 ppm. 1-hr. avg.
Carbon Monoxide CO	10 ppm, 12-hr. avg. 40 ppm, 1-hr. avg.	9 ppm, (10 mg/m^3) 8-hr avg. 35 ppm, (40 mg/m^3) 1-hr avg.	9 ppm, (10 mg/m^3) 8-hr. avg 35 ppm, (40 mg/m^3) 1-hr. avg.	20 ppm, 12-hr. avg 40 ppm, 1-hr. avg	35 ppm. 12-hr. avg. 75 ppm, 1-hr. avg.	50 ppm, 12-hr. avg. 100 ppm 1-hr. avg.	15 ppm, 8-hr. avg.	30 ppm, 8-hr. avg.	40 ppm. 8-hr. avg.	50 ppm. 8-hr. avg 75 ppm. 4-hr. avg 125 ppm. 1-hr avg.
Nitrogen Dioxide NO_2	0.25 ppm 1-hr. avg	0.05 ppm, (100 ug/m^3) AAM	0.05 ppm, (100 ug/m^3) AAM	***			0.15 ppm, 24-hr. avg. 0.60 ppm, 1-hr. avg.	0.30 ppm. 24-hr. avg. 1.2 ppm. 1-hr. avg.	0.40 ppm. 24-hr. avg 1.6 ppm. 1-hr. avg	0.50 ppm. 24-hr. avg 2.0 ppm. 1-hr avg.
Sulfur Dioxide SO_2	0.05 ppm.** 24-hr. avg. 0.50 ppm, 1-hr. avg	0.14 ppm, (365 ug/m^3) 24-hr. avg. 0.03 ppm, (80 ug/m^3) AAM	0.50 ppm (1300 ug/m^3) 3-hr avg.	0.20 ppm. 24-hr. avg 0.50 ppm. 1-hr avg.	0.70 ppm, 24-hr. avg. 1.0 ppm. 1-hr. avg.	0.90 ppm, 24-hr. avg. 2.0 ppm, 1-hr. avg.	0.30 ppm, 24-hr. avg.	0.60 ppm, 24-hr. avg.	0.80 ppm. 24-hr avg.	1.0 ppm. 24-hr. avg
Ozone in Combination With Sulfur Dioxide d)				0.20 ppm. 1-hr. avg	0.35 ppm. 1-hr. avg.	0.50 ppm. 1-hr. avg.				
Sulfate in Particulate Matter	25 ug/m^3, 24-hr. avg			25 ug/m^3, 24-hr. avg., combined with Ozone, 0.20 ppm, 1-hr. avg.						
Particulate Matter (TSP)	100 ug/m^3 24-hr. avg. 60 ug/m^3 AGM	260 ug/m^3 24-hr. avg 75 ug/m^3 AGM	150 ug/m^3 24-hr. avg. 60 ug/m^3 AGM				375 ug/m^3 24-hr. avg.	625 ug/m^3 24-hr. avg.	875 ug/m^3 24-hr. avg.	1000 ug/m^3 24-hr. avg.
Particulate Matter (ug/m^3) x SO_2 (ppm) x 2670							65,000 24-hr. avg.	261,000 24-hr. avg.	393,000 24-hr. avg.	490,000 24-hr. avg

* On February 8, 1979 the federal ozone standard was revised to 0.12 ppm, 1 hour average.

** Occurring in combination with a violation of the state Ozone or TSP standards.

*** No standard or criteria when blocks are blank.

(Continued)

TABLE XX (continued)

COMPARISONS OF AIR QUALITY STANDARDS AND EMERGENCY CRITERIA

Air Contaminant and Action Required	Air Quality Standards[a)]			Emergency Criteria						
		National[b)]		SCAQMD[c)] and California Episode			National Episode			
	California	Primary	Secondary	Stage 1 Health Advisory	Stage 2 Warning	Stage 3 Emergency	Alert Level	Warning Level	Emergency Action Level	Significant Harm To Health Level
Lead Pb	1.5 ug/m^3 30-day avg.	1.5 ug/m^3 calendar quarter average								
Non-Methane Hydrocarbons		0.24 ppm (160 ug/m^3) 3-hr. avg. 6-9 a.m.	0.24 ppm (160 ug/m^3) 3-hr. avg. 6-9 a.m.							
Hydrogen Sulfide H_2S	0.03 ppm. 1-hr. avg.									
Visibility Reducing Particles	In sufficient concentration to reduce visibility to less than ten miles at relative humidity of less than 70%									
Actions to be Taken				Voluntary reduction in physical activity and vehicle operation. Open burning banned (not an action at this level after 1976).	Action ranges from voluntary to mandatory.	Mandatory abatement measures. State can take action if local efforts fail.	Open burning prohibited. Requested reduction in vehicle operation. Industrial curtailment.	Incinerator used prohibited. Required reduction in vehicle operation. Industry curtailed further.	Vehicle use prohibited. Industry shut down or curtailment. Public activities cease.	Same as "Emergency" except most industry shut down

a) Standards shown in parenthesis are restatements of the preceding standard but expressed on an alternative basis.
b) Concentrations other than annual averages not to be exceeded more than once a year.
c) SCAQMD - South Coast Air Quality Management District.
d) Ozone and sulfur dioxide concentrations both must be greater than 0.10 ppm.

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VISIBILITY

Visibility, or visual range, is defined as the distance an observer can see an ideal black object against the horizon. The National Weather Service standards for observations require that prevailing visibility be defined and reported as the greatest visibility attained or surpassed around at least one-half of the horizon, but not necessarily in continuous quadrants.

Reduced visibility has been one of the most apparent manifestations of smog in the greater Los Angeles atmosphere since the 1940's, when smog was recognized as an area-wide problem. Factors that limit visibility are atmospheric aerosols and particulates that reflect, scatter, and/or absorb light.

Visibility and Air Quality

Reduction in visibility is attributed to natural and man-made sources. In the South Coast Air Basin, naturally-occurring visibility restrictors are principally water droplets evidenced by fog and haze, salt particles, smoke and other particulates from wild fires, and wind-blown dust. Contributions from human activities range widely from combustion by-products to aerosols produced in the ambient air of the Basin by photochemical and other complex processes.

Visibility is the single meteorological element that is also an air quality criterion. The State air quality standard for visibility requires that the most restricted visibility of any hourly observation during the day at an observation station must be at least ten miles. Hourly observations are considered only if the relative humidity is less than seventy percent.

Humidity Effects

Visibility in the atmosphere is reduced mainly by particles much larger than molecules. The effective scattering or obscuring material occurs as a disperse phase of an atmospheric aerosol composed of both liquid and solid particles. Junge (19) has shown that practically all particles in the atmosphere act as nuclei upon which water will condense, adding that in the actual atmosphere, only those nuclei which require the lowest degree of supersaturation (i. e., haze droplets and larger nuclei droplets) are active. In addition, the influence of a large city is shown by the high content of large ions which act as condensation nuclei. Samples collected by dust counters consist of droplets to a considerable extent, the proportion of droplets increasing with humidity. Many of these droplets contain both soluble and insoluble substances. Over the oceans, practically all haze droplets consist of sodium chloride solutions.

The reason for the use of the seventy percent level as a criterion in the State visibility air quality standard is that in the condensation stage, noticeable growth of nuclei starts only after a humidity of seventy percent has been attained. This growth accelerates as the humidity approaches saturation. See Figure 23. Below seventy percent relative humidity, the solid nucleus is covered by only a thin solution film with the radius remaining almost constant and there is little effect on light-scattering until the particle begins to grow. Since the size of nuclei in the atmosphere remains essentially constant below seventy percent relative humidity, visibility and opacity remain constant for a given concentration of pollution particles and are not affected by the water content. Thus, the seventy percent humidity limit is valid for defining a "dry" day.

Two exceptions to this generalized definition exist. First, when the predominate particles in the atmosphere are sodium chloride, growth in the condensation stage begins at about sixty percent relative humidity. See Figure 24. Second, in the evaporative stage, visibility-restricting water droplets can exist at relative humidities down to about sixty percent. But if the seventy percent requirement were lowered to sixty, many days would be considered as not having exceeded

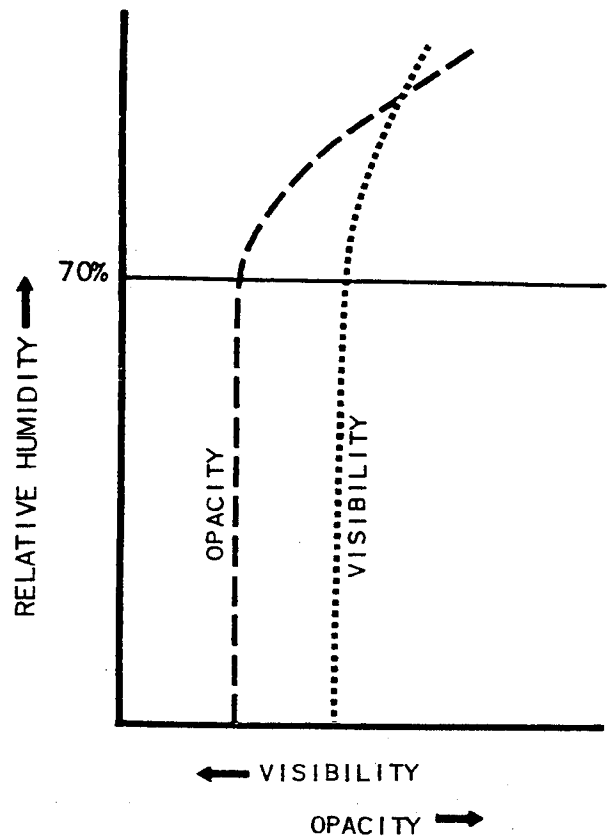

Figure 23 shows the effect of the growth of nuclei with increasing relative humidity on opacity and visibility in the atmosphere. (After Junge)

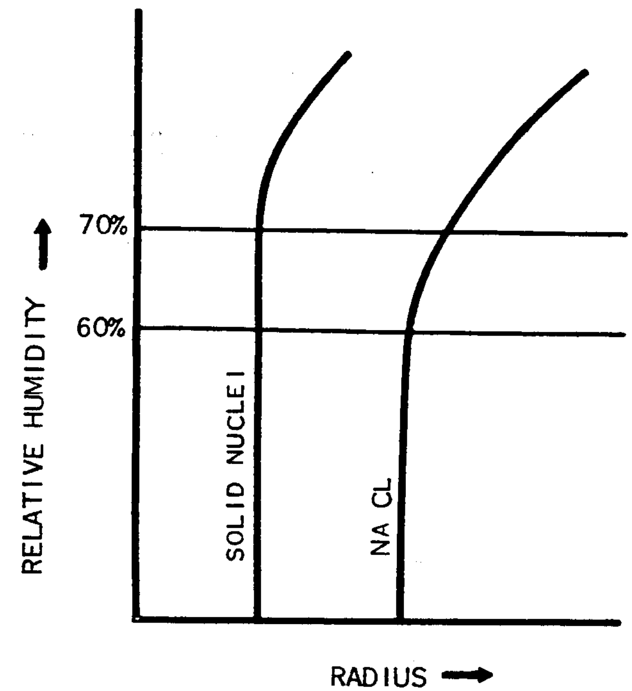

Figure 24 presents curves that relate the growth rates of solid nuclei and sodium chloride (NaCl) to humidity. (After Junge) the air quality standard when the principal cause of visibility restriction was contaminants rather than water particles.

Photochemical Aerosols and Visibility

During the summer photochemical smog season, visibility reduction is caused by a combination of naturally-occurring haze plus photochemical aerosols. During early morning hours, the moisture-laden sea haze is generally the cause of most of the visibility reduction, although particulate remnants of smog from the previous day may add to the effects at times. As the day progresses, the relative humidity of the air normally decreases with the usual increase in air temperature. As a consequence, the sizes of the visibility-reducing water droplets diminish during this period or the droplets evaporate completely. (It is normal to find that an evaporated droplet leaves a particulate nucleus that can "seed" the formation of a photochemical aerosol later in the day.) As this evaporation is occurring, the photochemical reaction has begun and additional visibility-reducing aerosols are produced. By mid-afternoon, these photochemical aerosols are responsible for much of the visibility reduction.

The aerosol-forming reactions also involve oxidizing various hydrocarbons and hydrocarbon derivatives. In this process, the first products are gases that have no effect on visibility reduction. As oxidation proceeds further, the chemical compounds formed are characterized by higher and higher molecular weights and lower volatilities and have less tendency to remain in the gaseous phase. Eventually, if the molecular weights and the concentrations are high enough, these compounds can no longer remain gaseous and condense out into tiny liquid particles that reduce visibility. The compounds also act as nuclei for condensation; the resultant particulates reduce visibility even further. The process is analogous to the formation of fog from water vapor, except that this aspect of photochemical smog is not water but a complex mixture of organic substances. Still further oxidation may break up these liquid particles by splitting the chemical compounds, of which they are composed, into smaller fragments that again may be gaseous and, therefore, invisible.

Visibility Trends

One method employed to measure over-all air quality trends in the Basin is the determination of visibility trends. Calculating the increase or the decrease in the number of low-visibility days each year at several locations over a long period has been used in such a determination. (24, 25). In these studies, a low-visibility day was defined as a day when the minimum hourly visibility was less than three miles with a concurrent relative humidity of less than seventy percent. (Analyzing trends in various ranges of visibility is another method.) (23).

Limiting the definition of low visibilities to those observed to be less than three miles, in relatively dry air, is appropriate in determining visibility trends in the South Coast Air Basin. For the greater part, such reduced visibilities are due to man-made particulates. Also, the three-mile level is much more meaningful as a measure of pollution than the State air quality standard for visibility, ten miles. This standard is much too restrictive for use in trend analyses in Southern California. Near that visual range, naturally-occurring haze, fine dust or salt particles will limit the visibility on many days even when ambient air contaminant levels are relatively low. Lastly, dry days with extremely reduced visibilities are associated with high pollution levels by the public experiencing the pollution as well as by actual measurements.

Visibility trends from 1950 through 1978 are discussed in Reference No. 24. In general, since 1950, the area of the greatest number of low-visibility days per year has shifted from central Los Angeles to the sub-basin east of the Chino Hills. All of the four stations in the western portion of the Basin showed improving visibility trends during the period. Figure 25, for example, shows the trend in the number of low-visibility days in Downtown Los Angeles, 1950-1978.

Table XXI is a listing of the number of days each year the daily minimum visibility was less than three miles at relative humidity under seventy percent at seven Basin locations. This climatological air quality data can be used to evaluate visibility trends in future years.

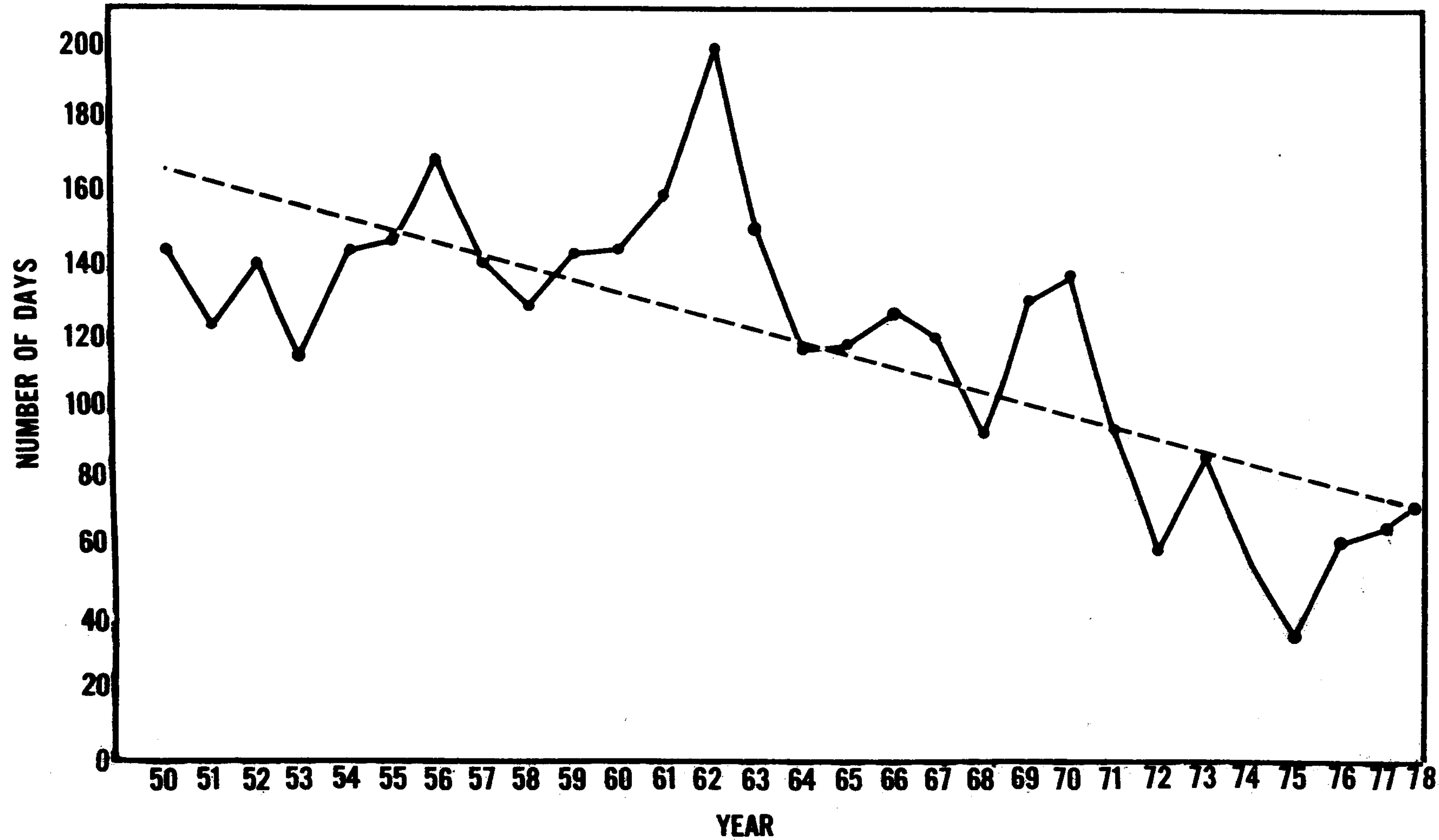

Figure 25 is a plot of the number of low-visibility days per year in Downtown Los Angeles (PLX/CAP) with best-fit trend line.

TABLE XXI

DAYS PER YEAR MINIMUM VISIBILITY LESS THAN THREE MILES AT RELATIVE HUMIDITY LESS THAN SEVENTY PERCENT

SOUTH COAST AIR BASIN STATIONS

	STATION						
YEAR	LAX	LGB	PLX/CAP[a]	BUR	ONT	SBD	RIV
1950	72	67	143	121		94	18*
1951	72	66	122	93		99	40
1952	86	99	140	108		96	40
1953	91	91	113	100		77	25
1954	113•	86	145	145•		116	61
1955	96	80	147	115		121	50
1956	113•	85	169	114		151	57
1957	89	71	139	67		124	34
1958	94	100	128	88		137	57
1959	77	95	144	75		122	49
1960	39	89	145	73		98	43
1961	53	77	159	79		93	33
1962	57	102	200•	123	140	153•	70
1963	65	88	150	76	126	135	51
1964	39	51	117	66	114	118	31
1965	56	80	117	86	120	143	66
1966	38	94	127	91	153	138	98
1967	62	128•	120	121	153	112	72
1968	46	98	92	111	136	107	71
1969	32	91	130	106	157	111	110•
1970	27	66	135	100	141	115	77
1971	16	53	94	84	136	95	65[b]
1972	19	51	57	61	138	87	55
1973	27	73	85	71	159•	144	81
1974	18	65	57	59	140	114	68
1975	26	54	35*	58	152	125	70
1976	10	43	60	21*	115	90	58
1977	8*	50	65	24	136	96	90
1978	9	25*	70	29	96*	71*	62
Average	53	76	117	85	136	113	59

(a) Downtown Los Angeles

(b) Estimated

• Years that maximum number of days occurred

* Years that minimum number of days occurred.

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METEOROLOGY AND CONTAMINANT CONCENTRATIONS

Ambient concentrations of contaminants are measured continuously, 24 hours per day, by the District network of monitoring stations. Levels of pollution that people are subjected to in representative areas of the Basin are determined by data generated by this network. Primary contaminants and secondary contaminants (those produced principally by chemical reactions in the atmosphere) are monitored by continuously-recording instruments. Particulate matter is an exception. Total suspended particulates are collected by high-volume samplers every sixth day. Materials gathered on the sampler filters are then analyzed to determine concentrations of particulates that include metals, nitrates and sulfates.

The District also measures contaminant concentrations in the discharges of stationary industrial equipment and processes. These measurements of pollution concentrations at the various sources is not a continuous-sampling program. However, these source tests of emissions are made regularly at power plant stacks, industrial and chemical stacks and flues, and other stationary sources. Mobile source sampling involves testing vehicle exhaust emissions. This program is not a prerogative of the District.

Between sources and receptors, primary contaminants are subject to considerable dilution. Concentrations of secondary pollutants at receptors are related directly to source strengths of precursors, but are subject to complex chemical reactions before daily maximum concentrations are reached. But with either type contaminant, ultimate ambient concentrations or dosage strengths and durations are determined by meteorological factors for given initial concentrations.

In the remainder of this section, meteorological parameters (except wind flow) that lead to high concentrations of five major Basin pollutants are summarized. In the final sections, pollution transport within the South Coast Air Basin and transport between air basins in Southern California are discussed.

Ozone (O_3)

Ozone is a nearly colorless (but faintly blue) gaseous form of oxygen with a characteristic odor like that of weak chlorine.

In the smog-forming reactions involving hydrocarbons and nitrogen dioxide, ozone is one of the most significant products. Ozone is not an eye irritant, but it causes part of the distinctive odor of smog. Ozone also re-enters the reaction to oxidize hydrocarbons and other organic gases to produce more eye irritants and particulate matter.

Ozone is formed when nitrogen dioxide breaks down under the influence of sunlight. In the process, nitric oxide and active (atomic) oxygen are released. The nitric oxide re-enters the processes described previously, and the active oxygen can re-combine with the nitric oxide to form more nitrogen dioxide or combine with hydrocarbons, or it may combine with ordinary oxygen to produce ozone.

Ozone is continually being formed and used up during the photochemical reaction process, but cannot begin to accumulate significantly until substantially all the nitric oxide has been converted to nitrogen dioxide. Only the ozone that accumulates can be measured by air monitoring instruments.

Meteorology and High-Ozone Days

To profile meteorological parameters that describe a "high-ozone" day, ten summer days during 1975 and 1976 when ozone concentrations in the Basin exceeded 0.30 ppm (one-hour average) were chosen. Every day of the week was represented with two occurrences on Thursday, Friday and Saturday. This frequency fits the general pattern of the weekly ozone curve that shows a gradual build-up of ozone concentrations toward the end of the week, meteorological factors being equal.

The height of the inversion base above ground level is the most important weather parameter that affects daily ozone maximum concentrations, since it limits the extent of vertical dilution. Wind speed is a measure of horizontal dispersion, but since one characteristic of subsidence inversions is that wind speed correlates positively with inversion height, light wind speeds occur with low inversion. Thus, on days of limited vertical mixing, horizontal diffusion is also limited.

The height of the inversion base at sunrise measures the initial vertical extent of the mixed layer. The maximum mixing height, as discussed previously, is the highest altitude to which the inversion base rises and indicates the maximum vertical mixing that day. On high-ozone days, the morning inversion must be near the surface to allow accumulation of primary pollutants, and the maximum mixing height (or the mixing height at the time of the ozone maximum) must be low enough to prevent excessive vertical ozone dilution. On a characteristically high-ozone day, the coastal inversion base is low in the morning and the mixed layer rises little during the day.

Analysis of meteorological data on the ten high-ozone days produced these factors associated with restricted vertical mixing during the summer smog season. See Figure 26.

- The morning inversion base at the coast averaged 912 feet (278 meters) above mean sea level (msl). The range was from surface inversions to bases at 1969 feet (600m).

- The coastal inversion base at noon was slightly lower than the morning inversion base, and averaged 869 feet (265 m) with a range from 489 feet to 1575 feet (149 m to 480 m).

  (Lowering of the inversion base during the morning does not apply to the special case of the surface inversion which can occur with a marine layer during the summer in the absence of cloud cover. However, with surface heating and turbulent mixing shortly after sunrise, the inversion base is reestablished at the top of the marine layer.)

- The top of the inversion averaged 3465 feet (1056 m) and 27.1°C in the morning, and 3120 feet (951 m) and 28.9°C at noon. The lowering of the inversion top and an increase of the top temperature during daylight hours indicate continuing subsidence that strengthens the inversion top and suppresses vertical mixing.

Nitrogen Dioxide (NO_2)

Nitrogen dioxide is a gas with a yellowish-brown tinge. It is the primary absorber of sunlight in the photochemical process. It is a secondary product in the atmosphere formed by the oxidation of nitric oxide. (36).

Nitric oxide (NO), a primary pollutant, is formed from the oxygen and nitrogen of the air during combustion processes, and the rate of formation increases with the combustion temperature. It is the predominant oxide of nitrogen emitted to the atmosphere from nearly all burning processes.

Nitric oxide will oxidize slowly in the air to form the dioxide but by reacting with hydrocarbons in the presence of adequate sunlight, this oxidation appears to be accelerated. The nitrogen dioxide, in turn, absorbs certain ultraviolet light and produces nitric oxide and active (atomic) oxygen. This active oxygen can then combine with nitric oxide to produce more nitrogen dioxide, with oxygen to produce ozone, or with hydrocarbons to produce various intermediate products, some of which are physiological irritants and others of which contribute to particulate matter that reduces visibility. The quantity of oxides of nitrogen in the initial mixture governs the total amount of ozone that can be formed.

Meteorology and High-Nitrogen Dioxide Days

A meteorological profile for high-nitrogen dioxide days was drawn, based on eight occurrences of elevated nitrogen dioxide concentrations between 1973 and 1976. The daily maximum range was 0.47 ppm to 0.76 ppm, one-hour average. Meteorological conditions on those days were surprisingly similar.

Morning and noon inversion base heights at the coast averaged 500 feet (152 m) msl with the range from surface inversions to 1000 feet (305 m). Maximum mixing heights in Downtown Los Angeles averaged a very shallow 2000 feet (610 m), although on one October day the inversion was broken and mixing was unlimited. On that day, however, vertical mixing was limited to an extremely shallow surface layer prior to 1100 PST. The Basin maximum concentration (0.76 ppm) occurred near the coast (West Los Angeles) at 0900 PST.

With the exception of a single day in late August, the high concentration of nitrogen dioxide were attained on days in the autumn and winter. But meteorological conditions on those days were typical of summer, with very high surface temperatures. Maximum temperatures in Downtown Los Angeles averaged 87°F, the range 77°F to 98°F. Off-shore pressure gradients on all of the days caused light land-to-ocean winds during the early morning hours and some stagnation after sunrise. The days were hazy and fairly dry due to the absence of a thick marine layer at the surface.

Although nitrogen dioxide is not a primary pollutant, the highest nitrogen dioxide concentrations occur in roughly the same part of the Basin where maximum nitric oxide and carbon monoxide concentrations are measured--central and southwestern Los Angeles County and northern Orange County. These areas also correspond to the section of the Basin with the highest vehicular and stationary sources of oxides of nitrogen. High carbon monoxide concentrations are attained with relatively short transport from source to receptor and with strong enrichment of a polluted air mass from local vehicle emissions. Nitrogen dioxide maxima occur under similar transport conditions but, in addition, the accelerated production of NO_2 requires sunlight and hydrocarbons.

In the above discussion, emphasis was placed upon photochemistry since nitrogen dioxide is an important intermediate product of the process. But, nitric oxide does convert to the dioxide in the absence of light although the conversion is slowed. Daily maxima can occur after sunset with restricted dispersion and available nitric oxide. The typical nitrogen dioxide diurnal peak is bimodal, about 8:00 a.m. and 8:00 p.m., although at times concentrations continue to rise during the evening hours. Times of daily peaks vary from station to station in the Basin because of meteorological factors as well as locations in respect to high nitric acid source areas.[35]

On the eight high-nitrogen dioxide study days, the times of the autumn peaks ranged from 0900 to 1300 PST; while on one winter day, the nitrogen dioxide maxima occurred in Downtown Los Angeles and Lennox at 2100 PST. Considering daytime nitrogen dioxide peak concentrations that are due to photochemical reactions (as opposed to dark chemical conversion), autumn and winter peaks occur later than peaks during the summer because of weaker radiation and fewer hours of sunshine. Assuming identical cloud cover conditions, the photochemical reaction is slowed, day to day, from the longest day to the shortest day each year.

On the eight high-nitrogen dioxide days, there was poor correlation between nitrogen dioxide concentrations and Basin maximum zone concentrations. Although there may be an abundance of nitrogen dioxide in the morning, the production of ozone later in the day varies with changing vertical and horizontal diffusion, cloud cover, and availability of ultraviolet radiation. The minimum daily ozone maximum concentration achieved on any of the study days was 0.10 ppm during January. At the other extreme, on August 30, 1976, with a nitrogen dioxide 0.53 ppm one-hour average in Downtown

Los Angeles, the maximum Basin ozone concentration was 0.38 ppm one-hour average at Upland. See Table XXII.

The table referred to above shows that only one of the eight high-nitrogen dioxide days occurred during the summer. On many summer days, even with source areas measuring high oxides of nitrogen concentrations during the early morning, nitrogen dioxide concentrations begin to decrease as ozone is formed. In contrast, during the fall and winter with weaker solar radiation, ozone formation is retarded; hence there is a greater chance for accumulation of nitrogen dioxide.

October 18, 1974 was a typical high-nitrogen dioxide day (0.64 ppm, one-hour average). The morning and noon inversion bases were 800 feet (244 meters) msl. Vertical mixing was extremely limited during the day; the maximum mixing height based on the morning sounding was 1700 feet (518 meters) msl, and based on the noon upper air sounding was 1200 feet (366 meters). The strong morning inversion was strengthened further during the day by low-level subsidence. The maximum temperature in Downtown Los Angeles was 83°F. Daytime visibilities were poor throughout the Basin.

Although the highest nitrogen dioxide concentrations on October 18 were attained in Downtown Los Aneles, values above the California air quality standard (0.25 ppm, 1-hour average) were widespread. Figure 27 shows the Basin daily maximum nitrogen dioxide values on that day. At most stations the nitrogen dioxide peaked between 1000 and 1100 PST; at inland stations peaks were attained at 1000 PST and again between 1800 and 2000 PST. Ozone concentrations were above average for October and were highest at Upland where a value of 0.31 ppm was measured.

Carbon Monoxide (CO)

Carbon monoxide is a colorless, odorless, toxic gas. It is produced by the incomplete combustion of carbonaceous fuels. In the South Coast Air Basin, the nearly-exclusive source (greater than 95 percent) is the motor vehicle. As a primary pollutant, and one not subject to important chemical changes in the ambient air, carbon monoxide concentrations can be correlated directly to the major source.

Meteorology and High-Carbon Monoxide Days

The basic meteorological requirement for a high-carbon monoxide day is the presence of a surface inversion. Such an inversion is caused by radiational cooling of the earth's surface on cloudless nights. Vertical mixing, under such conditions, is restricted to a shallow layer of air at the ground; this limited mixing is due to mechanical action of light winds.

TABLE XXII

SELECTED HIGH-NITROGEN DIOXIDE DAYS WITH BASIN OZONE MAXIMA

Date	Daily Basin Maximum Nitrogen Dioxide [a]		Daily Basin Maximum Ozone [a]	
	Location	Conc.	Location	Conc.
10/16/73	Downtown Los Angeles	0.58	Azusa	0.30
10/17/73	Downtown Los Angeles	0.52	Azusa	0.19
10/15/74	West Los Angeles	0.76	Burbank	0.12
10/18/74	Downtown Los Angeles	0.64	Upland	0.31
1/15/75	Pasadena	0.47	Pasadena	0.10
1/17/75	Whittier	0.62	Downtown Los Angeles	0.14
8/30/76	Downtown Los Angeles	0.53	Upland	0.38
11/23/76	Pico Rivera	0.52	Pico Rivera	0.18

a) In parts per million, one hour average.

During November, December and January, night and early morning surface inversions occur on 70 percent of the days. It follows that average carbon monoxide concentrations are highest during the winter because of the frequency of surface inversions. However, the mere existence of a surface inversion does not ensure maximum carbon monoxide values. To achieve such high concentrations, the surface inversion must be strong (defined as the temperature difference between the top and the bottom of the inversion) and flat (defined as a rapid increase in temperature with altitude in the surface layer of air). A final requirement to achieve maximum carbon monoxide concentrations is the gradual advection of a polluted air mass to a stagnation area with local reinforcement of the polluted air by vehicle emissions during morning or evening traffic peaks.

Figure 28 shows the diurnal pattern of carbon monoxide concentrations for the 1978 summer and 1977-1978 winter periods at the Lynwood air monitoring station. (16) The bimodal curve peaks at 0700 PST and midnight during the winter. Summer peaks are displaced one hour earlier because of earlier sunrises and daylight savings time that accounts for correspondingly earlier traffic maxima. The relationship between carbon monoxide peaks and traffic peaks in the morning is obvious in the diagram; the same relationship in the evening is complicated by weather factors.

In the winter, there is maximum instability about midafternoon. From that point, on the average, the air begins to stabilize at the same time that traffic increases. The stabilization continues after nightfall and new emissions are continuously added to the surface layer of air already rich in carbon monoxide. The decrease after midnight at inland stations is caused by drainage winds moving the polluted air mass to the coast during the period when traffic is approaching the daily minimum. At Lynwood, the summer afternoon peak is low and there is only a small increase in average concentrations from 1800 PST until midnight. Other areas, the San Fernando Valley and Lennox, do show a midnight peak, but this is caused by earlier stagnation in the inland valleys and, in the case of Lennox, by advection and its location immediately downwind of a heavily-traveled freeway. Carbon monoxide concentrations are affected at all stations by less stabilization of the air at the surface during summer evenings than during winter evenings.

Morning carbon monoxide maxima during winter and summer correspond to the time of the greatest daily stabilization, which is also coupled with the morning traffic peak. In both seasons, surface heating after sunrise quickly establishes vertical mixing and carbon monoxide concentrations drop rapidly from daybreak to the midafternoon minimum.

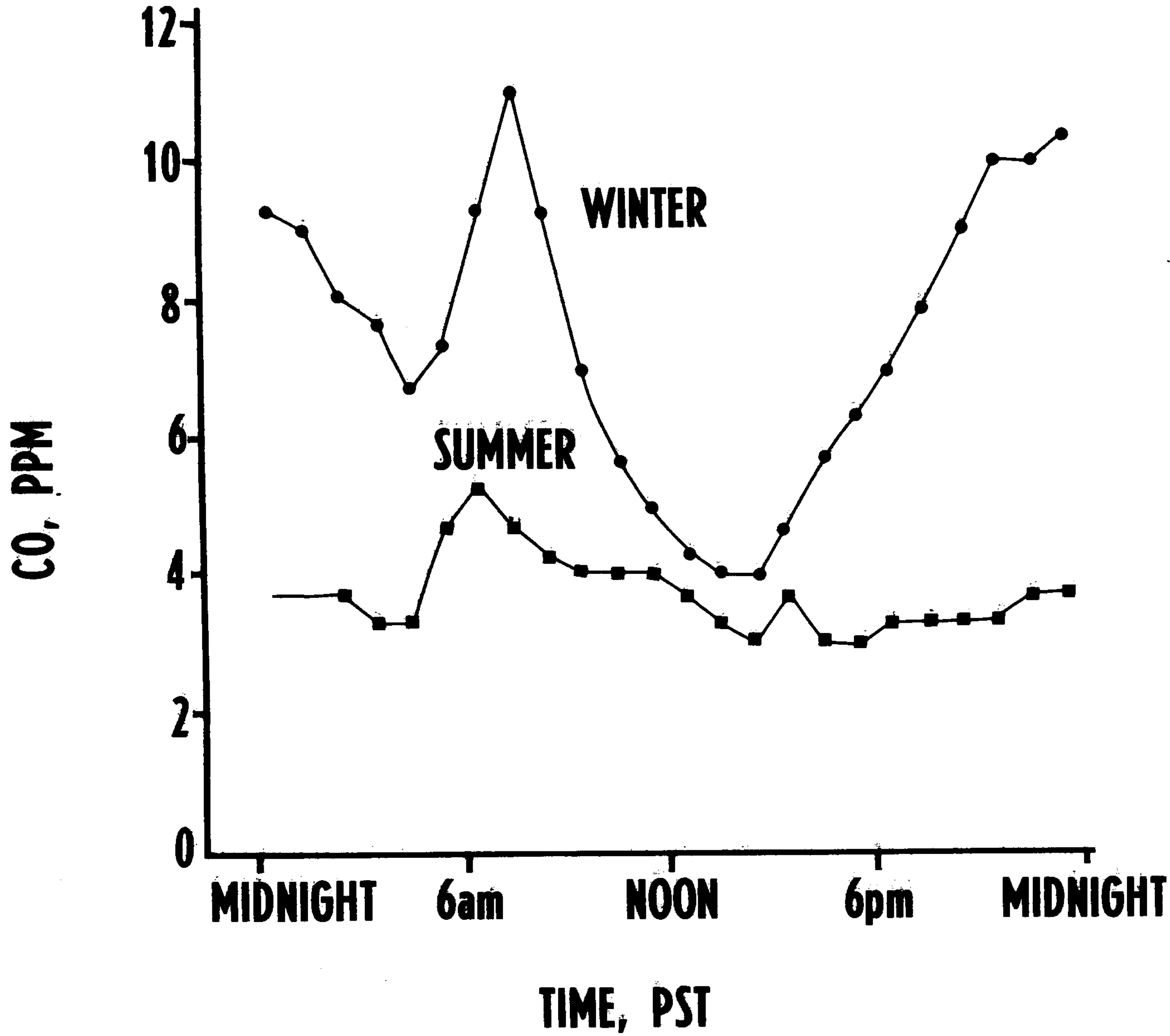

Figure 28 plots diurnal carbon monoxide concentrations in parts per million at Lynwood, summer 1978 and winter 1977-1978. (After Hoggan)

Table XXIII lists eight days during 1975 and 1976 when elevated carbon monoxide concentrations were attained in the Basin. Half were associated with the morning driving peak hours and the others with the evening traffic rush. None of the days were Saturdays or Sundays, which conforms to weekend traffic patterns that do not exhibit morning and evening peaks comparable to weekday peaks in time or traffic volume.

Strong surface inversions in the morning, light winds, and clear skies characterized the eight high-carbon monoxide days. In addition, the time of the one-hour maximum concentration on each of the days fell in place along the typical diurnal winter curve: four at 0700-0800 PST, and four between 1700 and midnight PST.

Area wide, the geographical location of maximum carbon monoxide concentrations is the western portion of the South Coast Air Basin: northern Orange County and Los Angeles County south of the San Gabriel Mountains. Figure 29 shows the spatial distribution of maximum one-hour average carbon monoxide values on January 13, 1975, a day when a 40 ppm, one-hour average was recorded in Downtown Los Angeles. More frequently, the Basin pattern is one with the maximum center shifted southwestward to the Lennox-Lynwood area.

Maximum carbon monoxide concentrations normally occur during November, December and January. But in years with frequent winter storms and rain, conditions for elevated values may exist on but a few, if any, days. In years with many winter-time stagnant high pressure systems over the Basin, the chance to get a considerable number of high-carbon monoxide days is increased.

Sulfur Dioxide (SO_2) and Sulfates (SO_4)

Sulfur dioxide is a colorless gas with a pungent odor. It is an effluent of industrial combustion processes. The odor threshold level is 0.3 ppm to 1.0 ppm. These concentrations are seldom attained in the ambient air in the South Coast Air Basin, although historically, maximum levels measured at air monitoring stations were 2.49 ppm, instantaneous reading, at El Segundo in 1957, and 1.00 ppm one-hour average at Lennox in 1972. Most sulfur-type odors detected in the Basin are mercaptans or hydrogen sulfide.

Sulfates are a broad class of particulate sulfur oxides in the atmosphere. Among the components of the particulate complex are sulfuric acid mist, ammonium sulfate and bisulfate, and metallic salts.[6]

TABLE XXIII

HIGH-CARBON MONOXIDE DAYS 1975 - 1976
SOUTH COAST AIR BASIN

Date	Location	Maximum 1-Hour Concentration	Time of Maximum	Associated Traffic Peak
1/16/75	Lennox	40 ppm	0800 PST	Morning
1/16/76	Lennox	38 ppm	0700 PST	Morning
1/20/76	Lennox	43 ppm	0700 PST	Morning
12/1/76	La Habra	45 ppm	0700 PST	Morning
1/13/75	Downtown Los Angeles	40 ppm	1700 PST	Evening
11/24/75	Lynwood	41 ppm	2000 PST	Evening
11/25/75	West Los Angeles	37 ppm	1900 PST	Evening
12/9/76	Burbank	25 ppm	0000 PST	Evening

Figure 29 shows the spatial distribution of maximum one-hour-average carbon monoxide concentrations on January 13, 1975. The Basin daily maximum was 40 ppm at Downtown Los Angeles.

Meteorology and Sulfur Dioxide Concentrations

The principal sulfur dioxide sources in the Basin are power plants, refineries, chemical plants, coke kilns, and metal industries. Mobile sources contribute fifteen percent of total emissions.[6]

About three-fourths of the sulfur dioxide emission sources are located in the coastal strip from El Segundo to northern Orange County. Other sources, power plants and the Fontana steel mill, are found in inland valleys. The source locations are important because the source-receptor relationship is direct; that is, maximum sulfur dioxide concentrations are found along the downwind path from the sources. Along transport routes, the sulfur dioxide-polluted air becomes diffuse with vertical and horizontal mixing; concentrations also decrease as sulfur dioxide is removed at the boundary layer and as the conversion to sulfates takes place. As a result, maximum concentrations will be found directly downwind and within a few miles of sources.

Sulfur dioxide emissions from stacks released above a low inversion base usually have a minor effect on ambient concentrations. The altitude of release is actually the "effective stack height" which is determined by stack gas velocity, plume buoyancy, wind speed, and stability of the air. See Figure 30.

After sulfur dioxide is emitted into the inversion layer, several different processes may affect the effluent. In one case, the wind flow in the inversion layer transports the gas out of the Basin before it can be mixed downward to the surface. More frequently, the sulfur dioxide remains aloft long enough so that it never reaches the ground in significant concentrations because of dilution and/or transformation into sulfate. Under another condition, sulfur dioxide in the inversion layer is brought down to the surface when daytime ground heating produces sufficient vertical mixing to tap the elevated plume. Less dilution occurs with this condition than with the second case.

Highest concentrations of sulfur dioxide are found at receptors near sources, either high stacks or low stacks or ground level, under conditions of unstable air (sometimes referred to as strong lapse rate) and moderately strong winds. Under these conditions, the gas in the plumes from the source is quickly looped or fumigated to the surface without much dilution.

Mobile sources of sulfur dioxide (vehicles, ships, trains and aircraft) are lesser contributors to ambient sulfur dioxide concentrations than stationary sources. However, the

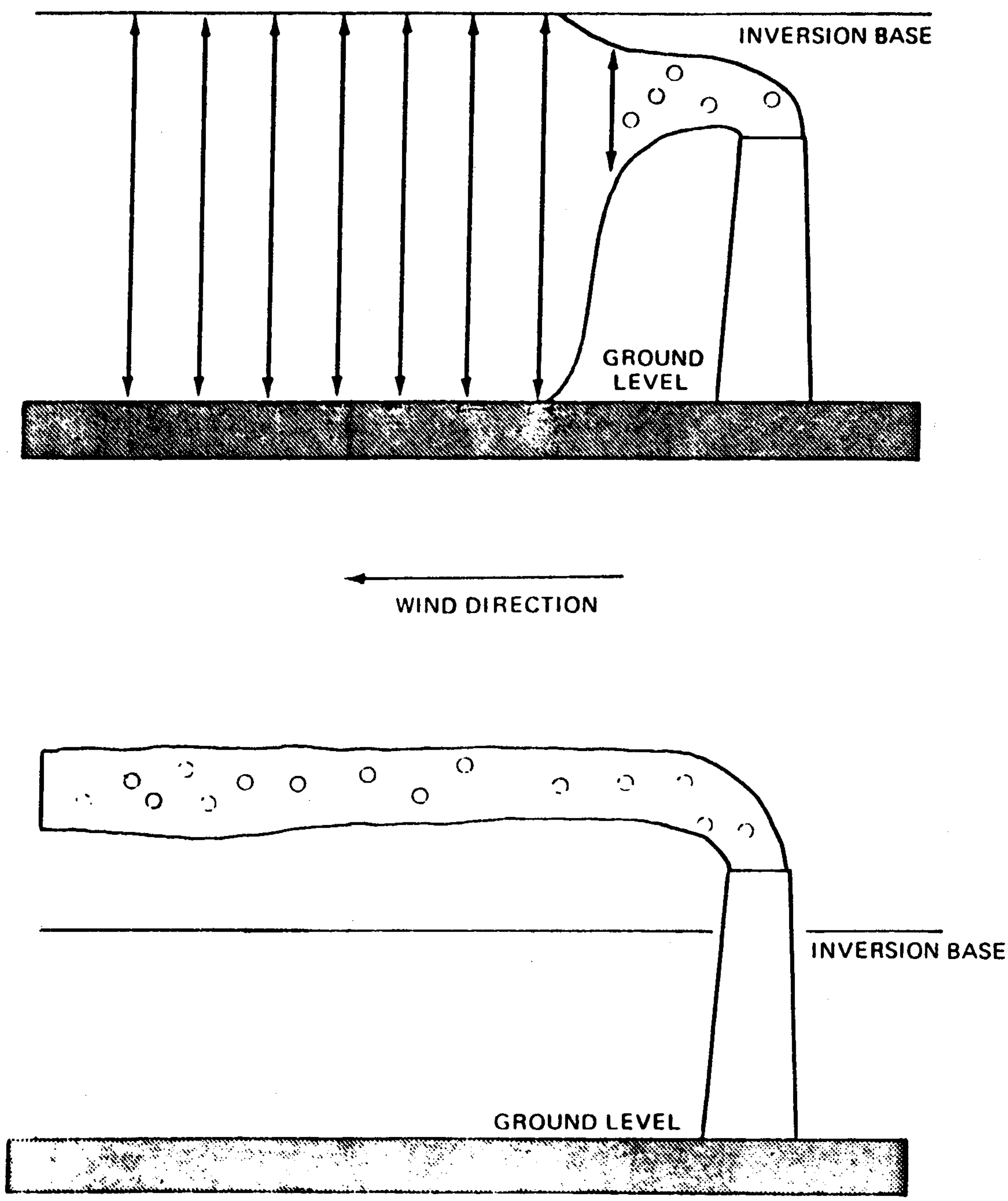

Figure 30 shows the insertion of stack effluents into the atmosphere below the inversion base (top diagram) and above the inversion base (lower diagram). (From Cass, 1978) mobile sources are important in that they emit sulfur dioxide (and some sulfate) at ground level, and conversion of sulfur dioxide to sulfates from these sources takes place near the surface, thus enhancing ground level concentrations.

In relation to meeting air quality standards, sulfur dioxide emissions in recent years have not been great enough to produce exceedances of the sulfur dioxide standards in the South Coast Air Basin, with rare exceptions. However, the contribution of sulfur dioxide emissions to the eventual sulfate load in the atmosphere is highly important, since these emissions cause the state sulfate standard to be violated a significant percentage of the time.

Meteorology and Sulfate Concentrations

The effects of varying meteorological conditions on sulfates are more subtle than on sulfur dioxide concentrations in the Basin atmosphere, since most of the sulfate in the Basin is formed by chemical action in the ambient air. The most important weather factors that control sulfate concentrations are vertical mixing, relative humidity and residence time in the Basin.

Background Sulfates

According to Cass (6), on a global basis, over seventy percent of the emissions of sulfur compounds to the atmosphere arise from natural sources. These include sulfates from wind-blown sea salt, reduced sulfur compounds from biological decay, and emissions from volcanic activity. Cass summarized background sulfate levels in Southern California as follows: "At great distances from the South Coast Air Basin, either out to sea or well into the desert, sulfate concentrations appear to be about one microgram per cubic meter. Immediately adjacent to the air Basin at San Nicholas Island or Lancaster (Antelope Valley), average sulfate concentrations are in the three-to-five ugm/m^3 range."

Sulfate Sources

The state air quality standard for sulfates is 25 ugm/m^3, twenty-four hour average. Air monitoring sulfate measurements in the Basin do include background levels, but the greater majority of sulfate concentrations observed can be attributed to activities of man. Of this portion, most sulfates result from the conversion of sulfur dioxide (30), while a few sources, such as catalytic converter-equipped automobiles and coke calcining plants, emit sulfates directly into the atmosphere. In the Basin, daily and seasonal fluctuations in sulfate concentrations are associated primarily with meteorological factors rather than change in sulfur dioxide emission rates, which remain relatively constant from day to day.

Meteorological Factors and Sulfate Concentrations

Sulfate dilution and transport are affected by changes in the inversion base height and vector wind speeds. As shown previously, very low inversions allow sulfur dioxide emissions from elevated sources to be injected above the mixed layer. More commonly, sulfur dioxide is emitted directly into the marine layer (below the inversion base) where it is available for conversion to sulfate. Sulfate concentrations in the marine layer are then determined by the conversion rate and dilution.

Maximum mixing heights in the afternoon limit the maximum vertical dilution of sulfates; vector winds determine how long air parcels are retained in the Basin. Thus, the maximum volume of Basin air available for dilution of sulfates each day can be likened to a box with the height of the box being the maximum mixing height and the size of the base of the box being determined by the net wind transport.

Ordinarily, very low morning inversion base heights are associated with low sulfate levels. With these low inversions are offshore wind flows and dry air that indicate the lack of a marine layer. In addition, with low inversions, high stacks emit effluents into the inversion proper and sulfur dioxide, the sulfate precursor, is not brought down to the ground. Surface inversions, especially during the winter, are often broken during the day and allow excellent afternoon vertical mixing which accounts for low sulfate concentrations under those conditions.

Higher inversions, based at 700 to 3600 feet (213 to 1097 m), are associated with high sulfate levels. When emissions are trapped in a thick marine layer that is not burned off during the day, sulfur dioxide conversion to sulfate is enhanced in an environment that is not diluted with dry, relatively clean air. A very high sulfate day typically has a morning inversion base height of about 2,000 feet (610 m) with very little lifting of that inversion base during the day. The relative humidity remains high all day in the absence of downward mixing of an appreciable amount of dry air from the inversion layer.

Conversion of Sulfur Dioxide to Sulfate

Several processes exist for oxidizing sulfur dioxide to produce sulfate aerosols, but the relative importance of various possible mechanisms is uncertain [6]. However, in the various processes, many atmospheric factors and components determine the degree to which sulfur dioxide will be converted to sulfuric acid and to other sulfates. They include:

- the presence of hydrocarbons and oxides of nitrogen,
- the presence of catalysts such as metallic salts,
- the presence of atmospheric ammonia,
- the presence of adsorbent particles such as soot and metal particulates,
- solar radiation intensity,
- temperature and humidity, and
- vertical mixing.

The total amount of sulfate produced in the ambient air is affected by the residence time of the sulfur dioxide in the atmosphere as well as by the oxidation rate. The rate of conversion can vary from 0.01 to 50 percent per hour. In the Los Angeles Basin, Roberts [33] found that oxidation rates vary from one to fifteen percent per hour. Cass estimated monthly mean oxidation rates to vary between 0.5 to three percent per hour from October through February and to increase to six percent per hour during late spring, summer and early fall.

Sulfates in the Basin show a broad summer peak on an annual basis with a lower winter peak that varies year to year. This reflects the persistence of the marine layer during summer months, an ideal environment for the conversion of sulfur dioxide to sulfate, and the lack of the deep marine layer on most days during the winter. However, when marine layer conditions are present during the winter, high sulfate concentrations usually occur.

INTRA—BASIN CONTAMINANT TRANSPORT

Pollutant transport within the South Coast Air Basin follows the well-known sea breeze-land breeze regime. Aside from occasional storm conditions or strong Santa Ana winds that blow continuously from the north or northeast, the daily pattern is a nighttime offshore drainage flow and the daytime reversal to an onshore flow. Variations in this basic wind pattern account for the complex pollution transport routes that are found to vary day-to-day and seasonally. Since the locations of Basin maxima are often different, depending upon which contaminant is considered, wind-flows are typed separately for five contaminants in the discussion below.

Ozone (O_3)

Ozone is the most pervasive air contaminant in the Basin because of local meteorological conditions and because it is one of the end products of the photochemical reaction. On a typical summer day, the sea breeze transports ozone and ozone precursors to all areas of the Basin except the immediate coastal zone. On a few days, with early morning easterly wind flows, even coastal areas are not exempt. As a contaminant that is formed in the ambient air, ozone affects receptor areas many miles removed from the sources of the primary pollutants necessary for its production. Since photochemical reactions in an air mass operate as long as necessary primary pollutants are present and ultraviolet radiation is adequate, ozone continues to be produced in air masses undergoing daily transport inland from the coast.

Daily Smog Routes

With the prevailing westerly seabreeze, the net daytime movement of ozone precursors and ozone during the summer smog season is from coastal source areas to inland receptor areas. There is considerable daily variation, however, in the strength and direction of the flow due to changing large-scale pressure gradients that modify local winds.

Essentially, there are two major smog routes on days of heavy ozone concentrations: northerly and southerly. In the first case, pollution from source areas in the western third of the Basin moves northeastward to the San Gabriels, then spreads eastward toward the San Bernardino area. When pollution follows the southern route, the pollution cloud during the morning is pushed southward into Orange County, then eastward through Santa Ana Canyon to the Riverside area.

With either of the two principal flows, there is a daily flow of pollution into the San Fernando Valley. Winds from the southwest blowing through central Los Angeles bifurcate north of the city, with one stream moving into the San Fernando Valley and the other stream moving northeastward to Pasadena and areas further east. On days when the smog follows the southern route, the movement of the smog cloud into the San Fernando Valley begins later in the morning than when the general flow is on the northern route.

On some days, the flow of pollution in the Basin does not follow exactly either of the two routes outlined above; instead, the general pattern may be a combination of the two. Additionally, the classification refers to the routes of maximum ozone concentrations and does not preclude the existence of high concentrations in areas removed from the main smog routes. In the descriptions and illustrations of the transport of ozone on high smog days, the northern transport route has been divided into types "A" and "B". The southern transport route has been typed as "C".

Ozone Transport, Type "A" Day

On a type "A" day, there are light offshore winds or stagnation in the western third of the Basin during the night and morning. Maximum ozone concentrations are found relatively close to source areas in Los Angeles County, although there can be considerable ozone transport along the northern route toward San Bernardino during the afternoon.

Figure 31 shows the distribution of the daily one-hour ozone maximum concentrations on September 11, 1979. This day was the middle period of an extended smog siege during that month. On September 11, a maximum of 0.44 ppm, one-hour average, was recorded at the District air monitoring station

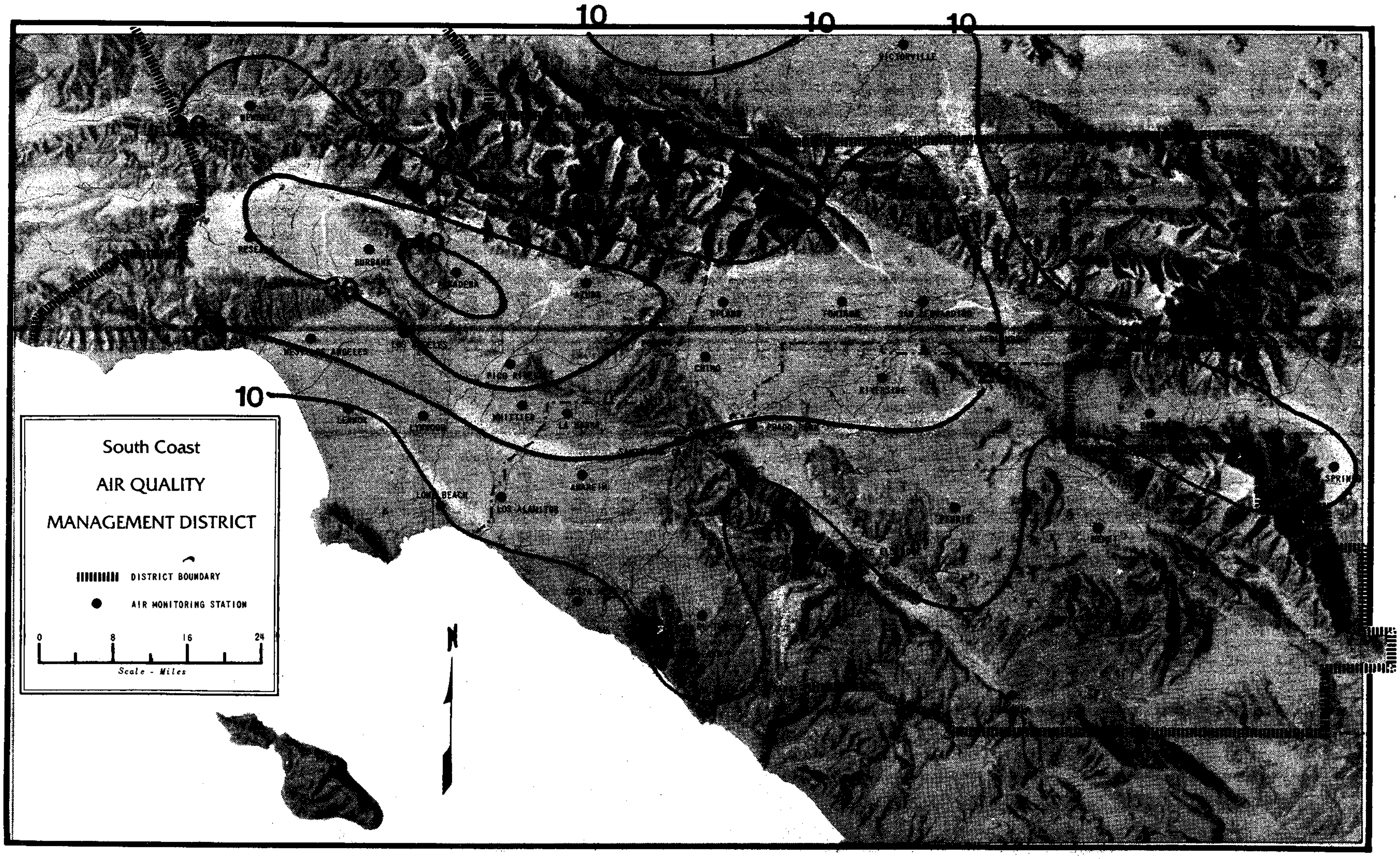

Figure 31 plots the distribution of the daily one-hour average maximum ozone concentrations on September 11, 1979, a high-ozone type "A" day. The Basin maxima were 0.47 ppm at Mt. Thom and 0.44 ppm at Pasadena.

at Pasadena, and 0.47 ppm was measured at the Mount Thom Air Resources Board air monitoring site in Glendale. High ozone levels were widespread; all stations in the northern two-thirds of the Basin attained the first stage episode level of 0.20 ppm. Also, the pollution was eventually transported to the Southeast Desert Air Basin. Concentrations of 0.11 ppm, ozone, were attained in desert receptor areas downwind of the three principal mountain passes that funnel ozone out of the Basin: Lancaster through Newhall Pass, Victorville through Cajon Pass, and Palm Springs through Banning Pass.

Figure 32 traces the backward trajectory of an air parcel arriving at Mount Thom at 1300 PST on September 11, 1979, the time of the ozone peak.

The parcel origination point was in the air mass over Santa Monica Bay at 1500 PST the previous day. Moving onshore with the seabreeze, the air mass (represented by the parcel) stagnated the entire night over Hollywood and Downtown Los Angeles, important sources for ozone precursors because of heavy vehicular traffic in the areas.

The parcel left the source area at 0900 PST and moved northward to Mount Thom, arriving at 1300 PST when the daily one-hour maximum ozone concentration of 0.47 ppm was reached. During the same hour, the maximum was 0.39 ppm at Burbank and 0.44 ppm at Pasadena, both locations being in the general flow that moved through central Los Angeles. Very limited vertical mixing, adequate morning sunshine, and strong ozone precursor sources were present while the air mass stagnated over Los Angeles before moving to receptor areas to the north.

Figure 32 also traces a trajectory to Azusa, where a maximum of 0.34 ppm, one-hour average, was attained at 1300 PST. Nighttime stagnation along this path was in southeastern Los Angeles County. This figure demonstrates that on an "A" type day, the Basin ozone maximum concentrations occur in areas further west than on the "B" type day described below.

Ozone Transport, Type "B" Day

The Basin windflow on a type "B" day corresponds closely to the most frequent summertime wind pattern. With this flow, the major smog mass moves from source areas in Los Angeles County northeastward and then eastward along the base of the San Gabriel Mountains. The daytime flow is similar on high ozone days to flows on days with lower ozone concentrations, but in the former case, there is longer stagnation over source areas during the night and early morning, plus an initial lower and stronger inversion.

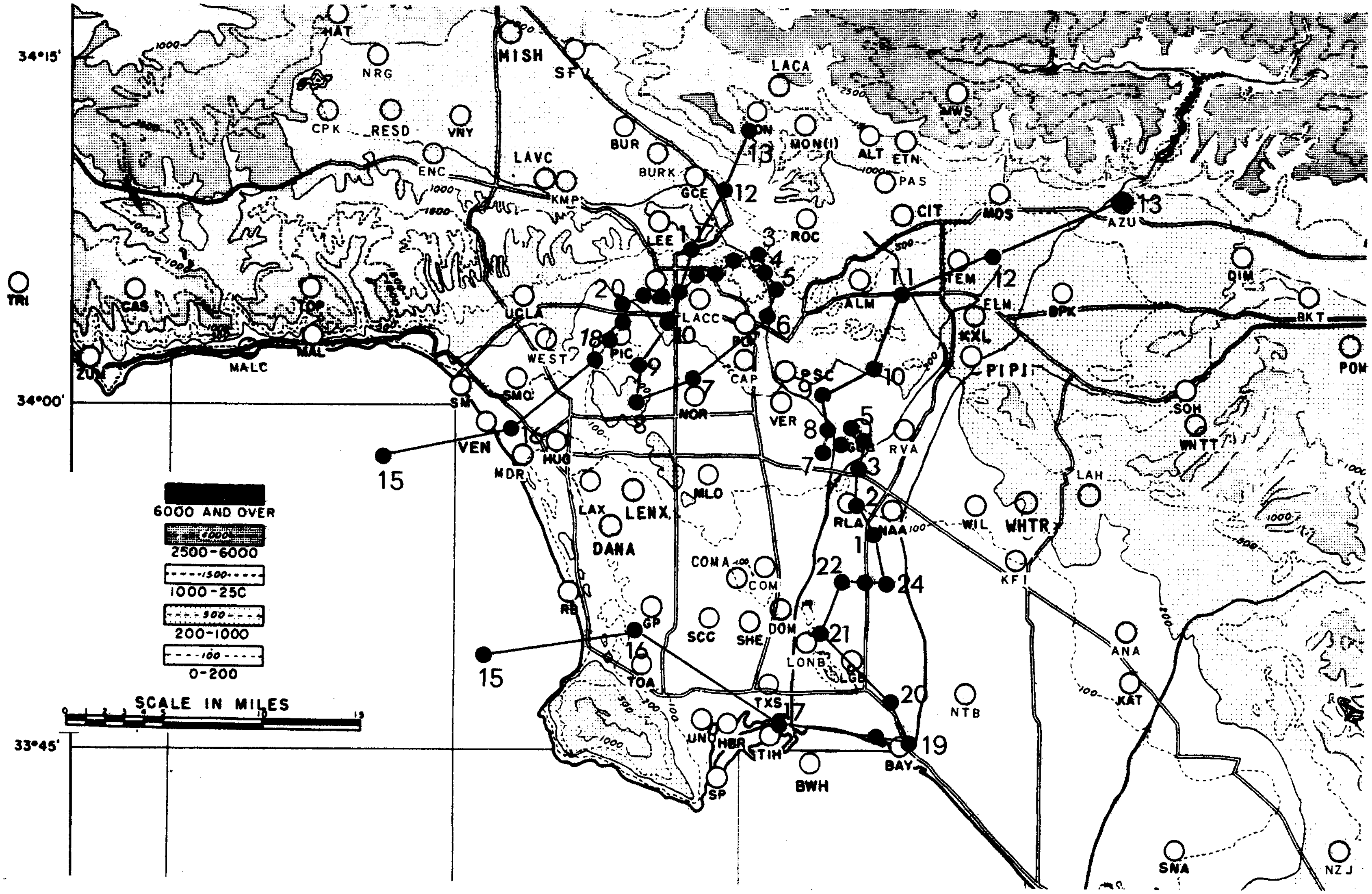

Figure 32 presents trajectories on a high-ozone type "A" day. The upper plot traces the path of an air parcel from Santa Monica Bay at 1500 PST on 10/79 to Mount Thom at 1300 PST on 9/11/79, the time of the one-hour maximum of 0.47 ppm. The lower plot is the path from 1500 PSTon 9/10/79 to Azusa at 1300 PST on 9/11/79, the time of the one-hour maximum of 0.34 ppm. Numbers are Pacific Standard times.

Figure 33 shows the spatial distribution of the daily maximum one-hour average ozone concentrations on September 29, 1978 when 0.43 ppm were recorded at Pico Rivera and 0.42 ppm at Fontana. A portion of the smog cloud was advected out of the Basin through Banning Pass on that day with Palm Springs attaining a Stage one episode level of 0.20 ppm. Concentrations were low in coastal areas and the western San Fernando Valley.

Figure 34a is a plot of two trajectories on September 29, 1978. The first traces a parcel of air from Santa Monica Bay at 1800 PST the previous day through the stagnation area east of the Lennox air monitoring station to Pasadena where a daily maximum ozone concentration of 0.38 ppm was reached at 1230 PST. The second trajectory is the path of the parcel that arrived at Fontana at 1530 PST, the time of its maximum ozone concentration of 0.42 ppm. The overnight stagnation area for this parcel was southeastern Los Angeles County west of Whittier, the parcel having moved into the area the previous day on the seabreeze.

The air mass that arrived at 1230 PST at Pico Rivera, where the Basin maximum of 0.43 ppm was attained, stagnated east of Redondo Beach before beginning a northeasterly course after 0900 PST. This trajectory is shown in Figure 34b.

Ozone Transport, Type "C" Day

On a type "C" day, the pollution cloud stagnates in central and eastern Los Angeles County and northern Orange County during the night and early morning. The daytime movement of the principal smog cloud is along a southern route through Santa Ana Canyon to the Riverside area.

Figure 35 shows the Basin daily maximum ozone concentrations on June 12, 1979. This day was a variation of the typical "C" day in that most of the stagnation occurred over the ocean prior to the advection of the principal smog cloud to receptor areas. A mild Santa Ana flow on June 10 had blown pollution from the Basin offshore to Santa Monica Bay and to the ocean area along the Orange County coast. The seabreeze of June 12 brought in the aged air mass from the ocean and added new pollution from coastal sources, subsequently pushing the main smog cloud through Santa Ana Canyon where the maximum ozone concentration of 0.35 ppm occurred. Because of high surface temperatures, good vertical mixing kept maximum concentrations in the Riverside area at 0.24 ppm. While the pollution was moving through Orange County west of the Santa Ana Mountains, the ozone concentration at El Toro held above 0.50 ppm for several minutes as the highly-polluted stream passed the station, although the hourly average was 0.32 ppm.

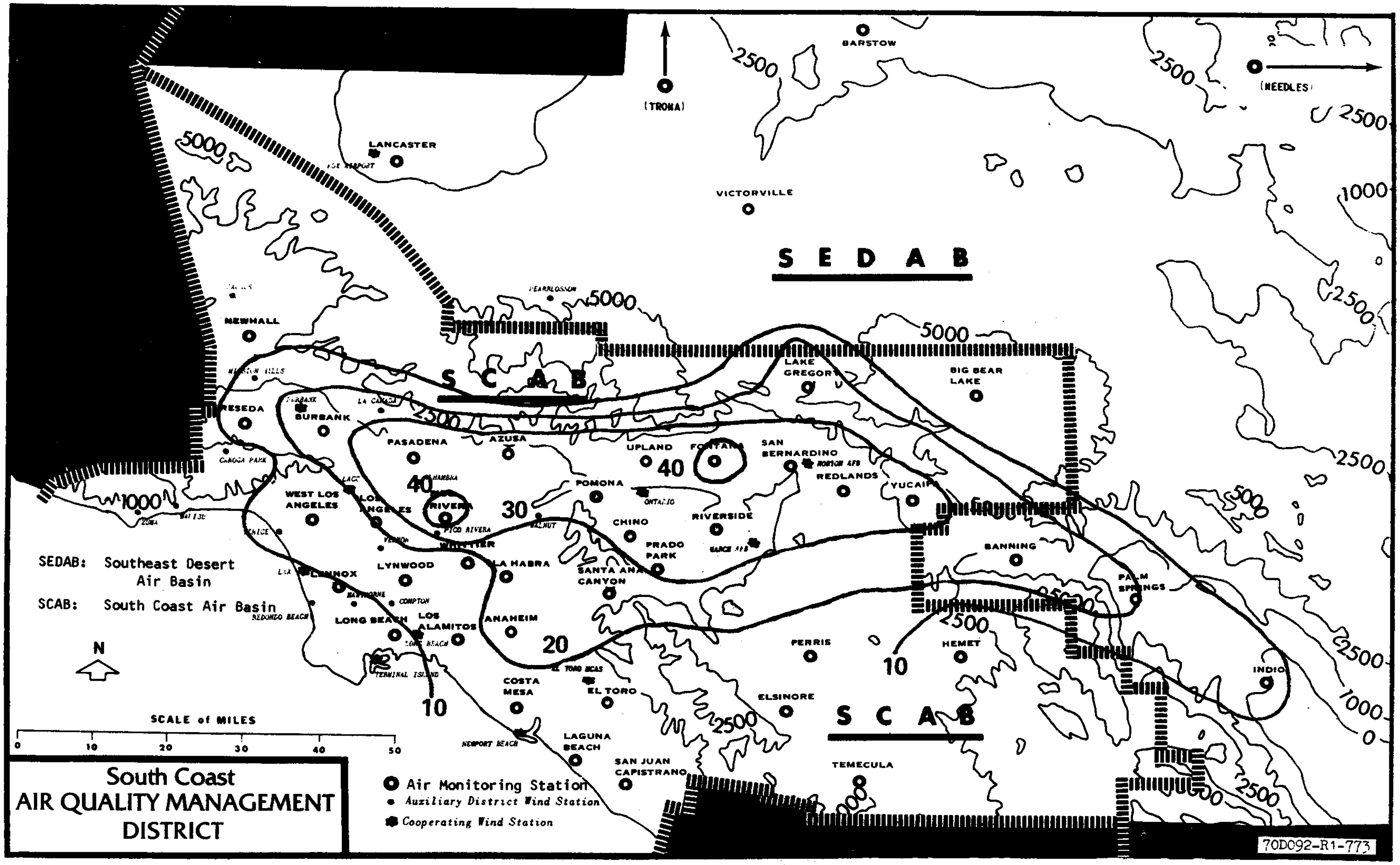

Figure 33 plots the areal distribution of the daily maximum one-hour-average ozone concentrations on September 29, 1978. Basin maxima were 0.43 ppm at Pico Rivera and 0.42 ppm at Fontana. Figure shows values in pphm.

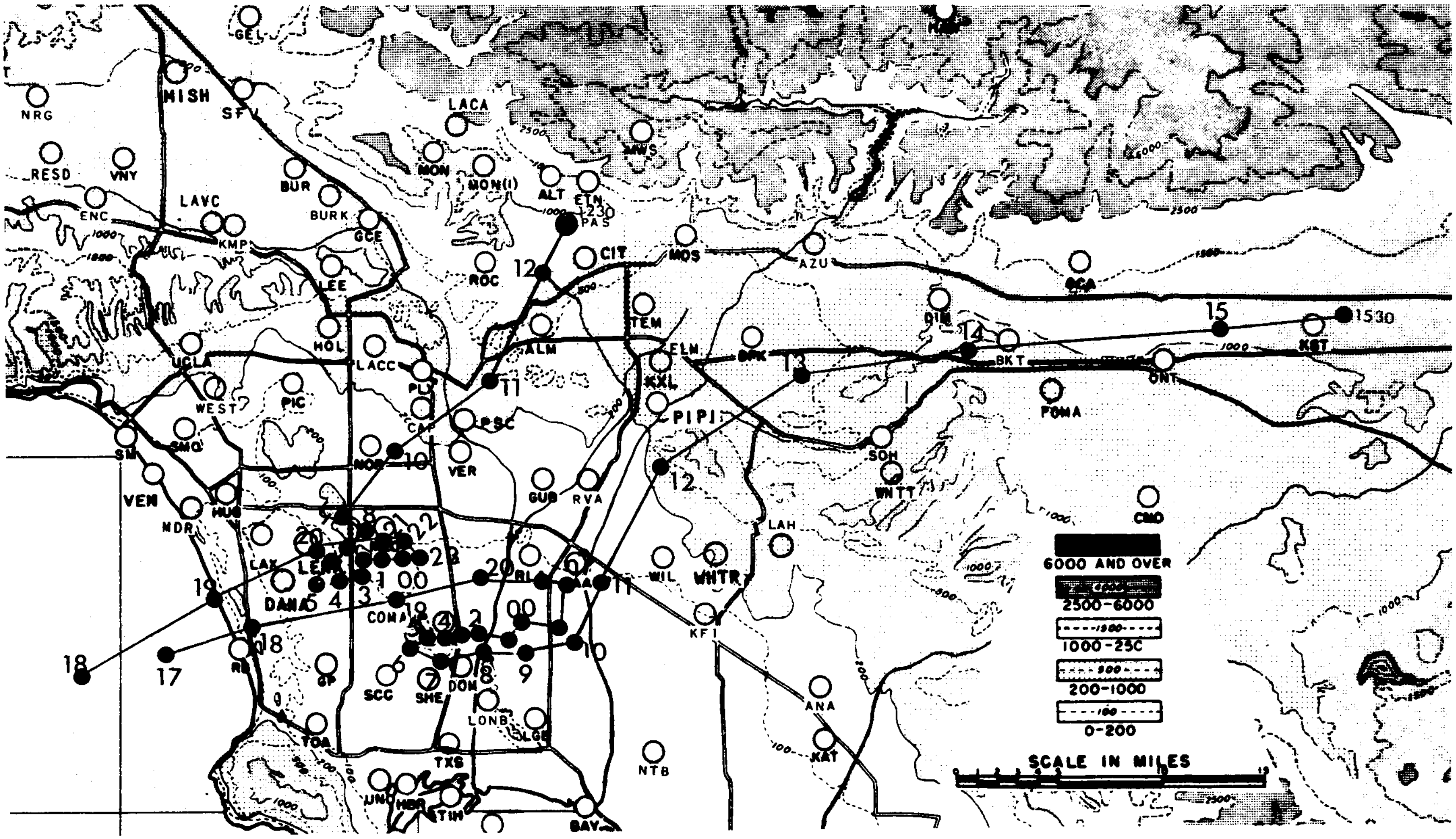

Figure 34a presents trajectories on a high-ozone type "B" day, September 29, 1978. The left plot traces the path of an air parcel from Santa Monica Bay to a stagnation area near Lennox, then to Pasadena at 1230 PST, the time of the one-hour maximum of 0.38 ppm. The plot at the right is from Santa Monica Bay to a stagnation area in southeastern Los Angeles County then to Fontana at 1530 PST, the time of the one-hour maximum of 0.42 ppm. (The Basin Maximum of 0.43 ppm was recorded at Pico Rivera. See Figure 34b.)

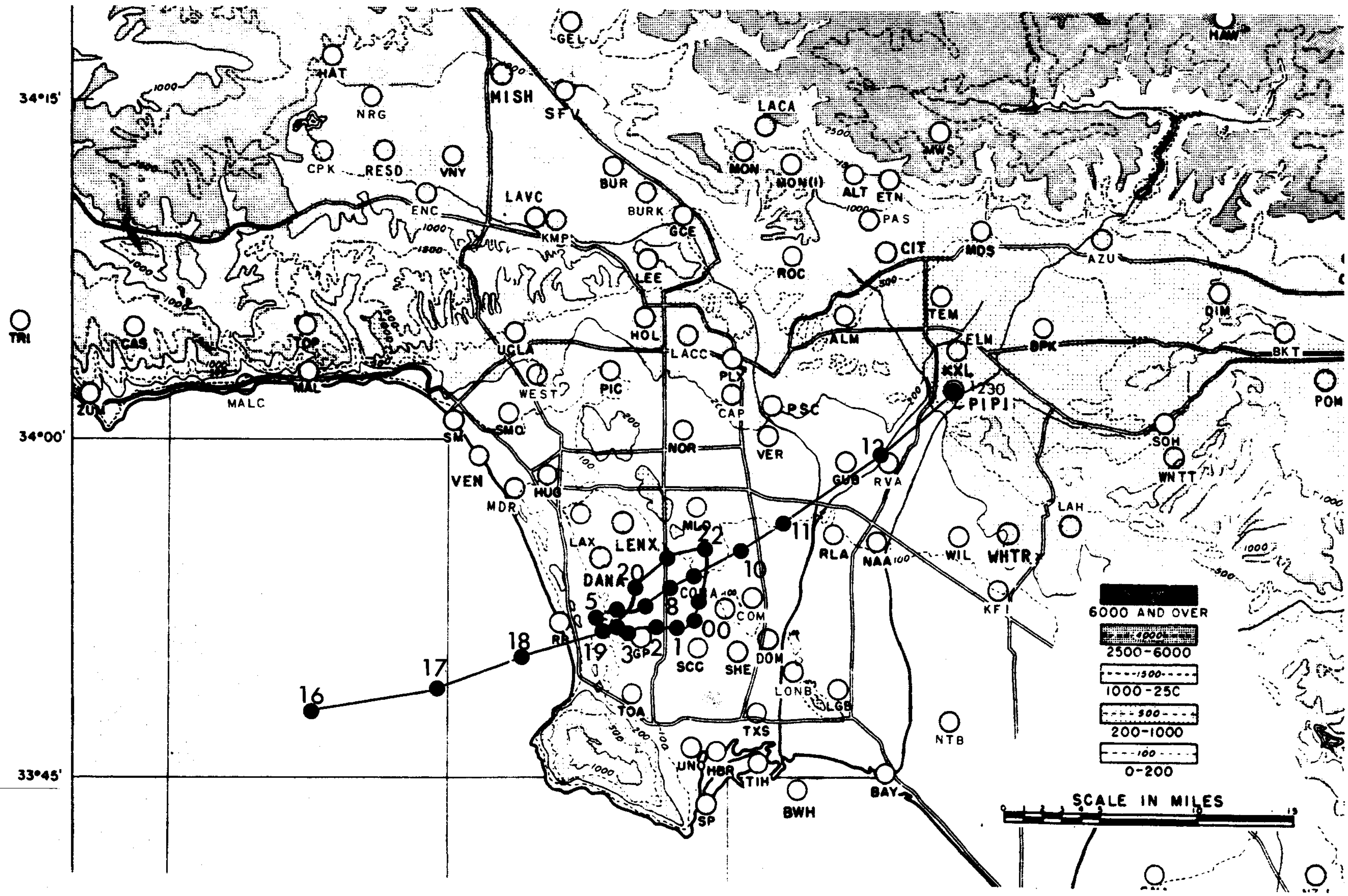

Figure 34b plots the path of an air parcel on a high-ozone type "B" day, September 29, 1978 from Santa Monica Bay to a stagnation area east of Redondo Beach, then to Pico Rivera at 12:30 PST, the time of the one-hour maximum of 0.43 ppm.

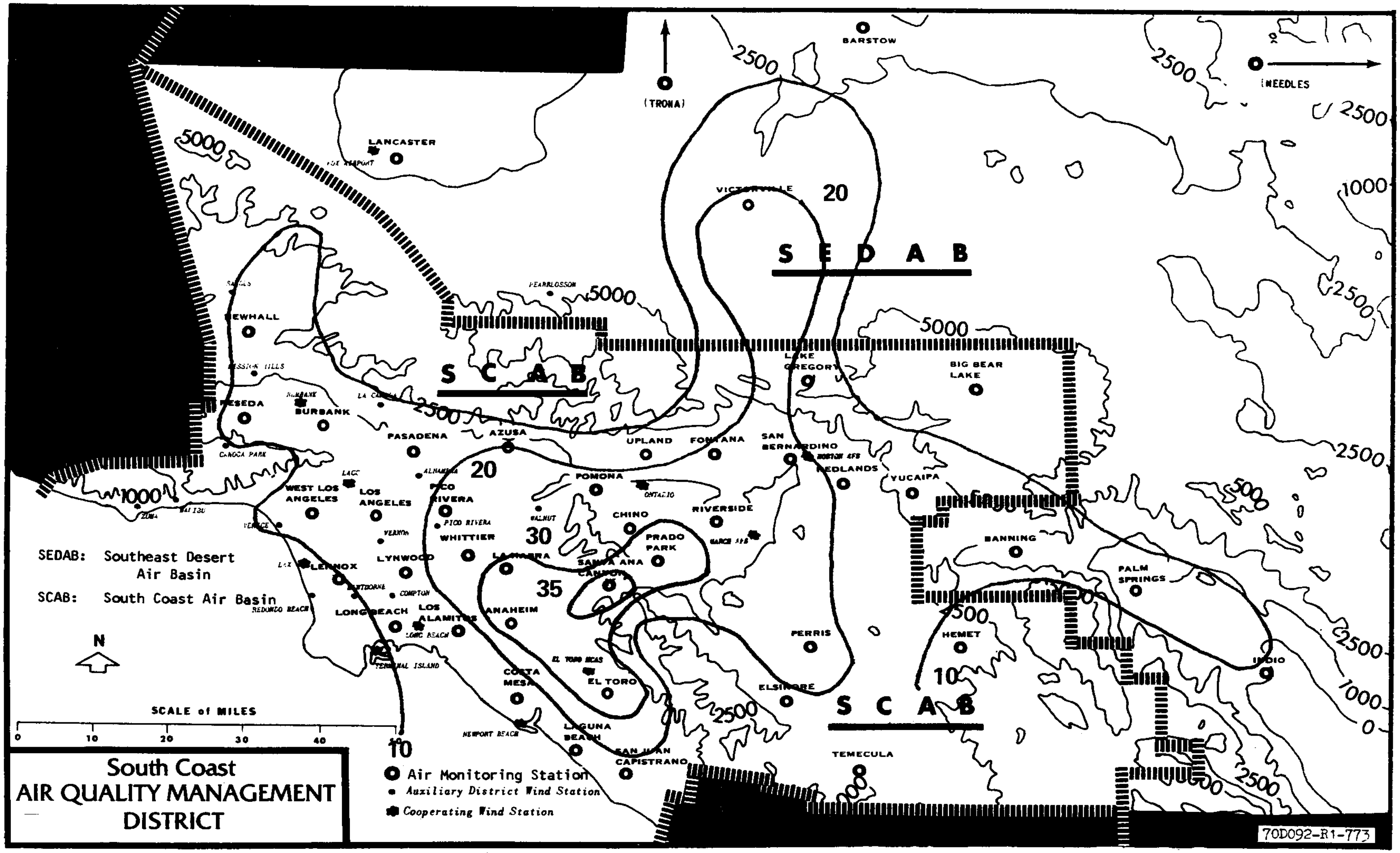

Figure 35 shows the spatial distribution of the daily one-hour-average maximum ozone concentrations on June 12, 1979. The Basin maximum on that day was 0.35 ppm at Santa Ana Canyon. Values in figure are in pphm.

Figure 36 depicts a more typical type "C" day, June 27, 1976. On this day, a Basin maximum ozone concentration of 0.37 ppm, one-hour average, was attained at the Whittier air monitoring staiton. Figure 37 shows the trajectory of the parcel that arrived at Whittier between 1100 and 1200 PST, the time of the ozone maximum.

On this day, June 27, there was night and early morning stagnation in western Los Angeles County with a strong surface inversion and light, offshore winds. The main pollution cloud of ozone and ozone precursors was pushed to the coast with northeast winds during the midmorning hours. Concentrations of ozone of 0.19 ppm at Lennox and 0.28 ppm at West Los Angeles were attained at 1000 PST and 1200 PST, respectively.

The Basin daily maximum at Whittier was also measured early in the day, 1100 PST. As Figure 37 demonstrates, the pollution cloud that moved into Whittier at the time of the daily peak stagnated over the Los Angeles/Long Beach Harbor area during the night and moved slowly northward during the morning.

With the afternoon seabreeze, the main pollution cloud moved through Santa Ana Canyon, then east-northeastward to Riverside; a second cloud moved from West Los Angeles and Downtown Los Angeles into the San Fernando Valley on a southeast flow. Maxima were reached in Los Angeles County by 1300 PST, mid-afternoon in Orange County, and early evening at Riverside.

Because of very strong surface heating and good vertical mixing during the afternoon before the principal smog cloud was advected to the northeast and eastern portions of the Basin, extremely high ozone concentrations were not attained there. Daily maximum temperatures were 110°F in Ontario and 106°F in San Bernardino. On the other hand, concentrations above 0.30 ppm were measured in the western portion of the Basin and through Santa Ana Canyon as far as Prado Park. These high values were attained prior to the time when maximum mixing occurred in these areas. Maximum temperatures reached 101°F in Downtown Los Angeles; 104°F in Long Beach, and 109°F in Burbank. However, in coastal source areas, morning vertical mixing was extremely limited, winds were stagnant until late morning, and sunshine was adequate on a clear day just one week past the longest day of the year.

With night and morning winds causing the main pollution cloud to move toward the coast, and with the principal smog track moving through Santa Ana Canyon on the afternoon seabreeze, this day typified the "C" ozone day with Basin maximum concentrations occurring further west and south than with average summer wind conditions.

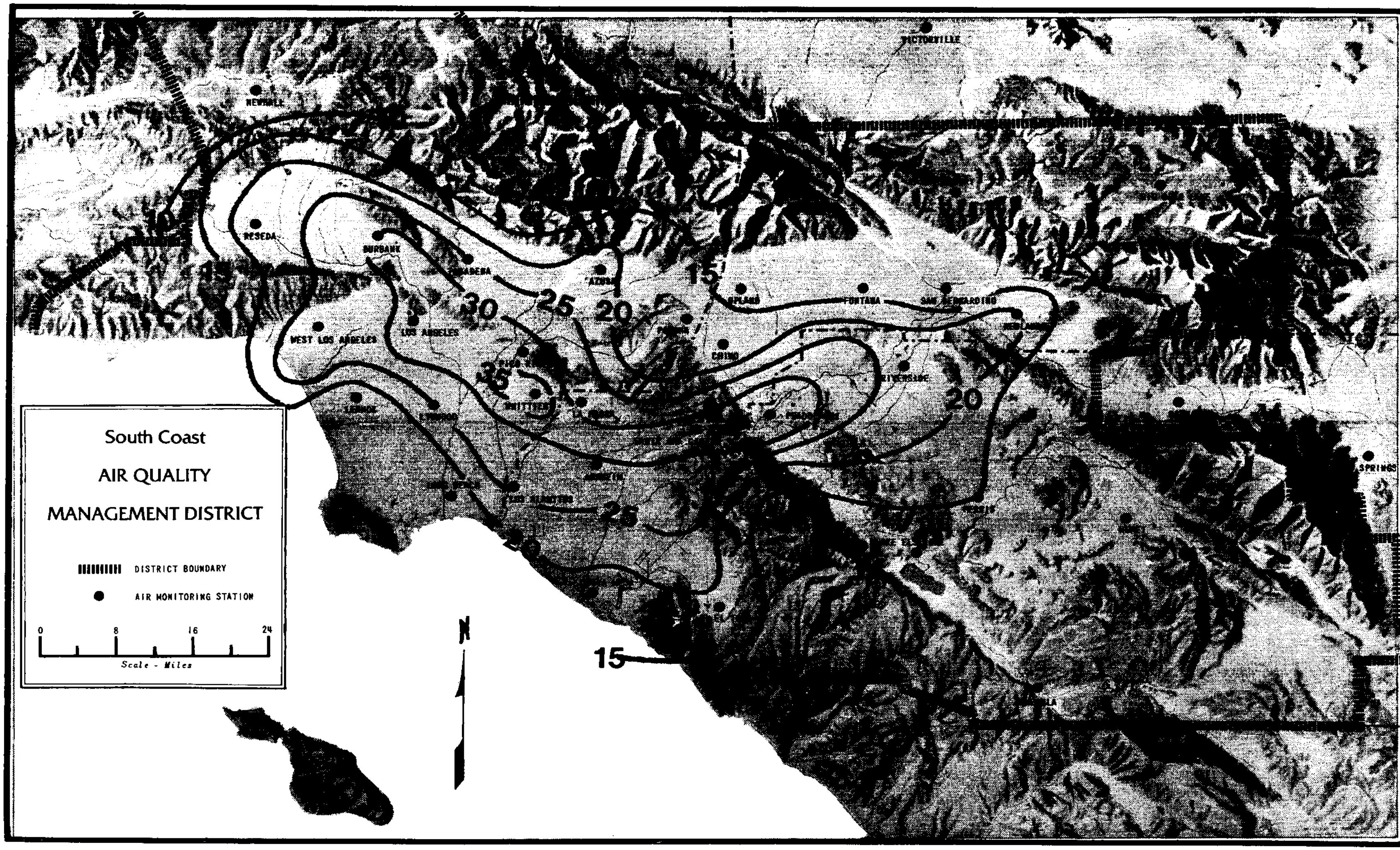

Figure 36 plots the areal distribution of the daily maximum one-hour-average ozone concentrations on June 27, 1976. Basin maximum was 0.37 ppm at Whittier. Figure shows values in pphm.

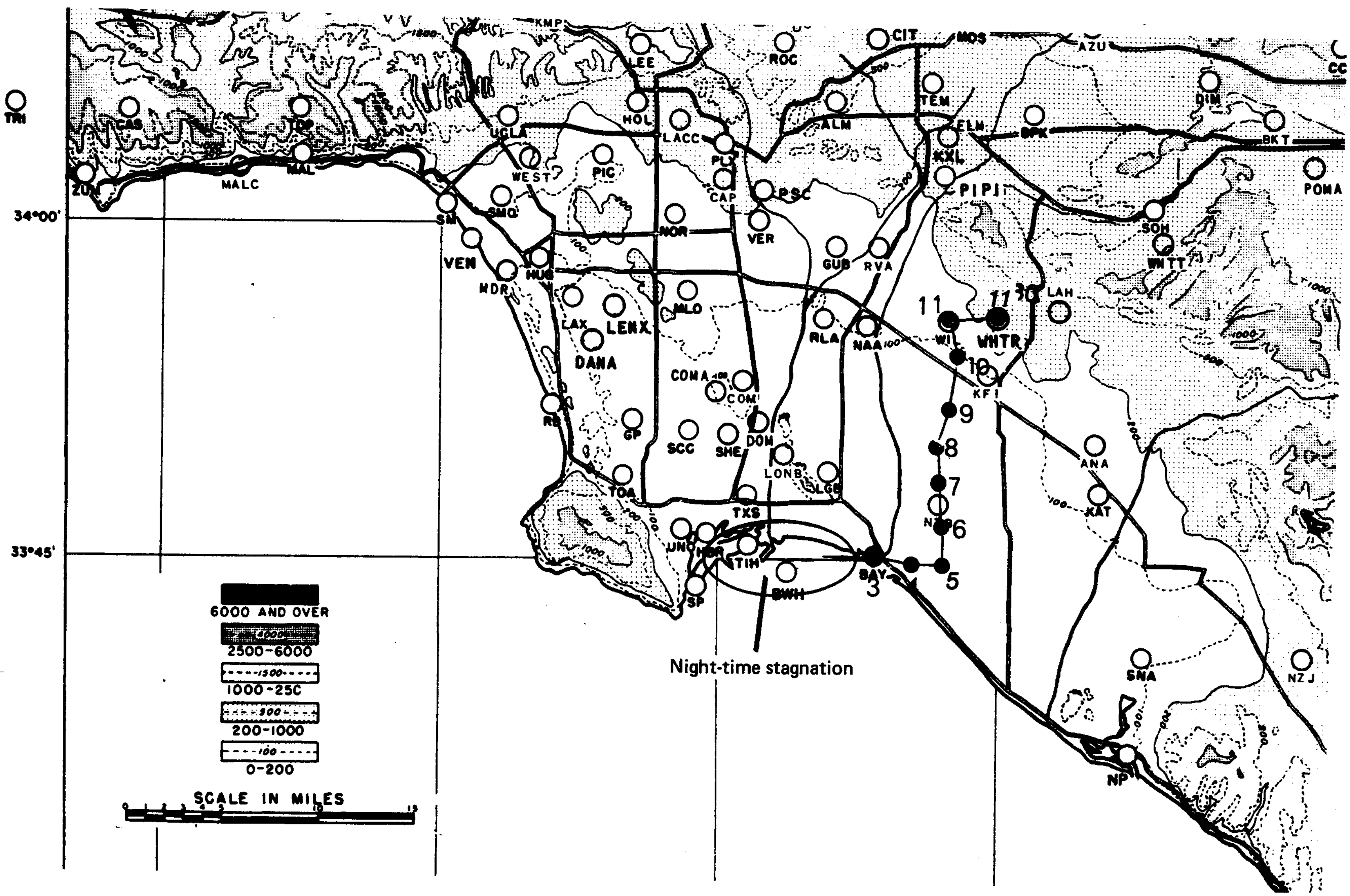

Figure 37 presents a trajectory on a high-ozone, type "C" day. The plot traces the path of an air parcel from the night-time stagnation area along the south coast to Whittier at 1130 PST, the time of the one-hour maximum of 0.37 ppm. Numbers along the path are Pacific Standard Times.

Nitrogen Dioxide (NO_2) Transport

On days of heavy concentrations of nitrogen dioxide (based on one-hour averages), transport of that contaminant from source to receptor during the summer is limited, compared with ozone transport that often involves transport from coastal areas to receptors in the eastern limits of the Basin. On these high-nitrogen dioxide days, daily maxima occur at or near high-density traffic sources in the Los Angeles area and immediate coastal valleys. Highest daily concentrations most frequently are found in Downtown Los Angeles, West Los Angeles, or Burbank. (The highest annual average of all hours is usually found in Pasadena, still not far removed from traffic sources.)

The typical sequence on a smoggy summer day is the peaking of nitric oxide early in the morning in conjunction with the morning traffic rush; two to three hours later (as NO is transformed into NO_2) nitrogen dioxide peak concentrations are reached. Then, by late morning, as ozone increases, there is a concurrent decrease in nitrogen dioxide as the photochemical reaction continues toward completion.(36) But, on high-nitrogen dioxide days, the principal polluted mass of air stagnates near source areas until after the nitrogen dioxide peak has passed, thus accounting for maximum Basin concentrations being found in the western part of the Basin.

Winter transport of nitrogen dioxide on days of heavy concentrations is confined mainly to the western third of the Basin. On these days, the inversion is low and strong, and the seabreeze is weak and of short duration. The result is a "sloshing" effect as the main mass of oxides of nitrogen is pushed seaward during the early morning then is returned a relatively short distance inland with light onshore winds. During the day, the photochemical reaction is incomplete and no appreciable amounts of ozone are produced. These photochemical reactions continue with the nitrogen dioxide peaking from late morning to early evening, depending upon weather conditions on a particular day. This is in contrast to the early morning peaks observed during the summer. On sunny winter days with strong, low inversions, widespread high nitrogen dioxide concentrations are common throughout the Basin portion of Los Angeles County and northern Orange County. As in the summer, the winter daily maximum frequently is located in Downtown Los Angeles.

Coastal areas are subject to high nitrogen dioxide levels during the winter when Basin pollution, that includes nitric oxide, is transported offshore during the night and early morning. Vertical mixing is limited under these conditions, and photochemical reactions to form nitrogen dioxide take place over the ocean with very little diffusion. When the polluted mass finally comes ashore with the weak seabreeze, coastal areas from Pacific Palisades to Newport Beach are subject to high nitrogen dioxide concentrations as well as a complex mixture of other secondary contaminants, including eye irritants. Complaints from citizens on these days attest to the presence and severity of the "smog", although ozone levels frequently do not exceed the air quality standards.

High Nitrogen Dioxide Day, January 15, 1975

As discussed in a previous section, January 15, 1975 is an example of a day with widespread high nitrogen dioxide concentrations in the western portion of the Basin. The daily maximum of 0.47 ppm occurred at Pasadena at 1800 PST. The seabreeze was weak on that date and lasted about eight hours. Peaks were reached along the San Gabriel Mountains during the early evening after which the drainage (offshore) winds began. Daily maxima were attained at Downtown Los Angeles, Lennox, and Long Beach at 2100 PST.

January 15 was one in a series of days with light winds and low inversions. As a result, there was stagnation of an aged polluted air mass over the western portion of the Basin. High concentrations of oxides of nitrogen continued for several days, with day-to-day carry-over being added to continuous, fresh emissions.

Twenty-Four Hour Average

As opposed to the one-hour average, the twenty-four hour average is a useful measure of long-term dosages of high concentrations of nitrogen dioxide. The Environmental Protection Agency criterion for the stage one episode is 0.15 ppm, averaged over twenty-four hours. Table XXIV summarizes the frequency of occurence of days when that stage one episode level was equalled or exceeded at various stations in the Basin during 1971-1975. At all stations, the great majority of occurrences fell during the winter months.

To achieve high, daily average concentrations, stagnation must be present over a considerable number of hours of the day and when this condition is met on winter days, the net transport of nitrogen dioxide is very restricted. It follows that maxima are near high-density traffic sources and, as was found with elevated one-hour averages, almost all occurrences were in the western portion of the Basin.

In summary, transport of nitrogen dioxide on days of high concentrations during the summer is limited to areas near high-density traffic sources in the City of Los Angeles and immediate inland valleys. During winter on like days, transport is mainly a meandering of the air mass, rich in oxides of nitrogen, in the western third of the Basin. The polluted air

Table XXIV

FREQUENCY DISTRIBUTION OF OCCURRENCES OF NITROGEN DIOXIDE EPISODE CONCENTRATIONS, SOUTH COAST AIR BASIN

1971-1975

Station	Month												
	J	F	M	A	M	J	J	A	S	O	N	D	
Anaheim	11	1	1	-	-	-	-	-	-	3	4	11	31
Costa Mesa	1	-	-	-	-	-	-	-	-	-	-	4	5
Santa Ana	-	-	-	-	-	-	-	-	-	-	3	-	3
La Habra	7	2	-	-	-	-	-	-	1	7	3	11	31
Los Alamitos	-	-	-	-	-	-	-	-	-	-	2	-	2
Whittier	16	5	-	-	-	-	1	-	2	4	5	14	46
Long Beach	10	5	-	1	-	-	-	-	-	2	5	10	33
Lynwood	2	-	-	-	-	-	-	-	-	-	-	8	10
Lennox	16	5	-	1	-	-	-	-	2	5	3	8	40
West Los Angeles	21	9	-	1	-	-	-	-	2	9	12	13	67
Downtown Los Angeles	22	13	2	1	-	1	-	-	1	16	19	17	91
Reseda	14	5	1	-	-	-	-	1	-	3	16	5	45
Burbank	8	9	-	-	-	3	12	2	5	12	26	13	90
Pasadena	4	3	3	-	-	-	-	-	-	1	9	13	33
Azusa	6	-	1	-	1	-	1	-	-	7	12	4	32
Pomona	6	-	-	-	-	-	-	-	-	6	16	2	30
Chino	2	-	-	-	-	-	-	-	-	-	-	-	2
Upland	-	-	-	-	-	-	-	-	-	-	3	4	7
San Bernardino	1	-	-	-	-	-	2	-	-	-	-	1	4
Riverside	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	147	57	8	4	1	4	16	3	13	75	138	138	602

Stage I EPA Episode: 0.15 ppm, 24-Hour Average. Table from EPA.

drifts seaward with offshore winds during the night and early morning, then moves inland during the afternoon on a weak onshore flow, sometimes as far as the foothills.

Even on an annual basis, nitrogen dioxide transport is restricted. For instance, during 1978, all stations in the Basin which violated the state air quality standard of 0.25 ppm, one-hour average, on ten or more days were located in Los Angeles County south of the San Gabriel Mountains, or in northern Orange County.

CARBON MONOXIDE (CO) TRANSPORT

Carbon monoxide transport and the source-receptor relationship between carbon monoxide emissions and ambient air concentrations are uncomplicated. Vehicle emission sources are spread widely across the basin with the maximum carbon monoxide occurring in the area of heaviest traffic: central and southwestern Los Angeles County. Without a very low, strong inversion, carbon monoxide concentrations are diluted rapidly--horizontally and vertically. As a result, the weather conditions associated with carbon monoxide buildups are surface inversions and either light drainage (offshore) winds or near-stagnant conditions (light, variable winds).

Morning peak carbon monoxide levels recorded in coastal areas are often enhanced by pollution carry-over from the previous day. Very light drainage winds from the inland valleys and Central Los Angeles transport the previous evening's traffic peak emissions slowly toward the coast. Here the polluted air mass stagnates in the early morning hours. Then, as the morning traffic emissions are added to this air mass already rich in carbon monoxide, concentrations continue to increase until daybreak when solar surface heating begins. With this surface heating, vertical mixing of the high carbon monoxide concentrations with cleaner air aloft starts, and the carbon monoxide dilutes rapidly as the mixed layer increases in depth.

The trajectory, shown in Figure 38, is an example of a path an air mass takes prior to its arrival at an air monitoring station at the peak hour of a high carbon monoxide day. On January 19, 1976, the parcel (representing an air mass) moved onshore with the afternoon seabreeze at Venice. During the evening traffic rush, the parcel was over an area of high-density traffic in central Los Angeles. After 2100 PST, the parcel moved to the southwest with nighttime drainage winds, arriving at Lennox at 0730 PST, January 20. The Basin daily one-hour carbon monoxide maximum on that day was 43 ppm at Lennox. The path during the night was over additional carbon monoxide sources, and the final two hours coincided with the morning traffic peak in the Los Angeles International Airport

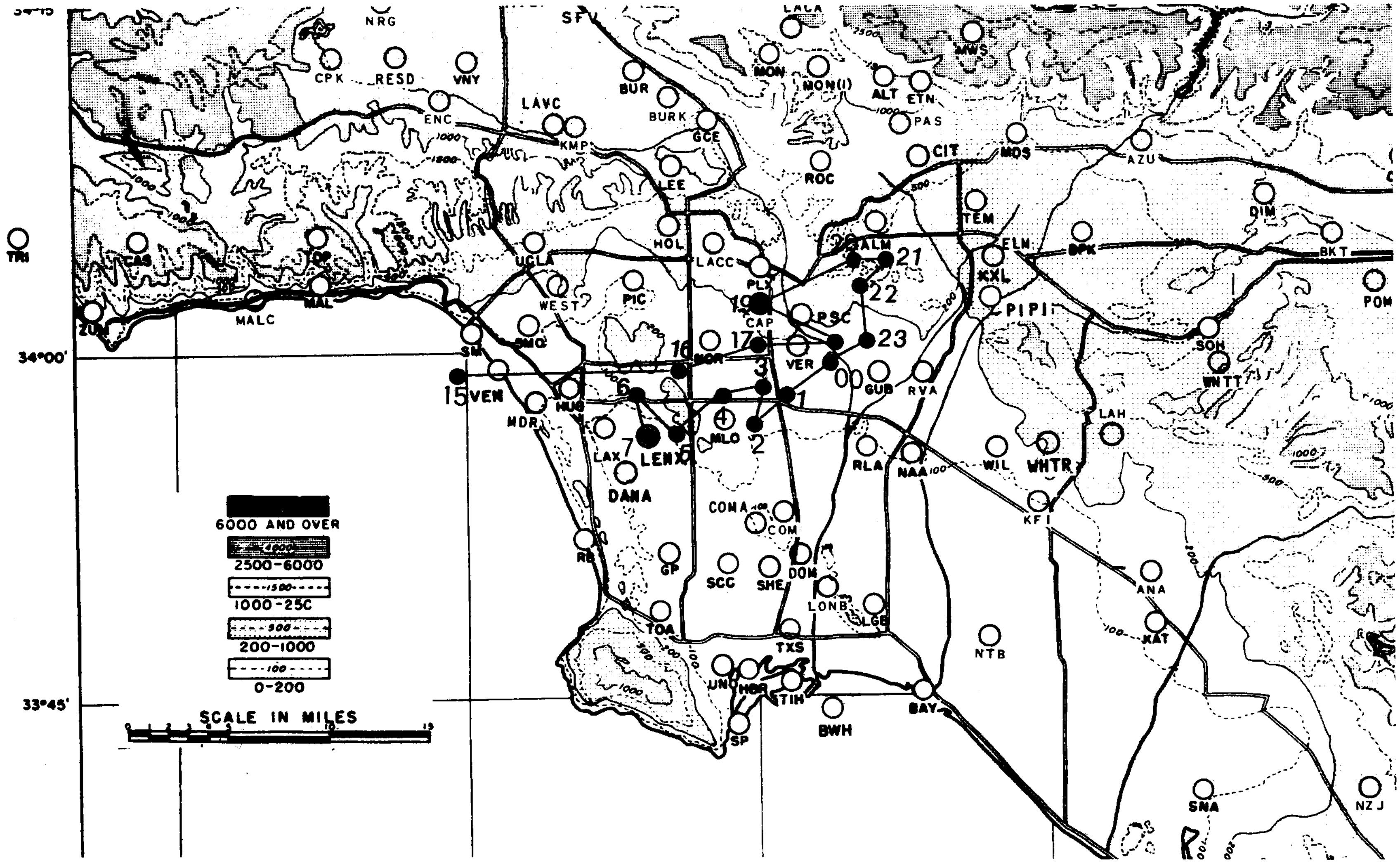

Figure 38 plots the trajectory of a parcel of air from Santa Monica Bay at 1500 PST on 1/19/76 to Lennox at 0730 PST on 1/20/76, the time of the one-hour carbon monoxide maximum of 43 ppm. Numbers along the path show Pacific Standard Times.

area. The final pollutant concentration reflects principally morning carbon monoxide emissions, since these were subject to considerably less diffusion than pollutants injected into the air mass during the previous evening traffic peak and during nighttime transport.

When carbon monoxide peak concentrations at the coast occur during the evening, drainage from inland areas to the coastal zone is more rapid than in the case shown above. Maximum concentrations usually occur prior to midnight, and the levels are dependent upon the carbon monoxide levels in the air mass being advected, plus emissions from nearby sources. However, overnight stagnation at the coast usually does not occur, and the polluted air is carried out to sea where horizontal and vertical dispersion dilute the air mass. Concentrations along the coast the following morning then result from local traffic emissions.

Carbon monoxide source areas that impact coastal receptors along Santa Monica Bay are the San Fernando and western San Gabriel Valleys and Central Los Angeles. Southern coastal and northern Orange County receptors are affected by source areas in eastern and southern San Gabriel Valley, the Pomona-Walnut Valley, and Santa Ana Canyon.

Locations of inland receptor areas in the Basin that frequently attain elevated carbon monoxide concentrations are: Burbank, Pasadena, Downtown Los Angeles, and the east-central areas of Lynwood, Whittier, and La Habra. Morning peaks at Burbank are attributed to drainage from sources in the San Fernando Valley, plus local morning emissions. Pasadena morning peak concentrations are due to advected pollution from central Los Angeles, during the evening, plus stagnation in the local area during the early morning hours through 0800 PST. Morning peaks in Downtown Los Angeles have source areas in the San Fernando Valley and western San Gabriel Valley, but principally, high concentrations are accounted for by the local, very heavy traffic complex that rings the central part of the city. In the area that includes Lynwood, La Habra, and Whittier, morning peaks are attributed to source areas in the eastern and southern portions of the San Gabriel Valley, the Pomona-Walnut Valley., and local traffic sources.

The most frequent times of occurrence of high carbon monoxide concentrations in inland areas are the hours from 1700 PST through midnight. Thus, for the greater part, these carbon monoxide maxima reflect the late afternoon traffic peak in individual receptor areas. On some days, there is a considerable spread in time from the evening traffic peak to when maximum carbon monoxide concentrations are achieved; in these cases, advection of carbon monoxide from high-density traffic source areas to receptors is responsible for the high concentrations in addition to local carbon monoxide emissions.

Sulfur Dioxide (SO_2) Transport

Basin sulfur dioxide transport is direct; that is, concentrations at receptors vary with downwind distance from sources. Atmospheric characteristics such as stability, turbulence, and wind speed and direction modify concentrations, since these elements control en-route diffusion. It follows that highest concentrations of sulfur dioxide are measured at air monitoring stations in the immediate vicinity of the principal emissions sources, the southwestern portion of Los Angeles County and northern Orange County. An exception is the Fontana station, a receptor for sulfur dioxide from the large steel mill in the area. Fontana is frequently the location of the daily Basin maximum.

Figure 39 shows the route of sulfur dioxide transport on September 21, 1974, when the Basin daily one-hour maximum of 0.25 ppm and twenty-four hour maximum of 0.108 ppm were measured at the Long Beach air monitoring station. The trajectory traced the air that arrived at the station at the time of the one-hour maximum, 1030 PST, back to its origin at the coast, Redondo Beach. The trajectory shows that the air entered the Basin at 2330 PST the previous night and moved over the Redondo Beach power generating plant. However, during the entire day of September 21, natural gas was burned in the plant, and that facility did not contribute to the elevated sulfur dioxide concentrations. Source emissions were attributed to refineries and industrial plants in the South Bay and harbor areas. Horizontal and vertical dispersion were extremely limited all day at Long Beach (the receptor) and over the sources to the west and south, a prolonged condition that was ideal for the accumulation of high concentrations on the basis of the one-hour average as well as the twenty-four hour average.

Power plant sulfur dioxide emissions have a relatively lesser effect on ground-level concentrations than other sources, since power plant sulfur dioxide is emitted from elevated stacks, and the stack plumes are usually well-diffused before surfacing. Exceptions are fumigating or looping plumes. Power plant sulfur dioxide emissions, however, are important contributors to the sulfate load in the Basin atmosphere.

In summary, sulfur dioxide concentrations measured at ground-level air monitoring stations reflect the proximity of the stations to sources. Here, the source-receptor relationships are dependent upon local wind flows and dispersion characteristics rather than Basin-wide weather conditions and long-range transport. Some temporary, relatively high sulfur dioxide concentrations are the result of equipment breakdown at the sources.

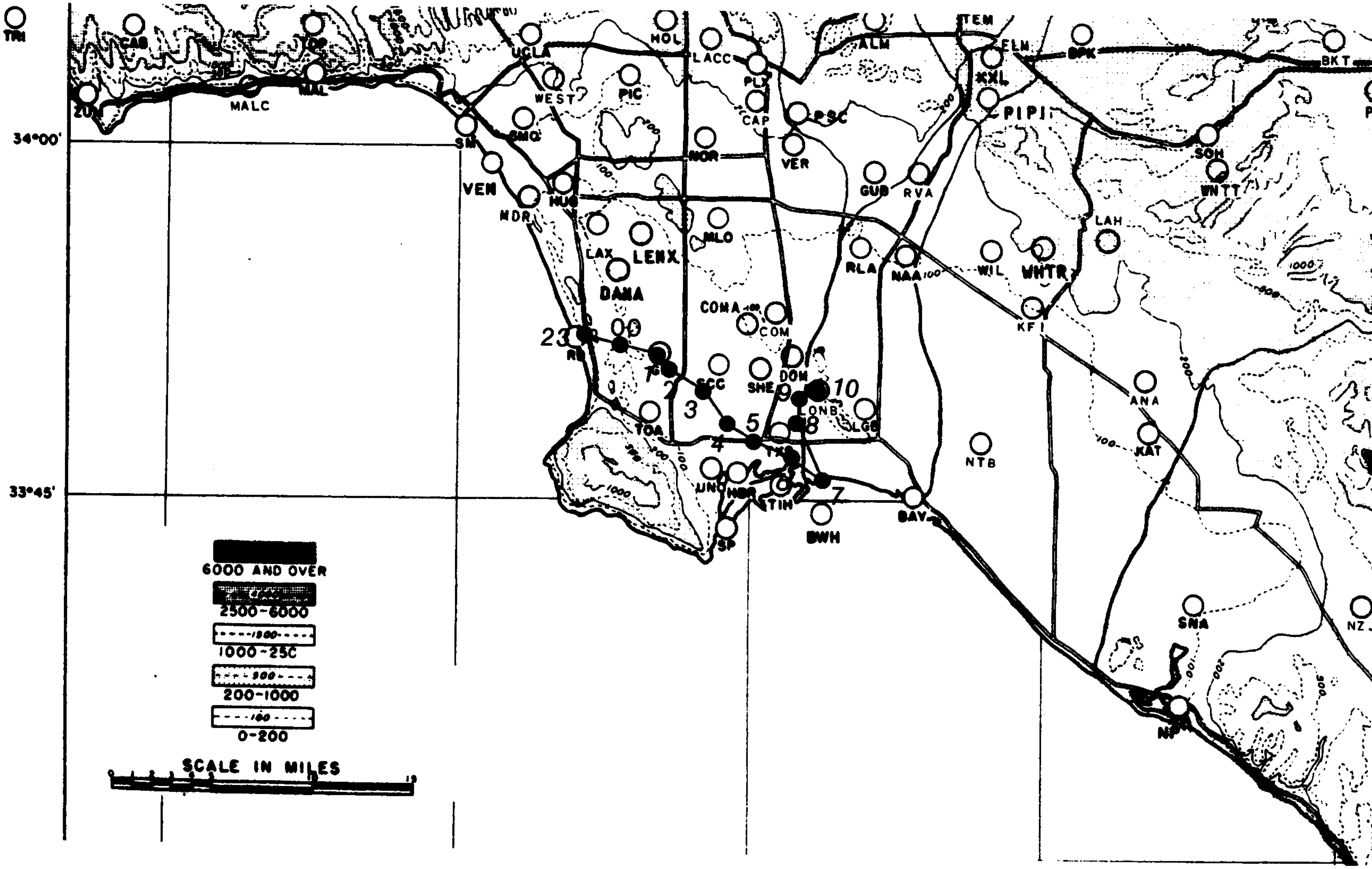

Figure 39 plots the trajectory of a parcel of air from Redondo Beach to Long Beach on 9/21/74. The arrival, 1000 PST, was the time of the daily one-hour sulfur dioxide maximum of 0.25 ppm. Numbers along the path are Pacific Standard Times.

Sulfate (SO_4) Transport

Since direct sources of significant sulfate emissions in the Basin are limited, sulfate transport is concerned primarily with the movement of marine air from sulfur dioxide source areas to sulfate receptors. This transport assumes continuous transformation of sulfur dioxide to sulfate along the transport paths. A limitation in the determination of this transport is caused by the sampling method: the measurement of sulfates from twenty-four hour total particulate samples. As a result, no sulfate data are available to compute transport on anything less than a full day scale, except for special study days.

Three wind flow patterns are associated with the highest surface sulfate concentrations measured in the Basin. The first, the weak seabreeze -landbreeze regime, involves direct source-receptor relationships; downwind receptors for major sources are impacted sequentially as sulfur dioxide emissions are converted to sulfates along the transport route. Along these paths from the sources, ground-level sulfate concentrations are fairly constant because the rate of conversion of sulfur dioxide to sulfates approximates the dilution caused by vertical and lateral mixing.[6]

The second wind flow pattern coupled with high sulfate concentrations, occurs during periods of light winds during the winter. Sulfur dioxide and sulfates emitted along the coast move a relatively short distance inland with the seabreeze (fifteen or twenty miles) and then drift back to the coast with light offshore winds. The resultant polluted air mass, already rich in sulfates, continues to have sulfur dioxide and sulfates added to it as it stagnates along the coast. The process can continue for several days until changed by a new weather regime moving into the Basin.

The final weather pattern, conducive to high sulfate concentrations in the Basin, is the most common. Here the transport is not distinct in that the air under a fairly deep inversion has a meandering path from source to receptor. This sloshing effect, caused by weak sea and land breezes, produces a fairly homogenous air mass in the Basin with high sulfate concentrations distributed fairly evenly throughout. This weather type can occur in any season, but is found most frequently during the autumn and winter when the strength of the seabreeze is at a minimum. With this weather type, maximum sulfate concentrations are found in the inland valleys rather than in coastal sections as found with the second type (above) since the daily net transport is slightly onshore.

INTER—BASIN CONTAMINANT TRANSPORT

Ventura County-South Coast Air Basin Transport

Transport to the South Coast Air Basin

Transport from Ventura County to the South Coast Air Basin takes place over water from the Ventura/Oxnard area to the Santa Monica Bay coast, and over land from the southern half of the county into the San Fernando Valley and the Upper Santa Clara River Valley. See Figure 40.

No quantitative data or frequency estimates are available to judge the impact of this transport on the Basin on an annual or seasonal basis. However, with a west-northwest air flow from Ventura County, primary pollutants from stationary sources and, to a lesser extent, vehicular pollutants are advected to the South Coast Air Basin. Although disperse, contaminants in the air entering the Basin from that direction add to the nitrogen oxides, ozone, sulfur dioxide, and sulfate concentrations generated by local sources.

The impact on the San Fernando Valley and the Newhall-Saugus areas is minimal, since the normal transport from the Oxnard plain to these areas is principally with the afternoon seabreeze. At that time, the advected air contains lower contaminant concentrations than the air transported earlier from the Basin to the San Fernando Valley and Newhall.

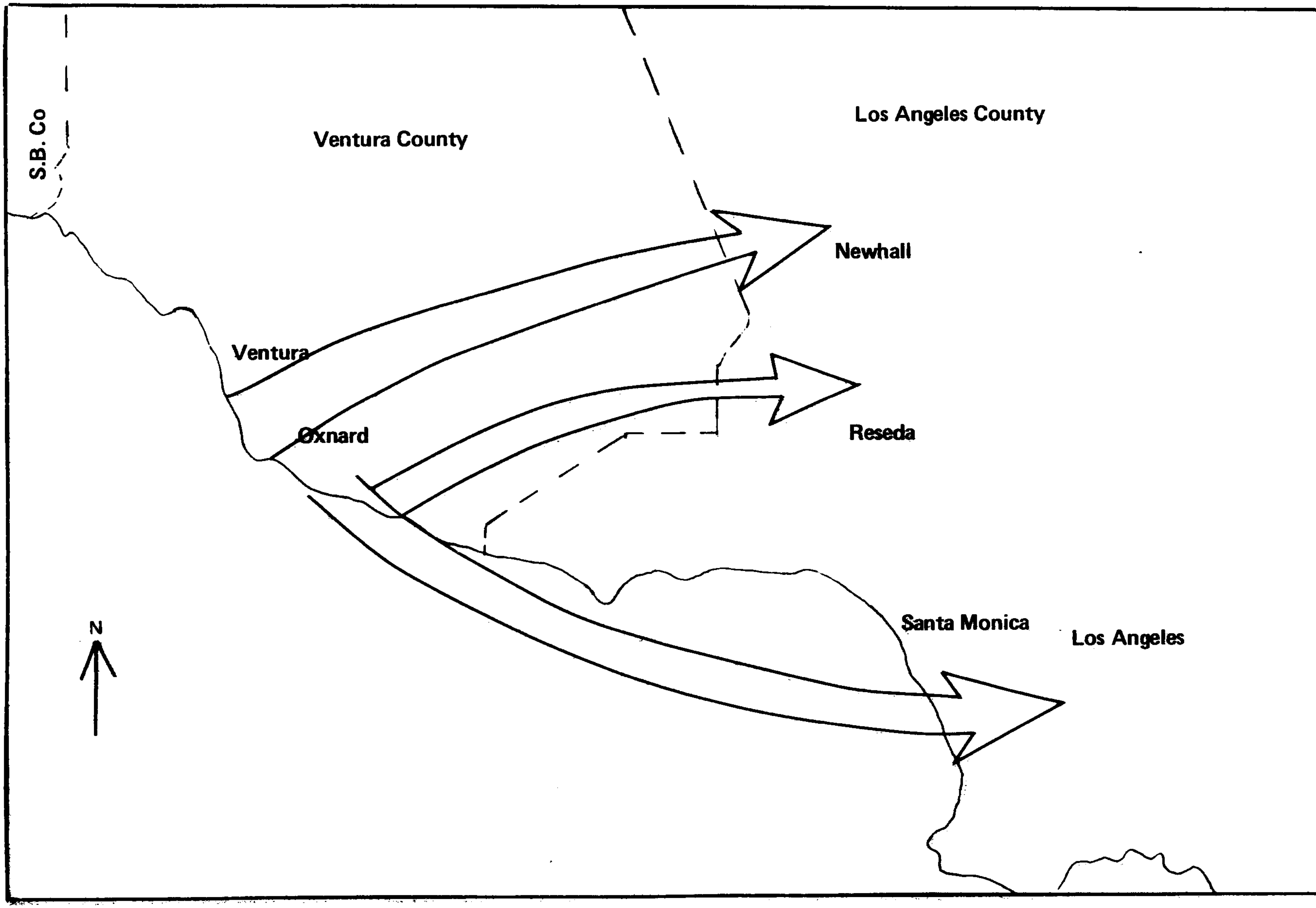

Figure 40 shows three pollutant transport routes from Ventura County to the South Coast Air Basin.

Support of the inter-basin transport outlined above is based upon wind flow and special contaminant studies. For instance, one conclusion drawn from a 1972 tracer study [26] was:

> "The data clearly shows that pollutant transport occurs from the Oxnard/Ventura Plain along the Malibu Coast into the Lennox area of the Los Angeles Basin, and along an inland route into the San Fernando Valley as far east as Burbank."

<u>Transport to Ventura County</u>

Two pertinent studies of transport from the South Coast Air Basin to Ventura County involve ozone. Lea, [27] in a study of high ozone concentrations aloft over Point Mugu, found that this condition existed with easterly winds aloft, aged smog from the Los Angeles area being trapped in the inversion layer. Although winds in the layer from the surface to the base of the inversion had a westerly component, a reversal of wind direction above the inversion base allowed transport over water to the Point Mugu area.

In a 1975 study, Kauper [20] projected three paths along which pollution in the Basin is transported to Ventura County. See Figure 41. His first conclusion was similar to that of Lea's--that is, ozone is transported aloft over water from Santa Monica Bay to the Oxnard area. He found ozone-rich layers aloft along the transport path with the most persistent layer just below the base of the inverison. A second layer was found near the top of the inversion at about 3,500 feet. Such ozone strata, especially when located under the inversion base, can affect ground-level concentrations under some meteorological conditions. With surface heating during the day, ozone aloft can be fumigated to the surface and mixed with locally-produced ozone and ozone precursors.

In Kauper's study, trajectories were drawn to verify the source of the ozone aloft over Oxnard:

> "A special trajectory was constructed to the parcel containing the highest concentration of ozone (0.43 ppm). From the wind data at 1,000 feet (0.3 km) it is possible to track the high ozone parcel back to the Los Angeles Basin, having passed over the coastline heading seaward between midnight and 0300 PDT on July 10, 1975."

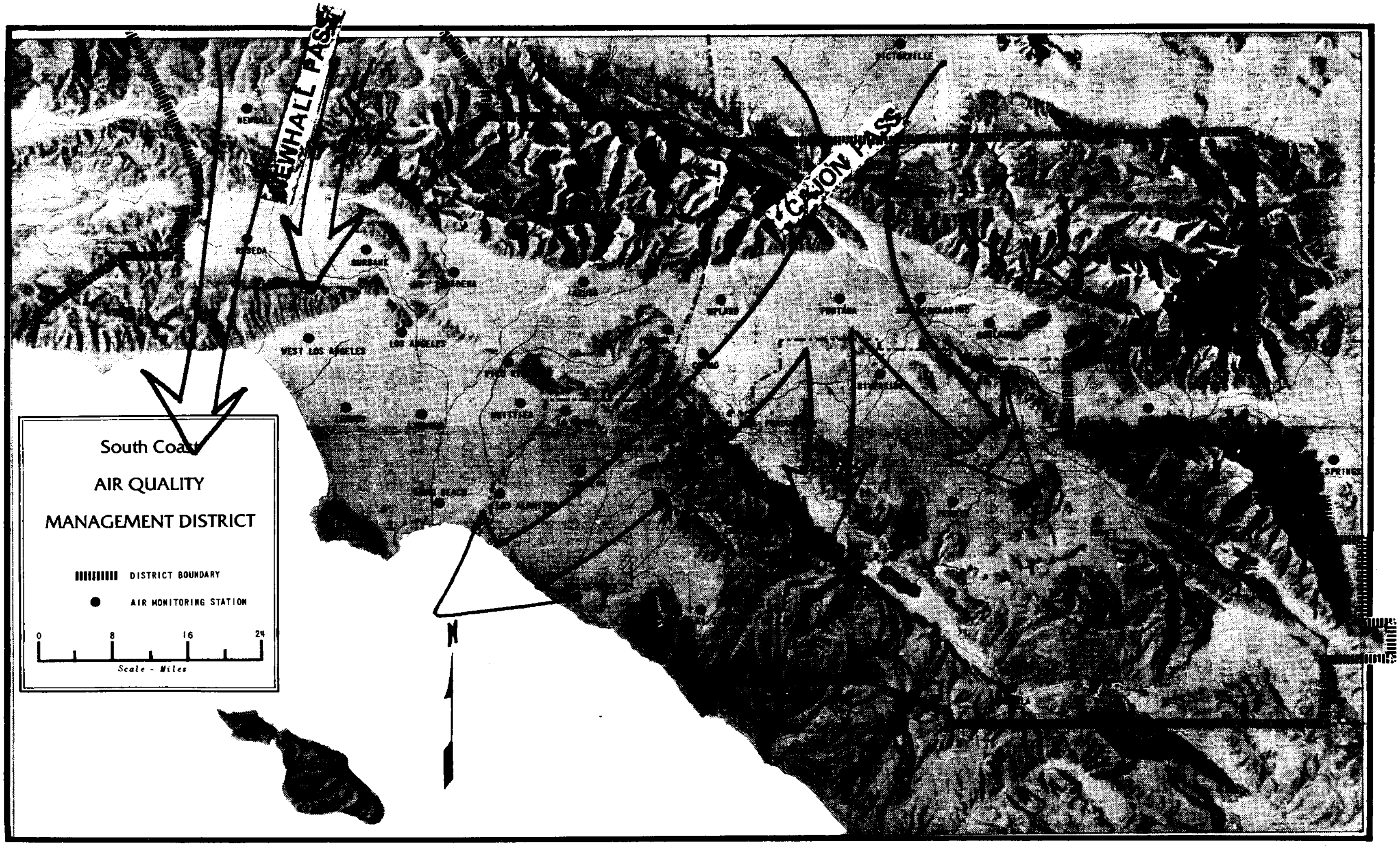

Figure 42 shows the tracks of Santa Ana winds blowing from the Upper Desert into the San Fernando Valley and thence through Malibu Canyon, and through Cajon Pass into the San Bernardino Valley and then through Santa Ana Canyon to the coast.

Transport from the South Coast Air Basin to the desert is substantiated by visual observations of smog clouds moving through the mountain passes, by analyses of daily wind patterns, and by contaminants measured at desert receptor areas. A 1974 study by Blumenthal (3) verifies that transport:

> "Data from both August 16 and 24 suggest strongly that ozone or precursors originating in the metropolitan area moved eastward through the Los Angeles Basin, through the Cajon Pass, and up the mountain slopes. Evidence is shown of the arrival of these air parcels at Arrowhead and Hesperia (about 90-100 km downwind of the central Los Angeles area)."

A tracer study by Drivas and Shair (11) is of particular interest because it demonstrated the extreme horizontal extent of pollutant transport:

> "In this study, 3.5 kilograms (7.4 lbs.) of SF_6 were released from ground level from the central region of the City of Anaheim and traced to five neighboring communities downwind, including Palm Springs, which, at 124 km, was the furthest location tested. A preliminary analysis of the data indicated that the cities of Riverside and Palm Springs possibly lie in a direct path of the pollutant transport from Anaheim."

Considering air quality, ambient pollution measurements in the desert show that ozone is the most important contaminant transported from the South Coast Air Basin, with other secondary pollutants such as particulate sulfate and nitrate being of less significance. Concentrations in the receptor areas are dependent upon each day's dispersion characteristics, but high concentrations are attained even on days with rather strong onshore flows, vertical dispersion being more critical than dispersion by horizontal transport.

The principal escape routes for Basin pollution moving into the Southeast Desert Air Basin are through the three major passes. See Figure 43. Late in the day, ozone-rich air masses are transported through Newhall Pass to the

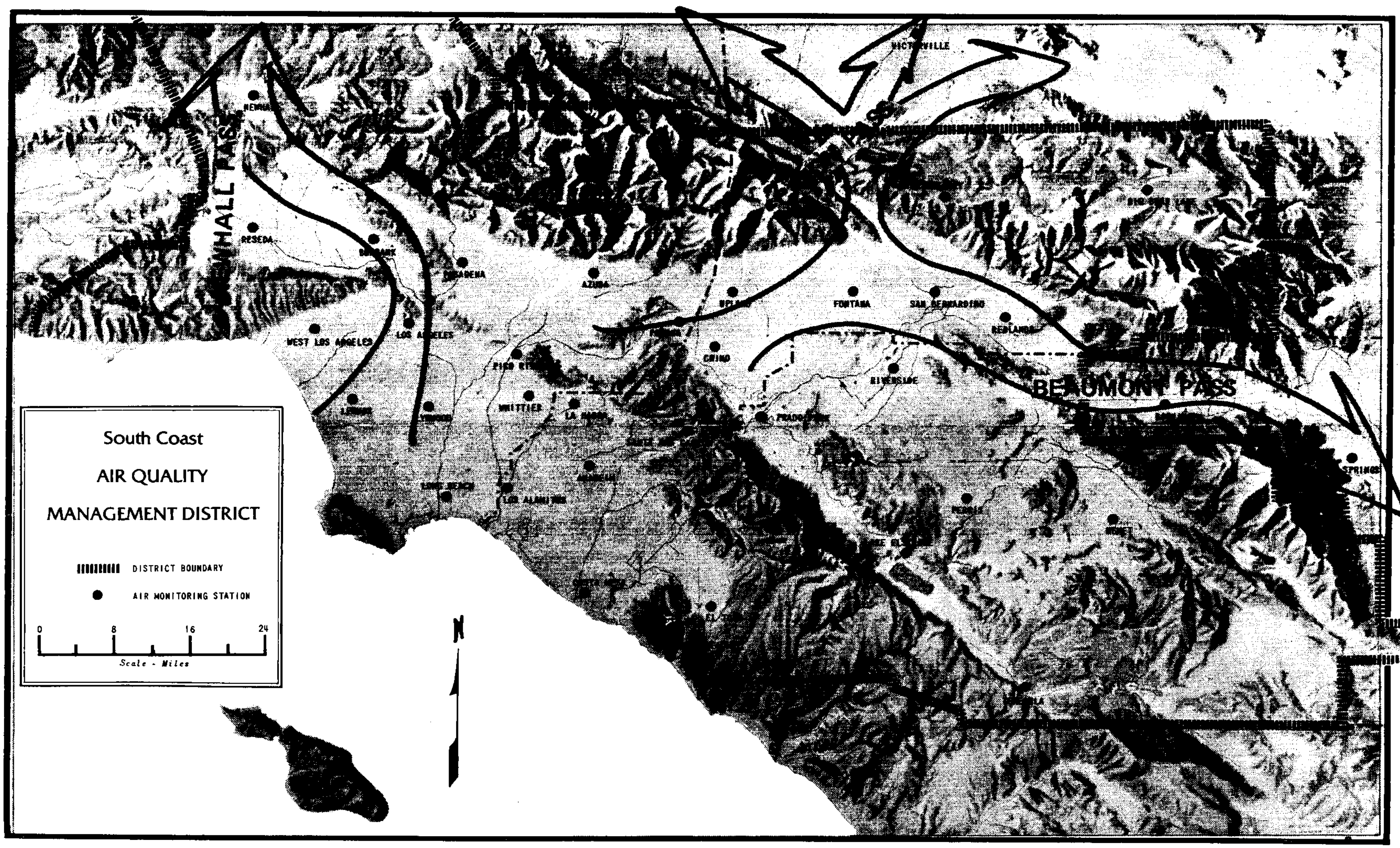

Figure 43 shows pollution transport routes from the South Coast Air Basin to the Southeast Desert Air Basin through the three principal mountain passes.

Palmdale/Lancaster area. On the north side of Cajon Pass, summer pollution clouds spread out in a fan-like pattern to impact the Victorville and Barstow areas. The Low Desert is impacted by transport through Banning Pass, late afternoon and evening, with the effect lessening with distance eastward because of continued dispersion with distance. Vertical dispersion in the Low Desert is excellent during daytime hours because of intense surface heating; this accounts for the evening ozone maxima at Palm Springs and Indio.

In 1977, to illustrate the importance of ozone transport to desert receptors, Stage one episode levels (0.20 ppm O_3, one-hour average) were attained at Lancaster for the first time since the episode program was initiated in 1974. (On July 20, 1978, an hourly average of 0.27 ppm was attained.) Stage one episodes were also attained that year (1974) in Barstow, Victorville, Banning, and Palm Springs. Ozone is transported these long distances at fairly high concentrations for two reasons. Control of the most reactive hydrocarbons in the South Coast Air Basin has delayed the time of the daily maximum ozone production; thus the photochemical reactions continue as the polluted air mass is carried great distances. The other reason is that ozone concentrations can remain high during transport in the desert due to the lack of nitric oxide sources; this prevents ozone loss by nitric oxide scavenging. Ozone concentrations peak in the High Desert during the late afternoon, while maxima at Palm Springs can occur as late as midnight.

San Diego County - South Coast Air Basin Transport

Transport to the South Coast Air Basin

Analyses of wind flow types along the Southern California coast indicate that on a yearly average, southerly winds blow along the coastal sections of San Diego County toward the Basin about eighteen percent of the time. These flows are a result of eddy wind circulation patterns off the coast and are associated with deep marine layers. Consequently, only the transport of total particulates (including sulfates) and sulfur dioxide from San Diego County to the Basin has an impact on the air quality of the Basin; and that limited impact is in direct proportion to the particulates and sulfur emissions along the transport path.

Sulfate transport can occur because a deep marine layer is the ideal environment for the conversion of sulfur dioxide to sulfates, and this process takes place even with extended transport.[(6)]

Transport from the South Coast Air Basin

Since the predominant wind flow along the coast of Southern California is westerly, transport between the South Coast Air Basin and San Diego County, in either direction, does not take place the majority of the time. Further analyses of Southern California coastal wind flow types show that east flows and Santa Ana winds combined occur about eighteen percent of the time on a yearly basis. With weak offshore flows, contaminated air masses in the Basin are moved to the immediate coast or off the coast where they stagnate and can be transported later to San Diego County on northwesterly winds.

Transport from San Diego County to the Basin occurs about the same percentage of time as transport in the opposite direction. Thus, inter-Basin transport is not more than one-third of the total time, including periods with good vertical mixing. During the remainder of the time, there is negligible transport.

Some transport from the Basin to San Diego County is important to the receptor areas because that transport occurs with low inversions along the coast. With such inversion conditions, ozone and ozone precursors are concentrated in the shallow surface layer below the inversion base. Further, with the transport taking place over water, nitric oxide is not available to scavenge ozone from the polluted air mass.

Bell (2) made a study of two days in 1959 when high ozone concentrations were attained in Oceanside and San Diego. On both days, the air masses that were over those locations at the times of the daily ozone maxima were traced backward in time to sources along the southern Los Angeles County coast. Figure 44 shows the trajectories of the air parcels (the transport path) from the South Coast Air Basin to the Oceanside and San Diego receptor areas on November 20, 1959.

A study in greater depth was made by Kauper (21) in 1977. In this work, trajectories were constructed for all days with elevated ozone concentrations in the San Diego Air Pollution Control District for the years 1974, 1975, and 1976. He concluded that all the high ozone occurrences in the District were the result of transport of pollutants from the South Coast Air Basin or the nearby offshore area. Two examples are shown in Figure 45.

The following, from the above study, is a list of daily one-hour average maximum ozone categories with the corresponding percentages of times the trajectories, drawn from San Diego County receptors, originated in or near the South Coast Air Basin:

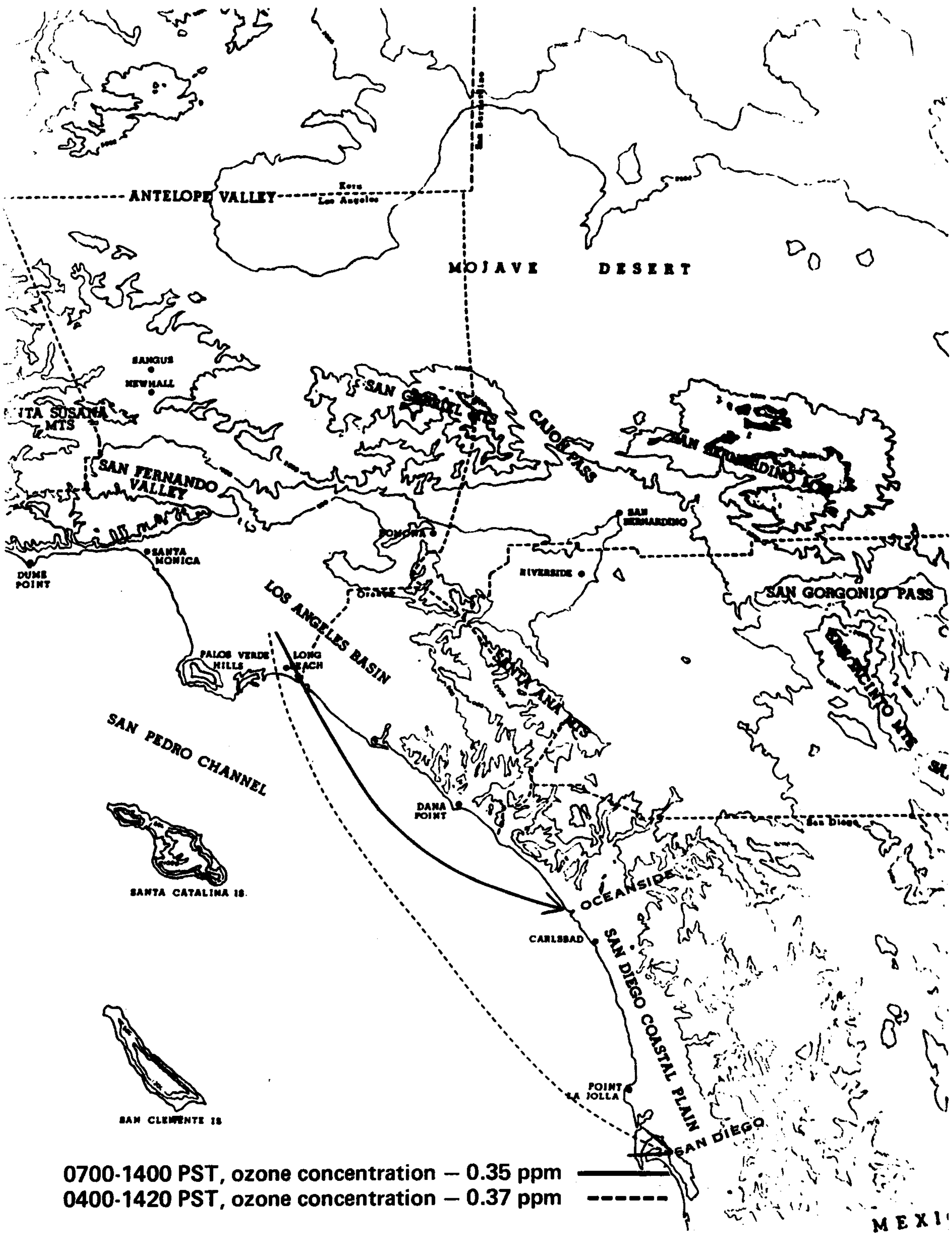

Figure 44 shows transport paths to Oceanside and San Diego, respectively, on November 20, 1959.

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