5.0 INVESTIGATION OF ANTHROPOGENIC INFLUENCES ON DAY-OF-THE-WEEK VARIATIONS IN SoCAB METEOROLOGICAL CONDITIONS

5.1 Introduction

Since urban heat islands are among the most robust and well-documented of anthropogenic meteorological effects, and since it seems physically plausible that in a massively urbanized area such as the SoCAB there could be many human influences that could potentially influence the surface temperature, we felt that if a detectable variation in anthropogenic meteorological influence by day-of-the-week did exist, it would most easily be found in the temperature data. In some sense, too, variations in surface air temperature resulting from human activity should represent the integrative net effect of many of the possible human influences on local meteorological conditions.

We could locate only a limited number of papers in the peer-reviewed literature concerning possible regional variations in meteorology by day-of-the-week due to anthropogenic influences, and only one of these studies was from the United States. All of the manuscripts we found focused primarily on potential day-of-the-week variation in rainfall or temperature, or both, although one also addressed wind speed, relative humidity and solar radiation (Fujibe 1987). Fujibe (1987, 1988a,b) published a series of papers examining weekday-weekend differences in urban climate (air temperature) in Tokyo, Osaka and other Japanese cities over a nine year period. He reported lower temperatures (about 0.2 °C) on Sundays compared with weekdays. Cehak (1982) examined weekday-weekend differences in precipitation in a medium size industrialized city, Wien, Austria, but could not demonstrate a statistically significant day-of-the-week effect. Simmonds and co-workers (Simmonds and Kaval 1986; Simmonds and Keay 1997) have investigated day-of-the-week variation in rainfall and temperature in Melbourne, Australia and found no statistically significant difference between days, although some day-of-the-week trends were found for the winter season. Winter weekday precipitation was significantly (at the 5% level) greater and they attributed this difference to atmospheric pollution (Simmonds and Kaval 1986). They concluded that pollution level had little effect on maximum temperature. In their more recent study covering 134 years of temperature records from Melbourne Simmonds and Keay (1997) found a statistically significant day-of-the-week effect only for winter, for which they found weekday maximum temperatures to be ~0.2-0.3 °C warmer than weekends. These authors considered the possible impacts of day-of-the-week variation in atmospheric pollution loading but concluded weekday-weekend differences in anthropogenic heat emissions were sufficient to explain the observed temperature differences.

More than forty years ago, Mitchell (1953) showed that the daily-minimum temperature in winter in New Haven, Connecticut, was lower on Sundays than on weekdays by about 0.6 °C. We are not aware of other such day-of-the-week analyses for U.S. cities, although we have not made an exhaustive search of the literature. To the best of our knowledge, there have been no reports in the peer-reviewed literature of studies of day-of-the-week anthropogenic meteorological conditions in the California South Coast Air Basin. In the following sections we present data from our investigations of such effects for the SoCAB.

5.2 Ambient Temperature Analysis

5.2.1 Day-of-the-Week Effects during Summer Seasons

We began by analyzing mean hourly temperature data from 11 SCAQMD air quality monitoring stations well-distributed through the region of the SoCAB. The 3-month interval 15 June to 15 September was considered for each of the five years between 1989 and 1993. We limited this analysis to a five-year period of time in order to diminish the possible effects of long-term trends in some of the anthropogenic influences (e.g., population shifts, reformulation of automotive fuels, changes in emissions regulations, and so forth).

For each of the 11 stations, weekday (Tuesday/Wednesday and Wednesday/Thursday) and weekend (Saturday/Sunday) mean temperatures were computed at 4 different times of day: 0500, 1100, 1700, and 2300 PST. The latter were then subtracted from the former to obtain the weekday/weekend temperature differences shown in Table 5-1. Interestingly, with only three minor exceptions, at every station and at each of the four times of day examined, both the average Tuesday/Wednesday temperature and the Wednesday/Thursday temperature were warmer than the corresponding Saturday/Sunday temperature. Thus in 85 of the 88 cases examined (11 stations times 4 times of day times 2 pairs of weekdays), the weekday temperature was warmer than the weekend temperature, while in just 3 cases the weekend temperature was warmer than the weekday temperature.

All of these weekday/weekend temperature differences were quite small, however. The average difference (across all stations and times of day) between the Tuesday/Wednesday mean temperature and the Saturday/Sunday mean temperature was 0.6 °F, while that between Wednesday/Thursday and Saturday/Sunday was 0.7 °F.

These data suggest there may be a small difference in temperature between weekdays and weekend days that can be associated with anthropogenic influences. However, several important points need to be made. First, the weekday/weekend temperature difference as found by this analysis is very small; in fact, the values are much smaller than the corresponding standard deviations (see Table 5-1). Thus while we have found evidence for an anthropogenically-produced difference in micrometeorological conditions between weekdays and weekend days in the SoCAB, the statistical robustness of the result appears to be limited. In addition, the small magnitudes of these temperature differences suggest that any feedback on SoCAB air pollution levels will be exceedingly small. Nonetheless, the result is certainly of general scientific interest, and to our knowledge is the first ever obtained that suggests the presence of an anthropogenically-produced weekday/weekend variation in microscale meteorological conditions in the SoCAB.

Table 5-1. SoCAB weekday/weekend differences in mean hourly average temperature from 15 June to 15 September (1989-93). All values in °F; ending time of observation hour indicated.

Site	Time (PST)	Mean T TU/WE	Std.dev. TU/WE	Mean T WE/TH	Std.dev. WE/TH	Mean T SA/SU	Std.dev. SA/SU	Δ T TU/WE -SA/SU	Δ T WE/TH -SA/SU
Anaheim	0500	64.7	3.1	65.1	3.1	65.0	3.2	-0.3	0.1
	1100	78.7	6.3	78.7	6.3	78.1	5.6	0.6	0.6
	1700	78.7	6.0	78.2	7.6	78.3	5.3	0.4	-0.1
	2300	67.3	3.3	66.8	5.7	66.9	3.0	0.4	-0.1
Azusa	0500	63.9	4.4	64.1	4.3	63.2	3.7	0.7	0.9
	1100	79.9	7.5	79.9	7.5	79.1	6.6	0.8	0.8
	1700	82.6	6.2	82.5	5.7	82.0	5.4	0.6	0.5
	2300	67.7	4.7	67.6	4.2	66.8	4.0	0.9	0.8
Burbank	0500	63.6	4.2	63.9	4.2	63.3	3.9	0.3	0.6
	1100	81.4	7.7	81.4	7.7	80.4	6.8	1.0	1.0
	1700	82.1	6.7	82.0	6.0	81.2	6.2	0.9	0.8
	2300	67.0	4.5	66.9	4.2	66.2	3.6	0.8	0.7
Hawthorne	0500	64.2	3.0	64.6	2.9	64.0	2.7	0.2	0.6
	1100	73.5	3.9	73.8	4.1	73.2	4.2	0.3	0.6
	1700	71.0	3.3	71.2	3.3	70.3	3.1	0.7	0.9
	2300	65.1	3.3	65.1	2.9	64.7	2.6	0.4	0.4
LA-Main	0500	64.5	3.9	64.7	3.8	64.1	3.4	0.4	0.6
	1100	79.8	6.8	79.7	6.8	78.7	6.2	1.1	1.0
	1700	76.7	5.6	76.6	5.0	75.7	4.6	1.0	0.9
	2300	66.4	4.1	66.4	3.7	65.6	3.4	0.8	0.8
Long Beach	0500	64.1	2.9	64.4	2.9	64.1	3.0	0.0	0.3
	1100	75.6	5.4	75.5	5.4	74.6	5.0	1.0	0.9
	1700	74.2	4.0	74.3	3.9	73.4	3.8	0.8	0.9
	2300	65.7	3.0	66.0	3.2	65.2	3.0	0.5	0.8
Newhall	0500	59.1	5.0	59.3	5.3	58.6	5.1	0.5	0.7
	1100	87.3	8.4	87.3	8.6	86.2	8.7	1.1	1.1
	1700	89.7	7.0	89.7	7.0	89.3	7.6	0.4	0.4
	2300	67.1	5.4	67.1	5.3	66.1	5.1	1.0	1.0
Pasadena	0500	61.5	4.1	61.7	4.1	61.2	3.9	0.3	0.5
	1100	81.7	7.6	81.5	7.5	80.3	7.1	1.4	1.2
	1700	82.7	6.4	82.7	5.8	81.9	6.0	0.8	0.8
	2300	64.0	3.8	64.1	4.0	63.5	3.7	0.5	0.6
Pico Rivera	0500	63.7	3.7	64.0	3.4	63.7	3.7	0.0	0.3
	1100	80.8	6.3	80.7	6.5	79.7	5.9	1.1	1.0
	1700	80.9	5.5	80.8	4.9	80.1	4.8	0.8	0.7
	2300	66.5	3.7	66.5	3.7	65.8	3.5	0.7	0.7
Riverside	0500	62.4	4.2	62.6	4.3	62.3	4.1	0.1	0.3
	1100	84.0	8.9	84.0	8.7	83.6	7.6	0.4	0.4
	1700	85.6	6.5	85.7	5.8	84.9	6.1	0.7	0.8
	2300	67.9	4.8	67.9	4.7	67.5	4.5	0.4	0.4
Upland	0500	62.4	4.7	62.5	4.8	61.8	4.4	0.6	0.7
	1100	81.5	8.5	81.6	8.4	81.3	7.4	0.2	0.3
	1700	83.4	6.3	83.6	5.7	82.8	5.7	0.6	0.8
	2300	66.5	5.1	66.5	4.8	65.9	4.6	0.6	0.6
Average		**72.7**	**5.2**	**72.7**	**5.2**	**72.1**	**4.8**	**0.6**	**0.7**

We subsequently expended significant effort to try to derive a similar result that could be shown to be statistically significant. In general, our objective was to find a way to combine the results from the different stations in a manner that would increase the overall statistical robustness. This is complicated, however, because the temperature at the different SoCAB stations, as well as at the same station at different times of day, are clearly not independent of each other. We therefore sought and received guidance in this regard from Professor William Cumberland in the UCLA Department of Biostatistics.

He suggested that we continue our investigation by focusing on the "urban core" region of the SoCAB over the six-year period 1990-95; the five sites selected to represent this area were Azusa, Burbank, Los Angeles, Pasadena, and Pico Rivera. By focusing on a group of stations in a region of more-or-less uniform meteorological conditions, an average weekday/weekend temperature difference across all 5 stations could reasonably be used, which it was hoped would yield a more statistically robust result (with regards to weekday/weekend temperature difference).

The histograms in Figures 5-1, 5-2, 5-3, and 5-4 show the basic results of these analyses. As expected, the distributions of the temperature differences vary diurnally, with increased variability during daytime hours. We calculated student-t statistics for each of these distributions but none were statistically significant at even the 95% confidence level (Table 5-2). Interestingly, when the analysis is limited to the four-year period 1990-93 (Table 5-3), the t-test indicated there are statistically significant temperature differences at 0500 PST and 2300 PST, but this is not the case when the six-year period 1990-95 is used.

Table 5-2. Urban core weekday/weekend temperature differences 1990-95.

Hour (PST)	0500	1100	1700	2300
N > 0	57	48	44	49
N = 0	0	1	0	2
N < 0	42	52	57	50
N	99	101	101	101
Average	0.3	0.4	0.0	0.4
Std Dev	3.7	6.7	5.6	3.6
t-stat	0.8	0.6	-0.1	1.1

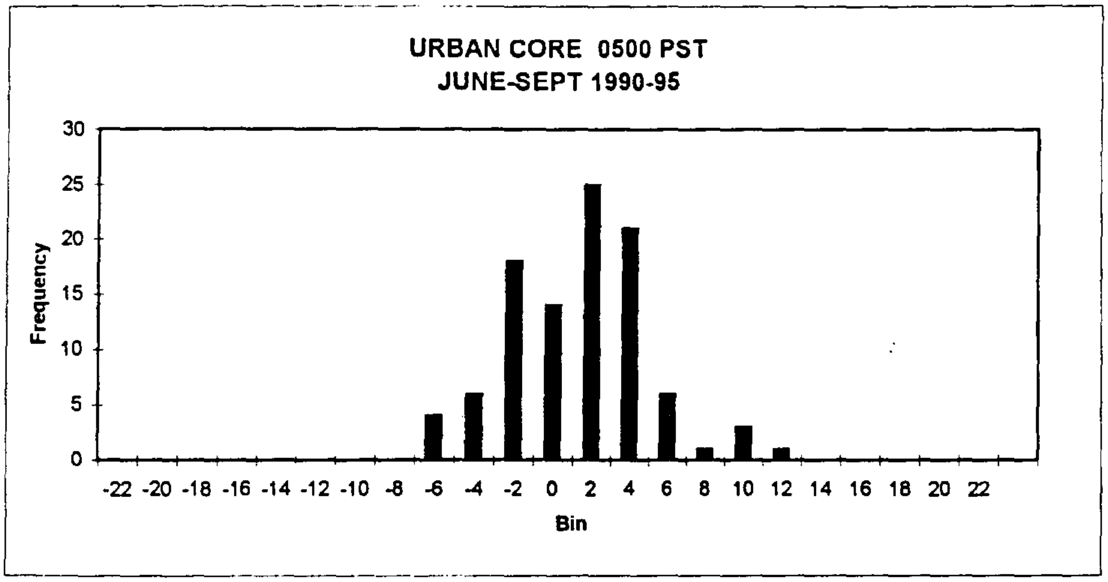

Figure 5-1. Histogram of urban core weekday/weekend average temperature (°F) differences (0500 PST). Note: The number below each bin represents the lower bound of that bin.

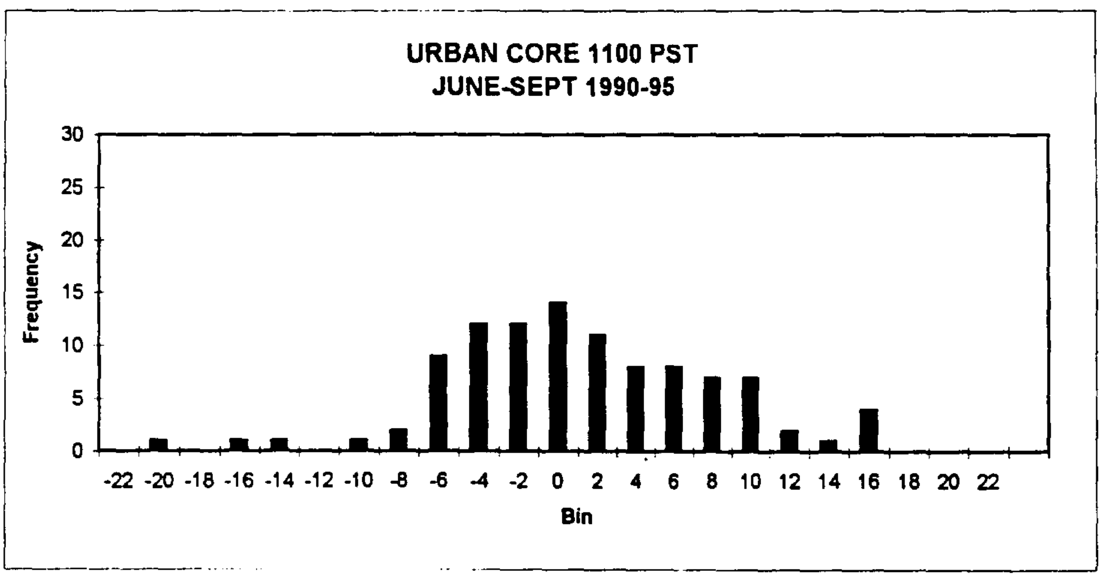

Figure 5-2. Histogram of urban core weekday/weekend average temperature (°F) differences (1100 PST). Note: The number below each bin represents the lower bound of that bin.

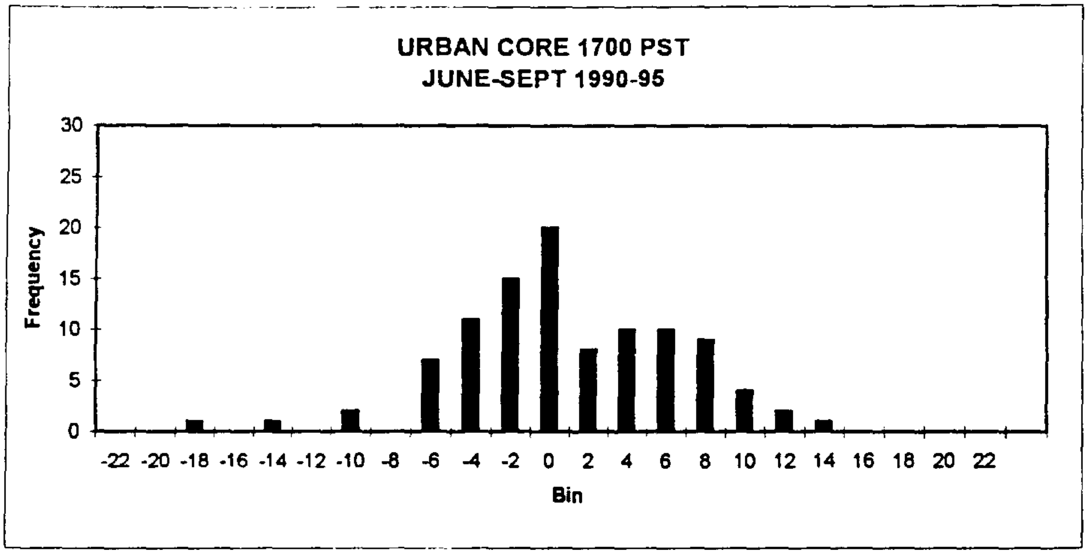

Figure 5-3. Histogram of urban core weekday/weekend average temperature (°F) differences (1700 PST). Note: The number below each bin represents the lower bound of that bin.

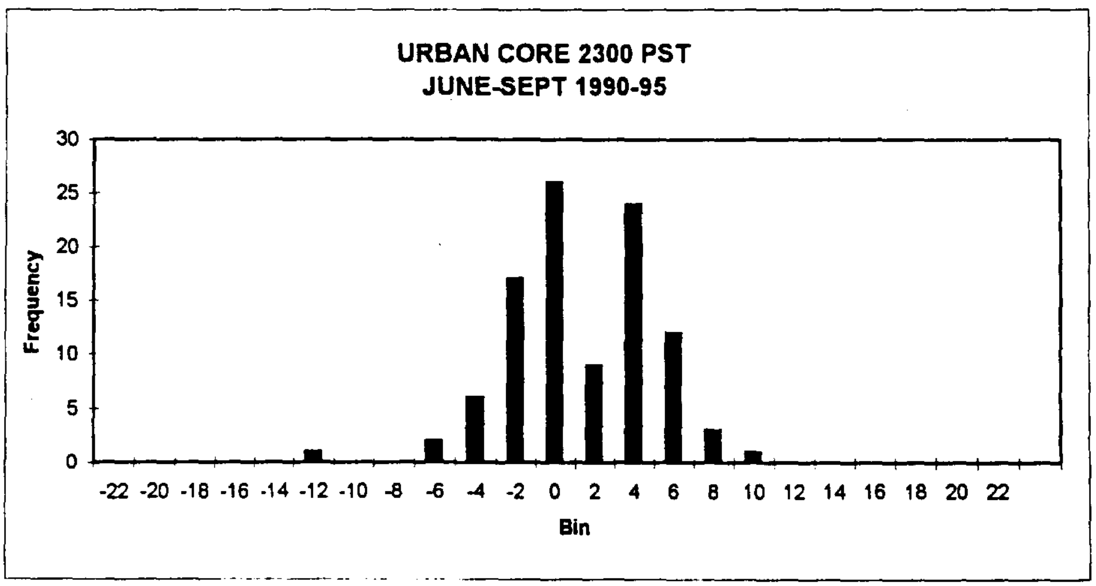

Figure 5-4. Histogram of urban core weekday/weekend average temperature (°F) differences (2300 PST). Note: The number below each bin represents the lower bound of that bin.

Table 5-3. Urban core weekday/weekend temperature differences 1990-93.

Hour (PST)	0500	1100	1700	2300
N > 0	42	32	31	39
N = 0	0	1	0	1
N < 0	24	35	37	28
N	68	68	68	68
Average	0.7	0.6	0.5	0.8
Std Dev	3.4	6.5	5.4	3.1
t-stat	1.6*	0.8	0.7	2.0**

* Significant at 90% level

** Significant at 95% level

Further reflection on these results suggests an intrinsic difficulty in attempting to establish statistical robustness of the weak weekday/weekend temperature difference suggested by our preliminary analyses. The essence of the problem is that even in a region with typically placid smog season weather conditions such as the SoCAB, there will from time-to-time be relatively dramatic changes in prevailing meteorological conditions over short time intervals (i.e., on the order of hours to days). And during the summer months, there will occasionally be relatively rapid development of either stronger onshore flow or anomalous offshore flow, or of a Catalina Eddy circulation, passage of a weak front, intrusions of warmer and cloudier subtropical air masses, and so forth. Typically a few times during the summer, such an event will likely occur between Wednesday/Thursday and the subsequent Saturday. Unlike the anthropogenic weekday/weekend temperature effect we have shown, however, the magnitude of the temperature influence of this sort of change in the prevailing synoptic-scale meteorological conditions can be quite large. Thus the small signal we are looking for could quite easily be hidden by the particular temporal distribution of these much larger-magnitude events. If our sample size was large enough, however, to encompass a very large number of these changes in meteorological conditions, they should more or less cancel each other, with the weak signal we are looking for remaining. But this would require a data set consisting of a very large number of smog season weeks, which in turn implies use of many years of data (since the period during each smog season that is comparatively quiescent meteorologically is only 12-16 weeks long). Using many years of data, though, would seem likely to introduce a new problem—namely that we would no longer be justified in assuming there is no significant year-to-year trend in anthropogenic influences. In fact, our analyses of ozone and other air pollutant data in this study show marked changes (i.e., improvements) in anthropogenically-caused air pollution over periods of even a few years or less. Ultimately, then, we are only able to conclude that if a day-of-the-week temperature effect does exist in the SoCAB, it is quite weak and therefore not likely to be of particular importance to air quality management efforts. Comparison of weekend day and weekday 850 mb temperatures & virtual temperature profiles from the 8 radar wind profile network and routine sondes in southern California would be available from 1997 onwards. Such a comparison was not available to our study.

5.2.2 Day-of-the-Week Effects at Los Angeles Civic Center: 1949-94

Table 5-4 shows the mean and standard deviation of the daily-maximum and daily-minimum temperature by day-of-the-week at Los Angeles Civic Center for the entire 12 months of 1949-94. This analysis was also performed using only the smog season months of May through October (Table 5-5). For both analyses there was no clear day-of-the-week effect in daily-maximum temperature, while there was a slight indication of cooler daily-minimum temperatures on weekends (especially Sundays). The mean and standard deviation temperatures by day-of-the-week were also computed for the smog seasons of 1949-71 (Table 5-6) and 1972-94 (Table 5-7). The daily-maximum temperatures for the latter period were about 1 °F warmer for each day of the week, and the daily-minimum temperatures were about 2 °F warmer for each day. This increase is presumably due to an enhancement of the urban heat island effect during the past 25 years as has been reported by many other investigators. No clear day-of-the-week effects were

Table 5-4. Temperature (°F) by day-of-the-week at Los Angeles Civic Center for January through December 1949-94.

Day	Daily-maximum Temperature	Standard Deviation	Daily-minimum Temperature	Standard Deviation
Monday	75.1	9.6	56.6	7.4
Tuesday	75.1	9.9	56.7	7.4
Wednesday	75.2	9.7	56.7	7.4
Thursday	74.8	9.7	56.7	7.4
Friday	74.8	9.6	56.6	7.5
Saturday	74.9	9.6	56.5	7.5
Sunday	75.0	9.7	56.3	7.6

Table 5-5. Temperature (°F) by day-of-the-week at Los Angeles Civic Center for May through October 1949-94.

Day	Daily-maximum Temperature	Standard Deviation	Daily-minimum Temperature	Standard Deviation
Monday	80.3	7.7	61.9	4.8
Tuesday	80.4	8.0	62.0	4.8
Wednesday	80.4	7.9	62.1	4.9
Thursday	80.2	8.0	62.1	4.9
Friday	80.2	7.7	62.1	4.9
Saturday	80.3	7.7	62.0	4.8
Sunday	80.4	7.7	61.8	4.8

Table 5-6. Temperature (°F) by day-of-the-week at Los Angeles Civic Center for May through October 1949-71.

Day	Daily-maximum Temperature	Standard Deviation	Daily-minimum Temperature	Standard Deviation
Monday	79.9	7.8	60.8	4.8
Tuesday	79.9	7.9	60.9	4.7
Wednesday	79.9	7.9	61.0	4.7
Thursday	79.6	8.0	61.0	4.7
Friday	79.8	8.0	61.1	5.0
Saturday	79.7	7.7	61.0	4.9
Sunday	79.9	7.8	60.8	4.9

Table 5-7. Temperature (°F) by day-of-the-week at Los Angeles Civic Center for May through October 1972-94.

Day	Daily-maximum Temperature	Standard Deviation	Daily-minimum Temperature	Standard Deviation
Monday	80.7	7.6	63.0	4.5
Tuesday	80.9	8.1	63.0	4.7
Wednesday	80.9	7.9	63.1	4.9
Thursday	80.8	7.9	63.1	4.7
Friday	80.6	7.4	63.2	4.7
Saturday	80.9	7.6	62.9	4.5
Sunday	80.8	7.6	62.8	4.5

found in daily-maximum temperatures, but daily-minimum temperatures appeared to be slightly cooler on weekends during the latter period.

The mean weekday (Monday through Friday) daily-maximum temperature at Los Angeles Civic Center for the 1949-94 smog seasons is shown in Figure 5-5. The corresponding weekend analysis is shown in Figure 5-6. The difference between these two plots is shown in Figure 5-7. The best-fit least squares trendline revealed a gradual increase in the mean smog season daily-maximum temperature during the 1949-94 period of about 2 °F for both weekdays and weekends. This suggests the urban heat island effect has intensified during the period of investigation. Although the weekend daily-maximum temperatures increased over the 45-year period slightly more rapidly than the weekday values, as evidenced by the decreasing trendline in Figure 5-7, this effect is not likely to be statistically significant, given the large year-to-year fluctuations during the period of investigation. Thus there does not appear to exist a clear day-of-the-week temperature effect at the Los Angeles Civic Center during the 1949-94 smog seasons.

5.3 Relative Humidity Analysis

We have examined relative humidity data for an anthropogenic weekday/weekend effect. As with our initial analysis of the temperature data, we proceeded to analyze hourly-mean relative humidity data from the same 11 SCAQMD air quality monitoring stations that are well-distributed through the region of the SoCAB. Also consistent

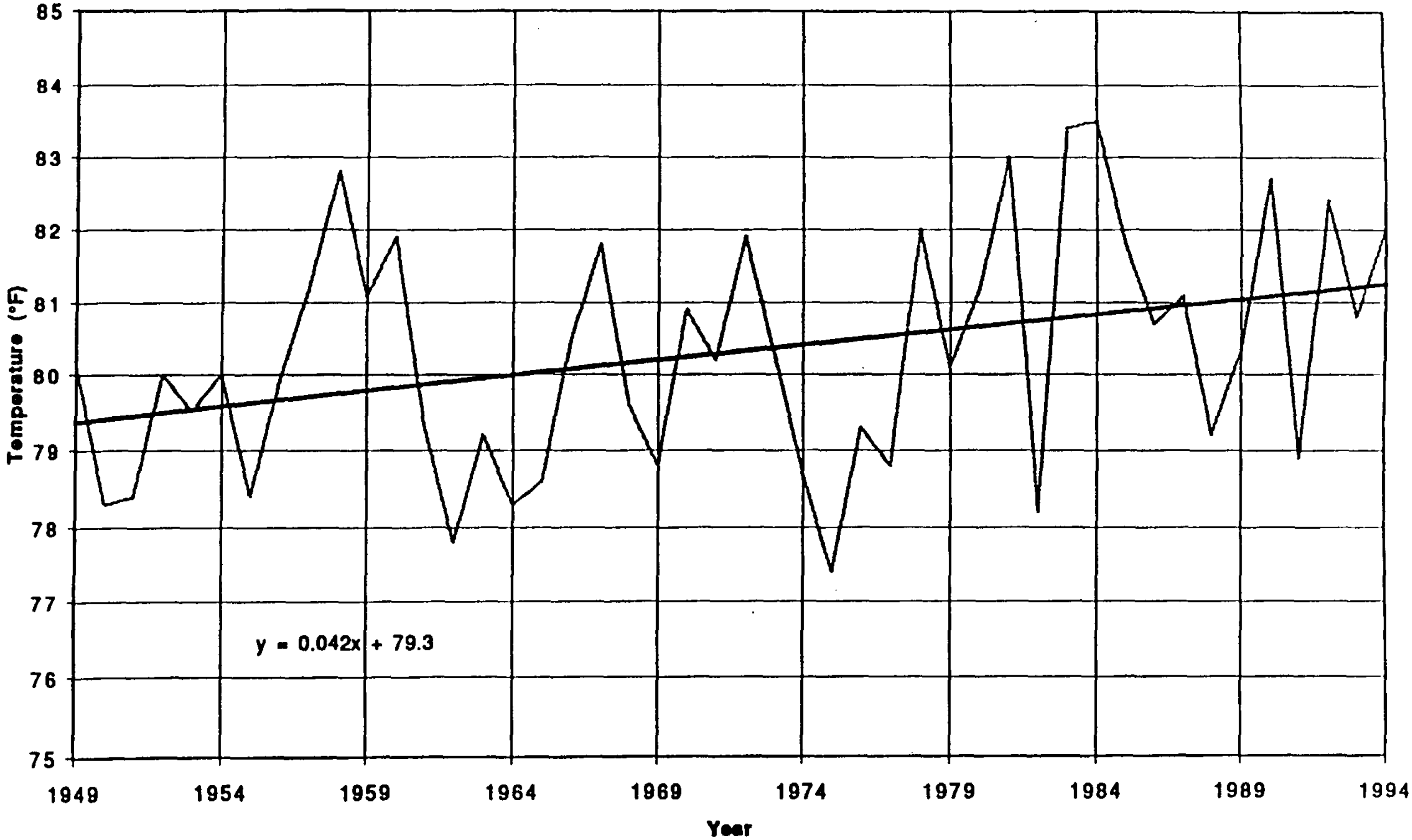

Figure 5-5. Los Angeles Civic Center mean weekday (Mon. - Fri.) daily-maximum temperature for 1949-94 smog seasons (1 May - 31 October).

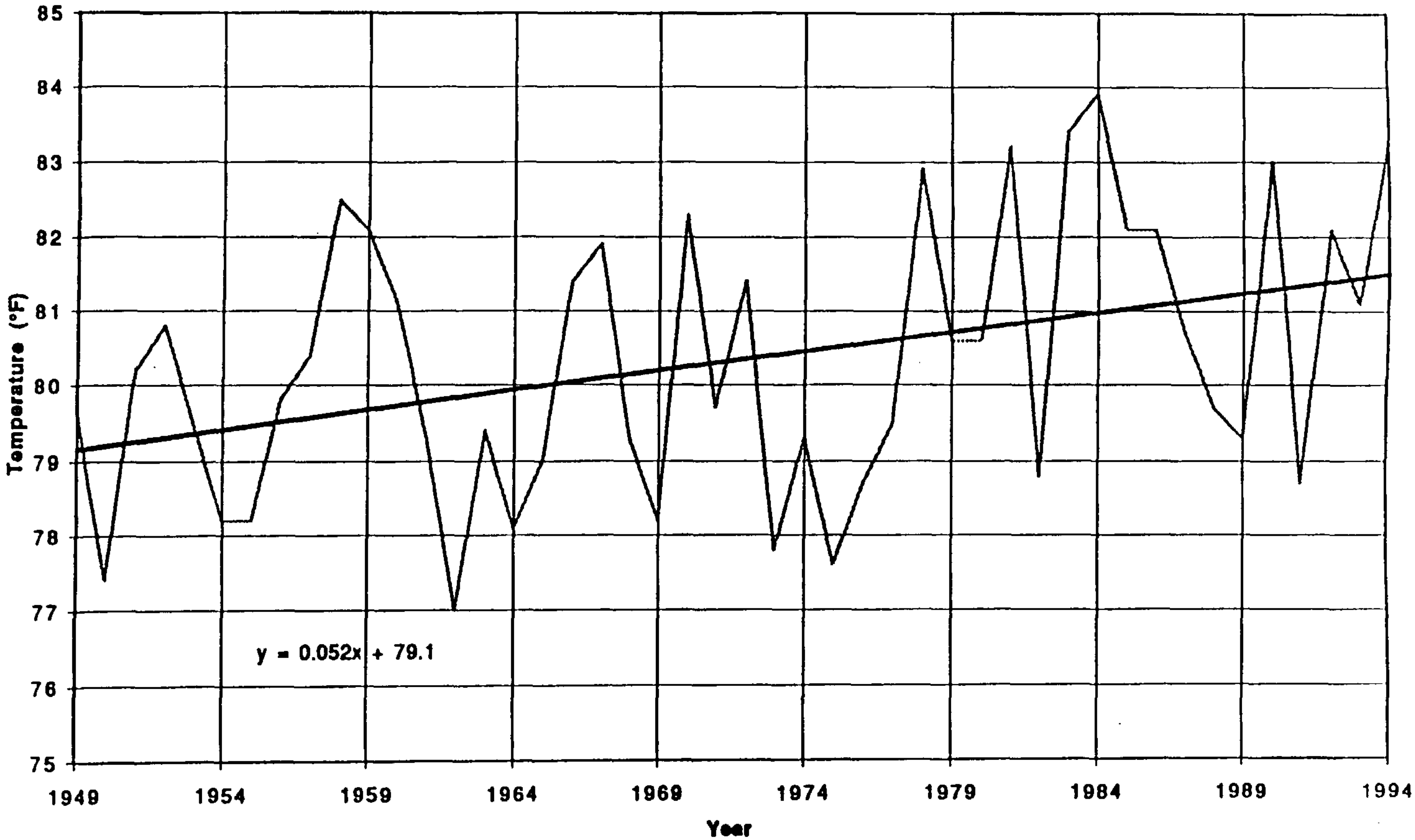

Figure 5-6. Los Angeles Civic Center mean weekend (Sat. - Sun.) daily-maximum temperature for 1949-94 smog seasons (1 May - 31 October).

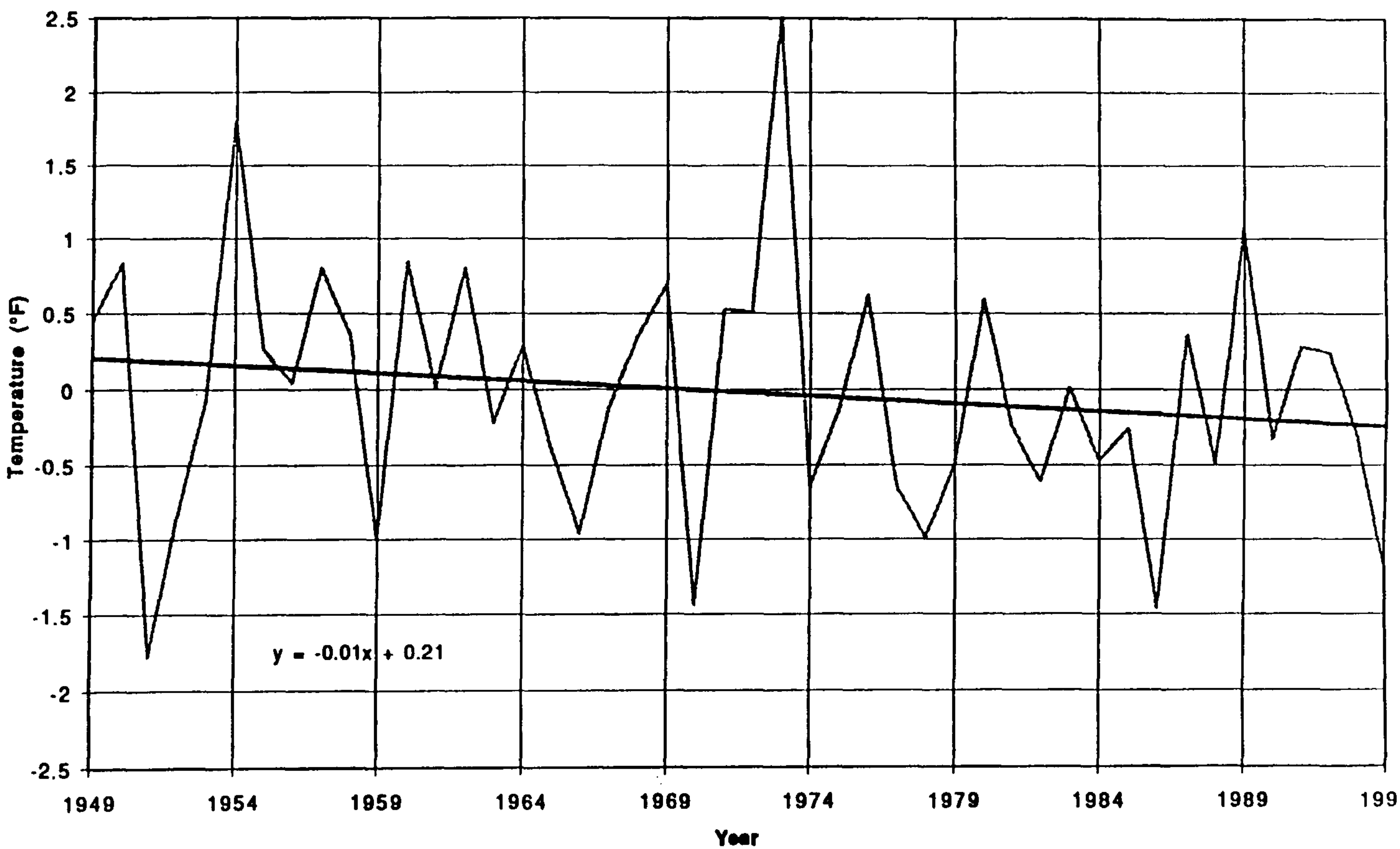

Figure 5-7. Los Angeles Civic Center mean weekday (Mon. - Fri.) minus weekend (Sat. - Sun.) daily-maximum temperature for 1949-94 smog seasons (1 May - 31 October).

with the analysis of temperature data, the 3-month interval 15 June to 15 September was used over the five-year period 1989-93.

For each of the 11 stations, weekday (Tuesday/Wednesday and Wednesday/Thursday) and weekend (Saturday/Sunday) mean relative humidities were computed for 4 different hours of the day: those ending at 0500, 1100, 1700, and 2300 PST. The weekend values were then subtracted from the weekday values to obtain the weekday/weekend relative humidity differences shown in Table 5-8. Although our results indicate a slight average increase in relative humidity on weekends (0.4%), unlike the temperature analysis there is no consistency in sign either between the various stations or the different times of day. In addition, the standard deviations are much larger than the weekday/weekend relative humidity differences. Thus no day-of-the-week signal is evident.

5.4 b_{scat} Analysis

Given that day-of-the-week differences in air quality have been documented in the SoCAB, it was hypothesized there could be a detectable variation in anthropogenic influence on visibility. We thus proceeded to analyze SCAQMD hourly-average b_{scat} data. Although the b_{scat} variable is not directly calibrated to a familiar visibility distance unit, and although these data are not considered to be entirely robust for a variety of technical reasons [i.e., the numerical values should not be interpreted directly (Miller 1997)], it is generally agreed the values can be considered relative to each other and thus may be used in the form of a ranking scale (that is, a lower value means better visibility).

Unfortunately, these b_{scat} data exist for only a few sites and for only some of the years during the 1986-96 smog seasons. Since Upland and Azusa had relatively high data completeness for the four smog seasons 1986-89, we performed a day-of-the-week analysis of b_{scat} at these two sites for this period. Table 5-9 shows the mean and standard deviation b_{scat} values for Upland for 15 June to 15 September 1986-89 for the hours 0400-0500, 1000-1100 am, 1600-1700, and 2200-2300 PST. A somewhat lower b_{scat} value (and thus better visibility) was evident for weekend days at Upland (Table 5-9) for all

Table 5-8. Basinwide weekday/weekend differences in mean-hourly average relative humidity from 15 June to 15 September (1989-93). All values in %; ending time of observation hour indicated.

Site	Time (PST)	Mean RH WE/TH	Std. Dev. WE/TH	Mean RH SA/SU	Std. Dev. SA/SU	Δ RH WE/TH-SA/SU
Anaheim	0500	65.6	9.7	65.9	9.6	-0.3
	1100	45.5	9.1	45.7	8.5	-0.2
	1700	44.5	9.8	43.9	9.5	0.6
	2300	63.5	10.2	62.2	9.8	1.3
Azusa	0500	66.1	11.5	68.8	10.0	-2.7
	1100	42.3	11.5	44.0	11.4	-1.7
	1700	38.7	9.3	38.6	10.4	0.1
	2300	62.3	10.6	62.5	11.9	-0.2
Burbank	0500	65.4	12.0	66.6	9.7	-1.2
	1100	39.6	10.6	40.3	10.2	-0.7
	1700	37.8	9.9	37.9	10.3	-0.1
	2300	61.9	11.1	62.1	10.6	-0.2
Crestline	0500	47.4	16.1	48.2	16.8	-0.8
	1100	33.1	14.4	33.7	13.2	-0.6
	1700	39.4	12.4	39.8	12.7	-0.4
	2300	47.0	15.4	46.8	15.9	0.2
Hawthorne	0500	74.6	10.2	74.4	9.5	0.2
	1100	59.1	8.4	59.0	8.8	0.1
	1700	62.8	10.0	63.3	9.0	-0.5
	2300	74.2	10.2	74.1	10.4	0.1
LA-Main	0500	69.9	10.8	70.7	9.2	-0.8
	1100	44.4	10.8	45.8	10.8	-1.4
	1700	48.1	9.9	49.1	10.1	-1.0
	2300	67.4	9.0	68.0	9.8	-0.6
Long Beach	0500	70.7	10.3	70.8	10.7	-0.1
	1100	51.1	7.3	51.2	7.8	-0.1
	1700	51.8	8.2	51.5	8.2	0.3
	2300	67.7	10.0	67.2	9.4	0.5
Pico Rivera	0500	71.7	8.7	72.0	7.7	-0.3
	1100	44.5	8.4	45.7	8.6	-1.2
	1700	42.9	7.6	42.6	8.2	0.3
	2300	67.1	7.4	66.8	7.5	0.3
Riverside	0500	65.1	14.5	67.1	12.8	-2.0
	1100	34.8	13.3	35.2	11.2	-0.4
	1700	32.4	8.8	32.5	9.4	-0.1
	2300	57.9	13.8	56.6	13.4	1.3
Upland	0500	64.6	12.3	67.5	10.1	-2.9
	1100	38.7	12.5	39.2	11.1	-0.5
	1700	36.5	8.8	36.9	8.6	-0.4
	2300	61.1	10.8	60.7	11.3	0.4

hours examined except 0400-0500 (with largest weekday/weekend differences for the hours 1000-1100 and 1600-1700). At Azusa, (Table 5-10) the b_{scat} values were also slightly lower on weekend days than on weekdays for each of the four examined hours. These results for Upland and Azusa, however, were not statistically significant, given the large standard deviations.

Table 5-9. Mean and standard deviation of b_{scat} values for the period 15 June to 15 September 1986-89 at 0400-0500, 1000-1100, 1600-1700, and 2200-2300 PST at Upland. Percent completeness represents percent of needed observations available to be used in the calculations. The number (N) of observations used in each calculation also shown.

Time (PST)	Days	Mean b_{scat}	Standard Deviation	Percent Completeness	N
0500	TU/WE	37.4	29.4	99.1	105
0500	SA/SU	39.1	28.5	100	105
1100	TU/WE	66.1	40.3	100	106
1100	SA/SU	57.1	31.5	100	105
1700	TU/WE	42.0	28.4	100	106
1700	SA/SU	33.8	22.3	99.0	104
2300	TU/WE	34.7	26.2	100	106
2300	SA/SU	32.2	24.9	100	105

Table 5-10. Mean and standard deviation of b_{scat} values for the period 15 June to 15 September 1986-89 at 0400-0500, 1000-1100, 1600-1700, and 2200-2300 PST at Azusa. Percent completeness represents percent of needed observations available to be used in the calculations. The number (N) of observations used in each calculation also shown.

Time (PST)	Days	Mean b_{scat}	Standard Deviation	Percent Completeness	N
0500	TU/WE	23.7	15.7	82.1	87
0500	SA/SU	20.4	18.8	83.8	88
1100	TU/WE	38.2	22.0	83.0	88
1100	SA/SU	35.1	35.3	84.8	89
1700	TU/WE	20.7	13.3	83.0	88
1700	SA/SU	19.2	20.9	84.8	89
2300	TU/WE	19.7	13.6	82.1	87
2300	SA/SU	18.4	17.2	84.8	89

To further investigate a possible day-of-the-week variation in visibility in the SoCAB, a more recent period (15 June to 15 September 1992-94) was selected. This period was also chosen because there happened to be high data completeness in the b_{scat} data set at Azusa (one of only two sites with available b_{scat} data for that period). The top 50 b_{scat} values (including any ties) were ranked at each of the following hours: 0400-0500, 1000-1100, 1600-1700, and 2200-2300 PST. For each of these four hours, the ranked values were distributed by day-of-the-week (Table 5-11).

The top 50 b_{scat} values at 0400-0500 PST (Table 5-11) occurred most often on Saturday. At 1000-1100 and 1600-1700 PST, the most frequent day was Friday. No clear day-of-the-week signal appeared at 2200-2300 PST. These results suggest there was a slight tendency for lower visibility days to occur most often on Friday or Saturday at Azusa during the period 15 June to 15 September 1992-94. This result was consistent with our work in the previous phase of the present project, where it was shown that Saturday was the favored day for high ozone episodes in the SoCAB.

Table 5-11. Number of occurrences (by day-of-the-week) of top 50 ranked b_{scat} values at Azusa for the period 15 June to 15 September 1992-94 at 0400-0500, 1000-1100, 1600-1700, and 2200-2300 PST. The number (N) of observations in each analysis also shown.

Day	0400-0500	1000-1100	1600-1700	2200-2300
Monday	3	8	8	8
Tuesday	8	6	8	5
Wednesday	4	6	7	9
Thursday	9	7	7	5
Friday	8	10	12	9
Saturday	12	8	5	8
Sunday	6	5	4	6
N	50	50	51	50
b_{scat} range	23 to 259	35 to 394	24 to 350	25 to 298

5.5 Solar Radiation Analysis

We reasoned that if there were an anthropogenic influence on visibility, the signal might be detectable as a day-of-the-week variation in solar radiation intensity. The 1994-96 SCAQMD solar radiation data were available only from Azusa, Pico Rivera, LA-North Main, and Upland; as an initial analysis, we chose to investigate the observations from Pico Rivera. Table 5-12 shows the mean solar radiation intensity at Pico Rivera for Tuesday/Wednesday and Saturday/Sunday during 1994-96 from 15 June to 15 September, for the hours 0700-0800, 1000-1100, 1300-1400, and 1600-1700 PST. In analyzing these data, however, we noted that smog season days with significantly reduced incoming solar radiation sometimes occurred for reasons unrelated to anthropogenic effects (e.g., intrusion of marine air, and especially fog or low clouds). In order to filter out the most dramatic of such days, we chose to exclude hourly observations in the computation of the mean if the measured incident solar radiation was less than 70% of the highest value reported at that same hour on any of the previous three days or following three days. Here it has been assumed that the maximum possible solar radiation intensity at some hour is closely approximated by the highest reported observation for that hour over a period of one week. Given the high data completeness and the fact that dramatic reductions in visibility (for non-anthropogenic reasons) are unlikely to persist for seven consecutive days during the smog season months, this would seem to be a reasonable approximation.

At Pico Rivera, the mean radiation intensity was found to be slightly lower on weekdays (Tuesday/Wednesday) than on weekend days (Saturday/Sunday) for each of the four hours examined (Table 5-12), consistent with our findings of weekday/weekend differences in b_{scat}. However, this result is not statistically significant, since the standard deviations are much larger than the difference of the means between weekdays and weekends.

Table 5-12. Mean solar radiation intensity (in gram calories per square cm per hour) at Pico Rivera for Tuesday/Wednesday and Saturday/Sunday during the 1994-96 period from 15 June to 15 September at hours 0700-0800, 1000-1100, 1300-1400, and 1600-1700 PST. Hourly observations not included in computation of mean/standard deviation if less than 70% of the highest value reported at that hour on any of the previous three days or following three days

Time (PST)	Days	Mean Radiation Intensity	Standard Deviation	Percent Completeness	N
0800	TU/WE	242.7	40.2	69.6	55
0800	SA/SU	250.6	43.2	71.2	57
1100	TU/WE	569.8	38.1	91.1	72
1100	SA/SU	577.2	45.4	93.8	75
1400	TU/WE	579.0	41.6	94.9	75
1400	SA/SU	587.7	44.9	98.8	79
1700	TU/WE	265.9	43.9	96.2	76
1700	SA/SU	270.9	46.6	97.5	78

Future studies taking advantage of more extensive solar radiation data from the 1997 Southern California Ozone Study (SCOS97) should separate solar radiation effects on Saturday from Sunday.

6.0 TRENDS IN OZONE AND OZONE-PRECURSOR AMBIENT CONCENTRATIONS

6.1 Basinwide Ambient Trends in NO_2, NO_x, and NO_2/NO_x

Following the acquisition of ambient data for the 1996 smog season, we examined Basinwide ozone-precursor trends over the eleven-year period 1986-96. Figure 6-1 shows a generally decreasing trend in 0600-0900 PDT Basinwide ambient NO_x concentration from 1986 to 1996, with a particularly dramatic decrease in 1996. Similarly, average 0600-0900 PDT Basinwide ambient NO_2 concentrations also decreased over the 11-yr study period (Figure 6-2). Figure 6-3 shows a consistent day-of-the-week effect for morning NO_x concentration as well as a general decrease in NO_x concentration between 1986 and 1996.

We also examined 2100-0000 PDT NO_x and NO_2 concentrations by day-of-the-week over the 11-yr study period. A downward trend in NO_x concentration is evident, as is a fairly consistent day-of-the-week difference in ambient NO_x levels (Figure 6-4). Figure 6-5 shows a similar decreases in NO_2 concentrations over the eleven-year period, with an approximate 25% reduction for the 1996 smog season over the average for the 1992-95 smog seasons. This reduction may be responsible, in part, for the corresponding decrease in the number of first stage ($[O_3] = 20$ pphm) episodes in the Basin from 13 in 1995 to 7 in 1996. In addition, the early evening (1800-2100 PDT) NO_2/NO_x ratio decreased significantly in 1996 (Figure 6-6).

6.2 Hydrocarbon Trends: 1986-95

To determine NMHC trends over the ten-year period 1986-95, we used the method of Fujita et al. (1992) to convert ambient total hydrocarbon data (THC) from the West Los Angeles, LA North-Main, Azusa, Lynwood, Long Beach, and Riverside monitoring stations to NMHC in parts-per-billion carbon (Figure 6-7). These results show a general decrease in 0600-0900 PDT NMHC over the ten-year period for all days

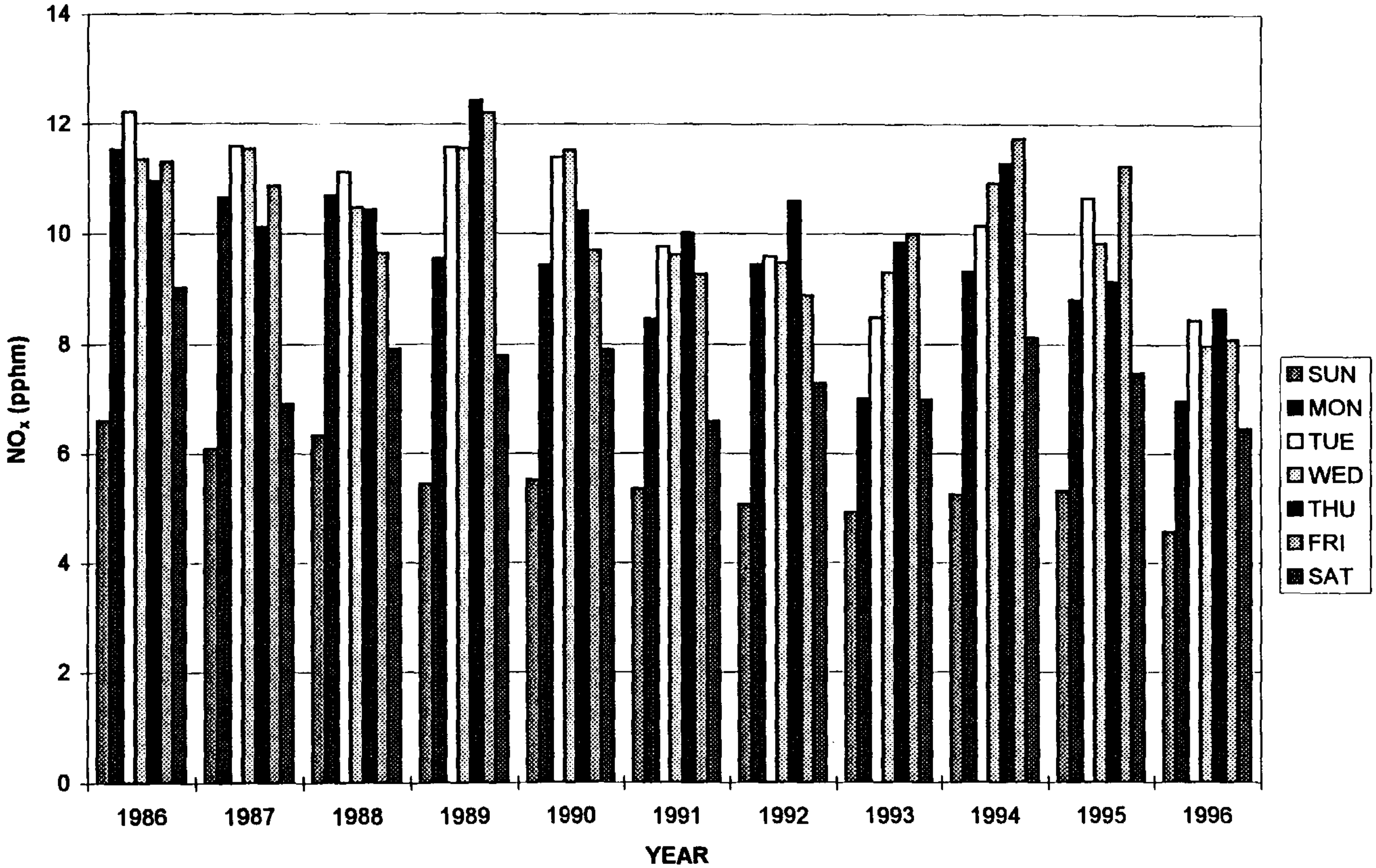

Figure 6-1. Basinwide average ambient NO_x concentration for 0600-0900 PDT from 1986 to 1996, May-October, by day-of-the-week.

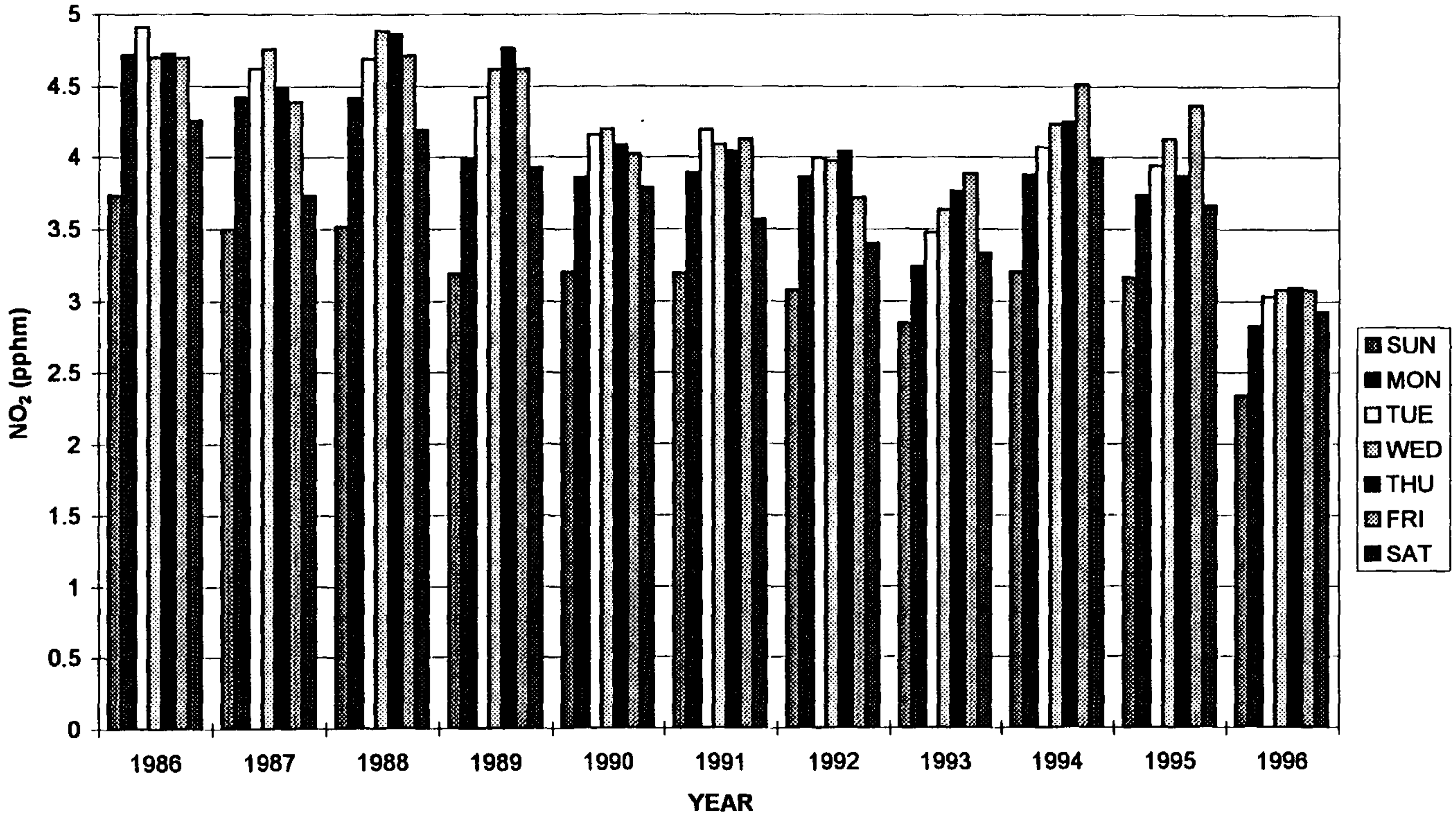

Figure 6-2. Basinwide average ambient NO_2 concentration for 0600-0900 PDT, from 1986 to 1996, May-October, by day-of-the-week.

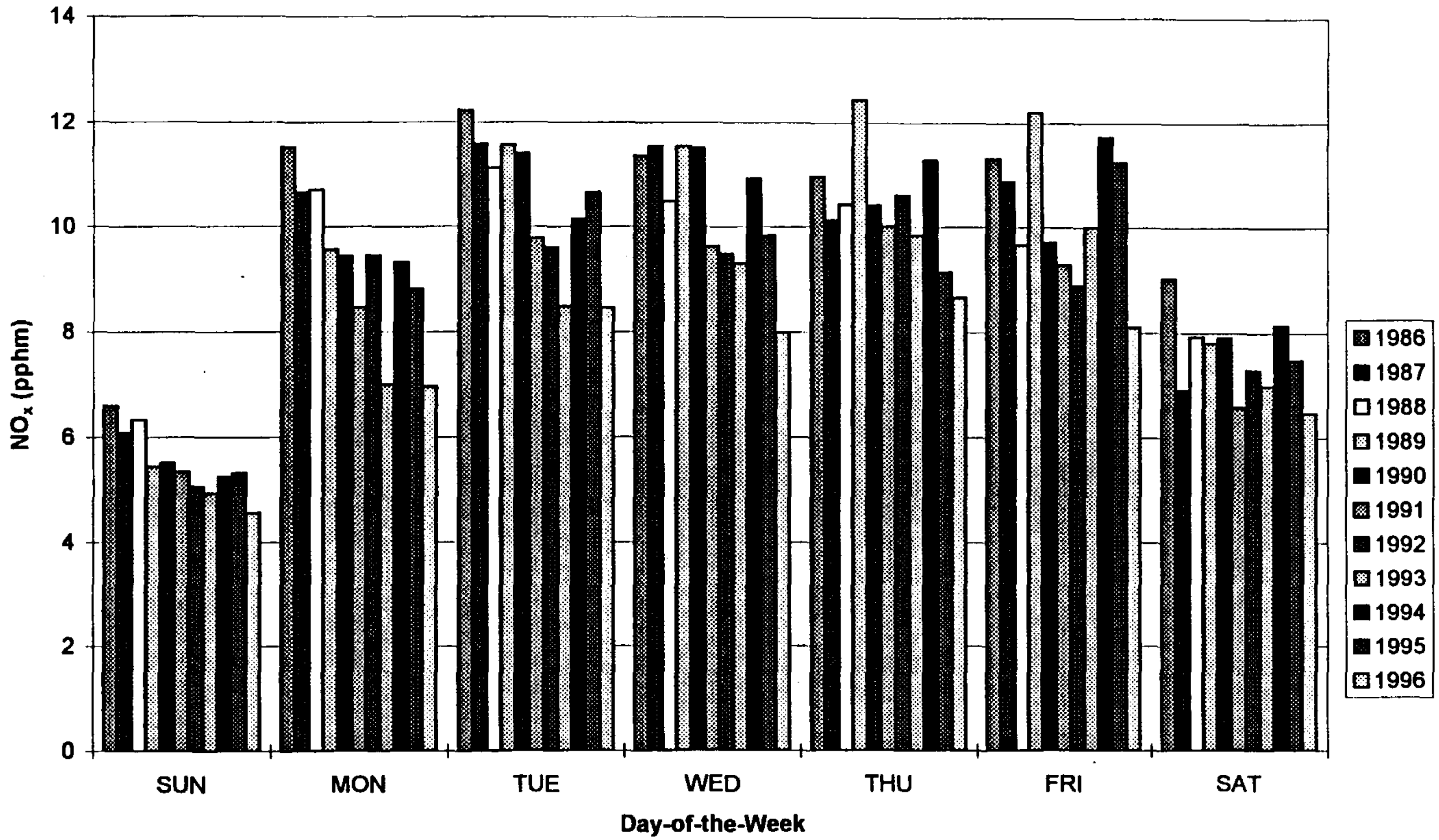

Figure 6-3. Basinwide average ambient NO_x concentration for 0600-0900 PDT. Day-of-the-week differences by year from 1986 to 1996, May-October.

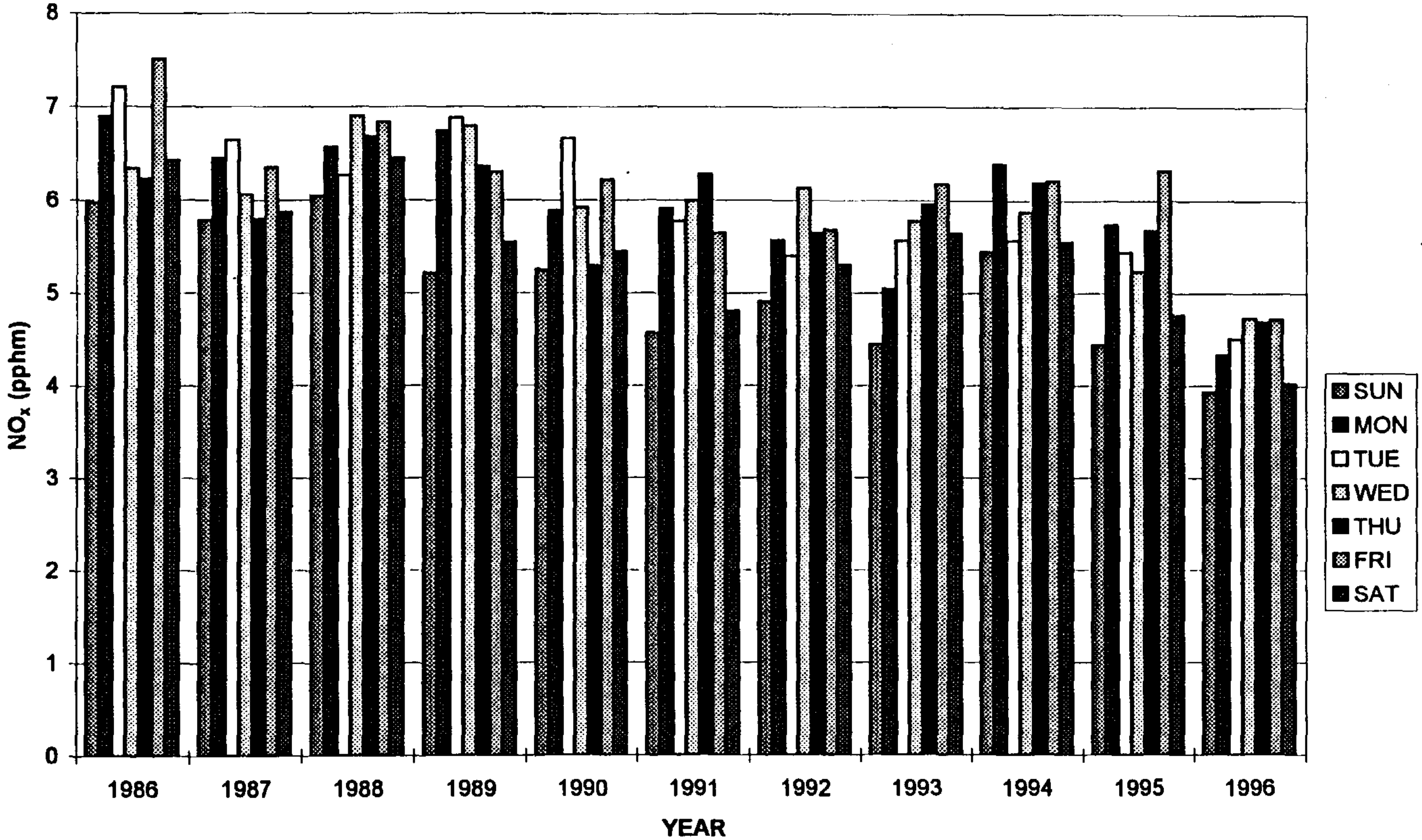

Figure 6-4. Basinwide average ambient NO_x concentration for 2100-0000 PDT from 1986 to 1996, May-October, by day-of-the-week.

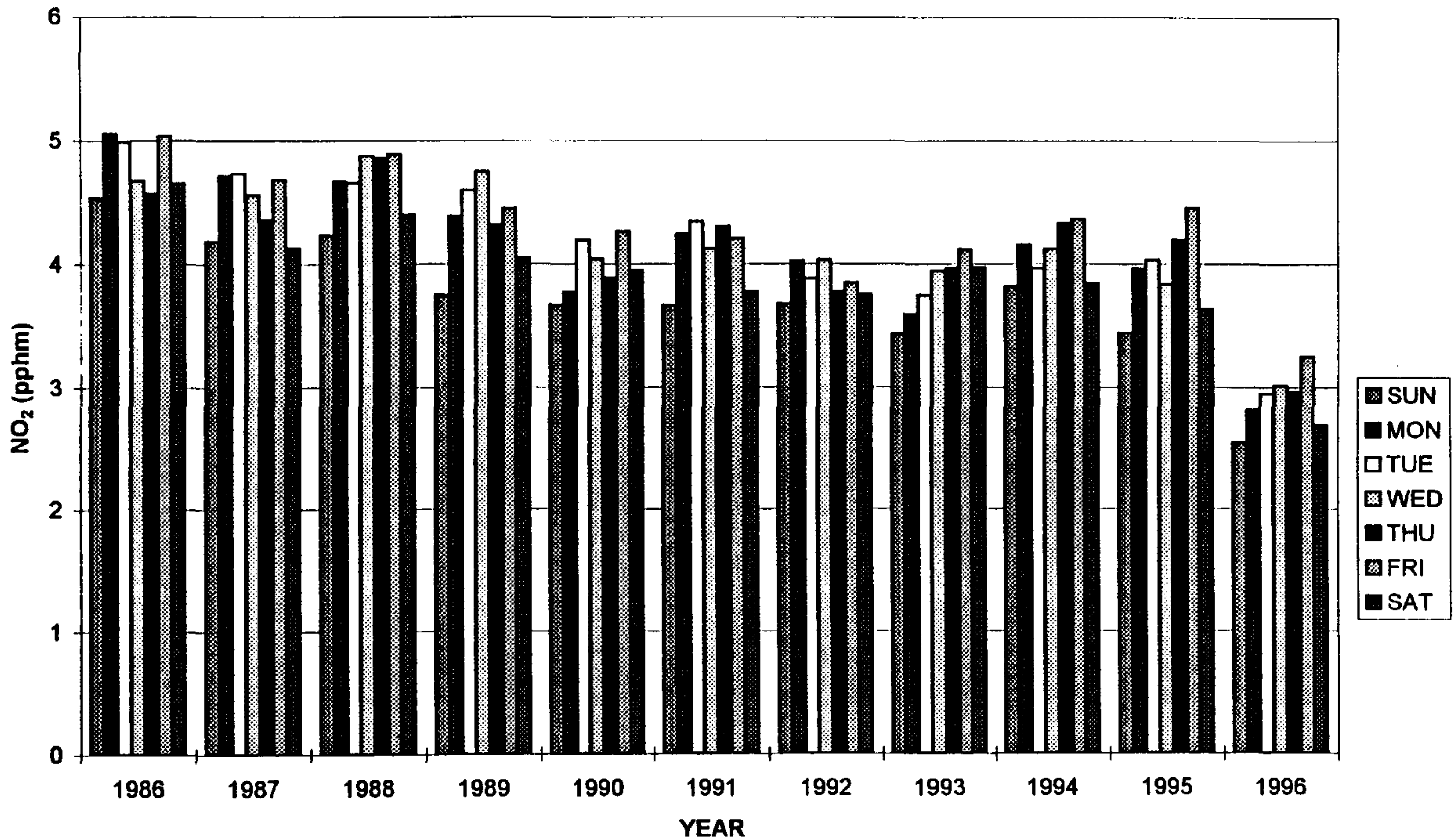

Figure 6-5. Basinwide average ambient NO_2 concentration for 2100-0000 PDT from 1986 to 1996, May-October, by day-of-the-week.

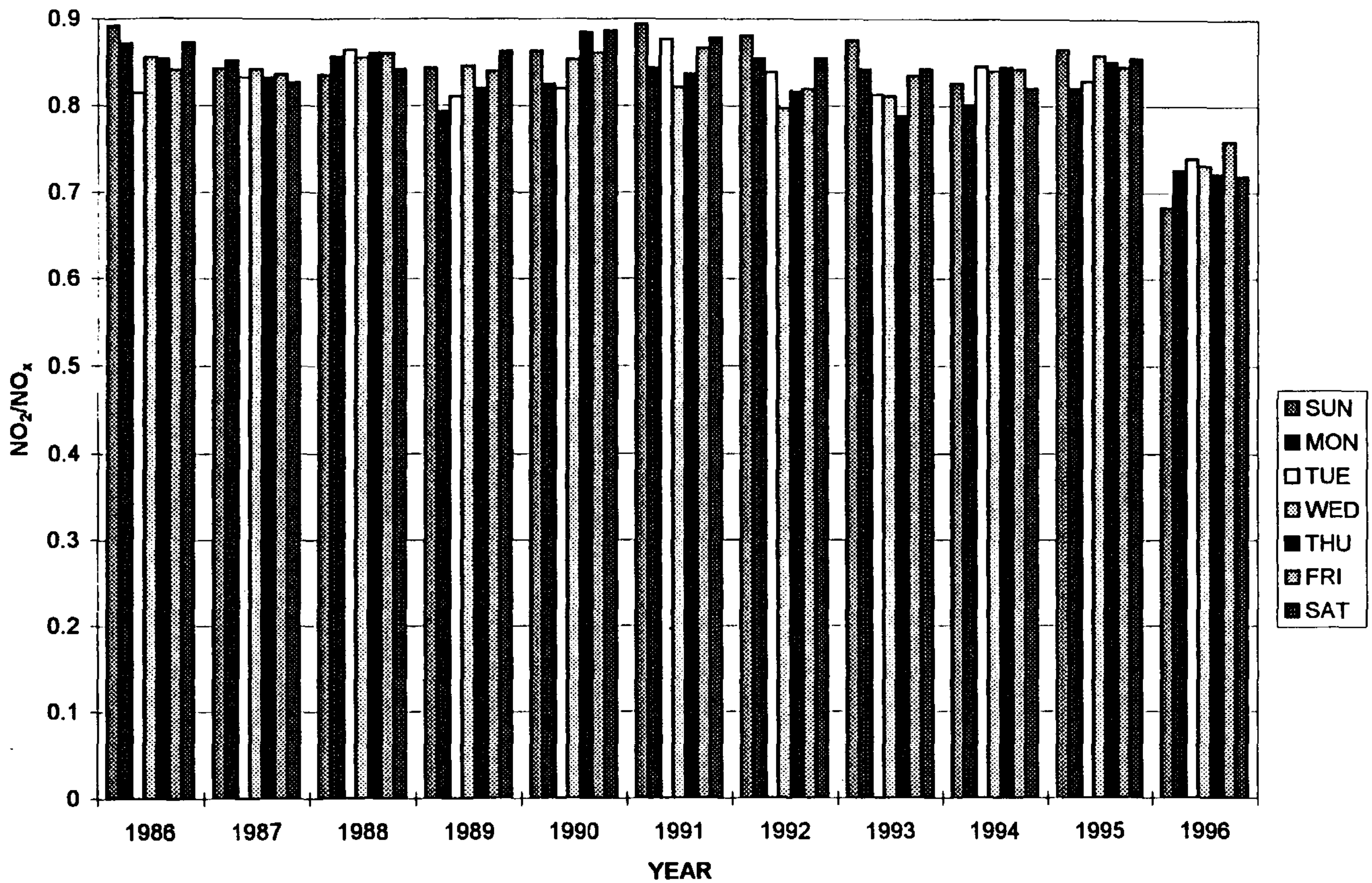

Figure 6-6. Basinwide average NO_2/NO_x ratio for 1800-2100 PDT from 1986 to 1996, May-October, by day-of-the-week.

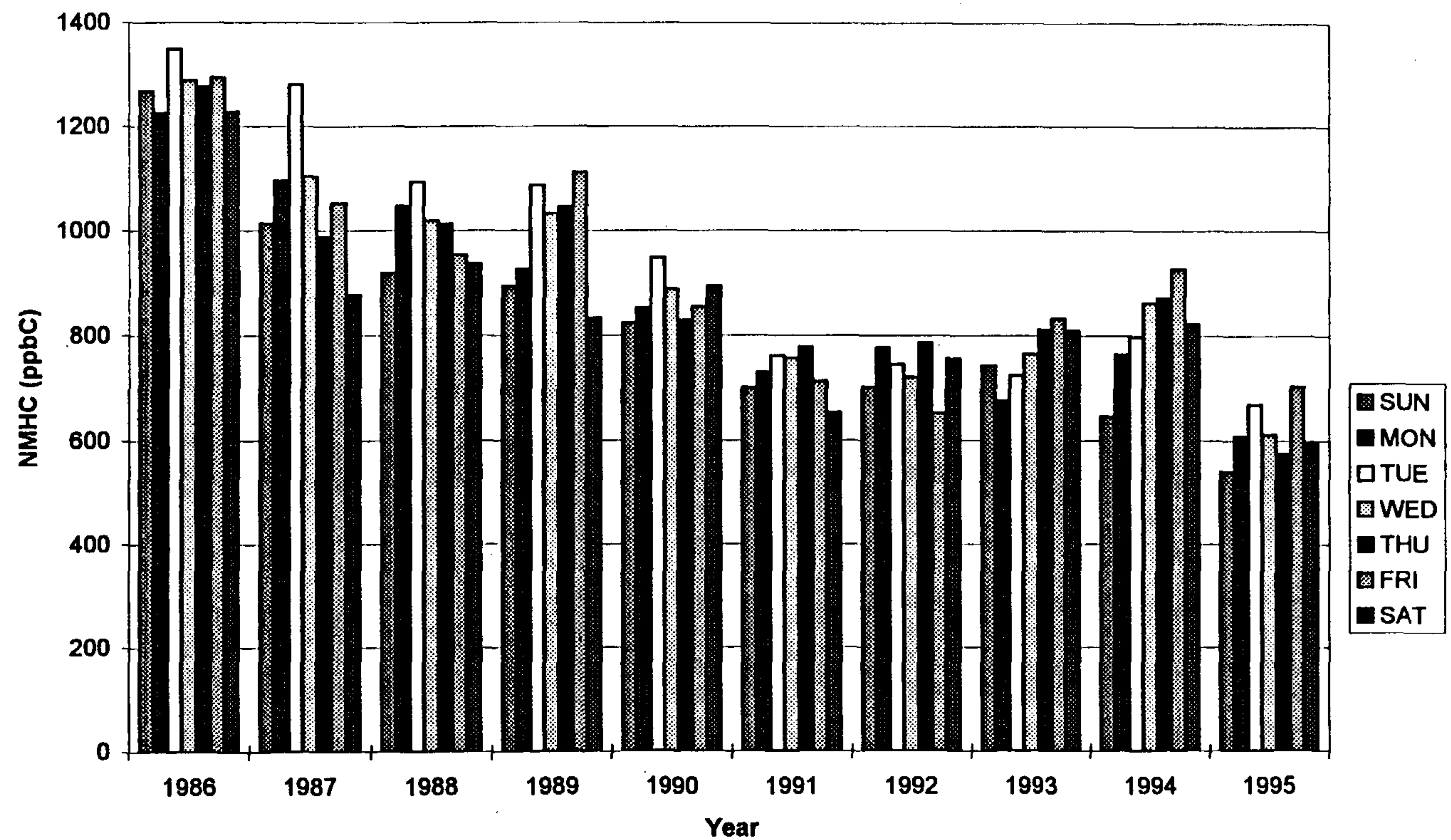

Figure 6-7. Six-site (five sites in 1995) Basin-average NMHC concentration for 0600-0900 PDT, May-October. NMHC concentrations derived from THC data.

of the week. Unfortunately, we could not include the 1996 smog season since THC monitoring was discontinued after the 1995 smog season.

6.3 Ozone Trends: 1986-96

6.3.1 Examination of Incidence and Distribution of Various Ozone Concentrations

Table 6-1 shows the number of days (D) and hours (H) of ozone concentration at or above 9, 12, 15, and 20 parts-per-hundred million (pphm) during smog season daytime hours, where "daytime" is defined as the period extending from 1100 to 2100 PDT. (Note that M represents the number of missing hourly observations during the daytime for each smog season; M generally has a value of 50 or less, but is sometimes much larger due to significant gaps in the ozone data set (which in some cases extend through the length of an entire smog season.)

The smallest number of exceedences occurred at sites in the coastal portion of the Basin, including Hawthorne, Lynwood, and Long Beach. Interestingly, West Los Angeles reported a considerably larger number of hours of ozone concentration at or above 9 pphm than these other three coastal sites.

The general trend during the 1986-96 period was toward an increasingly lower number of hours and days of exceedance, at all concentration levels. Although this trend was usually not in the form of a steady decrease (by the metrics used in this analysis), it is clear that substantial reduction in ambient ozone concentration in the Basin has occurred during the past decade. In particular, there has been substantial reduction in number of hours of *peak* ozone levels (i.e., hours with ozone concentrations at or above 20 pphm). The magnitudes of the percent decrease in number of ozone exceedances are generally much smaller (both hourly and daily) at the lower level of 9 pphm.

It is interesting to examine the H9 trend at Crestline, where slight decreases (from about 1300 hours of exceedance per year for 1986-89 to about 1200 hours of exceedance per year for 1990-94) are followed by a sudden discontinuous drop to a much lower value

Table 6-1. Number of daily ozone concentrations greater than or equal to 9, 12, 15, and 20 pphm (columns D9, D12, D15, and D20, respectively) during the 1986-96 smog seasons. Hourly ozone concentrations greater than or equal to 9, 12, 15, and 20 pphm (columns H9, H12, H15, and H20, respectively) also shown for same period. Number of missing hourly observations from 11 AM to 9 PM PDT for each smog season shown in column M. ARB data used for 1986-95, AQMD data for 1996.

Station: Anaheim-Harbor Blvd

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	1	11	29	60	1	26	82	242	60
1987	3	11	27	56	5	19	67	184	1
1988	2	8	23	54	4	15	59	179	6
1989	4	9	13	50	7	27	51	167	10
1990	0	8	16	34	0	12	36	102	12
1991	2	7	16	53	3	10	31	151	17
1992	1	5	24	60	2	10	51	172	11
1993	0	2	6	34	0	4	12	91	19
1994	1	4	9	33	2	9	21	97	2
1995	0	0	3	31	0	0	3	73	3
1996	0	0	2	14	0	0	3	33	29

Station: La Habra

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	7	26	51	101	10	66	167	413	3
1987	5	26	48	81	9	60	141	331	25
1988	2	18	41	90	5	44	111	315	26
1989	5	18	37	79	10	45	107	303	21
1990	4	20	40	79	4	42	105	306	7
1991	1	11	37	70	1	21	87	262	8
1992	0	8	32	59	0	12	77	205	14
1993	0	5	20	61	0	9	44	202	13
1994	2	4	14	49	5	9	44	169	6
1995	0	1	8	52	0	1	12	128	4
1996	0	1	7	29	0	1	14	76	14

Station: El Toro

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	0	3	11	37	0	4	26	118	22
1987	1	7	17	41	1	12	47	141	8
1988	1	6	18	41	1	11	41	137	28
1989	2	6	10	32	2	12	26	100	4
1990	0	5	16	34	0	9	26	90	9
1991	1	4	13	35	2	7	29	106	21
1992	0	4	12	35	0	6	20	93	16
1993	0	2	10	28	0	2	22	90	2
1994	0	2	6	28	0	2	14	80	4
1995	0	1	2	30	0	1	4	62	5
1996	0	0	6	23	0	0	10	69	3

Station: Los Alamitos-Orangewood Avenue

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	0	1	8	33	0	1	10	86	10
1987	0	2	7	21	0	2	10	46	21
1988	1	8	17	51	3	11	35	131	103
1989	0	4	12	38	0	8	29	121	12
1990	0	4	12	35	0	6	22	92	14
1991	0	4	10	47	0	5	16	116	1
1992	0	1	10	42	0	1	16	95	8
1993	0	1	7	28	0	1	12	65	9
1994	0	0	0	0	0	0	0	0	1840
1995	0	0	0	0	0	0	0	0	1840
1996	0	0	0	0	0	0	0	0	1840

Station: Costa Mesa-Placentia

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	0	1	7	20	0	2	14	55	9
1987	0	1	4	18	0	3	10	46	5
1988	0	1	1	10	0	1	1	20	395
1989	0	0	0	0	0	0	0	0	1840
1990	0	0	0	0	0	0	0	0	1840
1991	0	0	0	0	0	0	0	0	1840
1992	0	0	0	0	0	0	0	0	1840
1993	0	0	0	0	0	0	0	0	1840
1994	0	0	0	0	0	0	0	0	1840
1995	0	0	0	0	0	0	0	0	1840
1996	0	0	0	0	0	0	0	0	1840

Station: Costa Mesa-Mesa Verde Drive

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	0	0	0	0	0	0	0	0	1840
1987	0	0	0	0	0	0	0	0	1840
1988	0	0	0	0	0	0	0	0	1840
1989	0	0	0	0	0	0	0	0	1840
1990	0	1	4	19	0	2	8	41	29
1991	0	1	4	28	0	1	9	64	14
1992	0	0	6	26	0	0	7	64	7
1993	0	0	2	13	0	0	3	30	4
1994	0	0	1	7	0	0	1	13	19
1995	0	0	0	8	0	0	0	14	108
1996	0	0	0	6	0	0	0	12	6

Station: Hemet-State Street

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	0	3	18	56	0	5	39	252	0
1987	0	9	42	97	0	17	146	522	24
1988	0	5	44	108	0	12	127	577	1
1989	0	9	29	89	0	22	88	416	32
1990	1	11	28	79	1	22	97	346	17
1991	0	8	32	87	0	17	103	460	59
1992	0	1	13	77	0	1	19	225	4
1993	0	2	12	78	0	3	28	284	5
1994	0	5	15	67	0	7	43	280	2
1995	0	1	9	55	0	1	15	188	0
1996	0	0	1	5	0	0	1	25	1710

Station: Riverside-Rubidoux

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	19	63	104	148	47	206	467	904	3
1987	20	78	118	154	42	245	550	963	15
1988	15	72	127	160	36	222	556	972	75
1989	17	64	114	145	35	215	514	924	8
1990	15	58	97	129	27	173	398	763	11
1991	17	54	94	140	32	179	419	834	8
1992	4	42	89	141	7	117	352	776	3
1993	5	37	83	130	11	105	320	727	85
1994	2	27	94	131	6	71	340	789	4
1995	2	23	67	118	2	42	238	636	8
1996	1	15	45	110	2	31	153	544	9

Station: Perris

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	3	44	93	128	3	85	363	757	5
1987	1	47	95	138	1	99	350	791	18
1988	1	32	89	142	2	84	323	784	15
1989	4	46	92	130	6	114	367	755	4
1990	0	31	68	114	0	69	237	604	20
1991	5	40	83	134	6	112	347	787	5
1992	0	37	97	141	0	67	337	821	1
1993	3	39	81	127	3	121	333	766	14
1994	0	22	80	124	0	49	272	707	0
1995	1	14	58	121	1	34	175	586	0
1996	0	7	46	119	0	12	137	538	2

Station: Lake Elsinore-W Flint Street

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	0	0	0	0	0	0	0	0	1840
1987	0	0	0	0	0	0	0	0	1840
1988	0	0	0	0	0	0	0	0	1840
1989	4	30	70	115	10	75	261	650	3
1990	0	16	44	84	0	31	137	422	7
1991	1	25	58	107	2	52	197	520	2
1992	0	5	32	90	0	7	73	365	1
1993	0	15	41	88	0	23	105	414	21
1994	0	14	50	109	0	31	161	562	28
1995	0	7	36	97	0	16	96	404	35
1996	0	0	26	88	0	0	64	332	11

Station: Upland-San Bernardino Road

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	36	78	109	142	88	279	493	842	25
1987	23	69	106	140	47	186	410	738	22
1988	24	84	121	151	52	244	503	828	25
1989	19	64	100	132	41	196	398	730	9
1990	12	47	73	108	19	122	267	509	3
1991	14	53	77	118	21	132	268	549	9
1992	12	51	86	131	22	139	310	639	7
1993	7	34	73	122	13	99	237	558	3
1994	7	47	91	120	15	136	359	653	16
1995	6	38	78	120	10	101	286	602	0
1996	2	21	53	92	4	48	160	413	20

Station: Redlands-Grove

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	21	61	99	121	55	228	482	876	435
1987	0	0	0	0	0	0	0	0	1840
1988	0	0	0	0	0	0	0	0	1840
1989	0	0	0	0	0	0	0	0	1840
1990	0	0	0	0	0	0	0	0	1840
1991	0	0	0	0	0	0	0	0	1840
1992	0	0	0	0	0	0	0	0	1840
1993	0	0	0	0	0	0	0	0	1840
1994	0	0	0	0	0	0	0	0	1840
1995	0	0	0	0	0	0	0	0	1840
1996	0	0	0	0	0	0	0	0	1840

Station: Norco-Norconian

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	12	39	83	133	27	123	330	756	17
1987	8	39	84	137	14	102	306	729	6
1988	6	26	68	138	9	82	236	643	33
1989	3	26	61	117	5	61	225	600	14
1990	0	6	21	55	0	12	53	204	11
1991	7	32	67	112	11	105	265	643	42
1992	0	4	21	61	0	5	42	240	3
1993	0	7	31	87	0	14	86	368	14
1994	0	5	26	92	0	9	69	397	18
1995	0	4	37	92	0	8	104	429	5
1996	0	1	2	6	0	4	8	26	1690

Station: Temecula-Rancho California Roa

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	0	0	0	0	0	0	0	0	1840
1987	0	0	0	0	0	0	0	0	1840
1988	0	0	0	0	0	0	0	0	1840
1989	0	0	0	0	0	0	0	0	1840
1990	0	0	0	0	0	0	0	0	1840
1991	0	2	2	9	0	5	9	38	1535
1992	0	0	2	26	0	0	3	72	99
1993	0	0	3	25	0	0	4	77	15
1994	0	0	0	0	0	0	0	0	1840
1995	0	0	0	0	0	0	0	0	1840
1996	0	0	0	1	0	0	0	4	1710

Station: Lake Gregory (Crestline)

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	34	88	123	148	77	364	733	1310	5
1987	22	77	121	144	46	272	649	1225	19
1988	37	93	128	149	82	430	856	1420	4
1989	28	87	123	146	65	339	736	1365	7
1990	16	72	99	139	34	260	545	1139	7
1991	15	58	107	146	33	210	555	1202	3
1992	19	63	115	150	37	225	577	1269	7
1993	5	51	97	134	9	180	497	1094	12
1994	12	67	112	141	16	218	629	1229	14
1995	6	28	79	125	9	91	322	751	0
1996	4	35	73	123	5	110	380	890	5

Station: San Bernardino-East 3rd

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	1	8	14	21	4	24	65	121	1538
1987	0	0	0	0	0	0	0	0	1840
1988	0	0	0	0	0	0	0	0	1840
1989	0	0	0	0	0	0	0	0	1840
1990	0	0	0	0	0	0	0	0	1840
1991	0	0	0	0	0	0	0	0	1840
1992	0	0	0	0	0	0	0	0	1840
1993	0	0	0	0	0	0	0	0	1840
1994	0	0	0	0	0	0	0	0	1840
1995	0	0	0	0	0	0	0	0	1840
1996	0	0	0	0	0	0	0	0	1840

Station: Fontana-Arrow Highway

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	41	87	118	153	111	336	574	944	5
1987	28	80	121	150	57	259	537	893	8
1988	23	85	127	158	47	252	547	874	24
1989	27	75	108	138	60	243	495	824	26
1990	20	60	96	124	36	186	395	682	5
1991	16	56	88	131	32	178	358	692	15
1992	15	53	103	137	31	164	387	754	4
1993	5	32	79	128	7	95	265	646	1
1994	9	52	101	127	16	142	416	726	2
1995	2	33	71	111	2	89	248	556	22
1996	1	18	51	101	3	42	159	448	5

Station: Chino-Central

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	14	46	78	126	29	137	291	658	7
1987	0	0	0	0	0	0	0	0	1840
1988	0	0	0	0	0	0	0	0	1840
1989	0	0	0	0	0	0	0	0	1840
1990	0	0	0	0	0	0	0	0	1840
1991	0	0	0	0	0	0	0	0	1840
1992	0	0	0	0	0	0	0	0	1840
1993	0	0	0	0	0	0	0	0	1840
1994	0	0	0	0	0	0	0	0	1840
1995	0	0	0	0	0	0	0	0	1840
1996	0	0	0	0	0	0	0	0	1840

Station: San Bernardino-4th Street

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	40	69	95	121	98	294	517	838	314
1987	27	80	126	150	56	288	591	979	32
1988	30	90	129	157	68	328	622	1022	29
1989	22	79	110	144	46	248	538	930	15
1990	8	51	87	129	14	159	369	728	20
1991	9	57	89	136	16	173	401	796	0
1992	15	46	99	138	21	144	383	804	9
1993	4	34	77	128	5	104	303	689	8
1994	7	54	106	134	15	146	438	834	0
1995	4	32	80	123	5	95	314	687	4
1996	2	24	70	126	3	66	284	667	5

Station: Redlands-Dearborn

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	1	2	4	11	2	4	14	51	1490
1987	26	77	130	149	54	284	629	1068	3
1988	24	95	130	159	54	322	667	1145	8
1989	16	68	111	146	44	222	541	975	3
1990	11	53	90	131	20	157	380	777	5
1991	16	64	100	146	37	241	506	973	4
1992	5	53	107	150	7	161	466	991	3
1993	8	60	102	142	17	196	472	944	10
1994	4	35	80	107	7	99	329	673	302
1995	4	36	84	126	4	110	341	764	33
1996	1	30	75	127	2	58	273	720	3

Station: Azusa

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	42	87	119	154	98	288	507	835	7
1987	26	73	116	146	50	206	446	766	17
1988	33	87	122	157	59	247	467	795	22
1989	27	74	108	142	61	226	436	764	6
1990	13	56	84	123	18	121	299	548	11
1991	12	48	78	119	22	117	254	505	6
1992	14	51	98	136	26	127	307	608	6
1993	11	49	85	121	18	119	287	563	1
1994	2	37	83	122	5	79	263	563	0
1995	3	38	73	120	3	79	221	506	1
1996	1	17	39	86	1	33	102	323	1

Station: Burbank-W Palm Avenue

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	12	55	92	131	25	148	338	633	10
1987	6	41	90	131	6	91	288	587	31
1988	3	37	78	130	8	89	241	539	26
1989	4	20	46	97	6	49	152	395	18
1990	1	15	52	101	2	34	151	390	21
1991	4	28	63	115	6	74	209	478	20
1992	6	23	64	116	9	59	180	482	12
1993	0	7	21	60	0	14	57	198	5
1994	0	6	22	65	0	8	48	215	24
1995	0	3	27	73	0	5	60	274	9
1996	0	0	11	44	0	0	27	138	13

Station: North Long Beach

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	0	1	9	28	0	3	14	60	91
1987	0	1	6	13	0	1	9	31	46
1988	0	3	6	17	0	3	15	46	17
1989	0	2	4	16	0	2	9	40	13
1990	0	0	1	8	0	0	1	13	36
1991	0	0	0	12	0	0	0	18	8
1992	0	1	8	27	0	1	11	60	7
1993	0	0	2	18	0	0	4	30	42
1994	0	1	4	13	0	1	6	28	16
1995	0	0	0	8	0	0	0	15	3
1996	0	0	0	6	0	0	0	12	984

Station: Reseda

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	5	40	78	128	9	124	290	653	8
1987	2	33	78	130	2	80	251	594	46
1988	4	47	89	139	8	125	315	708	20
1989	5	30	60	120	7	98	230	588	46
1990	0	21	51	110	0	42	158	457	17
1991	2	31	64	119	3	64	217	565	33
1992	0	7	42	98	0	11	104	373	11
1993	0	17	38	89	0	39	130	376	15
1994	0	0	7	78	0	0	17	286	7
1995	0	0	15	61	0	0	30	205	5
1996	1	4	14	77	1	7	44	262	14

Station: Pomona

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	23	61	93	126	46	193	361	630	27
1987	16	43	82	127	23	112	242	537	18
1988	16	53	102	138	29	130	325	609	12
1989	10	36	71	115	19	88	231	477	11
1990	12	43	67	104	17	97	200	436	9
1991	8	41	65	109	15	97	224	465	8
1992	8	32	62	111	10	76	211	433	10
1993	6	25	60	109	8	69	181	432	12
1994	3	23	66	108	8	50	203	469	3
1995	2	23	58	95	3	51	172	409	3
1996	0	7	22	54	0	13	54	186	32

Station: Whittier-Leffingwell

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	4	22	38	86	4	47	113	325	13
1987	4	26	44	85	5	53	128	307	7
1988	4	11	35	75	7	29	88	234	20
1989	4	18	40	74	8	47	109	264	3
1990	0	8	30	59	0	14	61	177	2
1991	0	10	31	61	0	15	57	203	3
1992	0	14	33	74	0	22	77	225	10
1993	0	5	17	51	0	7	35	164	0
1994	0	0	0	0	0	0	0	0	1840
1995	0	0	0	0	0	0	0	0	1840
1996	0	0	0	0	0	0	0	0	1840

Station: Lynwood

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	0	6	14	53	0	10	34	135	63
1987	1	6	15	34	1	11	33	96	22
1988	1	4	12	27	1	8	28	80	13
1989	0	0	10	32	0	0	18	84	57
1990	0	1	4	11	0	1	6	30	16
1991	0	1	3	26	0	1	5	63	10
1992	0	0	4	14	0	0	4	38	17
1993	0	0	1	11	0	0	1	19	8
1994	0	0	1	5	0	0	1	9	5
1995	0	0	0	1	0	0	0	1	31
1996	0	0	0	1	0	0	0	1	3

Station: Pico Rivera

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	14	45	85	118	21	105	243	487	5
1987	7	38	70	120	10	76	187	452	22
1988	11	35	73	124	21	82	200	472	18
1989	16	36	68	107	27	91	186	418	6
1990	0	19	52	91	0	28	114	288	2
1991	6	35	59	99	8	65	152	337	13
1992	3	25	49	99	6	48	125	351	6
1993	0	20	40	78	0	26	96	279	36
1994	2	12	35	89	4	21	83	284	51
1995	0	2	36	83	0	5	66	268	11
1996	0	0	11	47	0	0	22	135	22

Station: Los Angeles-North Main Street

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	4	16	47	100	4	39	132	358	4
1987	2	15	44	100	3	26	103	366	26
1988	1	11	33	73	2	22	82	255	24
1989	1	11	35	79	1	19	94	290	13
1990	2	12	38	85	2	20	95	301	17
1991	0	6	28	72	0	11	73	245	43
1992	0	9	23	65	0	14	60	217	15
1993	0	1	12	44	0	1	21	123	6
1994	0	5	23	66	0	11	51	220	5
1995	0	2	15	58	0	2	28	149	2
1996	0	0	7	29	0	0	13	84	13

Station: Pasadena-S Wilson Avenue

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	28	82	107	146	51	232	429	756	40
1987	15	61	97	135	26	141	322	666	7
1988	16	71	120	150	28	174	410	766	16
1989	15	51	86	123	29	133	308	608	20
1990	7	45	77	121	11	96	243	521	9
1991	10	47	80	112	13	115	271	521	73
1992	7	29	68	122	10	60	192	500	54
1993	5	27	52	95	5	60	163	394	162
1994	2	34	70	107	3	59	190	480	11
1995	1	17	59	99	1	30	152	396	4
1996	0	8	23	64	0	12	61	238	18

Station: Santa Clarita-County Fire Stat

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	15	58	89	122	30	189	397	709	8
1987	2	30	80	134	4	70	264	646	20
1988	28	80	115	144	82	283	536	851	23
1989	10	40	75	121	28	150	321	635	10
1990	6	34	63	111	11	100	242	539	50
1991	8	46	84	121	18	151	328	656	6
1992	3	39	86	125	6	107	306	638	16
1993	3	21	53	97	5	68	207	466	0
1994	6	24	80	117	11	74	270	626	0
1995	1	10	36	95	1	22	114	397	3
1996	0	5	25	84	0	8	85	350	8

Station: West Los Angeles-VA Hospital

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	1	11	30	86	1	24	70	274	15
1987	1	8	20	61	3	24	62	205	49
1988	2	9	20	54	4	17	44	172	20
1989	0	4	15	69	0	7	32	218	10
1990	0	2	11	39	0	3	22	96	123
1991	0	4	10	46	0	7	25	139	4
1992	0	1	13	47	0	1	19	135	6
1993	0	1	7	24	0	2	14	73	14
1994	0	2	4	25	0	3	10	66	9
1995	0	0	5	29	0	0	7	65	218
1996	0	0	6	20	0	0	9	54	11

Station: Hawthorne

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	0	0	4	20	0	0	5	36	48
1987	1	2	4	14	1	5	16	42	28
1988	1	1	3	8	2	4	8	24	22
1989	0	0	3	15	0	0	3	27	13
1990	0	0	0	6	0	0	0	9	7
1991	0	0	0	25	0	0	0	63	11
1992	0	0	2	10	0	0	2	29	17
1993	0	0	2	11	0	0	2	29	5
1994	0	0	0	7	0	0	0	14	15
1995	0	0	1	7	0	0	3	15	6
1996	0	0	2	9	0	0	2	21	48

Station: Santa Clarita-Honby

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	0	0	0	0	0	0	0	0	1840
1987	0	0	0	0	0	0	0	0	1840
1988	0	0	0	0	0	0	0	0	1840
1989	10	38	71	113	22	130	290	627	49
1990	0	0	0	0	0	0	0	0	1840
1991	0	0	0	0	0	0	0	0	1840
1992	0	0	0	0	0	0	0	0	1840
1993	0	0	0	0	0	0	0	0	1840
1994	0	0	0	0	0	0	0	0	1840
1995	0	0	0	0	0	0	0	0	1840
1996	0	0	0	0	0	0	0	0	1840

Station: Avalon-Crescent Avenue

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	0	0	0	0	0	0	0	0	1840
1987	0	0	0	0	0	0	0	0	1840
1988	0	0	0	0	0	0	0	0	1840
1989	0	0	0	0	0	0	0	0	1840
1990	0	0	0	4	0	0	0	5	449
1991	0	0	0	0	0	0	0	0	1840
1992	0	0	0	0	0	0	0	0	1840
1993	0	0	0	0	0	0	0	0	1840
1994	0	0	0	0	0	0	0	0	1840
1995	0	0	0	0	0	0	0	0	1840
1996	0	0	0	0	0	0	0	0	1840

Station: Diamond Bar-E Copley Drive

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	0	0	0	0	0	0	0	0	1840
1987	0	0	0	0	0	0	0	0	1840
1988	0	0	0	0	0	0	0	0	1840
1989	0	0	0	0	0	0	0	0	1840
1990	0	0	0	0	0	0	0	0	1840
1991	0	0	0	0	0	0	0	0	1840
1992	0	0	0	0	0	0	0	0	1840
1993	0	0	0	0	0	0	0	0	1840
1994	2	9	38	98	6	21	116	364	1
1995	0	4	36	79	0	6	89	296	7
1996	0	0	0	0	0	0	0	0	1840

Station: Glendora-Laurel

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	62	109	131	158	186	468	717	1055	38
1987	50	103	129	154	105	353	612	957	25
1988	53	107	136	163	114	356	617	952	41
1989	35	80	115	143	81	269	493	830	35
1990	29	72	99	131	50	202	398	677	17
1991	34	67	102	134	59	202	377	674	10
1992	27	70	113	141	53	206	430	757	27
1993	19	61	101	138	41	175	368	713	6
1994	10	55	100	130	15	142	377	679	0
1995	9	47	84	126	12	116	282	607	3
1996	2	20	51	97	3	51	169	405	2

Station: Beverly Hills-Franklin Canyon

	D20	D15	D12	D9	H20	H15	H12	H9	M
1986	9	36	70	107	18	110	320	696	547
1987	0	0	0	0	0	0	0	0	1840
1988	0	0	0	0	0	0	0	0	1840
1989	1	10	42	88	3	22	102	348	73
1990	1	12	42	77	1	23	113	299	227
1991	0	9	23	78	0	21	67	270	83
1992	0	0	0	0	0	0	0	0	1840
1993	0	0	0	0	0	0	0	0	1840
1994	0	0	0	0	0	0	0	0	1840
1995	0	0	0	0	0	0	0	0	1840
1996	0	0	0	0	0	0	0	0	1840

(751) in 1995. This suggests an important change in 1995 may have occurred in the chemical composition of the air transported to Crestline from the Basin.

For comparison, Figure 6-8 shows the 20-year trend in stage 1 episodes in the SoCAB. When using this metric a steady decrease in unhealthful ozone levels can be easily observed over this period.

6.3.2 Frequency of Occurrence of Ozone Exceedances

The percent change (from year-to-year) in number of smog season hours equal or exceeding the ozone NAAQS was computed for three groups of four sites each within the SoCAB for the period 1986-96 (Figures 6-9, 6-10, and 6-11). Only sites located in the central or eastern part of the Basin were used in this analysis, since year-to-year variation in the small number of ozone NAAQS exceedances which occur in less polluted areas (e.g., Coastal subregion) is likely to be strongly influenced by anomalous meteorological conditions, whereas the variation at the more polluted sites farther inland is likely to be dominated by the effects of non-meteorological factors such as reductions in emissions. Pasadena data are not available for this analysis during the 1992-94 period due to low data completeness.

At each of the 12 sites, the percent change was generally, from one year to the next, less than 50% (the large 1993-94 value at Central Los Angeles reflects the small total number of exceedances during those years, and thus does not actually represent a large increase in the number of exceedances). For the San Gabriel Valley sites in Figure 6-10, the largest year-to-year percent change occurred between the 1995 and 1996 smog seasons. Less dramatic decreases were found at both the sites located farther inland (Figure 6-11), and those closer to the coast (Figure 6-9). The introduction of RFG with lower mass emissions of VOC and lower VOC reactivity throughout the Basin may be largely responsible for the significant reduction in ozone in the San Gabriel Valley (Figure 6-10).

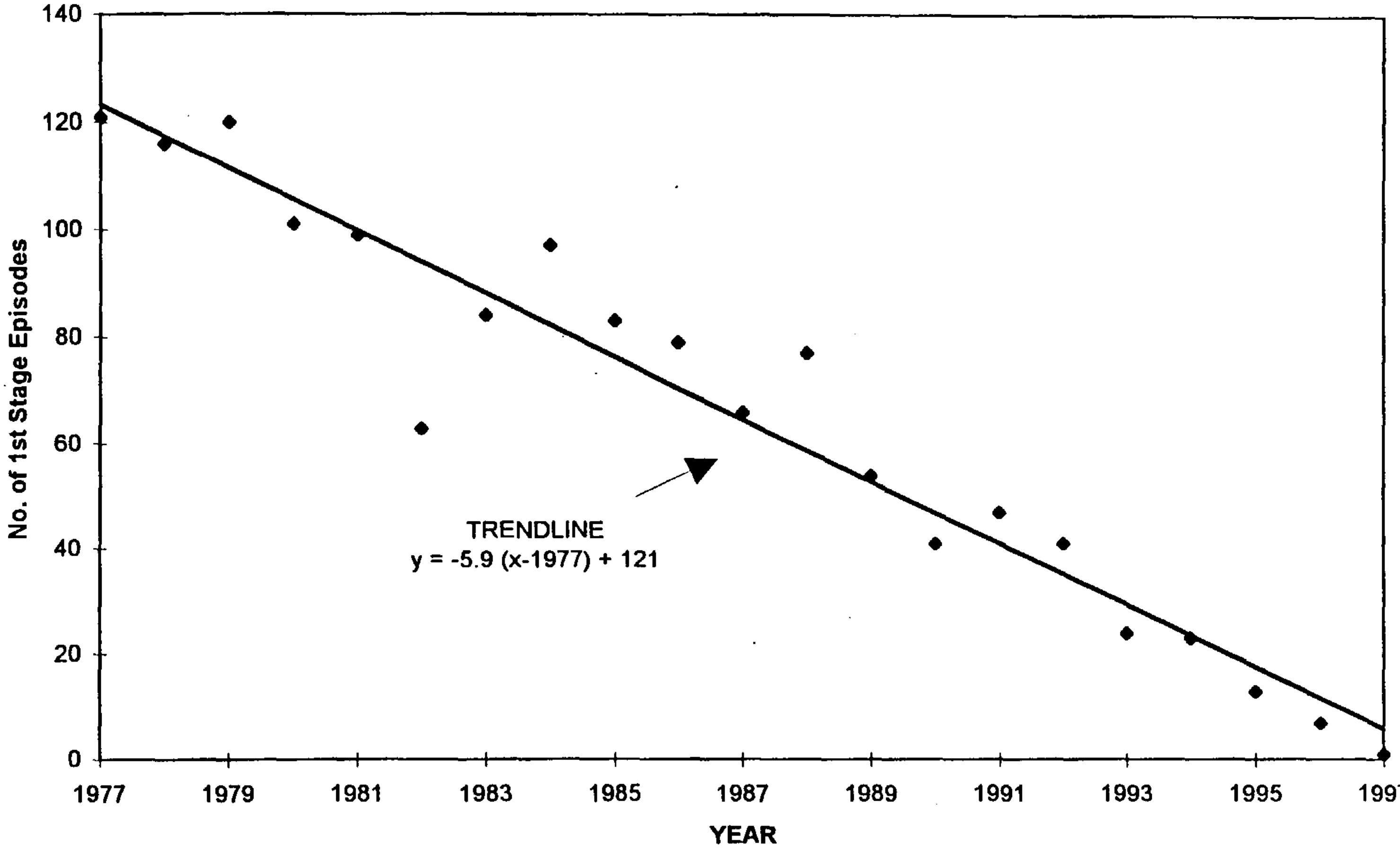

Figure 6-8. SoCAB Smog Season Stage 1 Episodes: 1977-97.

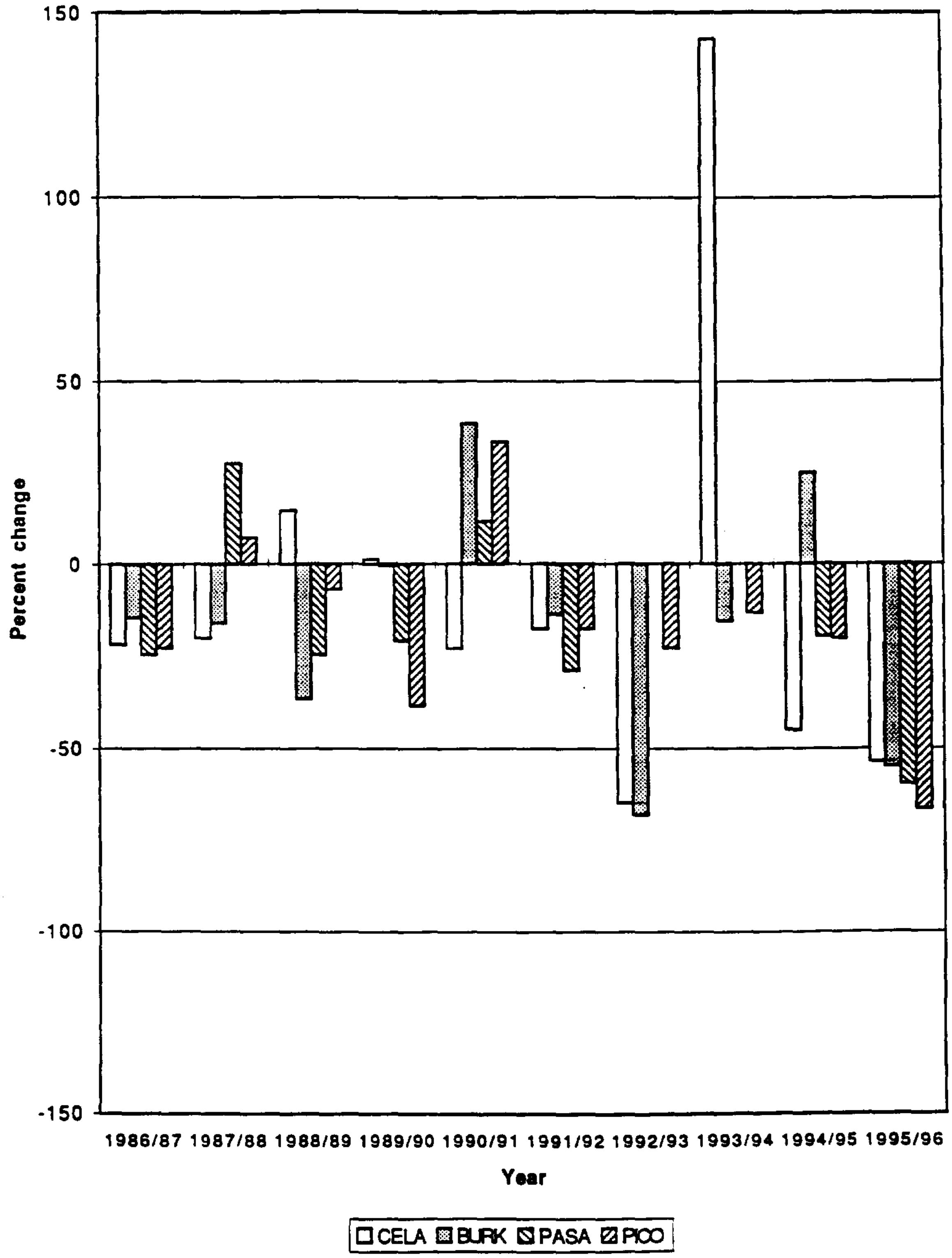

Figure 6-9. Percent change from previous smog season in number of smog season hours equal to or exceeding the ozone NAAQS.

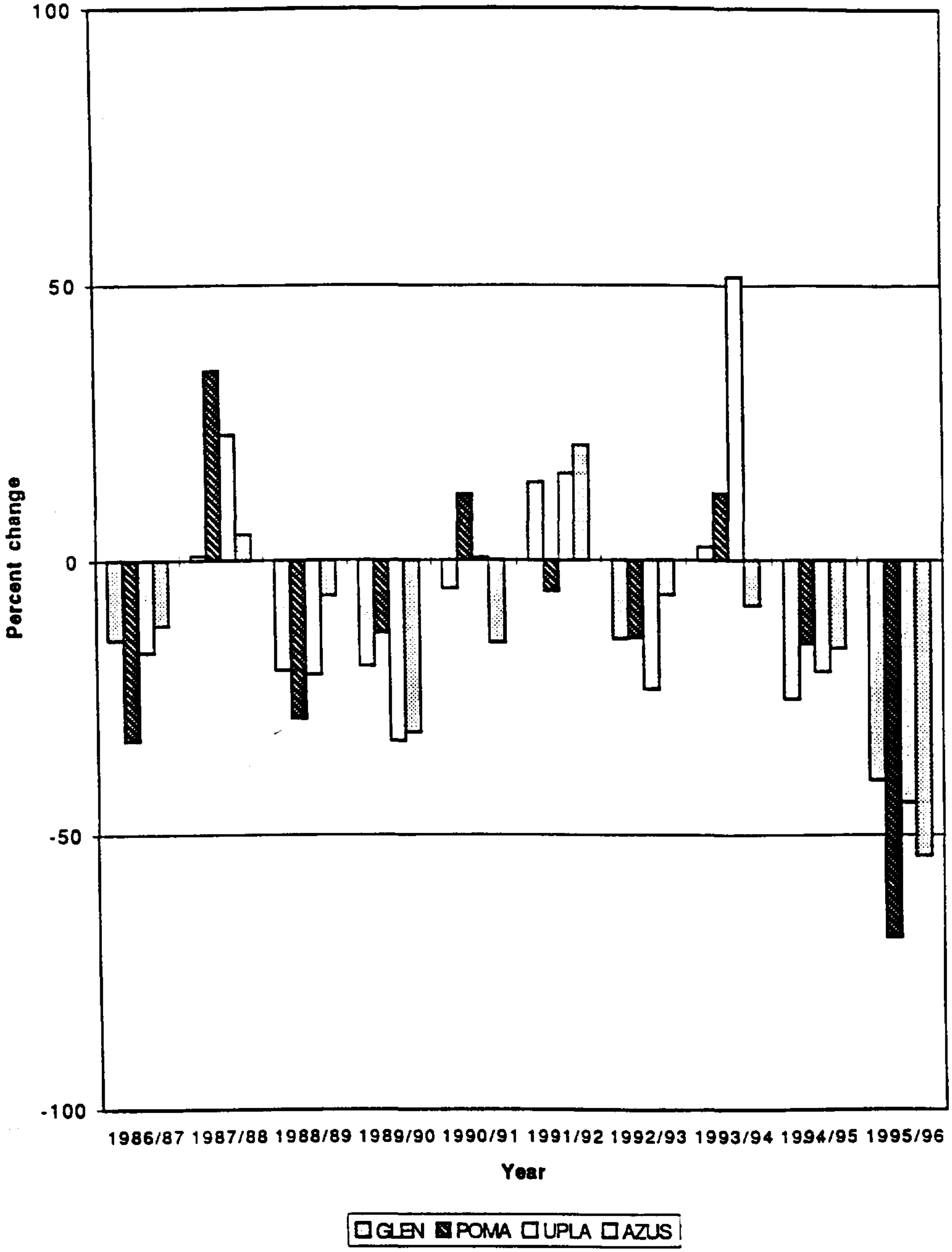

Figure 6-10. Percent change from previous smog season in number of smog season hours equal to or exceeding the ozone NAAQS.

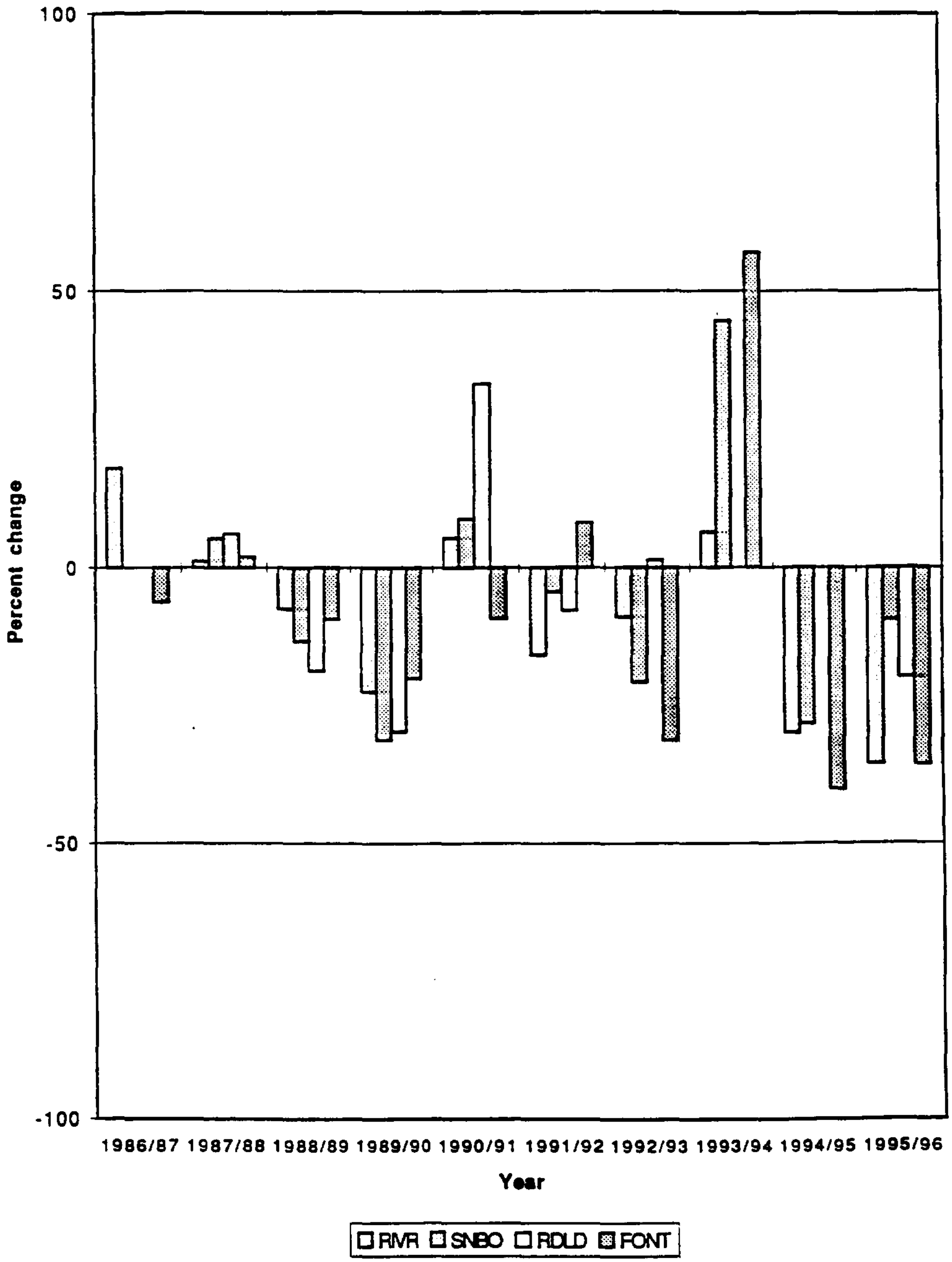

Figure 6-11. Percent change from previous smog season in number of smog season hours equal to or exceeding the ozone NAAQS.

6.4 Recent Air Quality Changes

6.4.1 1994-96 Smog Season Ambient Air Quality

Figures 6-12 and 6-13 show the average changes in ambient NO_x and NO_2 ambient concentrations over the 1994-96 smog seasons during the morning commute period (0600-0900 PDT). There was a substantial decrease in both NO_x and NO_2 in 1996 vs. 1994-95 for all days of the week, with weekend days having lower average ambient NO_x and NO_2 concentrations than weekdays. Also, Figure 6-13 shows that Saturday morning NO_2 concentrations were comparable to Monday morning NO_2 concentrations for the 1994-96 period. Figure 6-14 shows the variation by day-of-the-week in NO_2/NO_x ratios during the morning (0600-0900 PDT) hours for the 1994-96 period. These weekend/weekday differences in NO_2/NO_x ratio were not seen for either 1800-2100 PDT or 2100-0000 PDT, the two evening time intervals evaluated (Figure 6-15).

6.4.2 1995-96 Smog Season Meteorological Conditions vs. Climatology

The monthly-mean daily-maximum and daily-minimum temperatures were determined for the 1995-1996 smog season months of May through October for four sites (Figures 6-16 to 6-19): Los Angeles International Airport (LAX), Los Angeles Civic Center (LACC), San Gabriel Fire Department (SGFD), and San Bernardino County Hospital (SBCH). Also shown for these sites is the corresponding 1961-90 climatological average values. At LAX (Figure 6-16), the 1995 smog season was slightly cooler than the 1961-90 mean, while 1996 was slightly warmer than the long-term average (especially during May and August). At LACC, SGFD, and SBCH, the 1995 smog season was either near or above normal, except during the months of May and June which were cooler than normal; the 1996 smog season at these sites was clearly warmer than normal.

With the exception of May and June of 1995, the 1995-96 smog seasons appear to have recorded near or above normal surface temperatures in the central and eastern

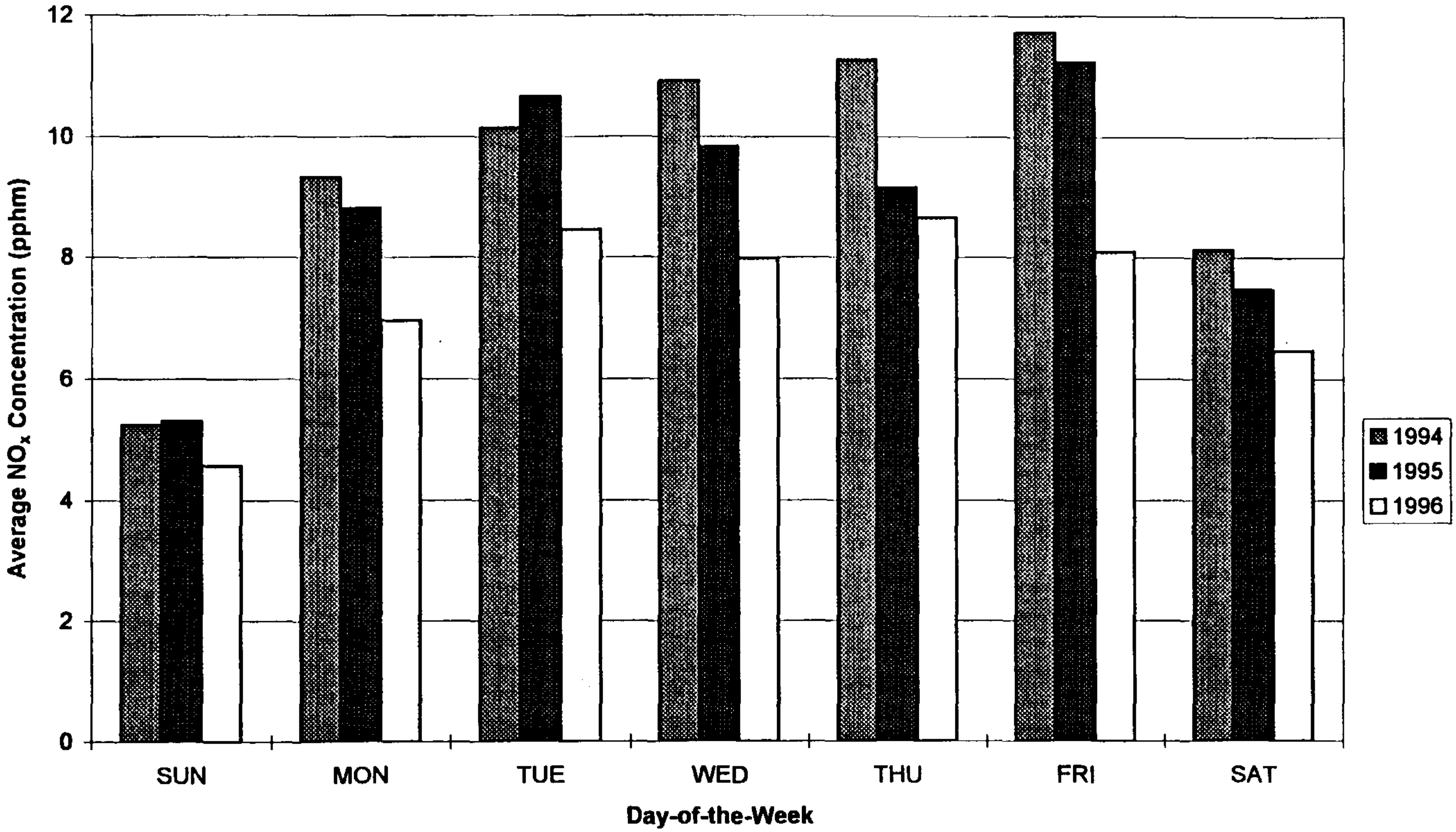

Figure 6-12. Basinwide average ambient NO_x concentration for 0600-0900 PDT, May-October, 1994-96.

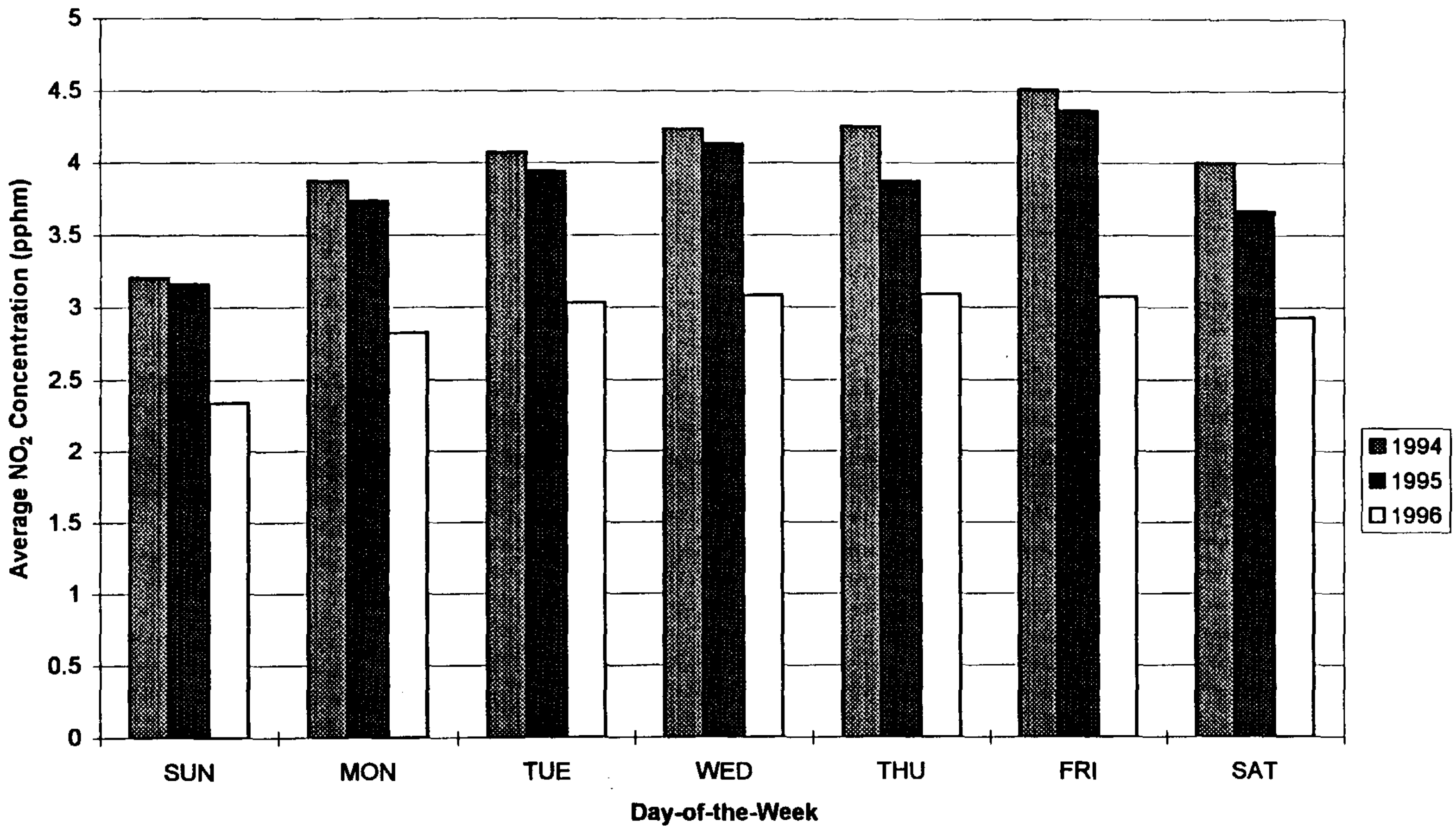

Figure 6-13. Basinwide average ambient NO_2 concentration for 0600-0900 PDT, May-October, 1994-96.

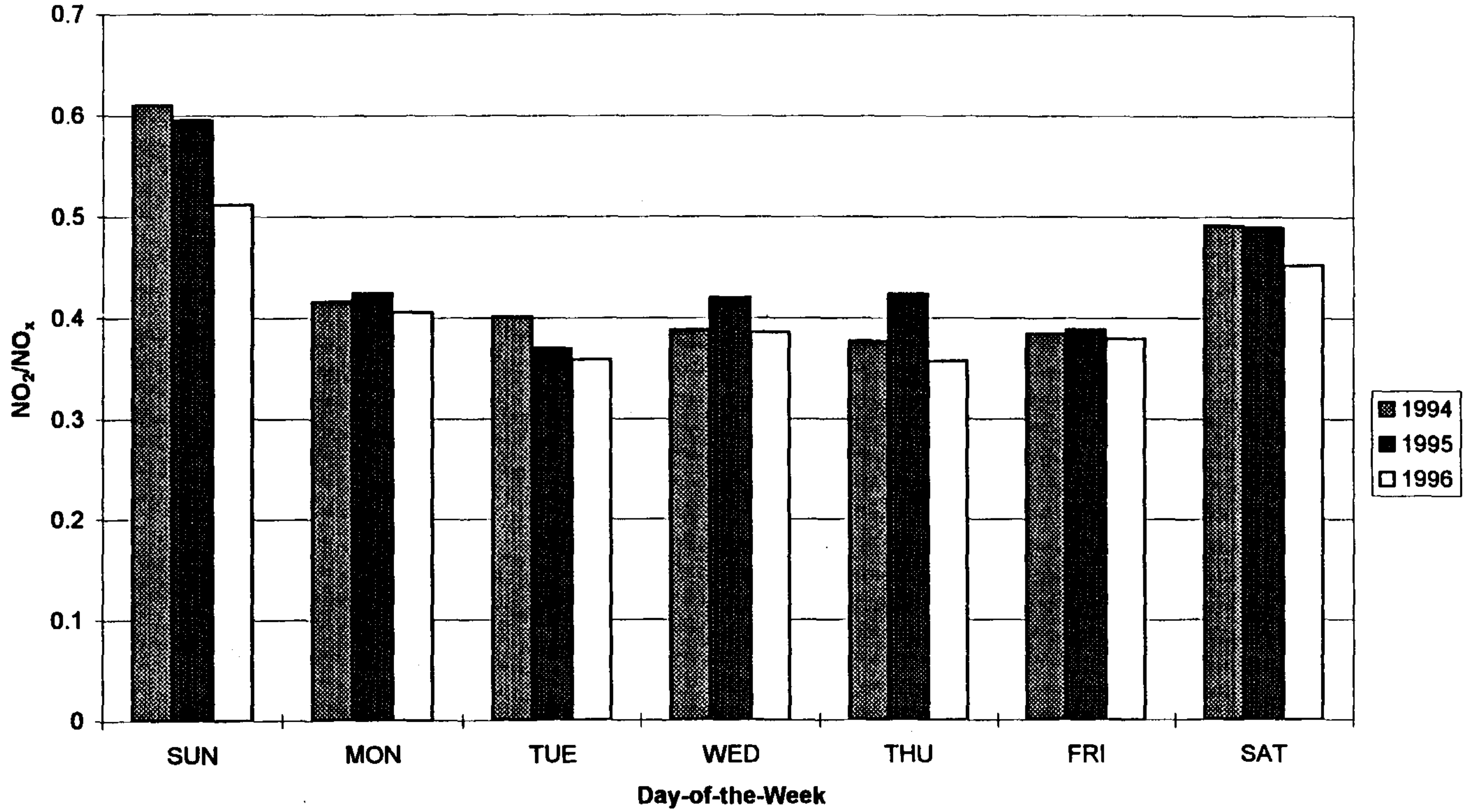

Figure 6-14. Basinwide average NO_2/NO_x ratio for 0600-0900 PDT, May-October, 1994-96.

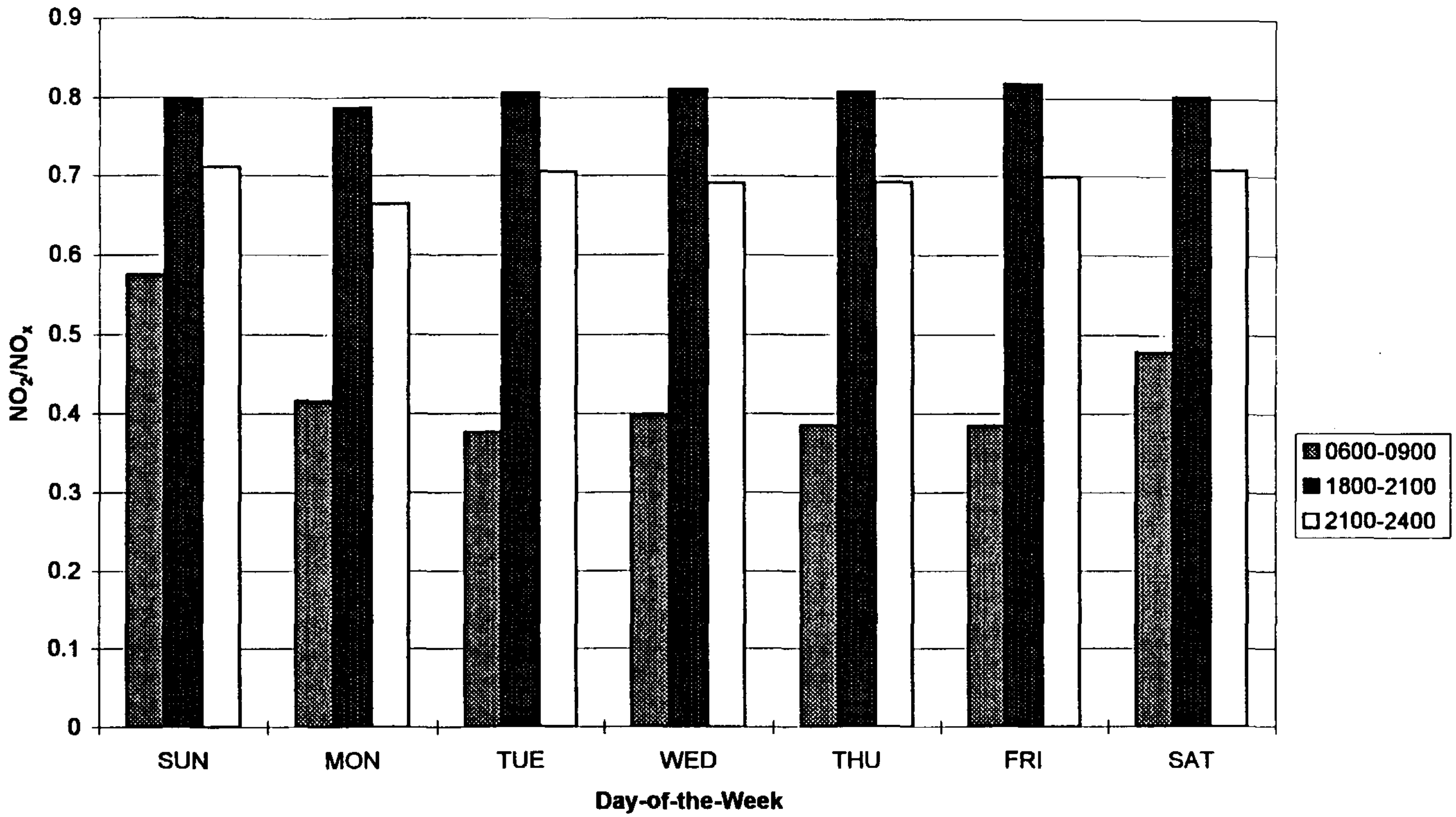

Figure 6-15. Basinwide average NO_2/NO_x ratio for May-October, 1994-96, for three time periods.

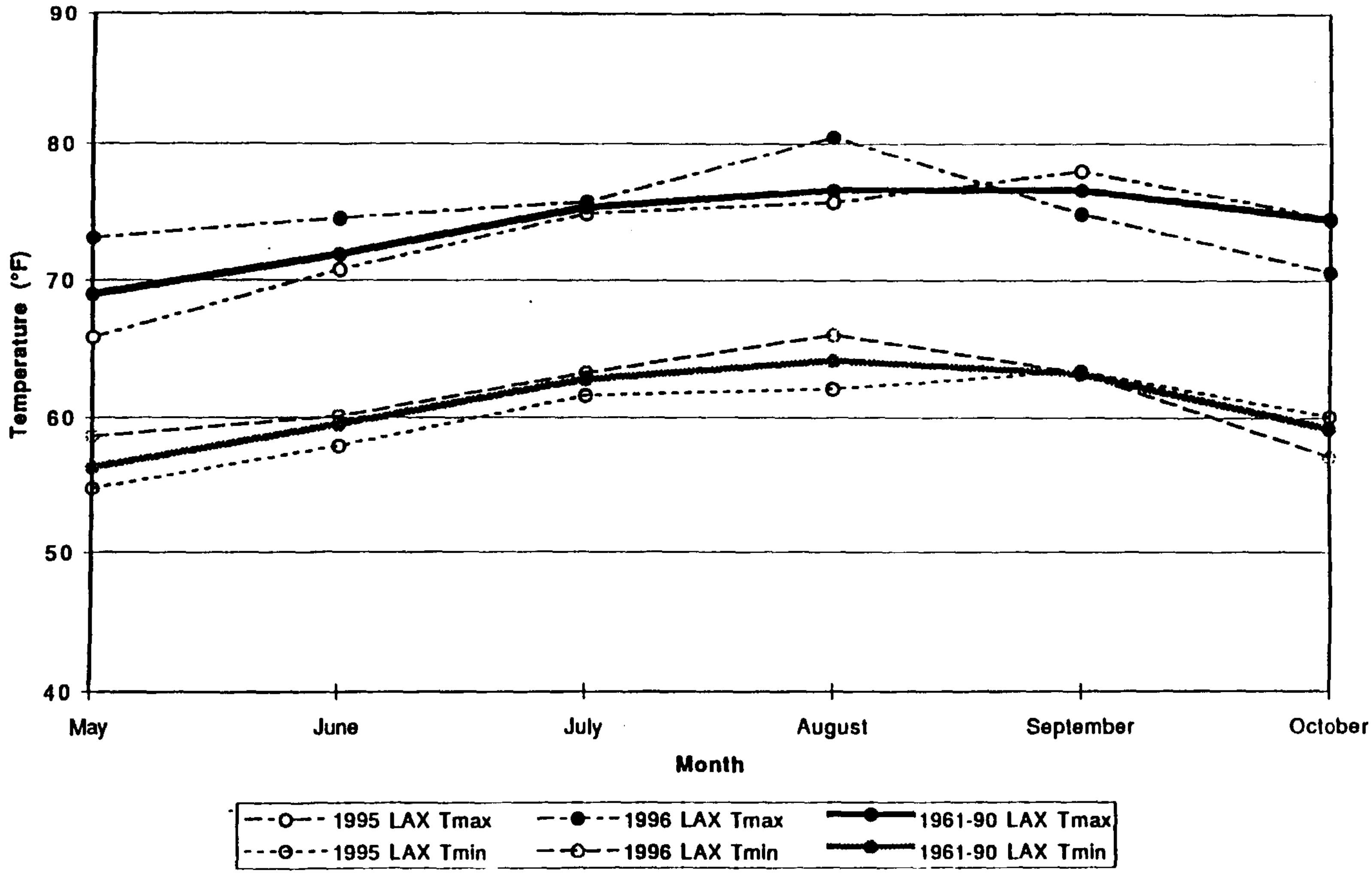

Figure 6-16. LAX mean monthly daily-maximum and daily-minimum temperature.

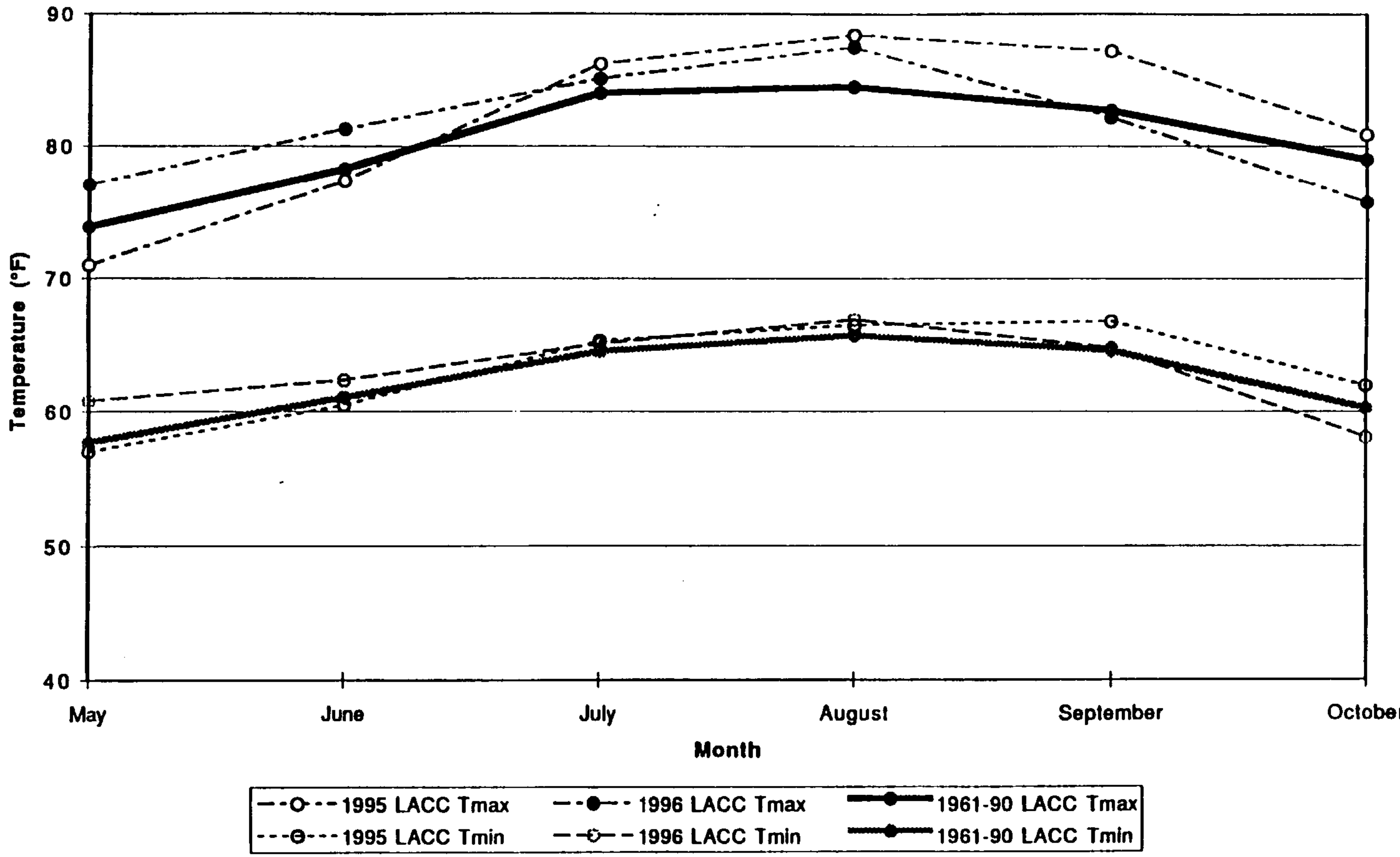

Figure 6-17. Los Angeles Civic Center mean monthly daily-maximum and daily-minimum temperature.

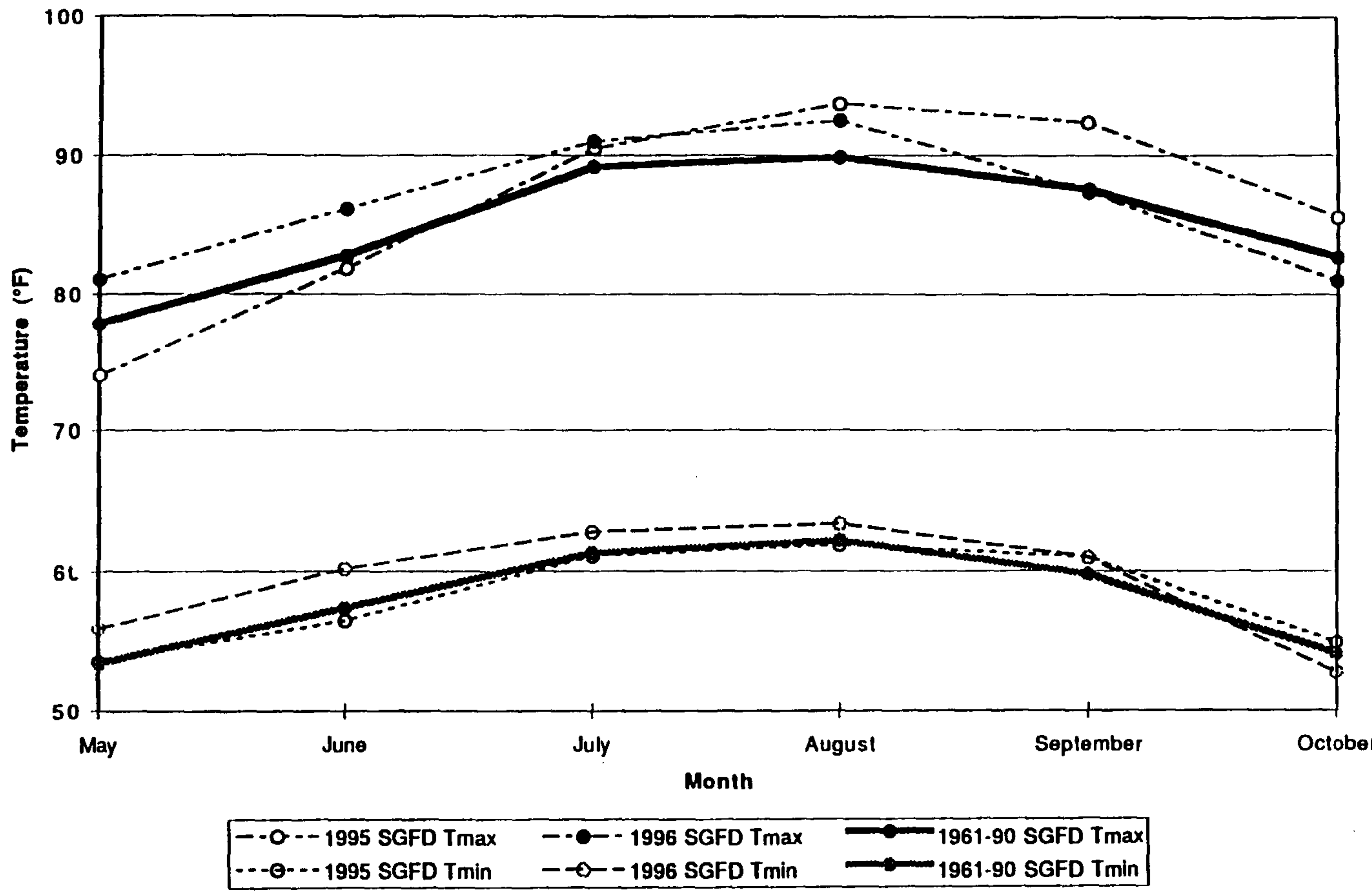

Figure 6-18. San Gabriel Fire Department mean monthly daily-maximum and daily-minimum temperature.

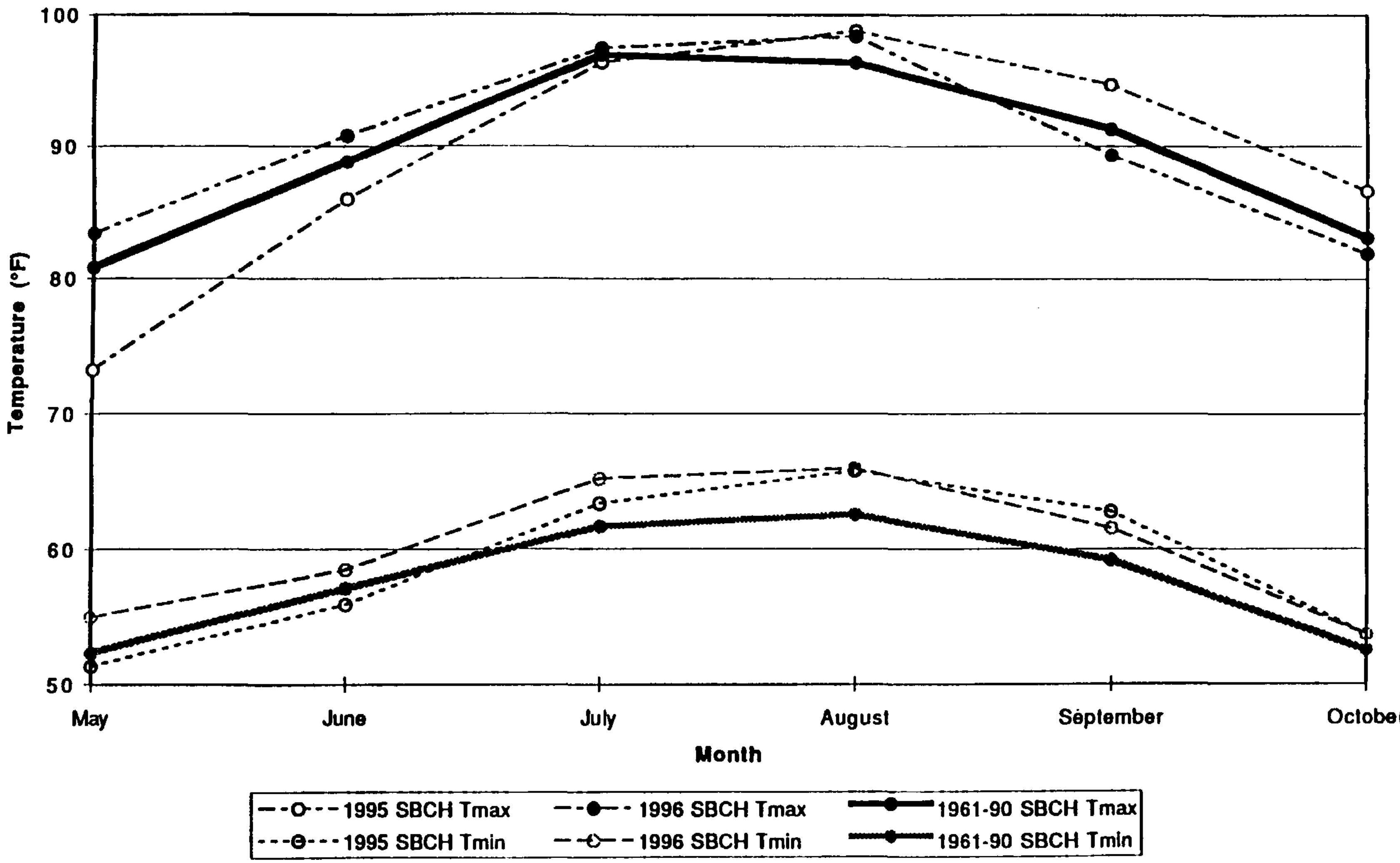

Figure 6-19. San Bernardino County Hospital mean monthly daily-maximum and daily-minimum temperature.

portions of the SoCAB. These conditions would seem to favor normal to above normal photochemical smog production rates [warmer SoCAB surface temperatures are associated with higher ozone concentrations (Blier and Winer 1996)]. This conclusion also follows from analysis of gridded 850 mb temperatures at a grid point near the SoCAB (see Figure 6-20) which showed near or above normal temperatures for the 1995-96 smog seasons (except during May-June 1995 and September-October 1996, which were cooler than the 1985-96 mean climatological values). Since a substantial *decrease* in the number of ozone exceedances was reported in the San Gabriel Valley (SGV) from 1995 to 1996 (see Table 6-1), and since this decrease was not likely due to meteorological variability, there appears to be evidence of a significant reduction in SGV ozone during the 1995-96 smog seasons resulting from non-meteorological factors.

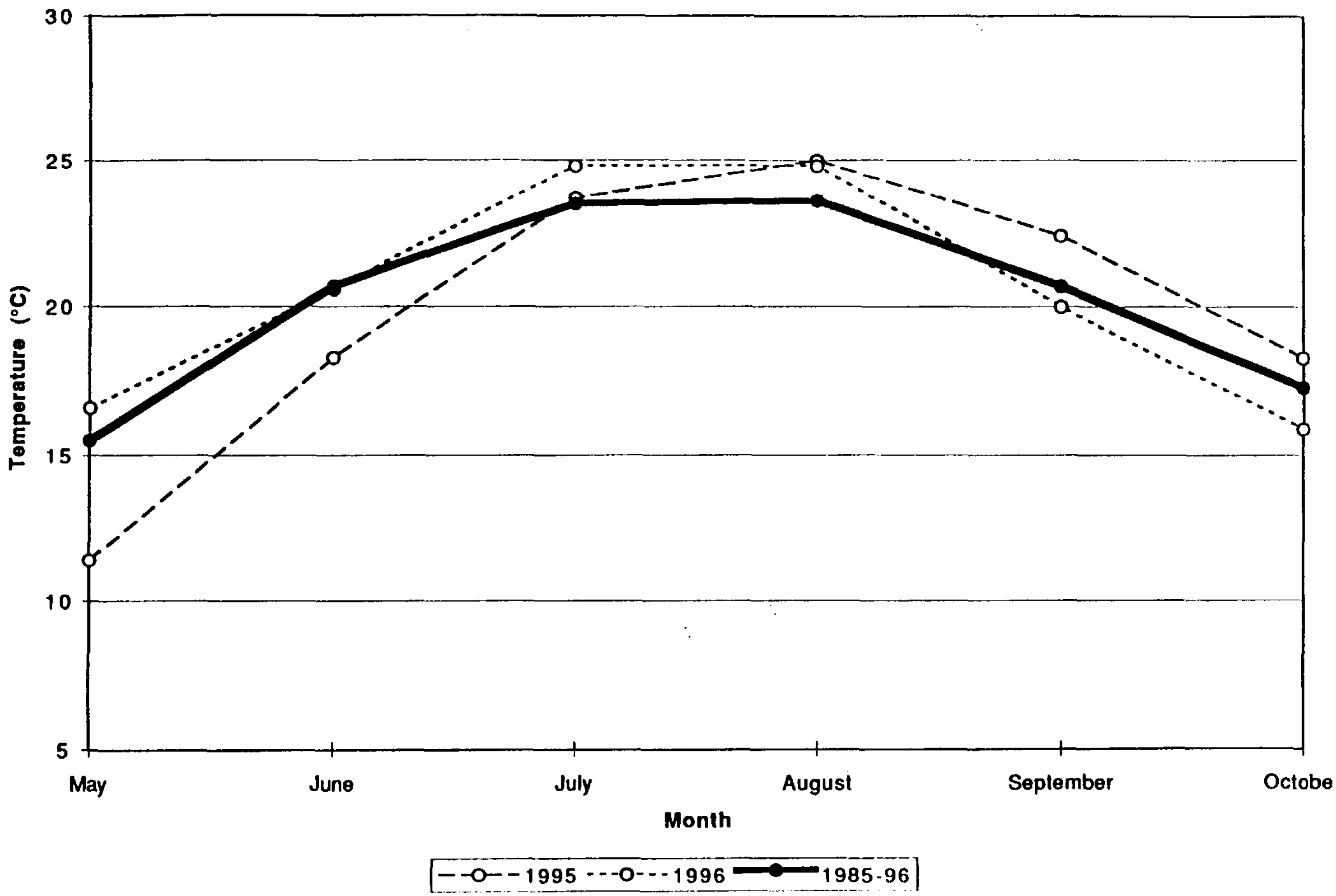

Figure 6-20. Mean 850 mb temperature (averaged over 0500 and 1700 PDT) at 33.21 °N, 116.98 °W.

7.0 EXPLORATORY STUDIES

7.1 Analyses of Distribution of High and Middle Ozone Days: 1986-96

In the first phase of the project, a methodology was developed to determine a set of high ozone days and a set of middle ozone days for the 1990-93 smog seasons (Blier and Winer 1996). This same general approach has now been used to define high and middle ozone days for the 1986-89 smog seasons, as well as for 1994-96. The daily-maximum hourly-average ozone concentrations on the high ozone days ranged from 28 to 35 pphm for 1986-89, from 25 to 33 pphm for 1990-93, and from 22 to 30 pphm for 1994-96. For the middle ozone days, daily-maximum hourly-average ozone concentrations were 17 pphm for 1986-89, 15 pphm for 1990-93, and 13 pphm for 1994-96.

For each of these three periods, the distribution of the high and middle ozone days through the smog season is shown (see Figures 7-1 through 7-3). Unsurprisingly, the high ozone days tended to occur mostly during the middle four months of the smog season, while the middle ozone days were generally more broadly distributed. Additionally, there appears to be a trend towards decreasing incidence of high ozone days in September and October, though further examination of the comparability of the meteorological conditions is needed. This discussion should be expanded to explain the further broad downward trend for ozone concentrations since 1995-96 and 97 (4-6 & 4-7), a noticeable shift to early season (May) peaks, and a general shift in ozone season from May through October to June through August.

The distribution by day-of-the-week of the high ozone days of 1986-89, 1990-93, and 1994-96 is shown in Table 7-1. Although previous research suggests that Saturdays tend to have higher ozone concentrations (Blier and Winer 1996), the results for the individual periods do not reveal a clear day-of-the-week pattern, perhaps because the number of days in the analysis is too small. To see if a day-of-the-week signal could be detected with a larger number of days in the calculation, the day-of-the-week distributions in Table 7-1 were summed for the high ozone days over all three periods of

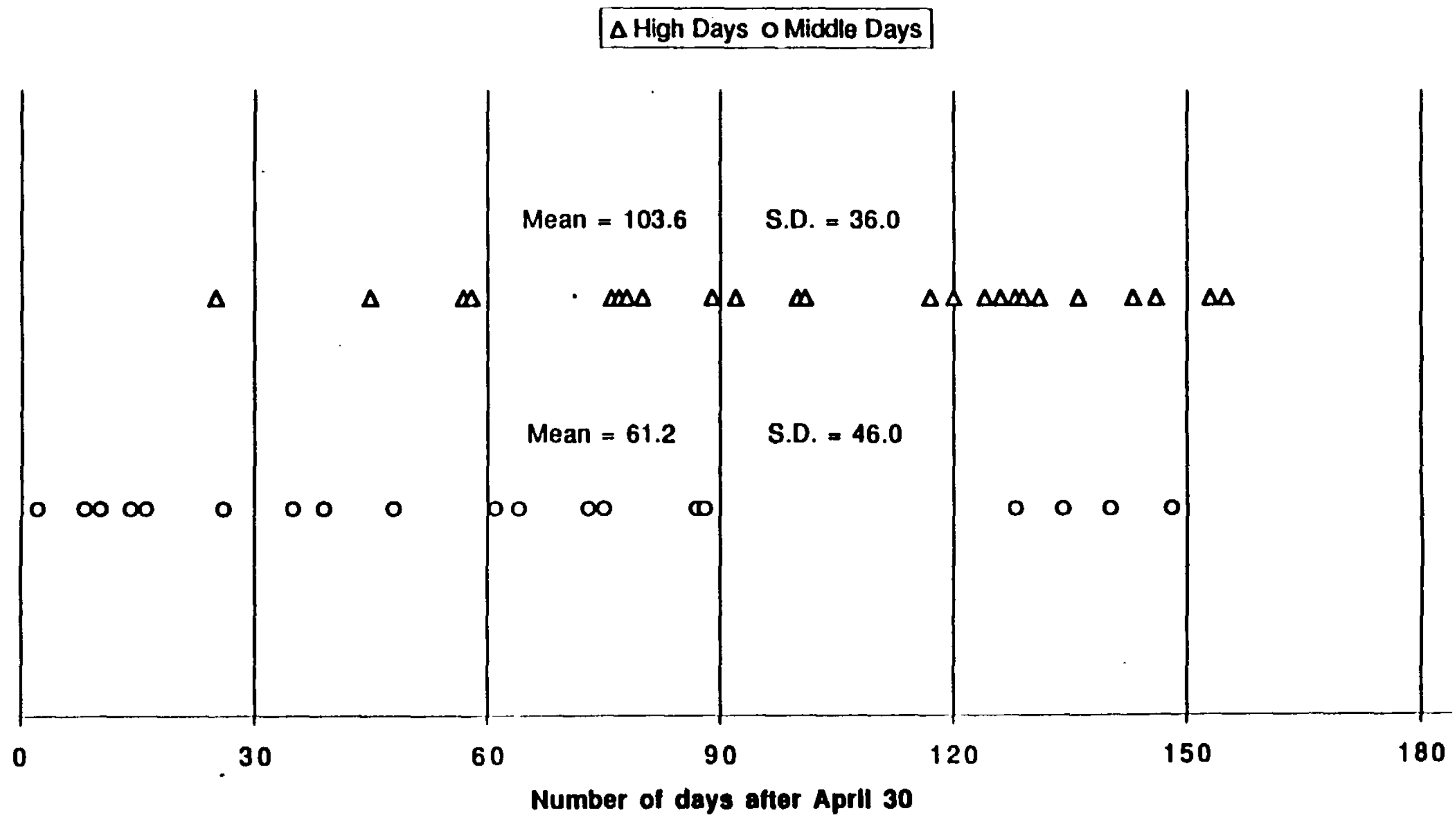

Figure 7-1. Distribution of 24 High and 21 Middle Ozone Days for 1986-89.

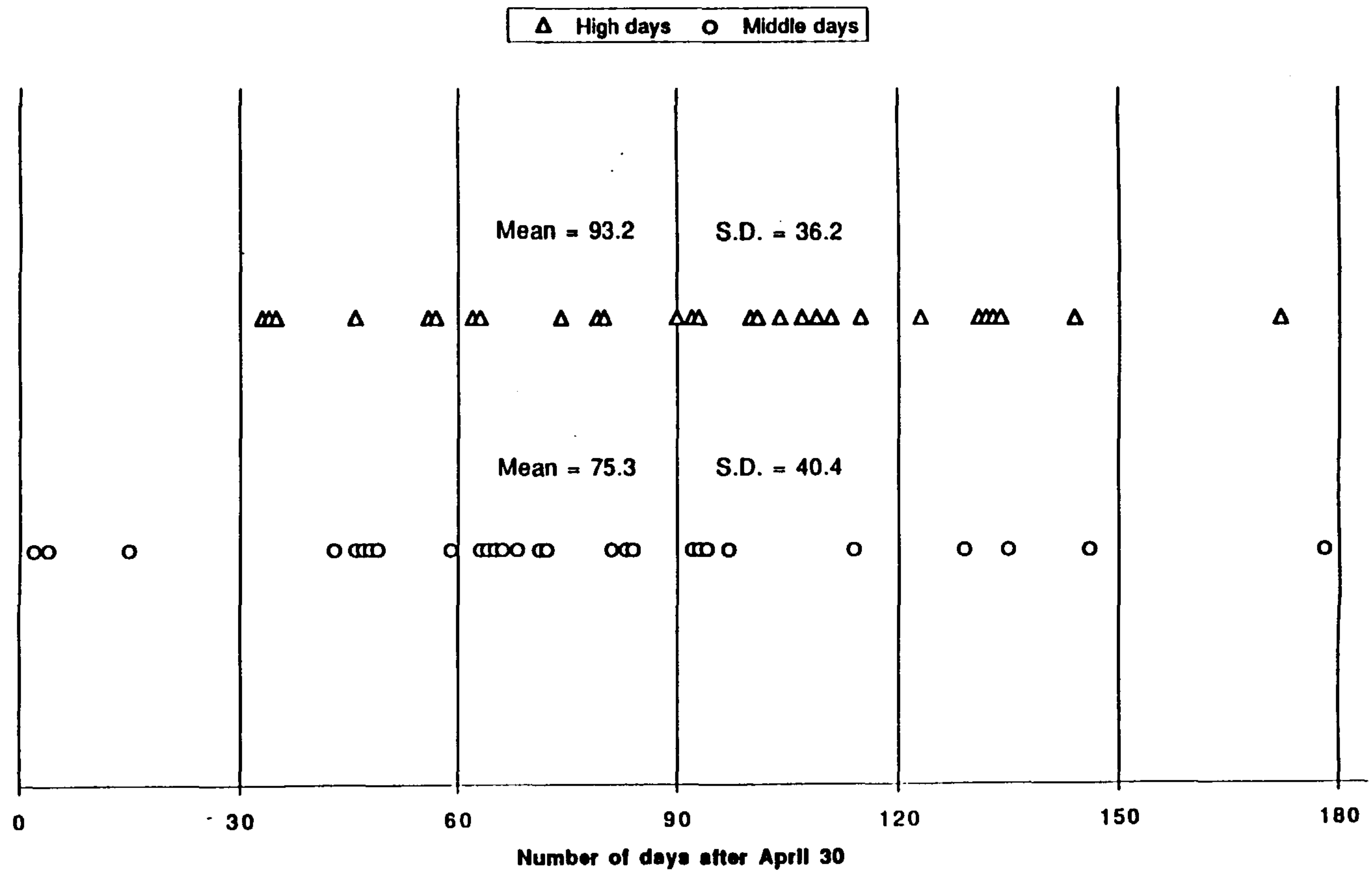

Figure 7-2. Distribution of 28 High and 28 Middle Ozone Days for 1990-93.

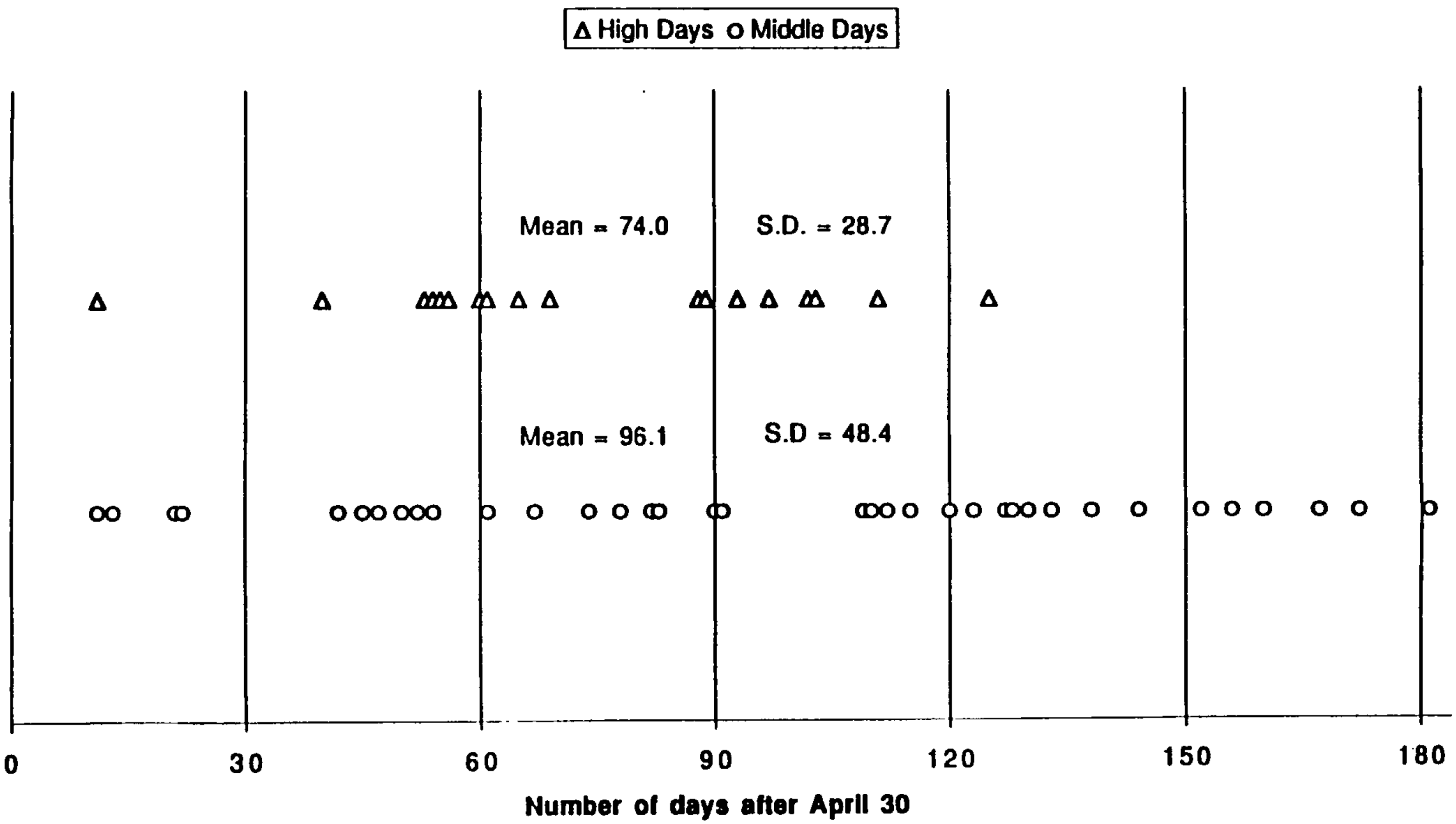

Figure 7-3. Distribution of 18 High and 36 Middle Ozone Days for 1994-96.

analysis (fourth column, Table 7-1). The summation showed a monotonic increase in number of occurrences of high ozone days by day-of-the-week, with a minimum number of occurrences on Sundays and a maximum on Saturdays. This appears consistent with our results from Phase I of this research.

Table 7-1. Distribution by day of week for the high ozone days of 1986-89, 1990-93 and 1994-96.

Day	1986-89	1990-93	1994-96	1986-96
Monday	0	6	0	6
Tuesday	2	4	1	7
Wednesday	4	2	2	8
Thursday	2	3	7	12
Friday	8	4	2	14
Saturday	5	8	6	19
Sunday	3	1	0	4
Total	24	28	18	70

7.2 Analyses Using Gridded Meteorological Data

7.2.1 Superposed Epoch Analysis of High Ozone Days

As an exploratory analysis, we chose to use the method of Superposed Epoch Analysis (Panofsky and Brier 1958) to examine the concurrent and antecedent synoptic-scale meteorological conditions associated with the occurrence of high ozone concentrations in the Basin. This method consists of the computation of the mean of some parameter P associated with a set of event of type E which are of interest to the researcher. The mean of P is computed for equidistant time intervals leading up to, and including the time of occurrence of E in order to examine the relationship between P and E. [Mass and Albright (1989) used this technique to analyze synoptic-scale conditions associated with California Catalina Eddy events].

Accordingly, the mean 500 mb synoptic-scale field was computed at 12-hr time intervals, beginning three time intervals prior to the occurrence of the 28 high ozone days

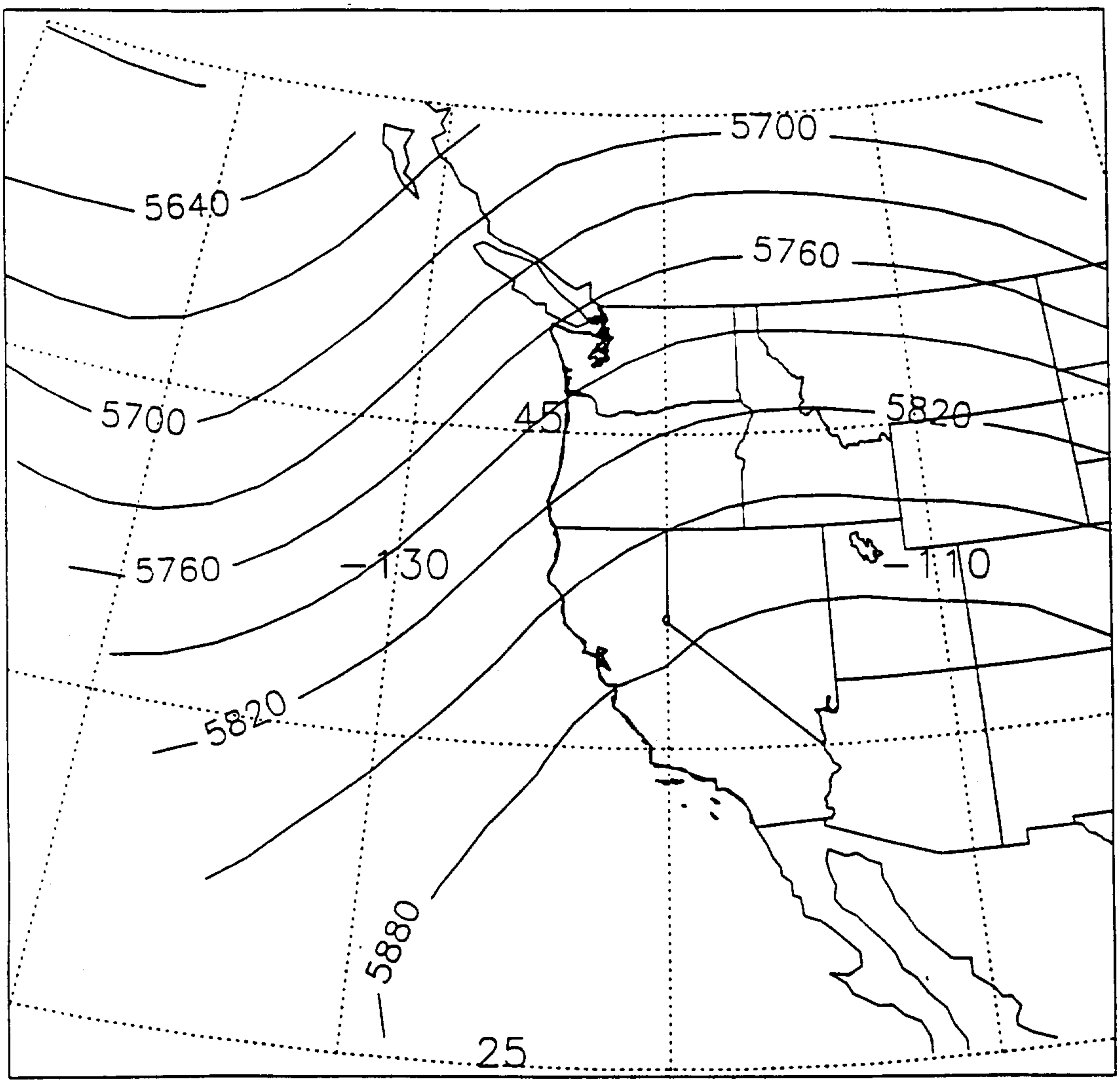

Figure 7-4. Mean 500 mb geopotential heights (gpm) at 05 PDT on 28 high ozone days (key day -1).

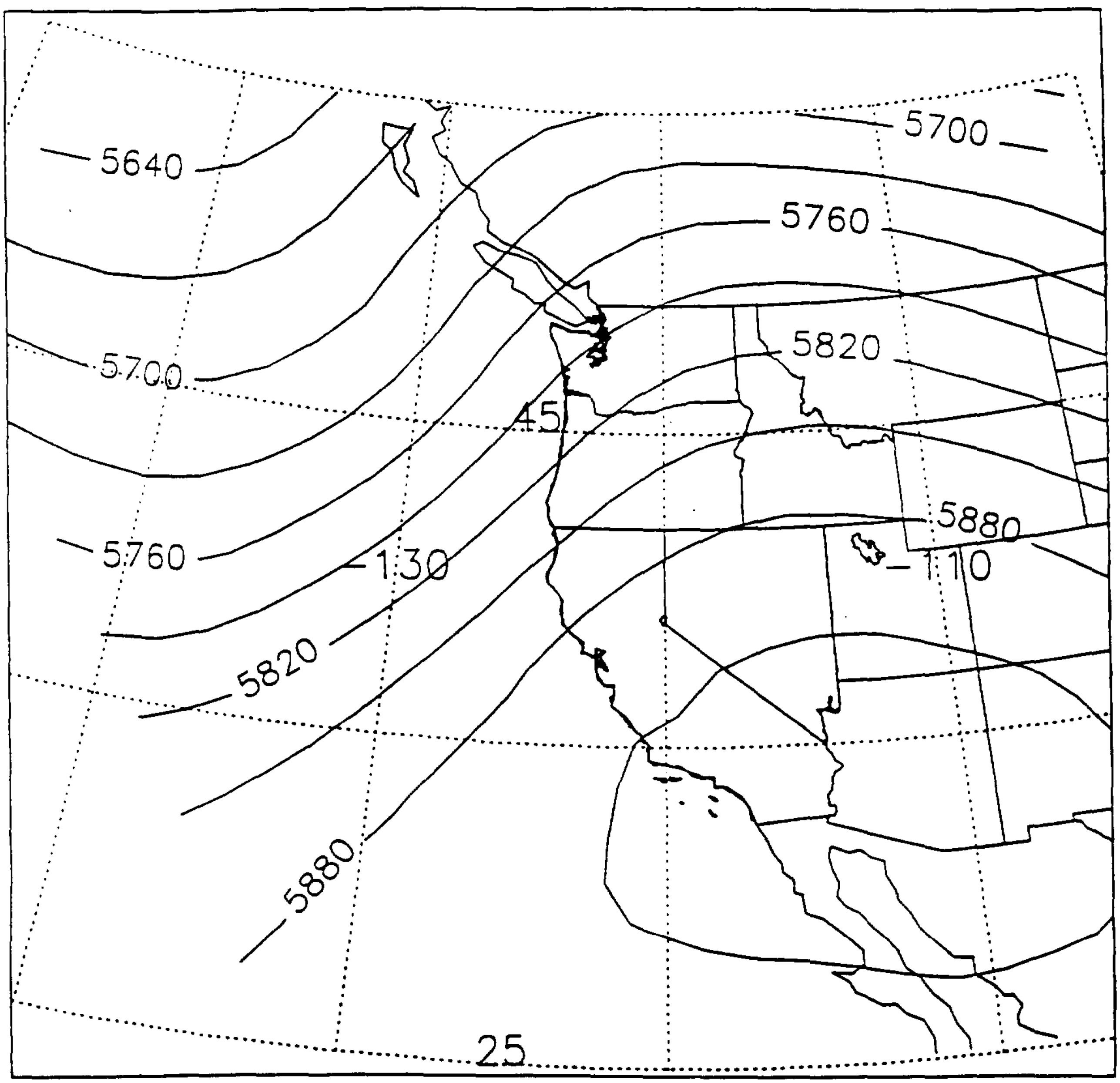

Figure 7-5. Mean 500 mb geopotential heights (gpm) at 17 PDT on 28 high ozone days (key day -1).

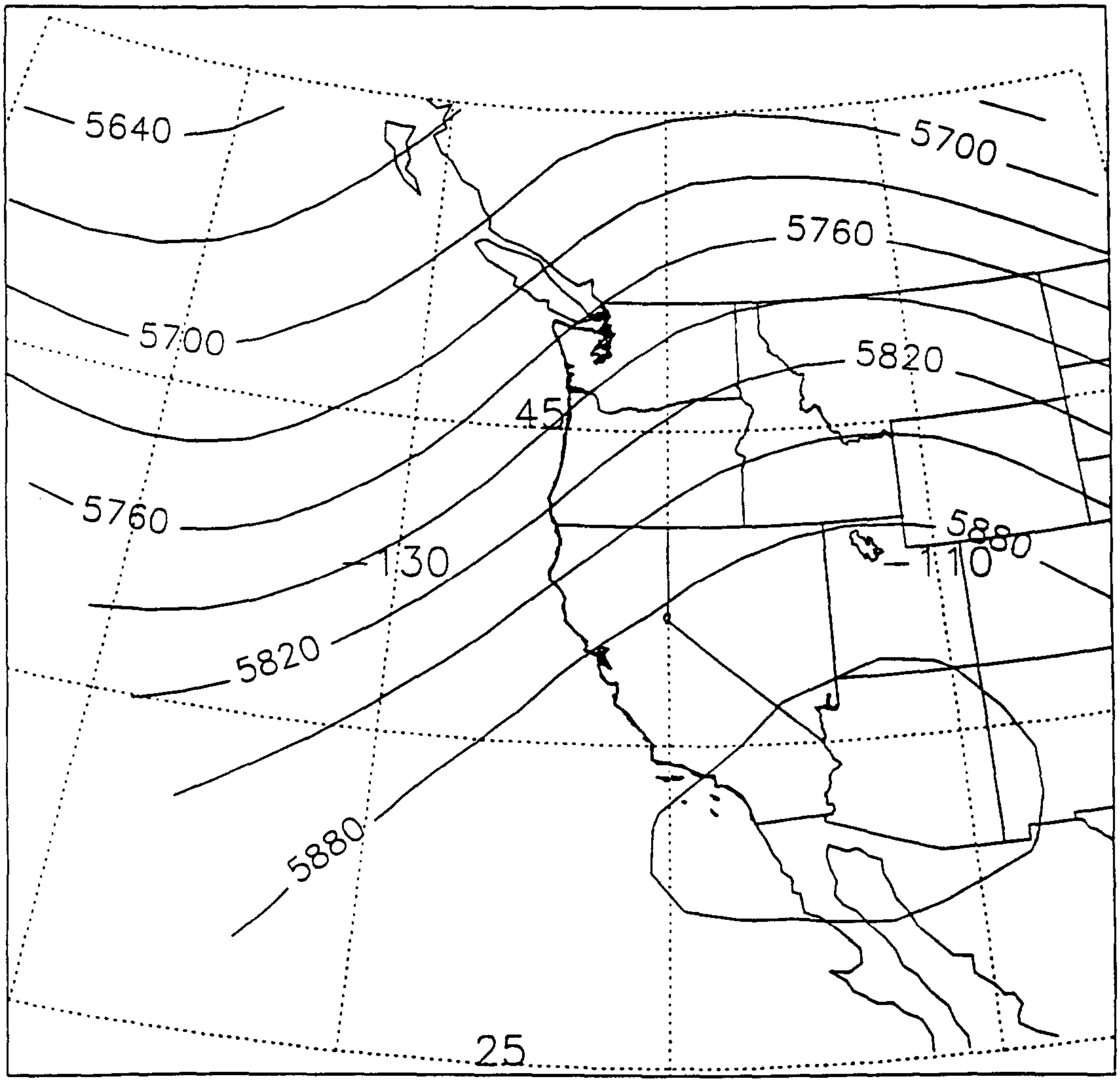

Figure 7-6. Mean 500 mb geopotential heights (gpm) at 05 PDT on 28 high ozone days (key day +0).

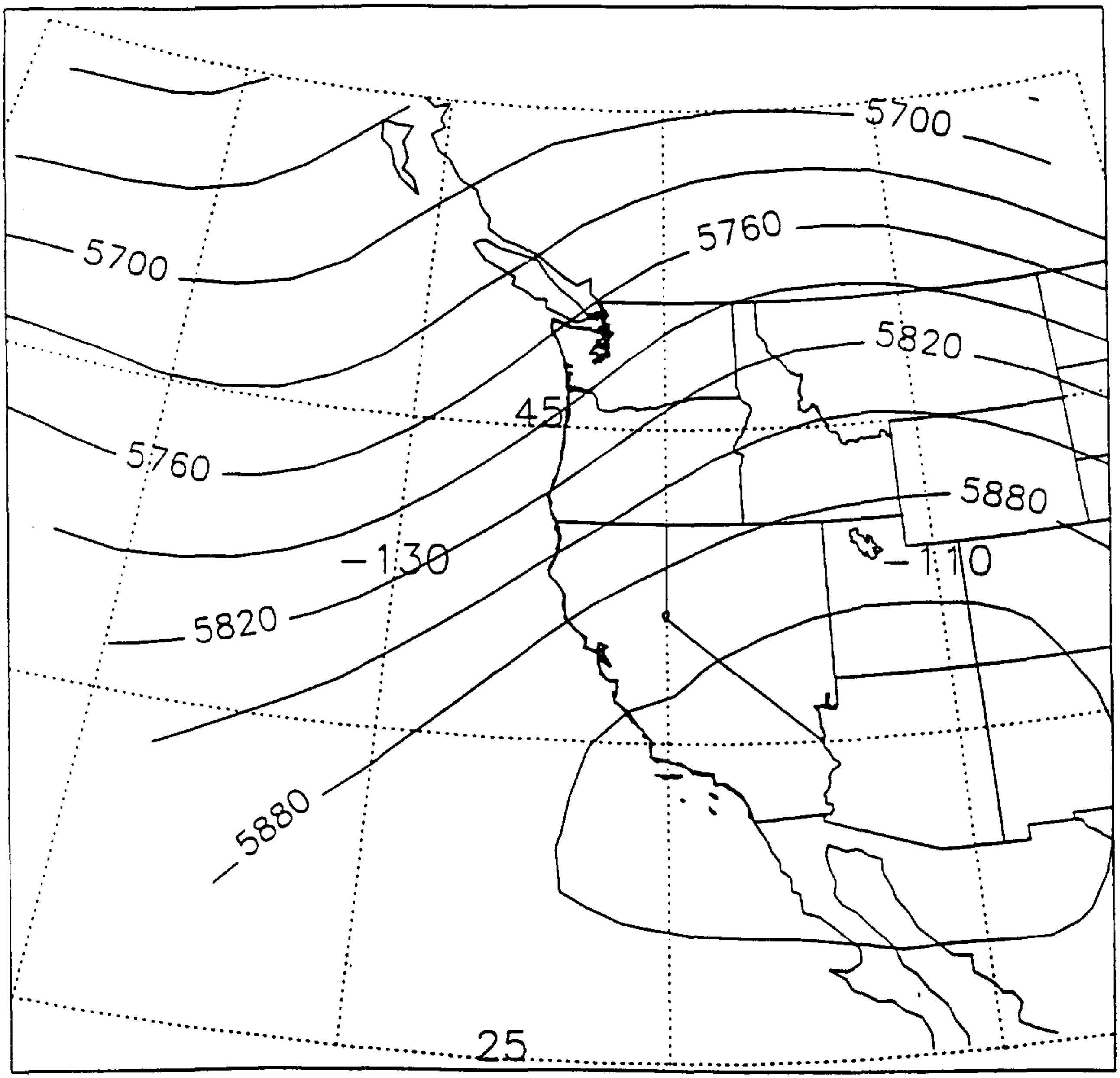

Figure 7-7. Mean 500 mb geopotential heights (gpm) at 17 PDT on 28 high ozone days (key day +0).

of 1990-93, and leading up to and including the time 1700 PDT on the afternoon of the occurrence of the high ozone days (Figures 7-4 to 7-7). The mean conditions associated with high ozone days in the SoCAB were clearly associated with a strong 500 mb ridge over the western portion of the United States, with relatively light southwest winds over the SoCAB at 500 mb, while a large trough was located over the eastern Pacific. Examination of the sequence of Figures (7-4 to 7-7) indicated that the West Coast ridge axis slowly moved eastward as the time of occurrence of high ozone in the SoCAB approached.

7.2.2 Correlation between Gridded Constant Pressure Level Data and Daily SoCAB-Maximum Ozone

The high correlation between 850 mb temperature and high SoCAB ozone has been known for many years (Davidson et al. 1985). To further investigate the relationship between SoCAB-maximum ozone concentrations and 850 mb temperature, we correlated the set of SoCAB-maximum ozone concentrations from the smog season days of 1994-96 with the corresponding objectively-analyzed 850 mb temperatures throughout the region occurring at 1700 PDT on the afternoon of the same day. These correlations were computed using the synoptic fields occurring at a succession of 12-hour time intervals leading up to the afternoon of occurrence of the Basin-maximum ozone concentrations (Figures 7-8 to 7-11). The region of maximum correlation coefficients was located over the SoCAB. As expected, the correlation increased as the time interval between the hour of observation of the 850 mb temperature and the occurrence of the SoCAB-maximum ozone concentration (approximately 1400-1600 PDT) decreased. The highest correlation coefficient of 0.82 occurred at 33.21 °N, 116.98 °W (Figure 7-11).

The time series of the daily SoCAB-maximum hourly-average ozone concentrations was also correlated with the corresponding time series (at each grid point) of 1700 PDT 850 mb temperatures for the 1986-89 smog seasons (Figure 7-12) and the 1990-93 smog seasons (Figure 7-13). As in the analysis for 1994-96 (Figure 7-11), both

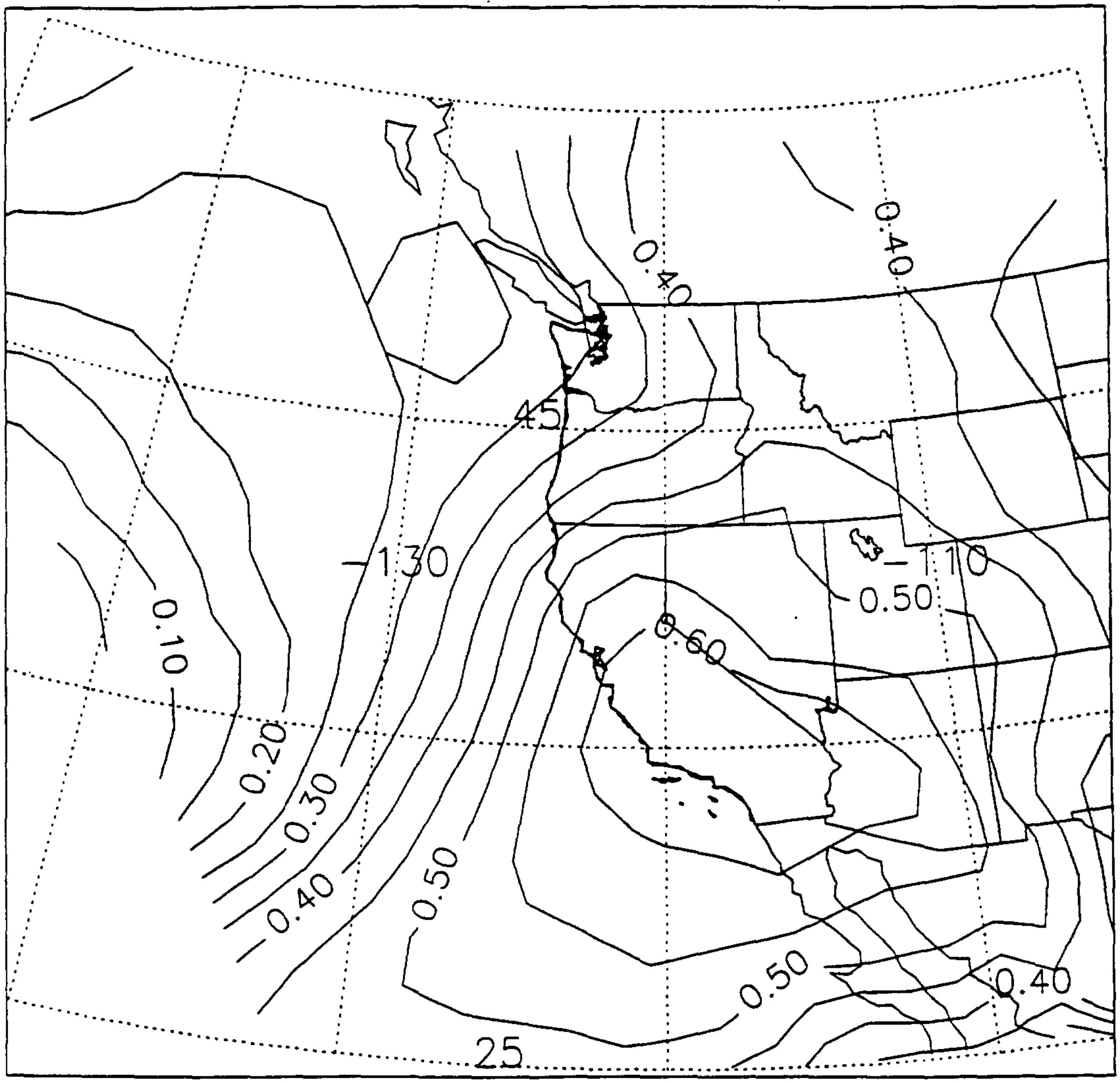

Figure 7-8. Correlation of 1994-96 smog season 05 PDT 850 mb temeprature (key day -1) vs. daily SoCAB-maximum hourly-average ozone.

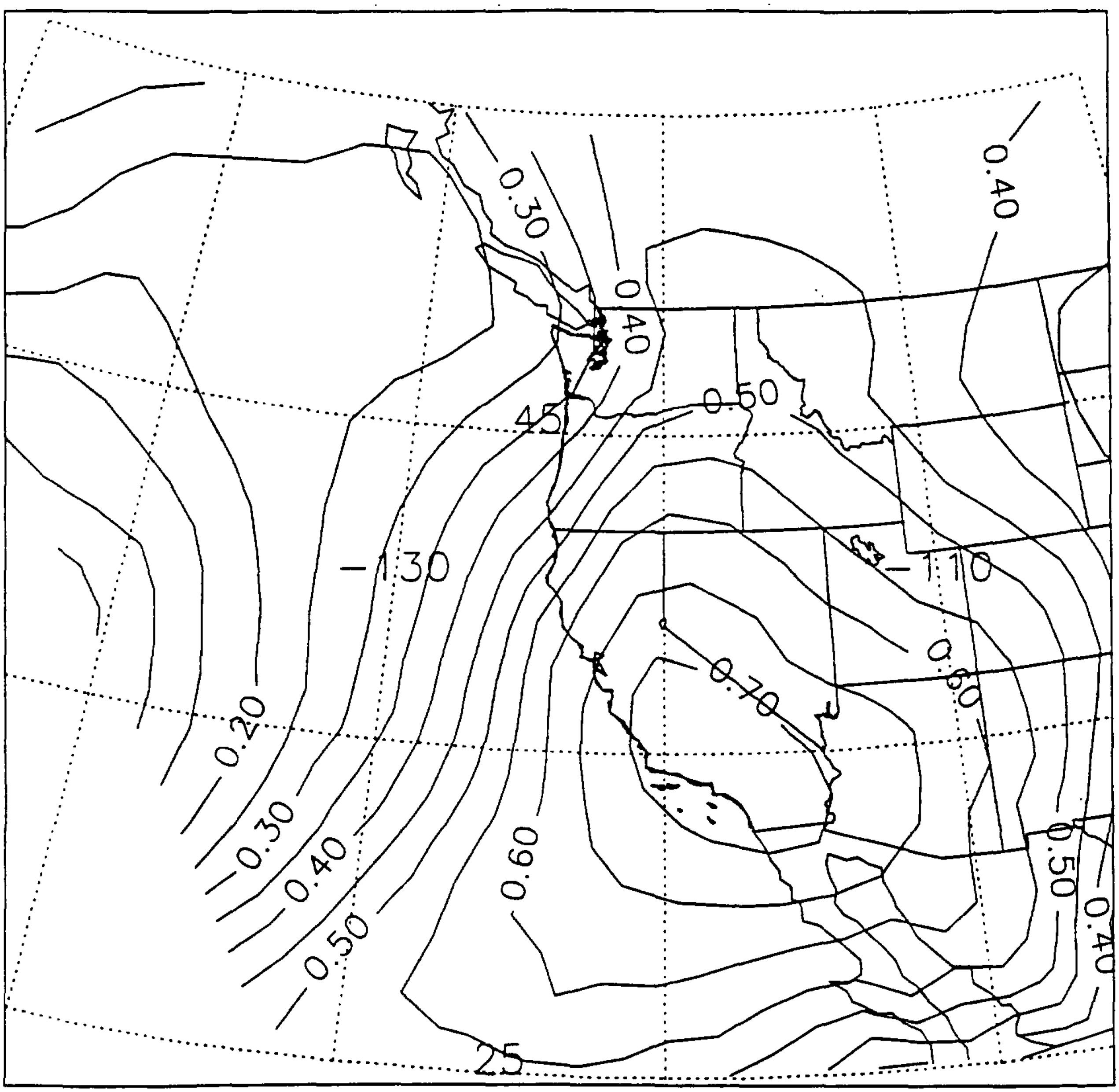

Figure 7-9. Correlation of 1994-96 smog season 17 PDT 850 mb temeprature (key day -1) vs. daily SoCAB-maximum hourly-average ozone.

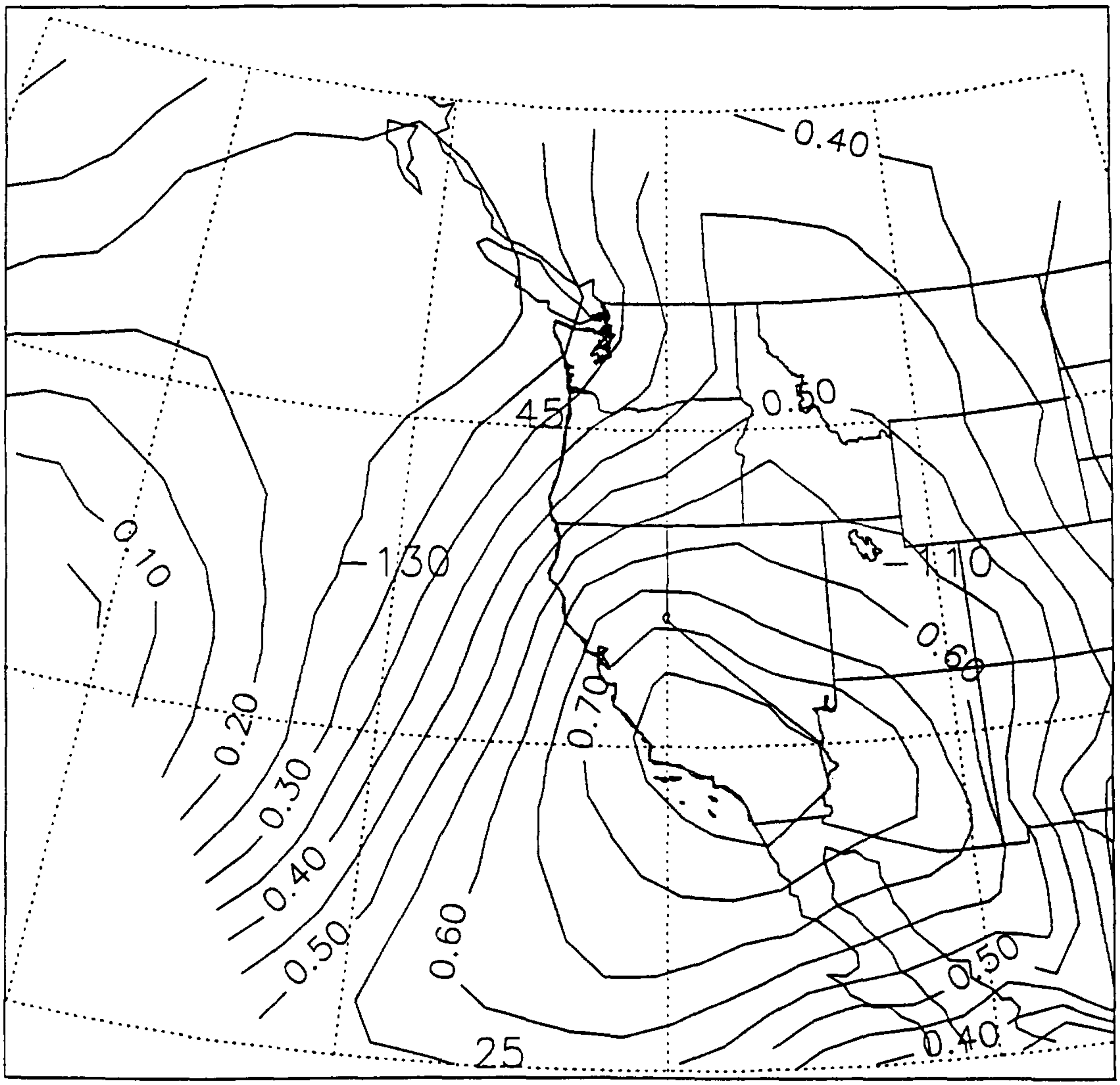

Figure 7-10. Correlation of 1994-96 smog season 05 PDT 850 mb temeprature (key day +0) vs. daily SoCAB-maximum hourly-average ozone.

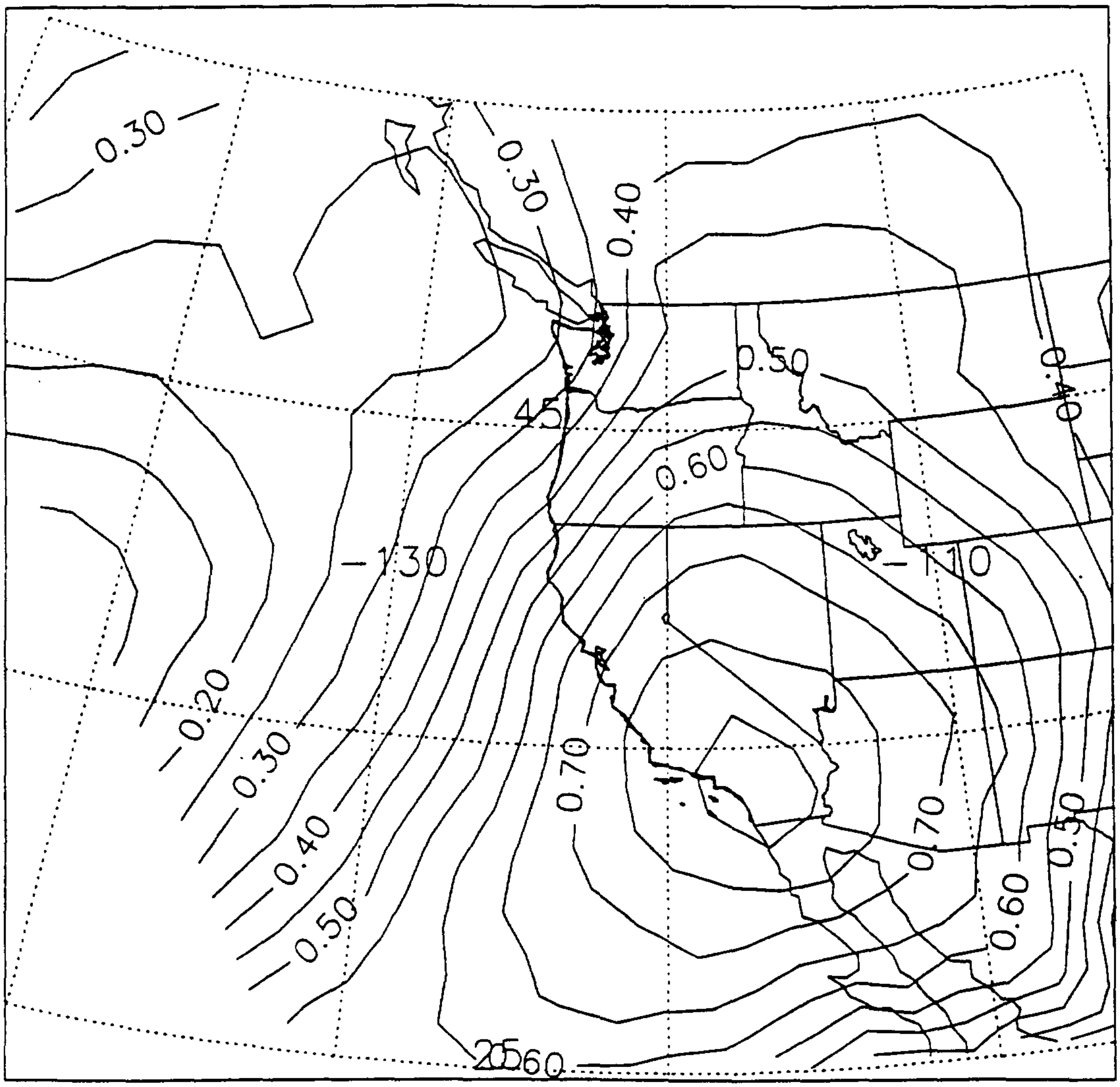

Figure 7-11. Correlation of 1994-96 smog season 17 PDT 850 mb temepratrure (key day +0) vs. daily SoCAB-maximum hourly-average ozone.

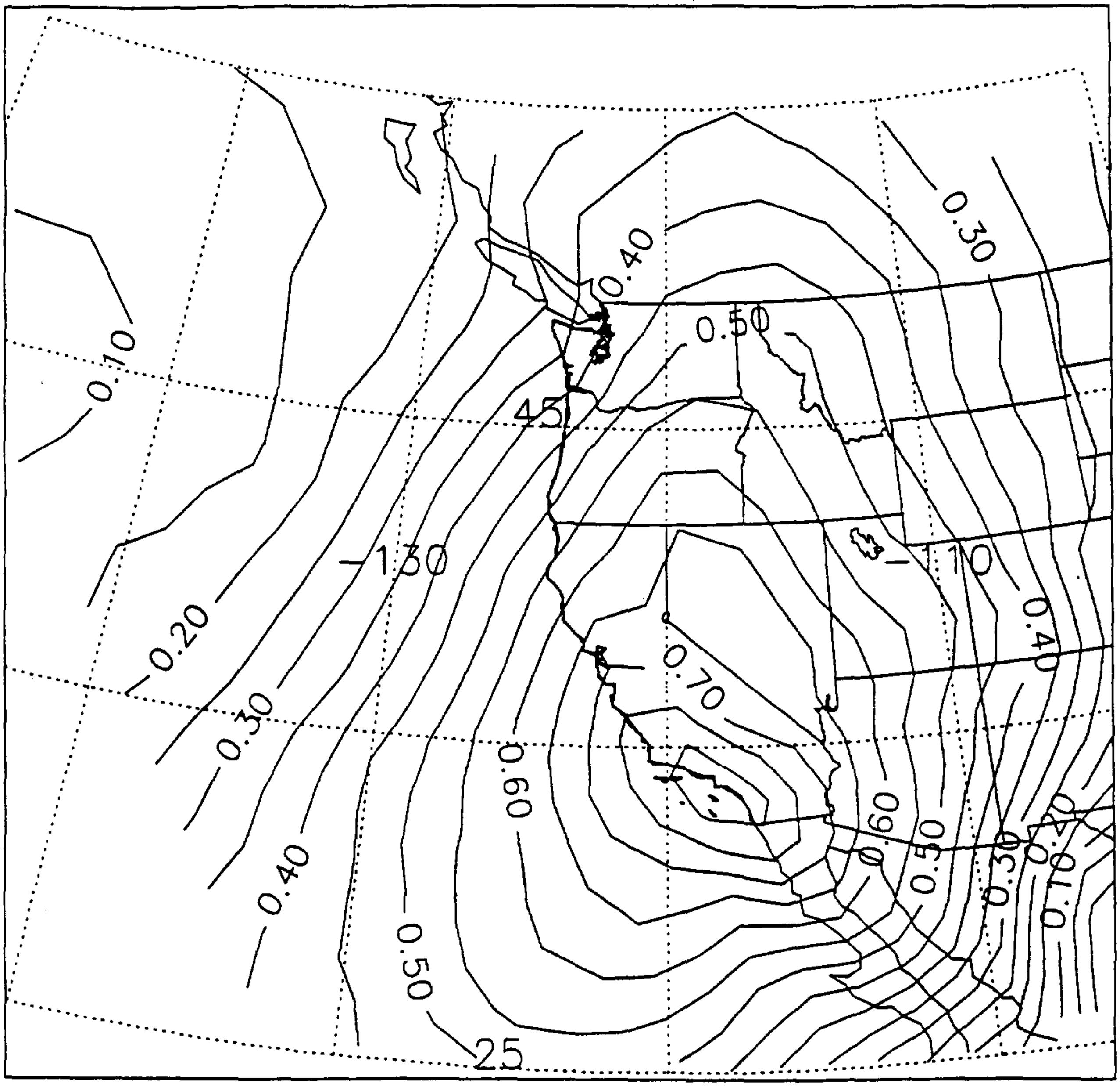

Figure 7-12. Correlation of 1986-89 smog season 17 PDT 850 mb temepratuure (key day +0) vs. daily SoCAB-maximum hourly-average ozone.

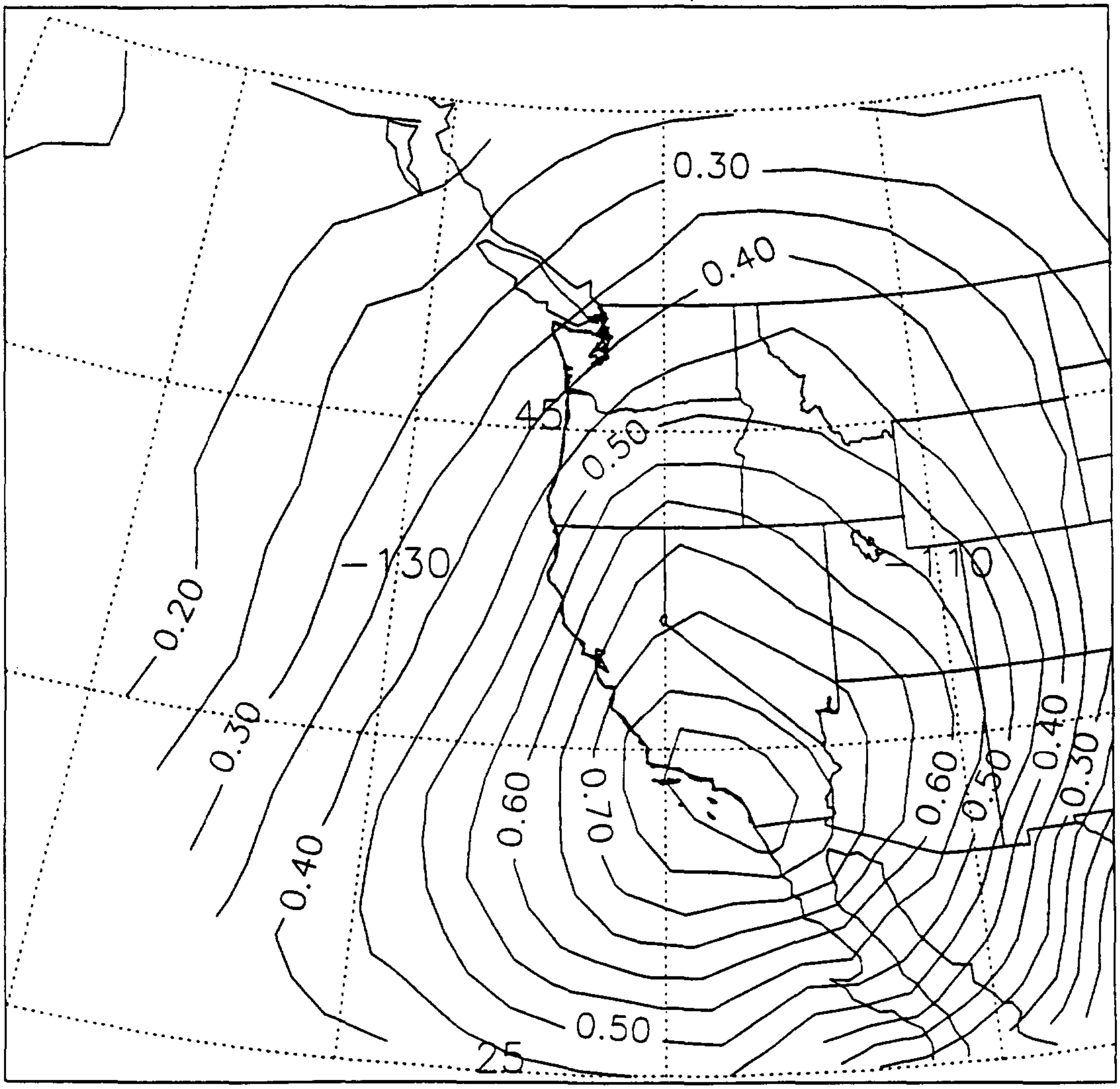

Figure 7-13. Correlation of 1990-93 smog season 17 PDT 850 mb temepratrure (key day +0) vs. daily SoCAB-maximum hourly-average ozone.

of these analyses also showed highest correlation over the region of the SoCAB. The highest correlation coefficient for 1986-89 was 0.83 and occurred at 34.28 °N, 119.04 °W, while the highest correlation coefficient for 1990-93 was 0.84 and occurred at 33.21 °N, 116.98 °W (Figure 7-14).

7.3 Evaluation of Industrial Emissions Data

To characterize differences in NO_x emissions by day-of-the-week for stationary sources, we examined data from approximately 80 RECLAIM sources in the SoCAB (out of approximately 200 sources regulated under RECLAIM) which reported daily NO_x emissions from May-September 1996. A summary of the results is given in Table 7-2.

Table 7-2. Summary of RECLAIM industrial emissions of NO_x for 82 sites from May-September 1996.

Day	Average (tons/d)	Std. Dev. (tons/d)
Sunday	126	122
Monday	161	171
Tuesday	146	166
Wednesday	168	200
Thursday	409	1058
Friday	125	152
Saturday	128	158
Average	182	436

Because of the large variation in reported emissions, we excluded data for those particular days for which the standard deviation was greater than twice the mean emissions for each day of the study period. For example, Figure 7-15 shows total reported NO_x emissions for each Thursday from May-September 1996.

Table 7-3 shows both the calculated average NO_x emissions and corresponding standard deviations by day-of-the-week after screening of the data. Reported emissions

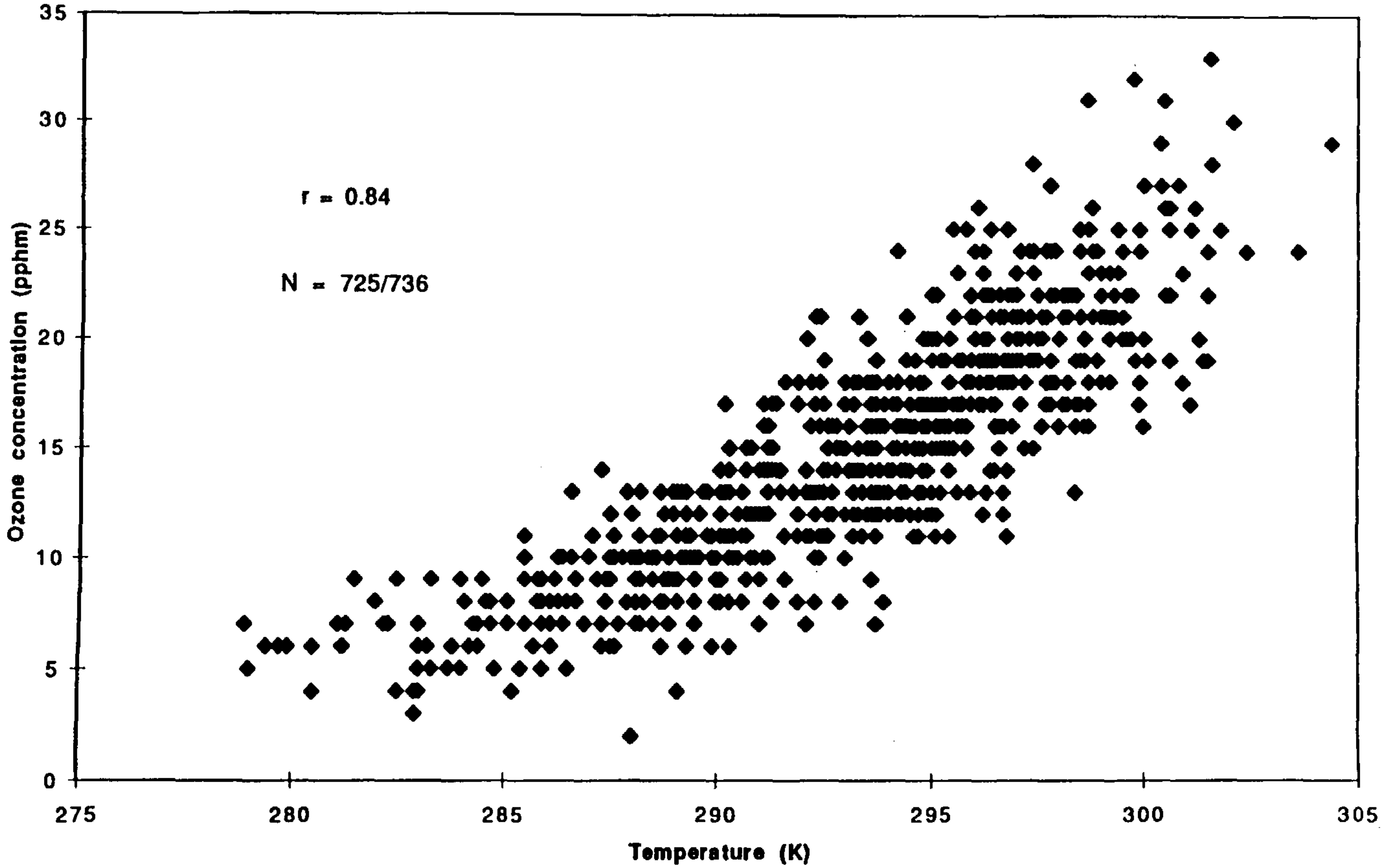

Figure 7-14. Correlation of 1990-93 smog season 1700 PDT 850 mb temperature (at 33.21 °N, 116.98 °W) vs. daily SoCAB-maximum hourly-average ozone.

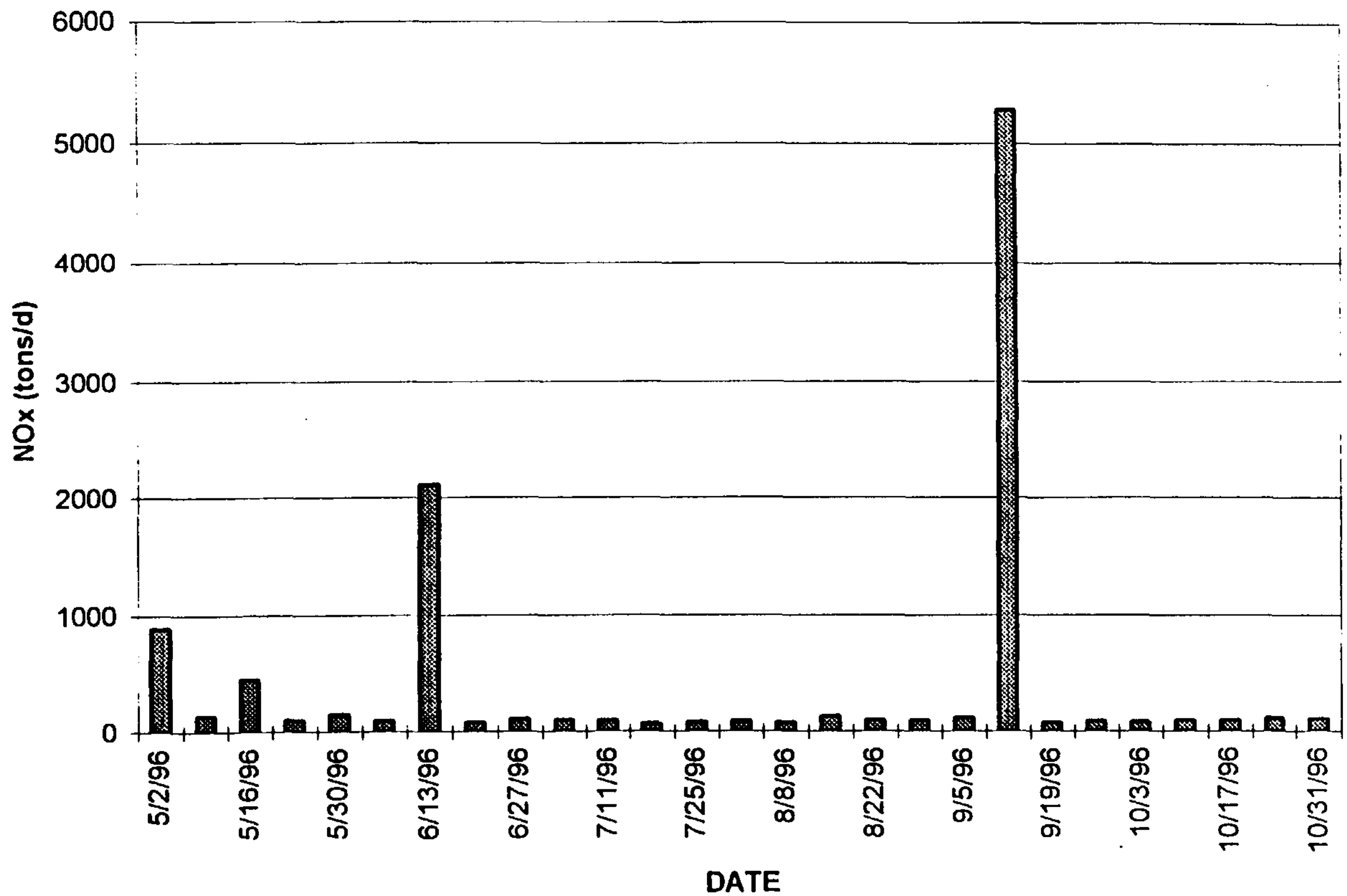

Figure 7-15. Thursday RECLAIM data for May-September 1996.

Table 7-3. RECLAIM NO_x emissions (extreme reporting days excluded).

Day	Average (tons/d)	Std. Dev (tons/d)
Sunday	103	20
Monday	103	14
Tuesday	103	34
Wednesday	102	20
Thursday	101	20
Friday	95	18
Saturday	98	21
Average	101	22

were slightly lower on Fridays and Saturdays. However, Sunday emissions were similar to weekday emissions.

Weekday/weekend differences (post-screening) in reported RECLAIM emissions for each site are shown in Figure 7-16. To represent weekday emissions, Tuesday and Wednesday were averaged together, while Saturday and Sunday were averaged to represent weekend emissions. Figure 7-16 suggests the majority of sources have higher emissions on weekdays than on weekends, with just three sites (No. 4, 18, and 21) exhibiting significantly higher overall emissions on weekend days. These three sites are all electric power generating facilities (SIC code = 4911). Note the differences in Figure 7-16 are small (pounds) compared with the mean in tons per day.

In general, these data were of limited use in meeting the objectives of this study because no significant day-of-the week differences were found (Table 7-3).

7.4 Investigation of Traffic Activity Patterns

We were interested in whether relationships could be established between 0600-0900 PDT ambient CO concentration and traffic count data, as expected from the fact that mobile sources are the only significant source of CO. Also, according to Fujita (1994), the early morning period reflects emissions primarily from on-road vehicles with minimal carryover of aged emissions at surface air monitoring stations. Towards this objective,

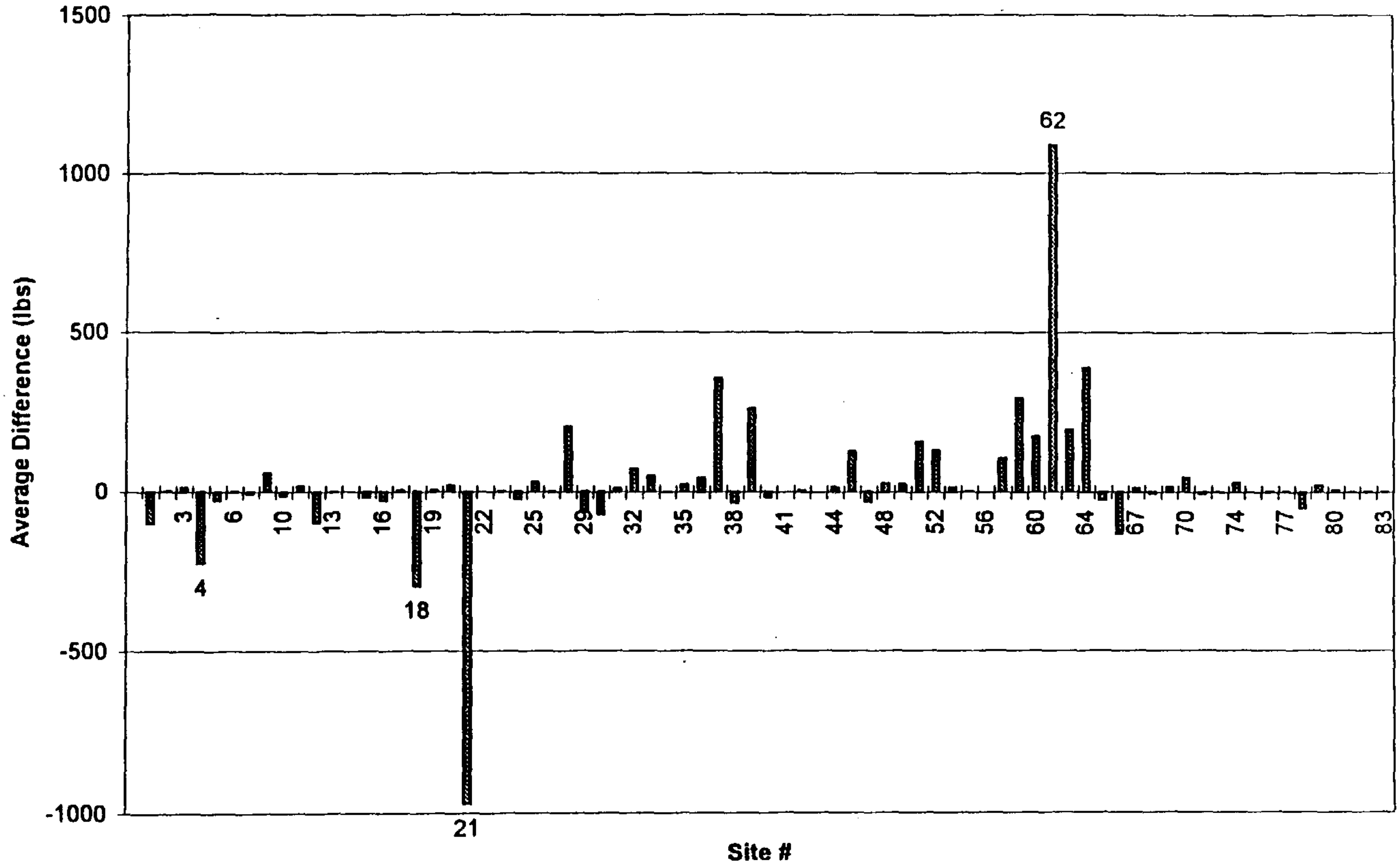

Figure 7-16. TU/WE - SA/SN differences (lbs) in reported RECLAIM NO_x emissions in the SoCAB, May-October 1996.

we explored the possible utility of a comparison (on a relative basis) between ambient CO concentrations from various SCAQMD air monitoring stations and traffic count data taken from the nearest Caltrans traffic control sites.

We were also interested in determining the degree to which traffic count data could serve as an indicator of day-of-the-week differences in the mobile source emission inventory.

To investigate whether vehicle use patterns can account for differences in SoCAB air quality between weekdays and weekend days, we performed a preliminary analysis of the Caltrans 1994-95 traffic count data for Los Angeles County. Preliminary results (from a total of 36 conventional traffic control sites) suggest a consistent day-of-the-week pattern throughout the SoCAB, with the largest traffic volume occurring on Fridays. There was also a slight upward trend in daily traffic volumes as the week progressed from Monday to Friday. In general, there was a significant decrease in traffic volume on Saturday and an even larger decrease on Sunday.

7.5 Analysis of Carbon Monoxide Trends by Day-of-the-Week: 1986-96

To elucidate day-of-the-week differences in mobile source activity and because of the paucity of hydrocarbon data, we investigated 0600-0900 PDT carbon monoxide (CO) concentrations at all air monitoring stations (N=14) in Los Angeles county (except Lancaster) for May-September 1986-96 (Figure 7-17). Despite an increase in vehicle miles traveled (VMT) over the eleven-year study period, 0600-0900 PDT ambient CO concentrations have decreased slightly during this period. Data completeness for all years inspected averaged over 98%. The detection limit of the continuous CO monitors used at the monitoring sites (NDIR, Bendix 8501) is 0.5 ppm, and CO data are reported to the nearest whole integer.

We examined differences in weekday/weekend 0600-0900 PDT CO trends over the eleven-year study period for the same Los Angeles county air monitoring sites (Figure 7-18). Whereas weekday (Monday through Friday average) ambient CO during the

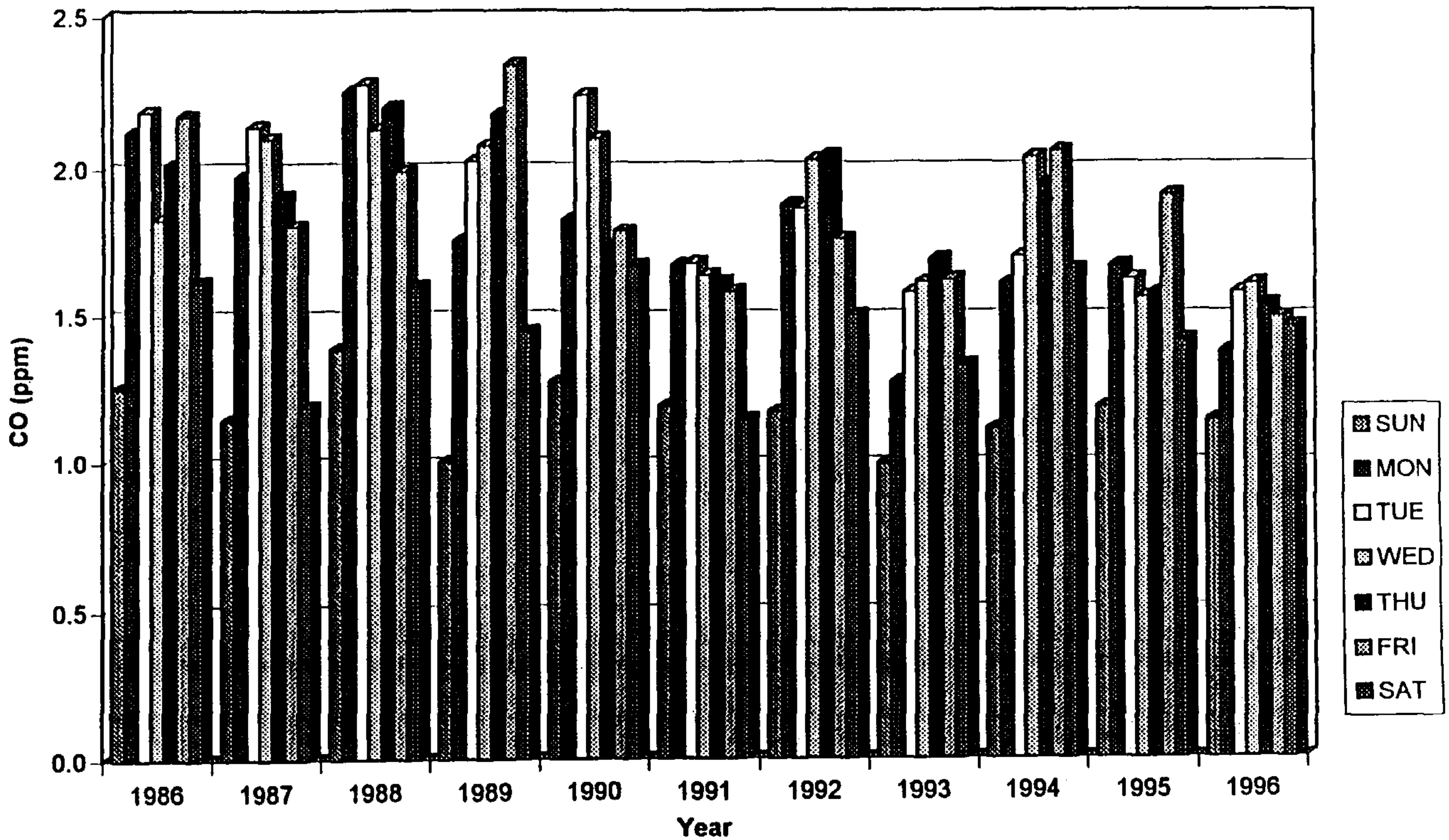

Figure 7-17. Ambient 0600-0900 PDT CO by day-of-the-week for Los Angeles County (except Lancaster) sites, May-September 1986-96.

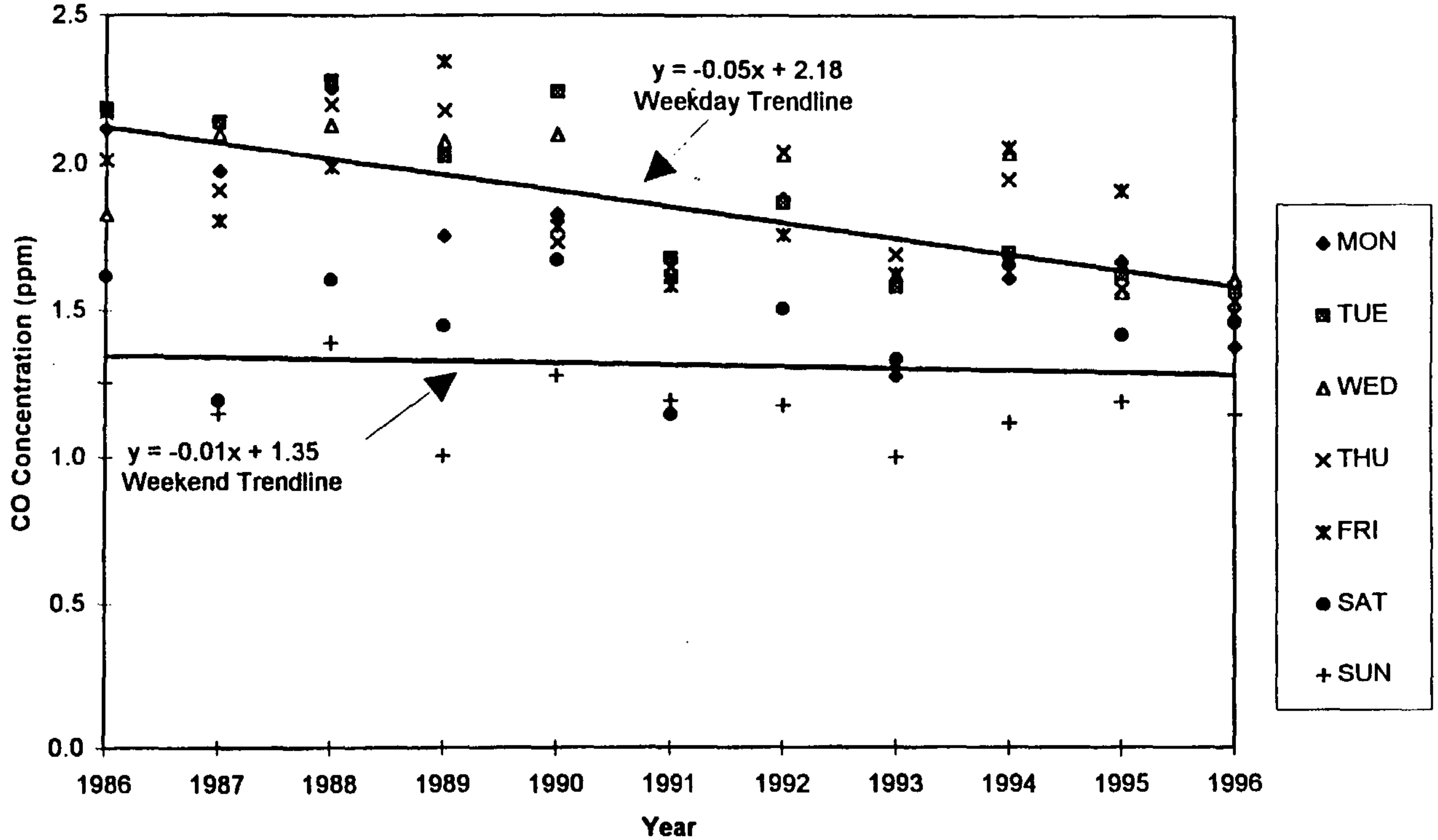

Figure 7-18. Ambient weekday/weekend 0600-0900 PDT CO concentration for Los Angeles county sites, May-September 1986-96.

morning hours has decreased steadily, weekend (Saturday/Sunday average) ambient CO does not show a similar trend over the eleven-year period. Interestingly, both weekday and weekend 0600-0900 PDT ambient CO concentrations appear to cycle by year which is consistent with results found by Fujita (1994) in evaluating ambient CO for the June through August period for the years 1987-93.

We next examined the growing contribution of weekend ambient CO to the seven-day weekly average for all 21 SoCAB sites which monitor CO. Here, the daily mean concentrations were normalized to the weekly average. Figure 7-19 shows the normalized CO contribution from each day-of-the-week to the average weekly concentration for each year. Saturday 0600-0900 PDT average ambient CO has increased relative to the weekly 0600-0900 PDT average CO concentration from approximately 80% to greater than 90% of the weekly average for the eleven-year period studied.

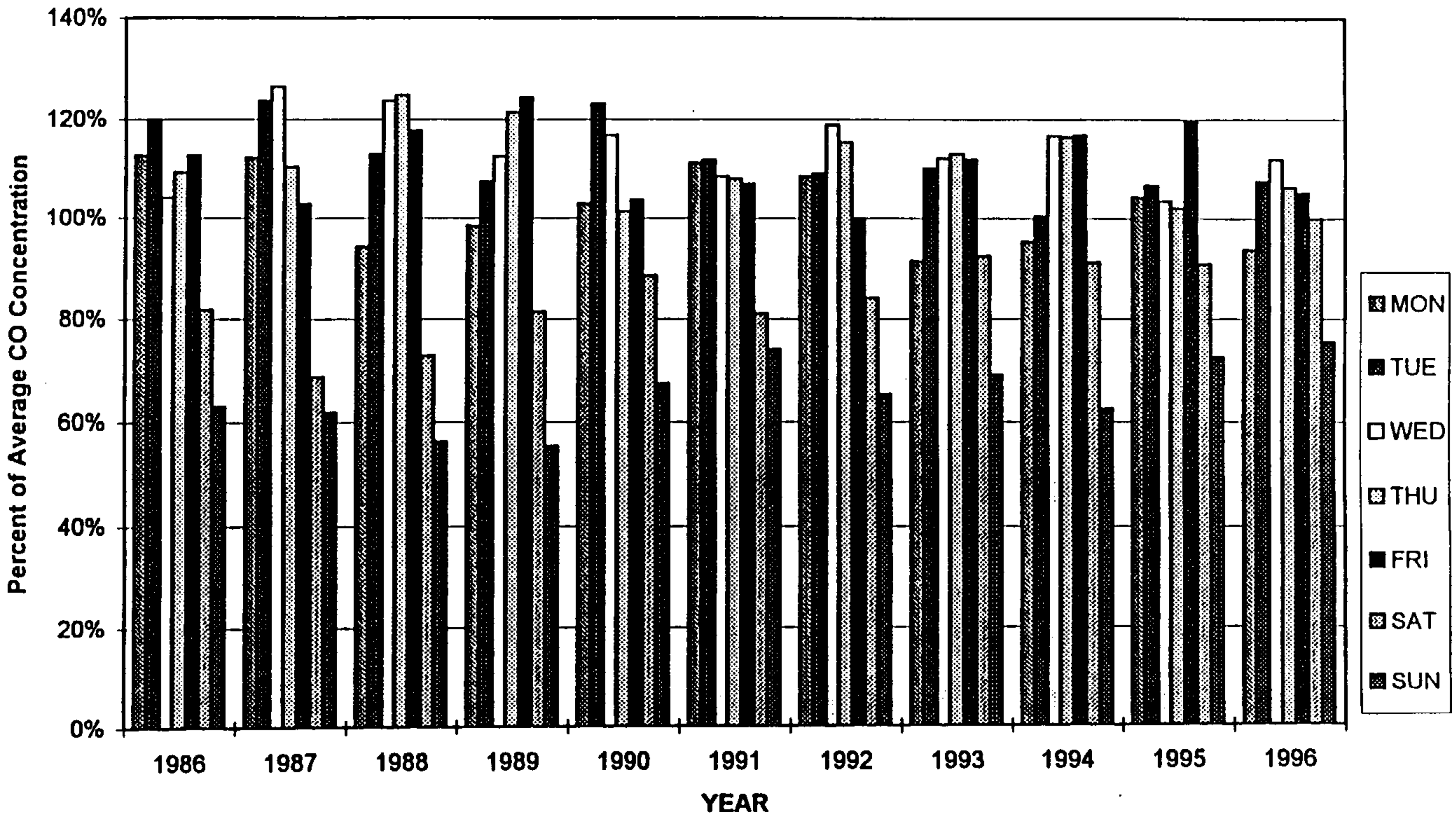

Figure 7-19. SoCAB normalized day-of-the-week ambient 0600-0900 PDT CO for May-September 1986-96.

8.0 SUMMARY AND CONCLUSIONS

The principal findings and conclusions of this study are summarized in brief below. See the corresponding report sections for detailed discussions.

8.1 Analysis of Weekday/Weekend Differences in Ambient Air Quality

- There may have been a stronger carryover effect of Friday evening NO_x on Saturday's Basin-maximum ozone than of Tuesday evening NO_x on Wednesday's Basin-maximum ozone.

- For the 1986-96 smog seasons, our results suggested a modest carryover effect of Friday evening NO_2 emissions from the Coastal/Metropolitan and San Gabriel Valley subregions on the daily ozone maximum, either within the subregion itself or in the Basin as a whole.

- In general, our results tended to confirm the findings in Phase I of this study that morning (0600-0900) NO_2 in the Coastal/Metropolitan and San Gabriel Valley correlates best with the ozone maximum in the same subregion, and that Coastal/Metropolitan NO_2 no longer correlates well with the afternoon Basin ozone maximum (if it ever did).

- The spatial variation in location of the daily SoCAB-maximum hourly-average ozone concentrations was investigated in order to characterize possible day-of-the-week effects. There was a tendency for the daily SoCAB-maximum ozone concentration to occur farther west on weekends.

- To determine day-of-the-week differences in ambient concentrations of NMHC, NO_x, and peak ozone, we adopted methods similar to those used by Tran et al. (1996), focusing on the 1994-95 period they did not analyze in their earlier study. In general, these results suggest that temporary reductions in ozone-precursor concentrations coincide with increases in weekend Basin peak ozone levels. However, based on our eleven-year trend analysis, ozone levels in the SoCAB have substantially decreased, coinciding with a decrease in both NO_x and NMHC ambient concentrations. Therefore, the transitory nature of the "weekend effect" does not provide evidence that further reduction of the NOx emission inventory will produce a corresponding increase in ambient ozone concentrations.

- Basinwide concentrations of both NO_x and NMHC decreased approximately 20 percent for July through September in 1996 over 1995. At least some of this decrease, especially for NMHC, can be attributed to the introduction of California Phase 2 reformulated gasoline.

8.2 Investigation of Anthropogenic Influences on Day-of-the-Week Variations in SoCAB Meteorological Conditions

- In 85 of the 88 cases examined, the weekday temperature was warmer than the weekend temperature, while in just 3 cases the weekend temperature was warmer than the weekday temperature. It thus appears there may have been a small difference in temperature between weekdays and weekend days that could be associated with anthropogenic influences. However, the weekday/weekend temperature difference found by this analysis was very small; in fact, the values were much smaller than the corresponding standard deviations. Thus while we have found evidence for an anthropogenically-produced difference in micrometeorological conditions between weekdays and weekend days in the SoCAB, the statistical robustness of the result would appear to be limited. In addition, the small magnitudes of the temperature differences suggest that any feedback on SoCAB air pollution levels will be exceedingly small. Nonetheless, the result is certainly of general scientific interest, and to our knowledge is the first ever obtained that suggests the presence of an anthropogenically-produced weekday/weekend variation in microscale meteorological conditions in the SoCAB. Ultimately, we conclude that if a day-of-the-week temperature effect does exist in the SoCAB, it is quite weak and therefore not likely to be of particular importance to air quality management efforts.

- A gradual increase in the mean smog season daily-maximum temperature during the 1949-94 period of about 2 °F can be observed for both weekdays and weekends at Los Angeles Civic Center. This suggests that the urban heat island effect intensified during the period of investigation. However, there did not appear to exist a clear day-of-the-week temperature effect at the Los Angeles Civic Center during the 1949-94 smog seasons.

- We have examined relative humidity data for an anthropogenic weekday/weekend effect. Although our results indicated a slight average increase in relative humidity on weekends (0.4%), unlike the temperature analysis there was no consistency in sign either between the various stations or the different times of day. In addition, the standard deviations were much larger than the weekday/weekend relative humidity differences. Thus no day-of-the-week signal was evident for relative humidity.

- Given that day-of-the-week differences in air quality have been documented in the SoCAB, it was hypothesized that there could be a detectable variation in anthropogenic influence on visibility. We thus analyzed SCAQMD hourly-average b_{scat} data. There was a slight tendency for lower visibility days to occur most often on Friday or Saturday at Azusa during the period 15 June to 15 September 1992-94. This result was consistent with our work in the previous phase of the present project, where it was shown that Saturday was the favored day for high ozone episodes in the SoCAB.

- We reasoned that if there were an anthropogenic influence on visibility, the signal might be detectable as a day-of-the-week variation in solar radiation intensity. At Pico Rivera, the mean radiation intensity was found to be slightly lower on weekdays (Tuesday/Wednesday) than on weekend days (Saturday/Sunday) for each of the four hours examined. However, this result was not statistically significant, since the standard deviations were much larger than the difference of the means between weekdays and weekends.

8.3 Trends in Ozone and Ozone-Precursor Ambient Concentrations

- We examined ozone-precursor trends over the eleven-year period 1986-96 and found an overall modest decrease in 0600-0900 PDT and 2100-0000 PDT Basinwide ambient NO_x and NO_2 concentrations from 1986 to 1996, with a more dramatic decrease from 1995 to 1996.

- Examination of 0600-0900 PDT Basinwide ambient NMHC concentration from 1986 to 1995 revealed a pronounced decreasing trend. A general decrease in 0600-0900 PDT NMHC over the ten-year period from 1986 to 1995 for all days of the week was observed.

- We examined the incidence and distribution of various ozone concentrations for 1986-1996. The general trend during the 1986-95 period was toward an increasingly lower number of hours and days of exceedance, at all concentration levels. In particular, there has been substantial reduction in number of hours of *peak* ozone levels (i.e., hours with ozone concentrations at or above 20 pphm).

- At Crestline, slight decreases (from about 1300 hours of exceedance per year for 1986-89 to about 1200 hours of exceedance per year for 1990-94) were followed by a sudden discontinuous drop to a much lower value (751) in 1995.

- The percent change (from year-to-year) in number of smog season hours equal or exceeding the ozone NAAQS was computed for three groups of four sites each within the SoCAB for the period 1986-96. A dramatic reduction in this metric occurred for the four mid-Basin sites between 1995 and 1996, coinciding with the introduction of RFG Phase II. [ARB data analysis on RFG Phase II has shown that although there were benefits for the rest of California, many basins other than the SoCAB had higher ozone concentrations in 1996 than in 1995.]

- The 1995 smog season was slightly cooler than the 1961-90 mean, while 1996 was slightly warmer than the long-term average. With the exception of May and June of 1995, the 1995-96 smog seasons appear to have recorded near or above normal surface temperatures in the central and eastern portions of the SoCAB. These conditions would seem to favor normal to above normal photochemical smog production rates [warmer SoCAB surface temperatures are associated with higher ozone concentrations (Blier and Winer 1996)]. This conclusion also follows from analysis of gridded 850 mb temperatures at a grid point near the SoCAB which showed near or above normal temperatures for the 1995-96 smog seasons (except during May-June 1995 and September-October 1996, which were cooler than the 1985-96 mean climatological values). Since a substantial *decrease* in the number of ozone exceedances was reported in the San Gabriel Valley (SGV) from 1995 to 1996, and since this decrease was not likely due to meteorological variability, there appears to be evidence of a significant reduction in SGV ozone during the 1995-96 smog seasons resulting from non-meteorological factors. This result is consistent with the substantial decrease in NMHC and NO_x ambient morning concentrations seen for 1996. [It should be noted that conclusions regarding cooler or warmer temperatures in the SoCAB did not include maximum temperatures or maximum solar radiation].

8.4 Exploratory Studies

8.4.1 Analyses of Distribution of High and Middle Ozone Days: 1986-96

- High ozone days tended to occur mostly during the middle four months of the smog season, while middle ozone days were more broadly distributed.

- There appeared to be a trend towards decreasing incidence of high ozone days in September and October, though the degree of similarity in the meteorological conditions has not yet been determined.

- The day-of-the-week distribution of the highest ozone days for 1986-89, 1990-93, and 1994-96 showed a monotonic increase from Sunday to Saturday.

8.4.2 Analyses Using Gridded Meteorological Data

- A strong west coast ridge and an offshore trough at 500 mb were associated with high SoCAB ozone episodes during the eleven-year period 1986-96.

- On average, the 500 mb ridge over the western United States and Canada shifted slightly eastward during the 36-hour period leading up to the afternoon of occurrence of a high ozone event.

- The maximum correlation coefficient between SoCAB-maximum ozone concentrations from the 1994-96 smog season days and the corresponding objectively-analyzed 1700 PDT same day 850 mb temperatures was 0.82 and occurred in the region of the SoCAB. Similarly-calculated values for the 1986-89 and 1990-93 smog seasons were 0.83 and 0.84, respectively.

9.0 RECOMMENDATIONS FOR FUTURE RESEARCH

Because of the prevailing nature of Saturdays (Figure 1-2) in the weekend weekday phenomenon, a better characterization would be the day-of-the-week phenomenon.

Based upon the present project we recommend the following future research: development of an improved quantitative relationship between SoCAB ozone concentration and meteorology; determination of ozone trends for meteorologically similar episodes; and examination of mesoscale airflow trajectories for SoCAB high ozone episodes through simulation with a high-resolution nonhydrostatic mesoscale model. Our specific and detailed suggestions are as follows.

Control strategy evaluation is dependent upon an understanding of how reliably airshed models can predict changes in air quality resulting from decreased emissions. Assessment of the accuracy of the airshed model predictions requires comparison with observed decreases in ozone concentration over a time interval during which significant reduction in emissions has occurred. However, since the observed ozone concentration results from a combination of emissions of precursor pollutants and the meteorological conditions, determination of the accuracy of the model predictions necessitates removing meteorological variability. To do so requires a means of robustly determining the meteorological similarity with respect to ozone formation.

Varieties of approaches have previously been used to relate peak ozone concentrations in the SoCAB to the meteorological conditions. At present, however, none appear to offer significant advantage over the simple linear relationships that have been developed between ozone concentration and 850 mb temperature. These relationships, though, described at most one-half to two-thirds of the (largely-meteorological) variance. It is therefore recommended that research be undertaken to develop more sophisticated ozone-meteorology relationships; these can then be used to develop air quality trends for meteorologically similar episodes over a wide range of years.

Also critical to the understanding of precursor transport and ozone development in the SoCAB is the determination of the three-dimensional parcel trajectories in various high-ozone episodes. Under the influence of the complex topography of the region, however, the airflow is complex and not resolvable from routinely available meteorological observations. It would therefore be desirable to determine airflow trajectories in South Coast Air Basin high ozone episodes through simulation with a high-resolution nonhydrostatic mesoscale model.

Most numerical model simulations thus far performed for the region of the SoCAB have used models that can only be started from an idealized initial state, rather than from a particular initial state as determined by objective-analysis of the observational data. Thus most previous model studies of the SoCAB show idealized airflow rather than the actual airflow associated with a particular pollution episode. Numerous previous high-resolution applications of the numerical model that is recommended for this research [the National Center for Atmospheric Research Mesoscale Model Version 5 (NCAR MM5)] demonstrate its capability of starting from a well-represented synoptic-scale initial state and accurately reproducing the very-high-resolution mesoscale circulations that develop as a result of interaction with the topography. (Nonhydrostatic simulations with this model have been successfully conducted at horizontal resolutions of less than 1 km.)

A reasonable approach would start with the selection of high ozone episodes that occurred during SCAQS, SCOS97, and other field programs with intensive meteorological and air quality observations for simulation with the NCAR MM5 – both to better understand the three-dimensional transport that occurred during these episodes, and to take advantage of the high density of observational data to verify the capability of the mesoscale model. Once the accuracy has been demonstrated, the model could then be used to examine the airflow and atmospheric structure associated with select additional high ozone episodes for which only routine meteorological observations are available.

An accurate Saturday and Sunday emission inventory is a fundamental requirement for air quality simulation and for general understanding of the day-of-the-week phenomenon. The traffic counts collected during the SCOS97 and further projects in refining RECLAIM and the day-specific emission inventories' data collected during the SCOS97 would contribute to this requirement. ARB is actively engaged in this work.

To study the three-dimensional nature of the carry-over effects, three-dimensional meteorological and specialty (non-routinely measured species) air pollutant data is needed. Such data are available from the SCOS97 and from southern California studies in 1995 (Transport Corridors Study) and 1992, and from SCAQS (1987).

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