

FIGURE 3-13. Forward trajectory from San Jose on 5 August 1990 at 0700 PST.

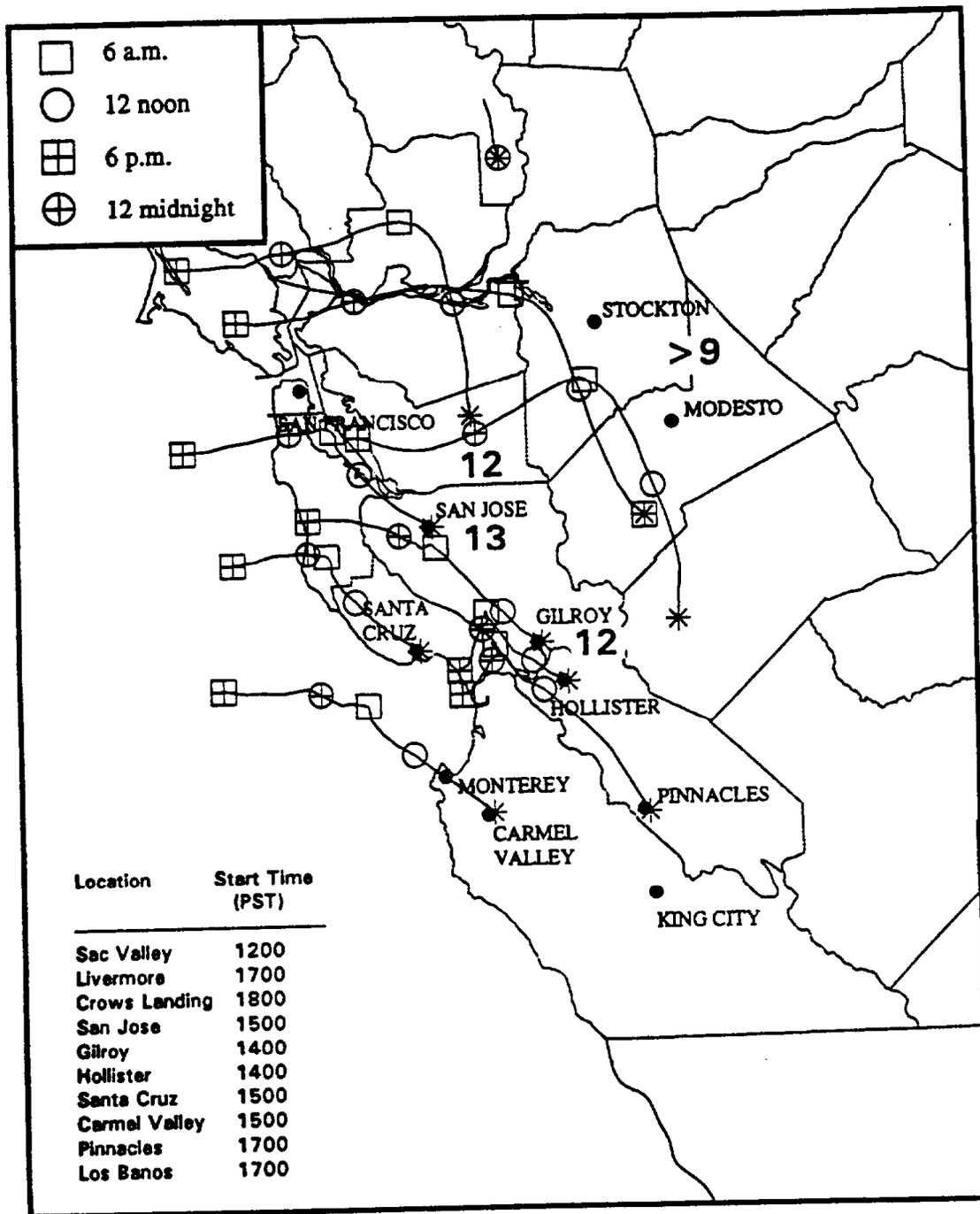


FIGURE 3-14. Backward trajectories from various locations and start times on 10 July 1990. Exceedance ozone concentrations (pphm) are shown on the map. These trajectories resemble northwesterly flow with convergence.

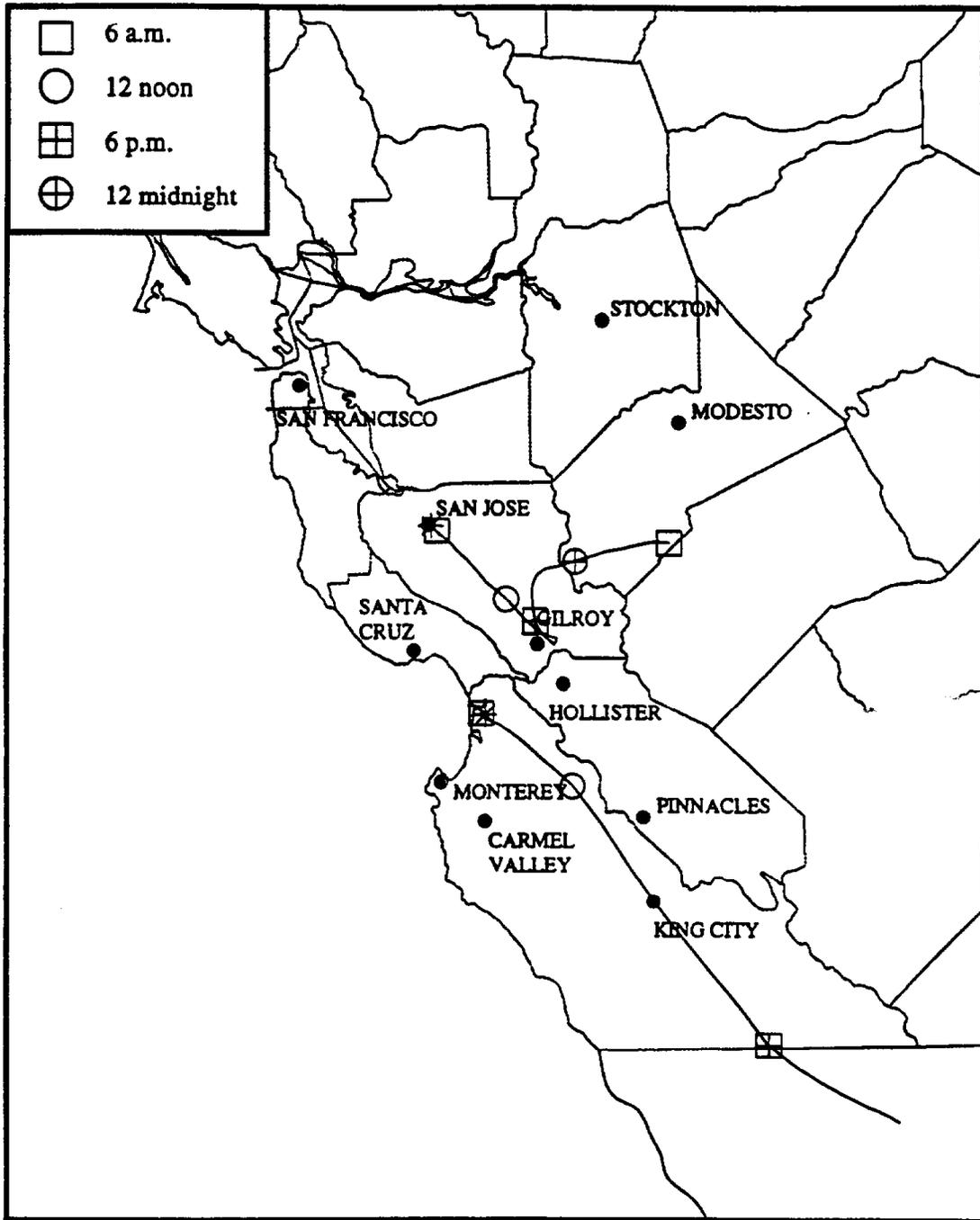


FIGURE 3-15. Forward trajectories from Moss Landing and San Jose on 10 July 1990 beginning at 0500 PST.

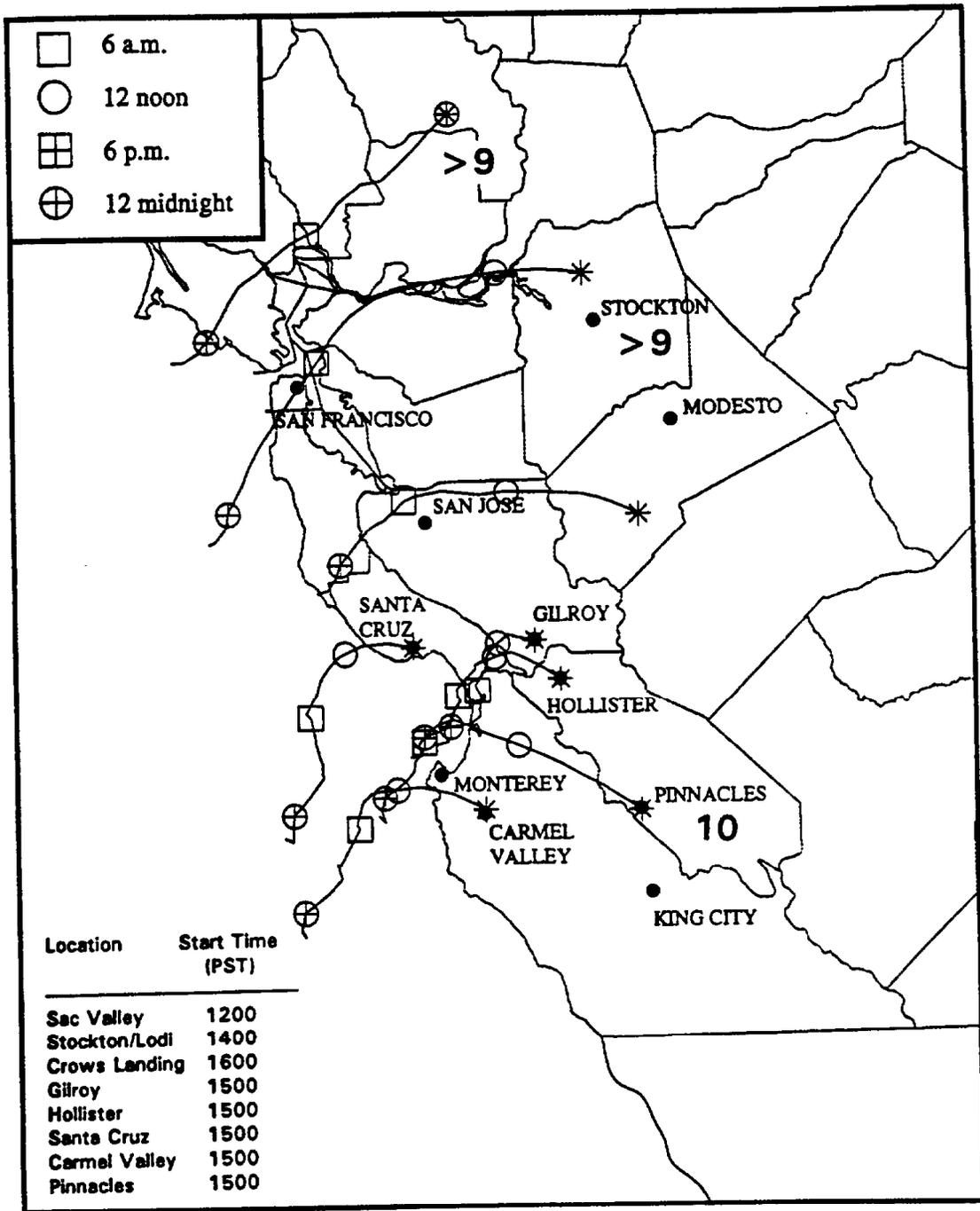
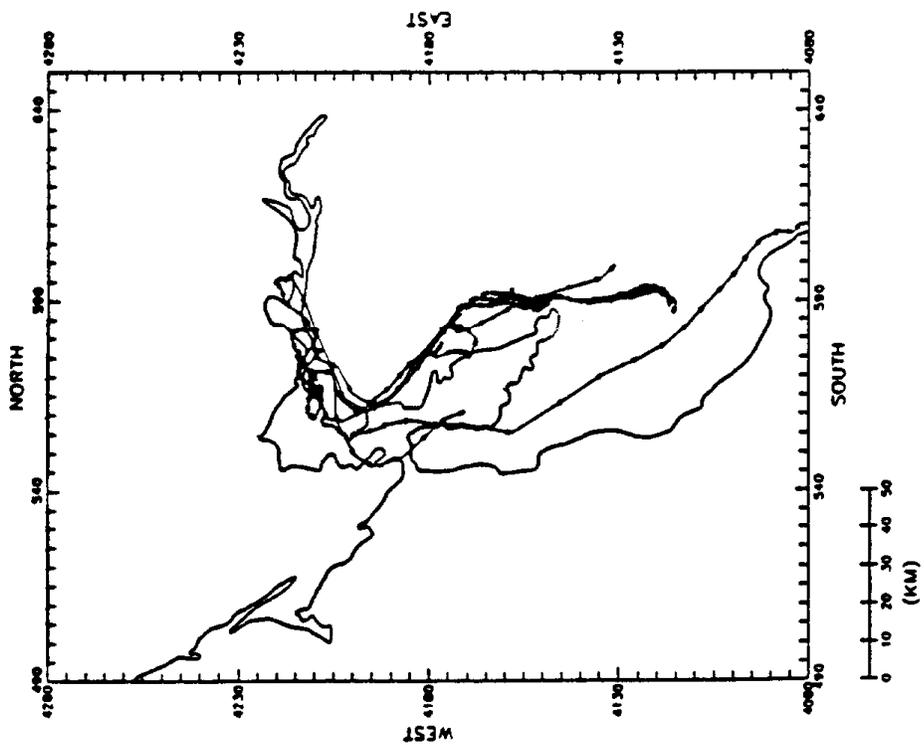
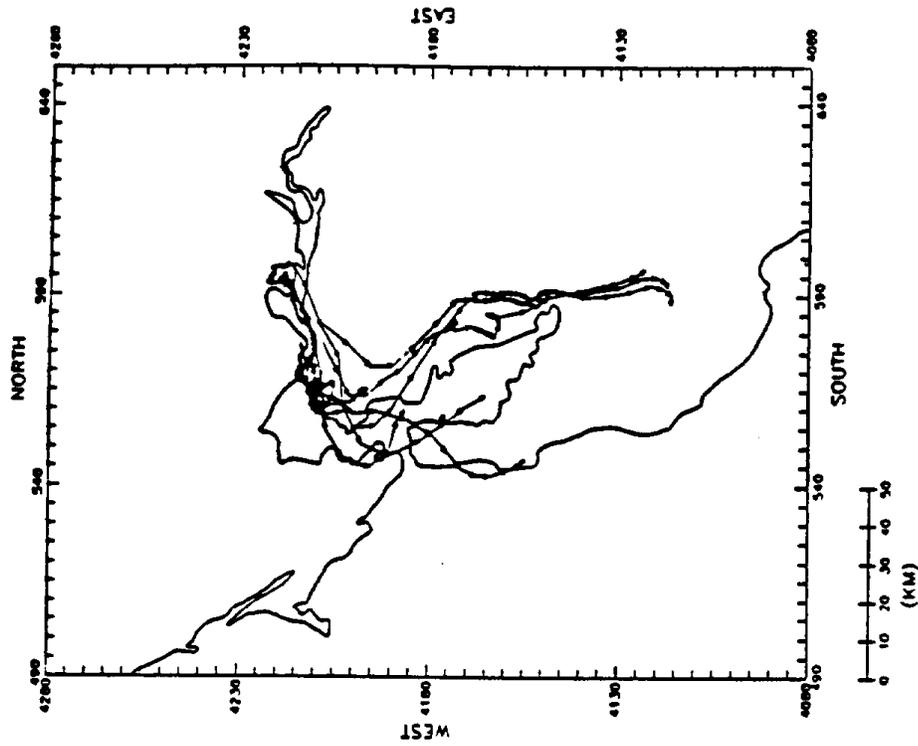


FIGURE 3-16. Backward trajectories from various locations and start times on 7 August 1990. Exceedance ozone concentrations (pphm) are shown on the map. These trajectories resemble southerly flow.

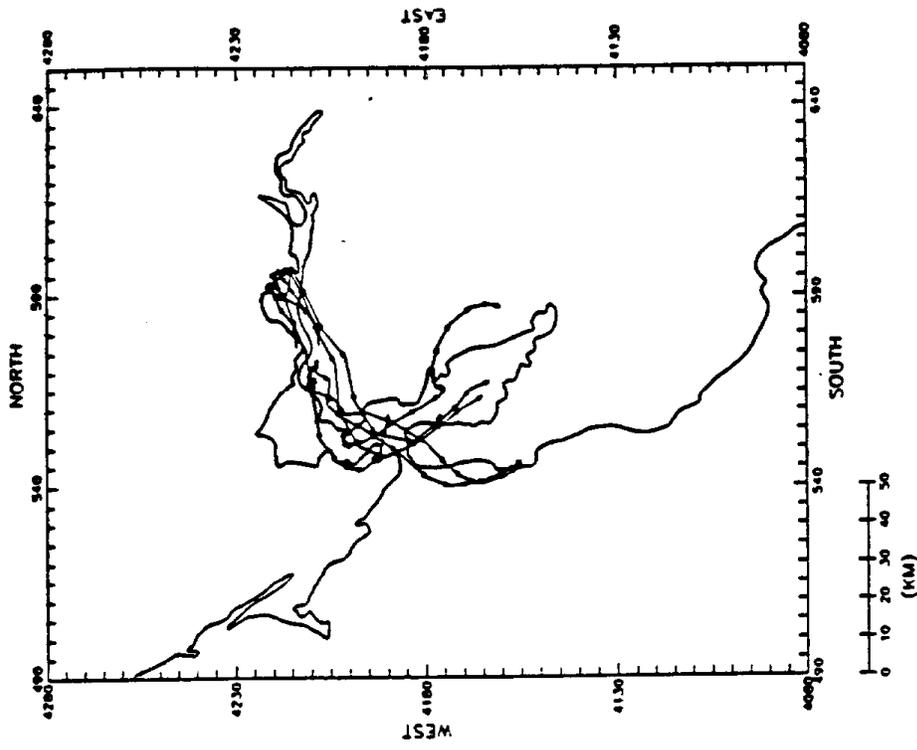


(a) 30 September 0600 PST

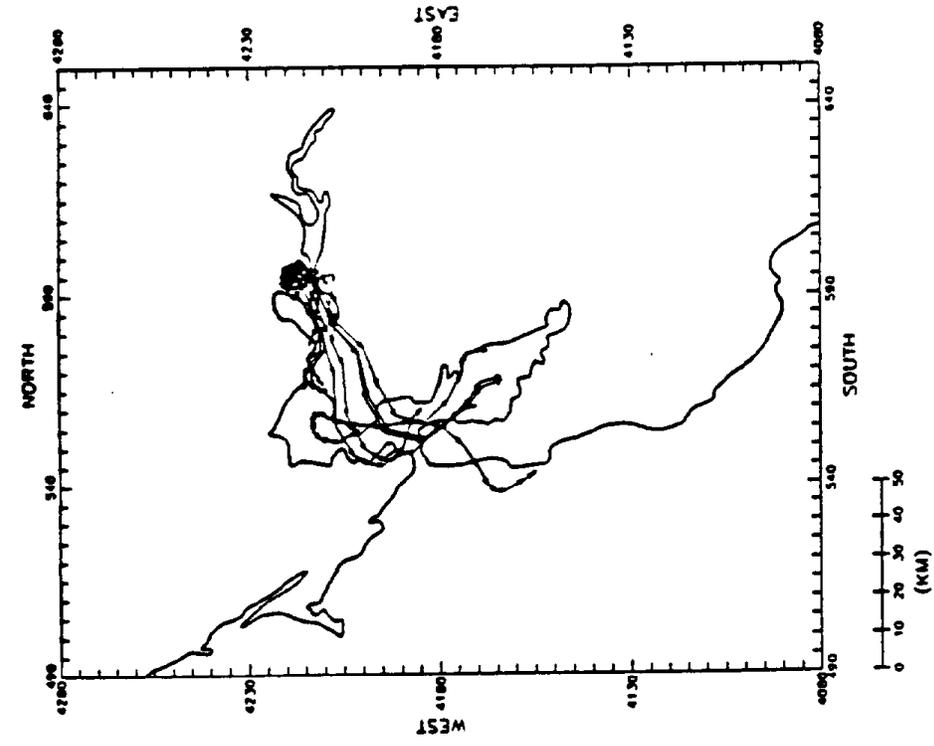


(b) 30 September 1200 PST

FIGURE 3-17. Forward trajectories initiated in the Carquinez Straits on 30 September and 1 October 1980 at various times (Douglas et al., 1989). These trajectories resemble northeasterly flow. Each arrow represents one hour.

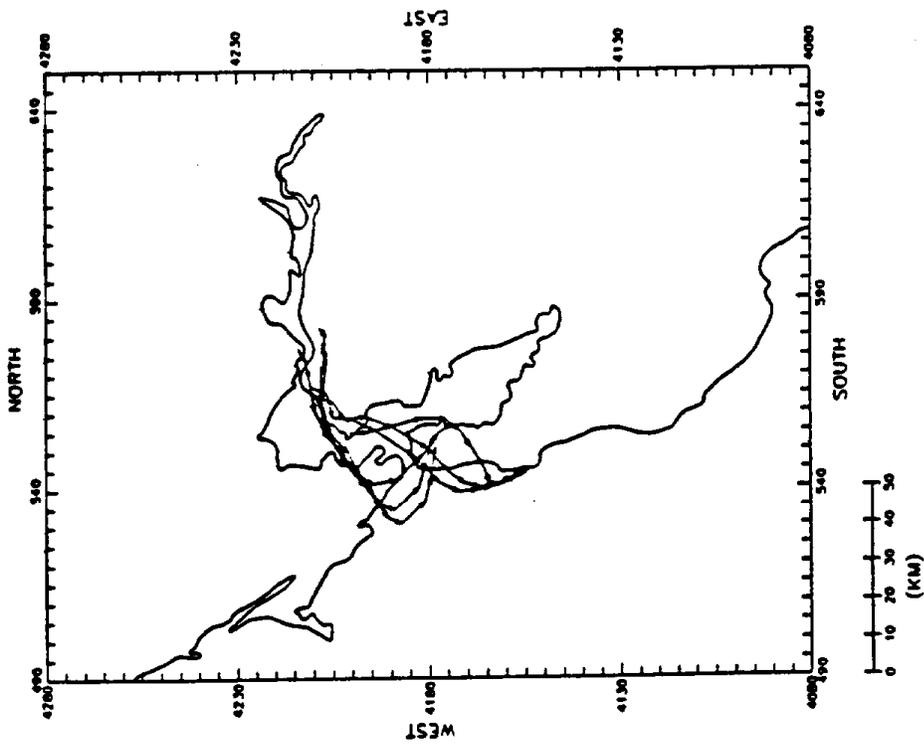


(c) 30 September 1800 PST

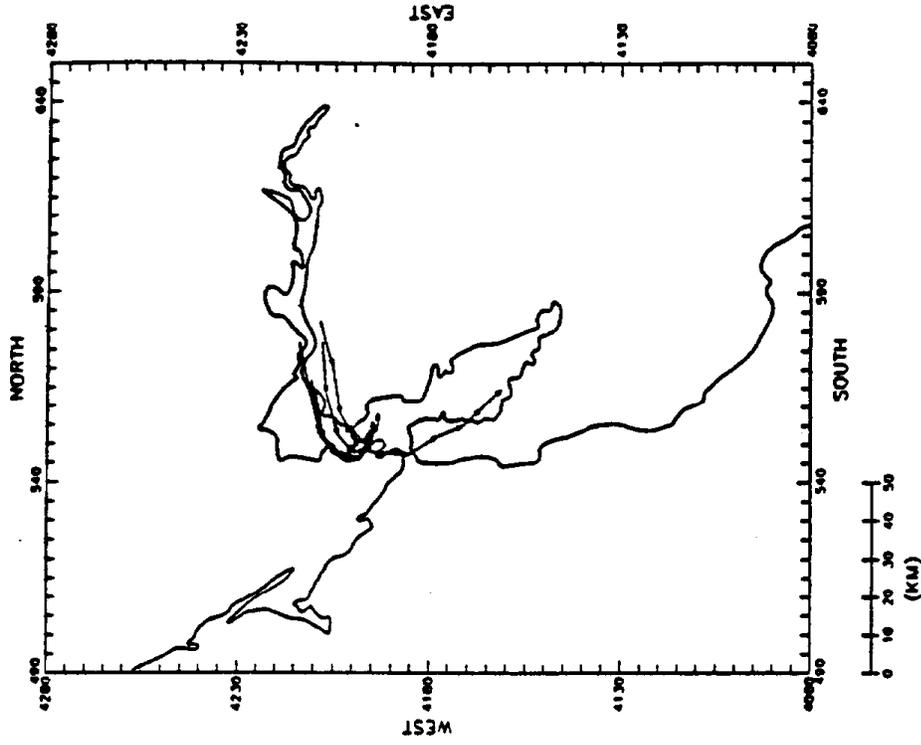


(d) 1 October 0000 PST

FIGURE 3-17. Continued.



(e) 1 October 0600 PST



(f) 1 October 1200 PST

FIGURE 3-17. Concluded.

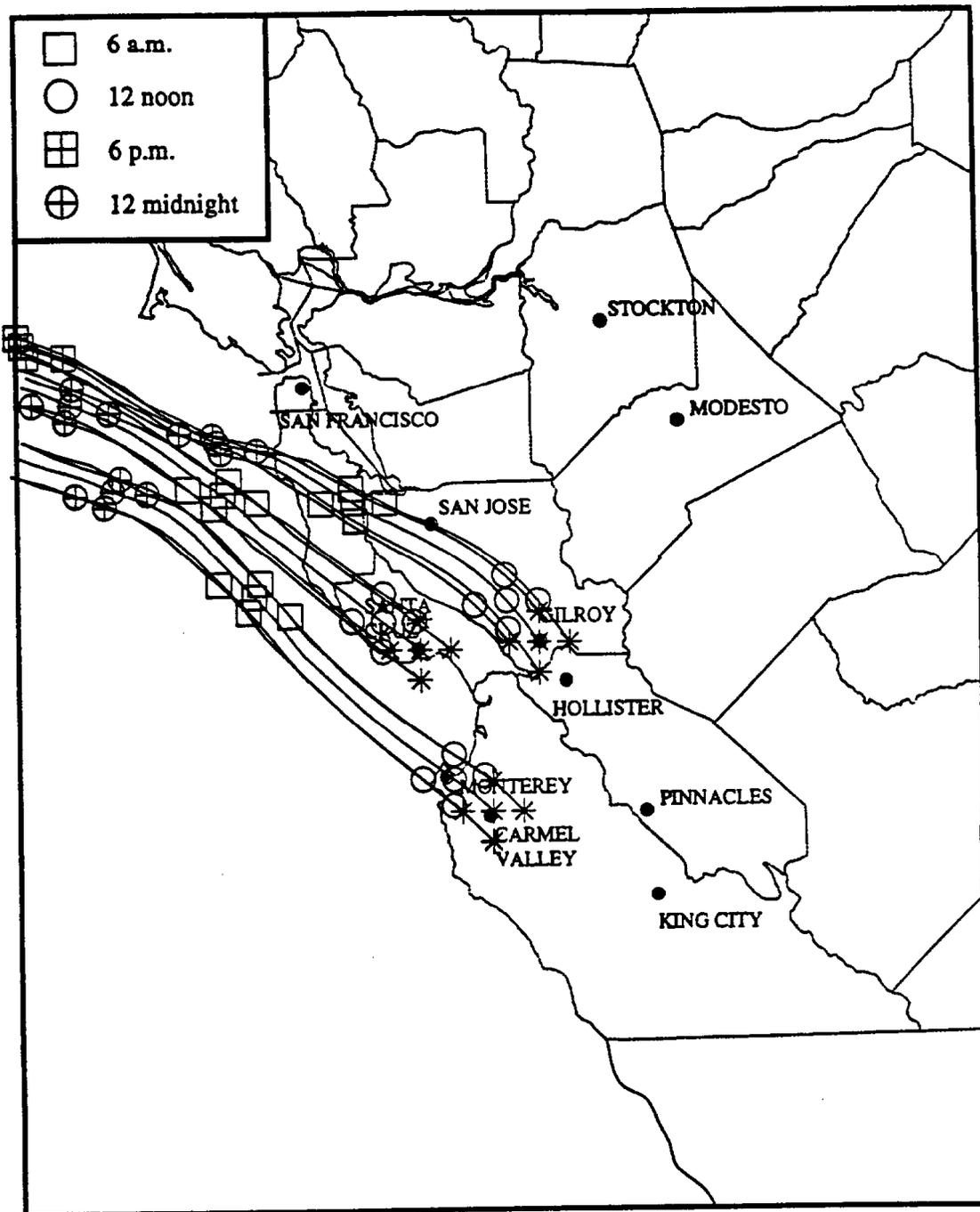


FIGURE 3-18. Backward trajectories from Gilroy, Santa Cruz, Carmel Valley, and locations 10 km to the east, west, north, and south of these locations beginning on 12 July 1990 at 1300 PST.

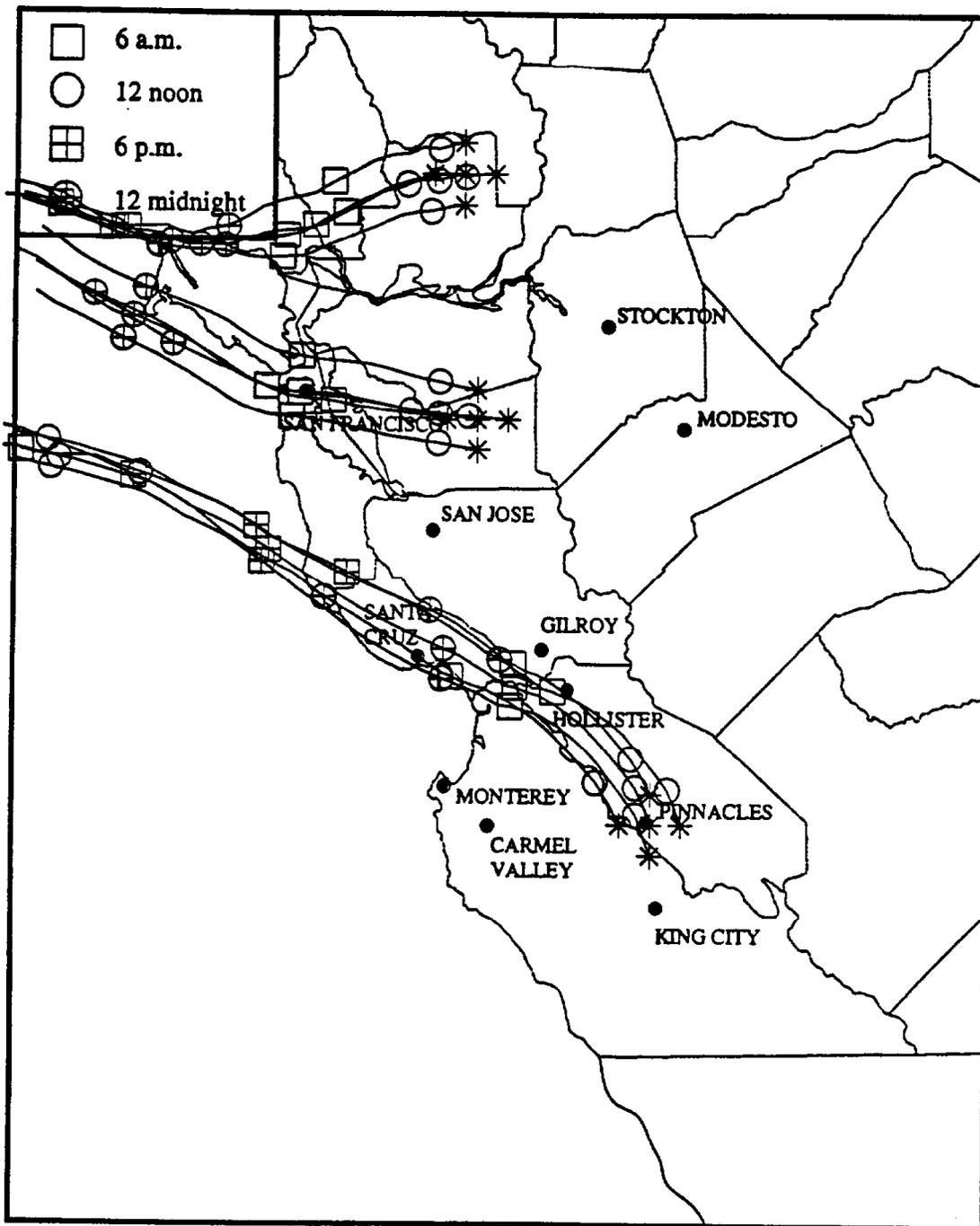


FIGURE 3-19. Backward trajectories from Pinnacles, Livermore, the Sacramento Valley, and locations 10 km to the east, west, north, and south of these locations beginning on 12 July 1990 at 1300 PST.

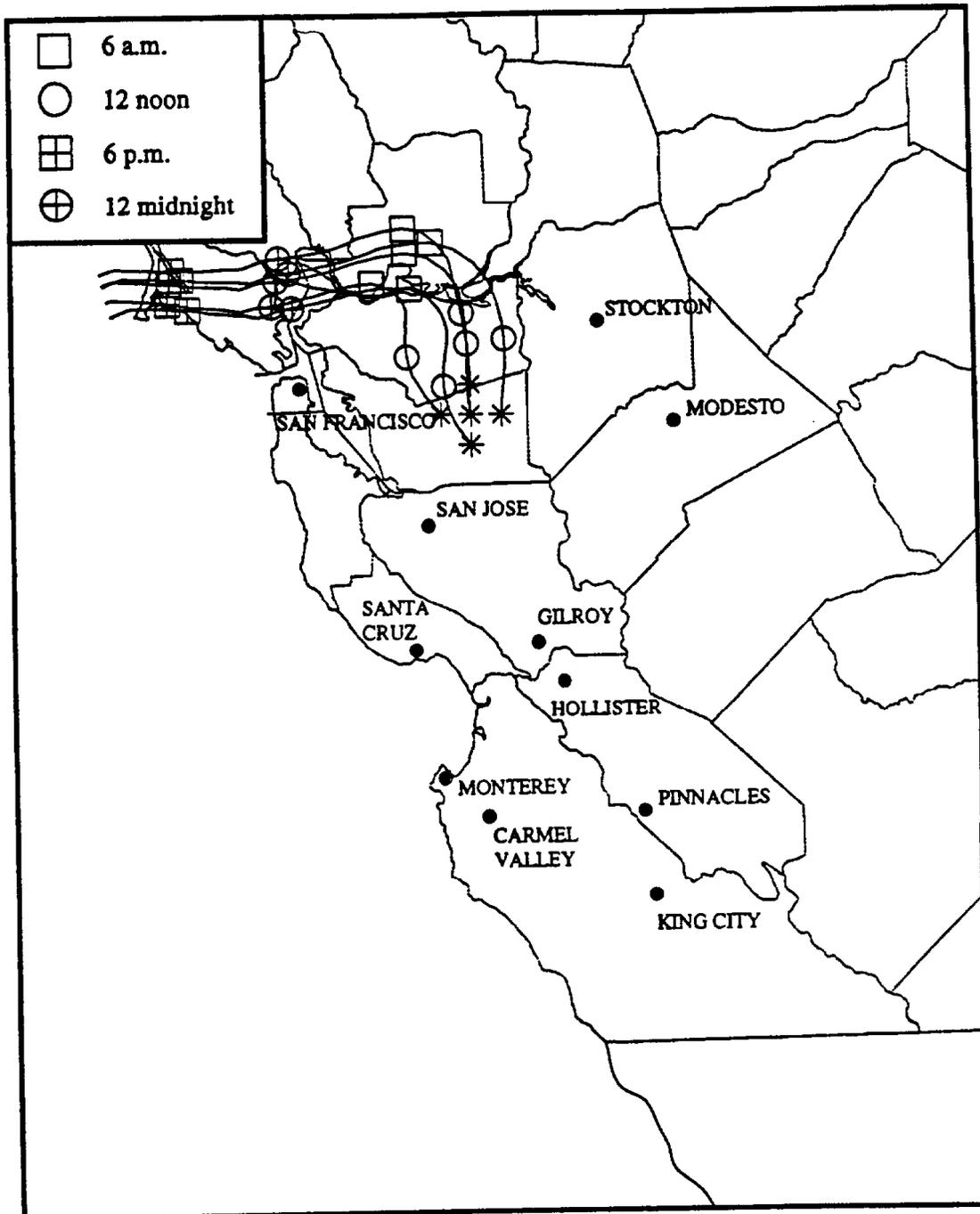


FIGURE 3-20. Backward trajectories from Livermore and locations 10 km to the east, west, north, and south of Livermore beginning on 10 July 1990 at 1500 PST.

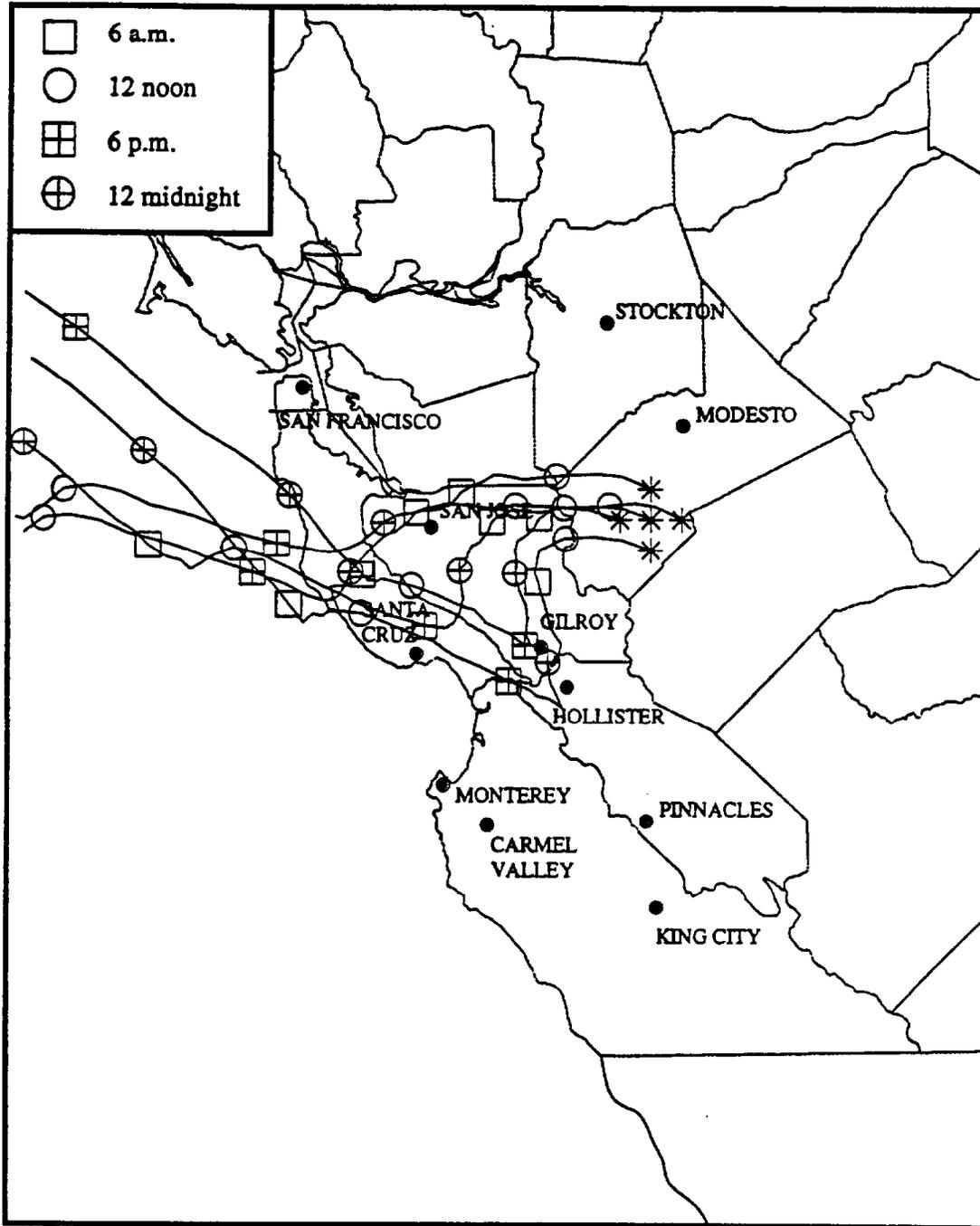


FIGURE 3-21. Backward trajectories from Crows Landing and locations 10 km to the east, west, north, and south of Crows Landing beginning on 7 August 1990 at 1500 PST.

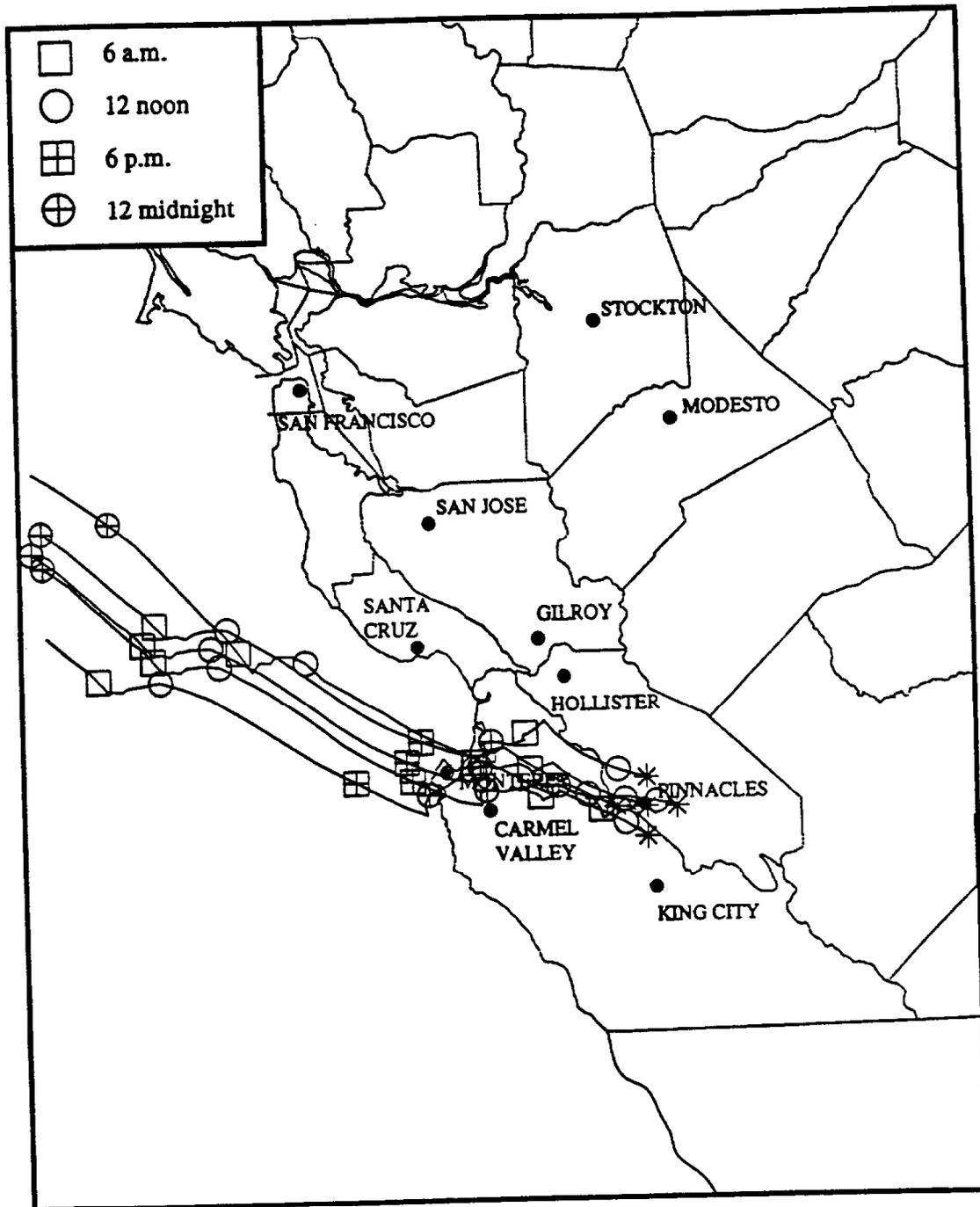


FIGURE 3-22. Backward trajectories from Pinnacles and locations 10 km to the east, west, north, and south of Pinnacles beginning on 7 August 1990 at 1300 PST.

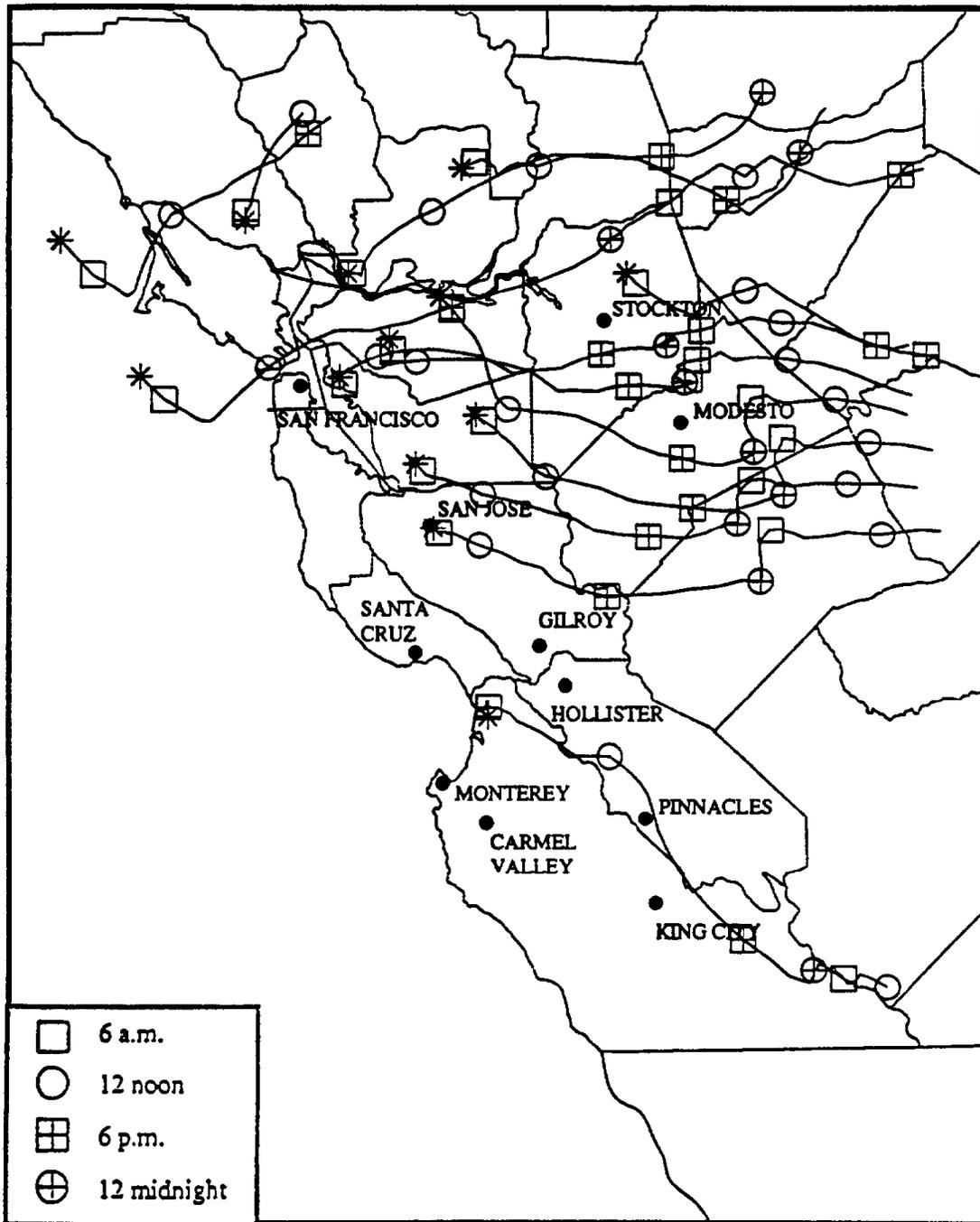


FIGURE 3-23. Backward trajectories from several locations on 6 August 1990 beginning at 0500 PST.

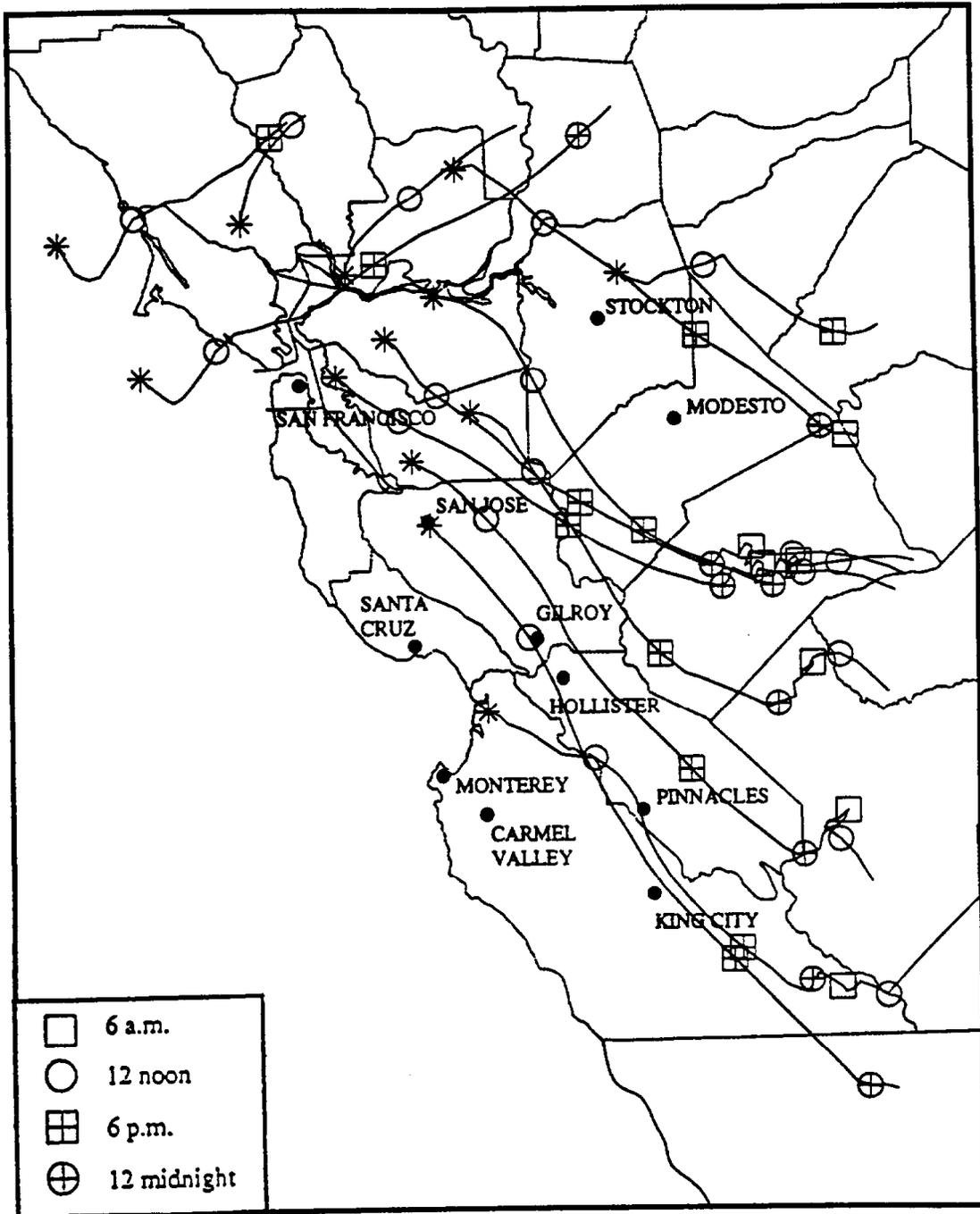


FIGURE 3-24. Backward trajectories from several locations on 6 August 1990 beginning at 0700 PST.

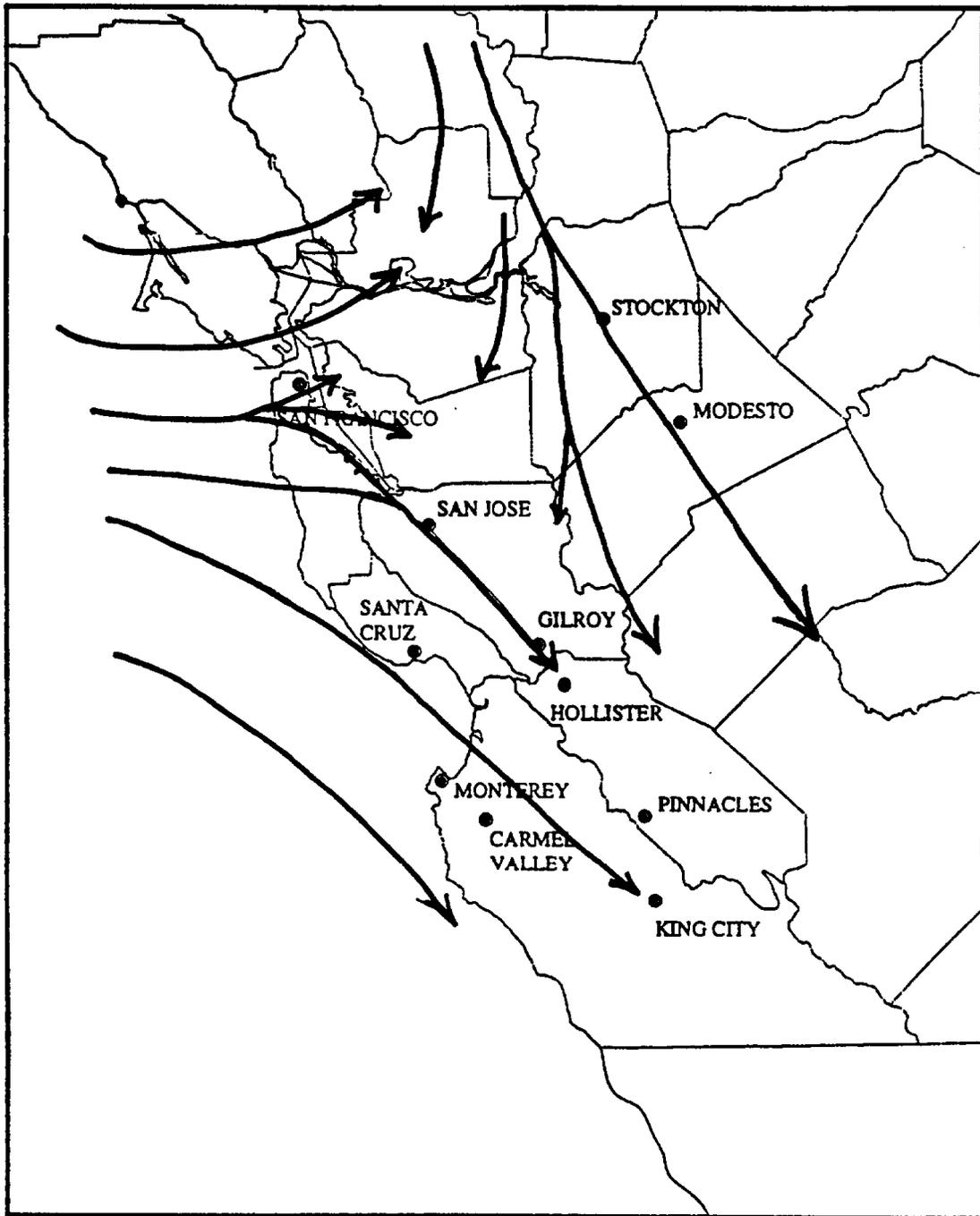


FIGURE 3-25a. Wind flow diagram based on supplementary data for 20-21 June 1989 (Northeasterly): 1600 PST, 20 June 1989.

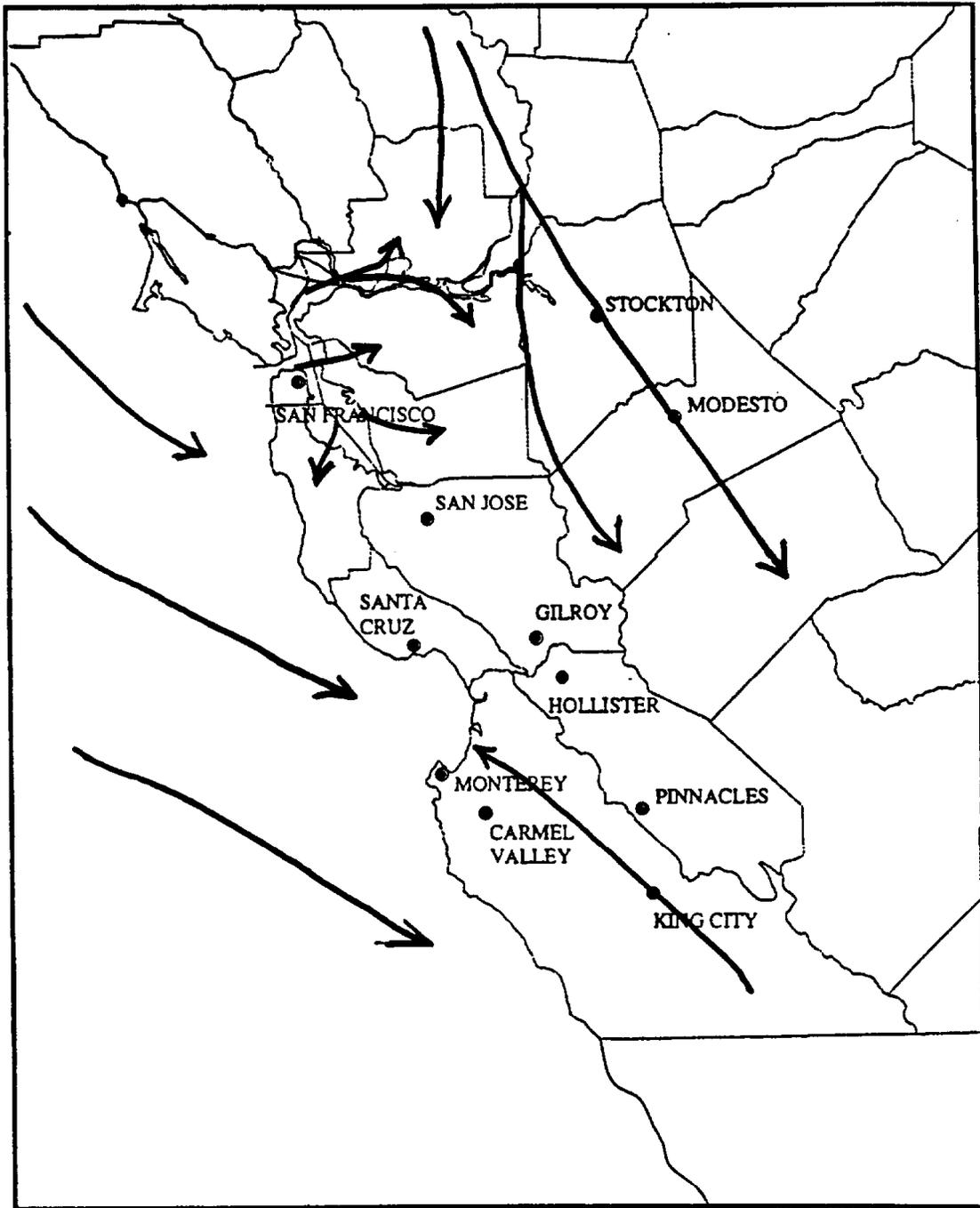


FIGURE 3-25b. Wind flow diagram based on supplementary data for 20-21 June 1989 (Northeasterly): 0400 PST, 21 June 1989.

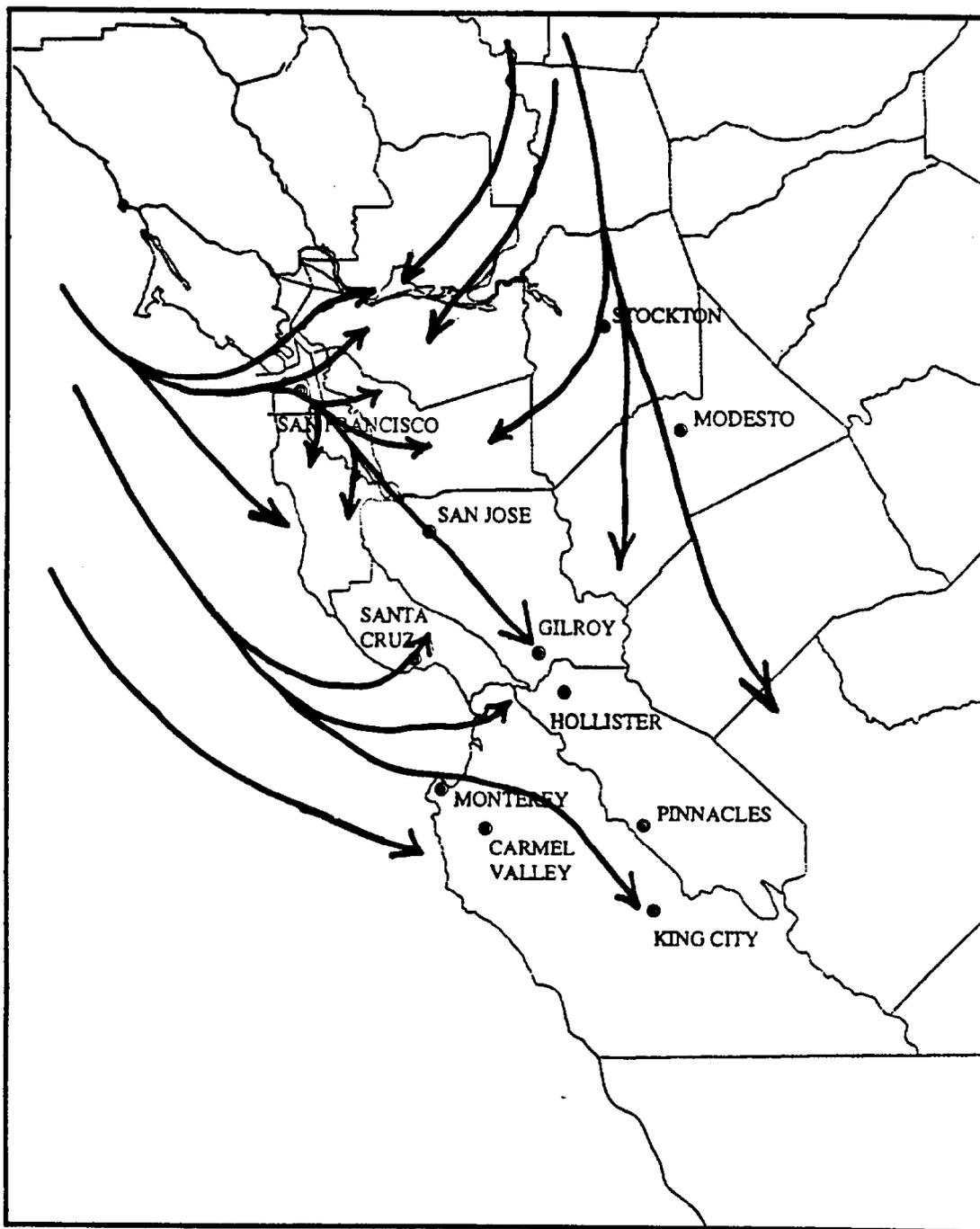


FIGURE 3-25c. Wind flow diagram based on supplementary data for 20-21 June 1989 (Northeasterly): 1000 PST, 21 June 1989.

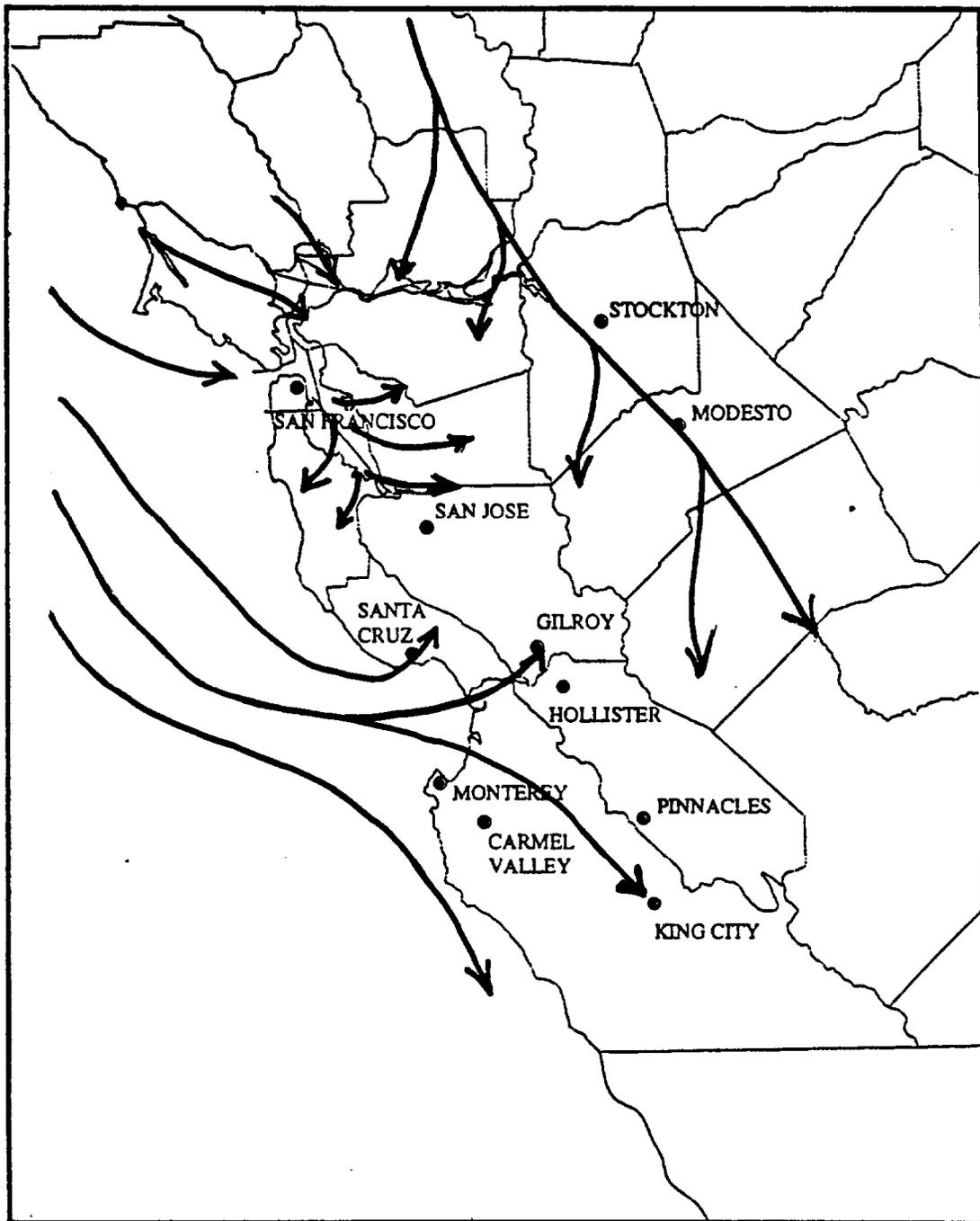


FIGURE 3-26a. Wind flow diagram based on supplementary data for 17-18 October 1989 (Northeasterly): 1600 PST, 17 October 1989.

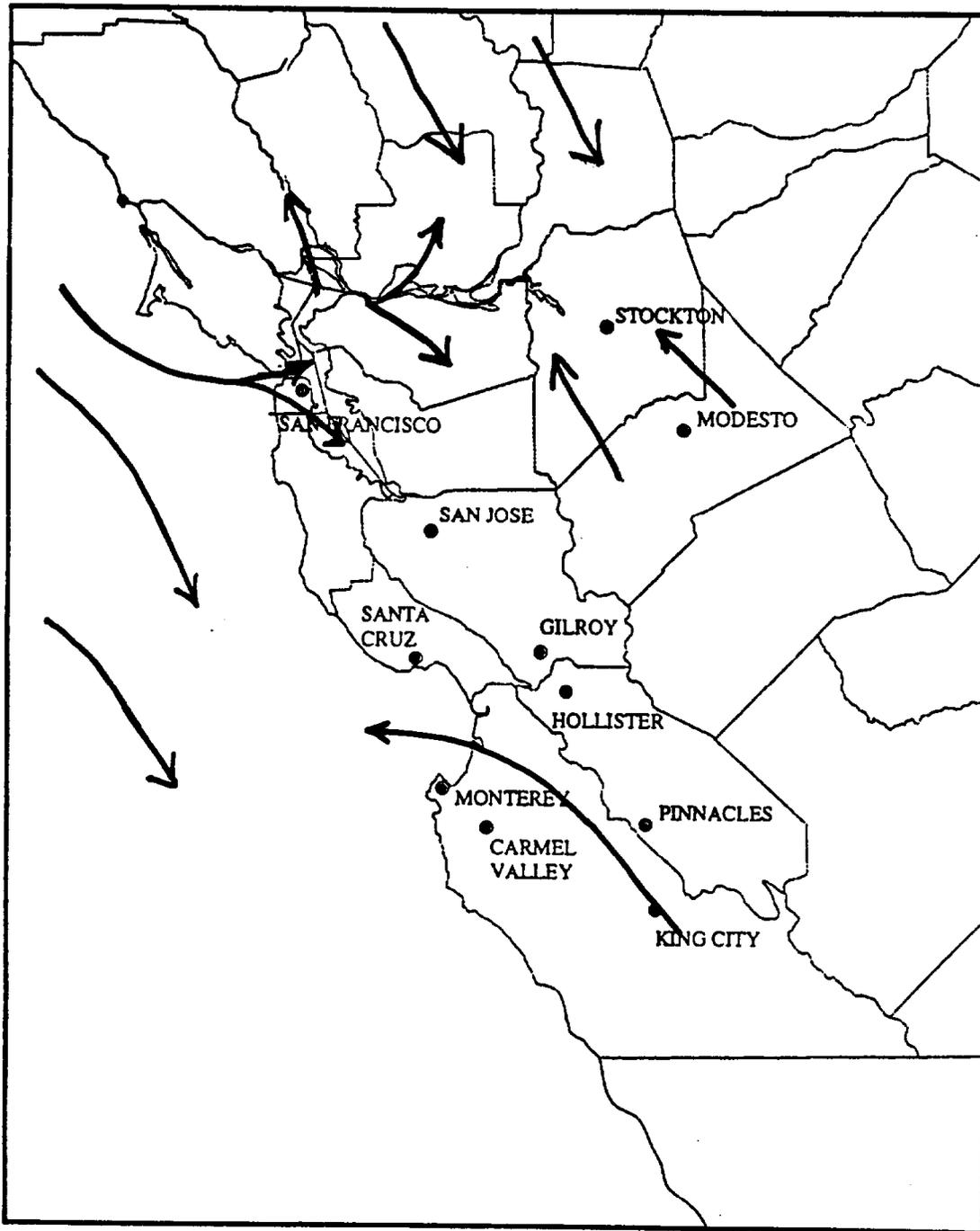


FIGURE 3-26b. Wind flow diagram based on supplementary data for 17-18 October 1989 (Northeasterly): 0400 PST, 18 October 1989.

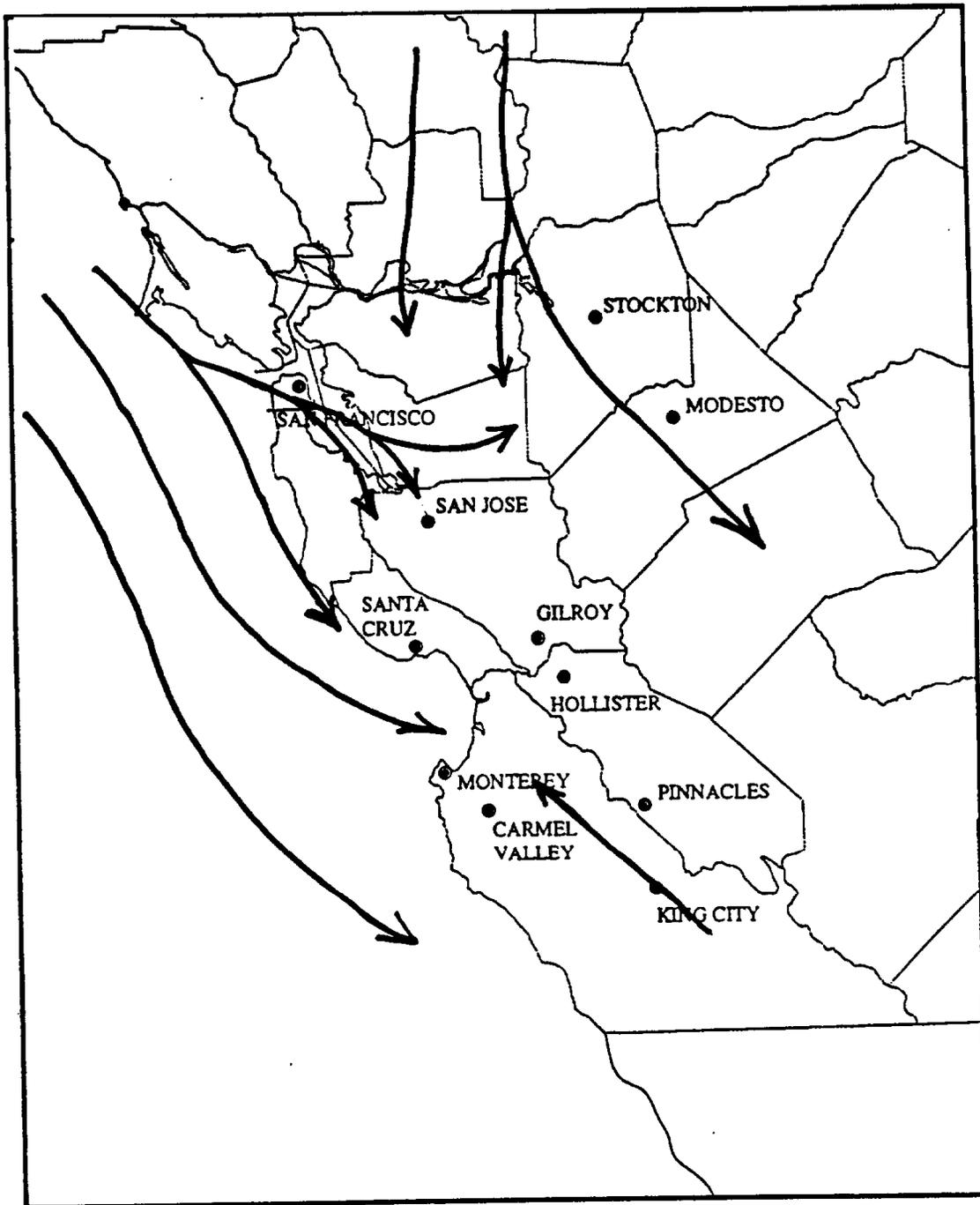


FIGURE 3-26c. Wind flow diagram based on supplementary data for 17-18 October 1989 (Northeasterly): 1000 PST, 18 October 1989.

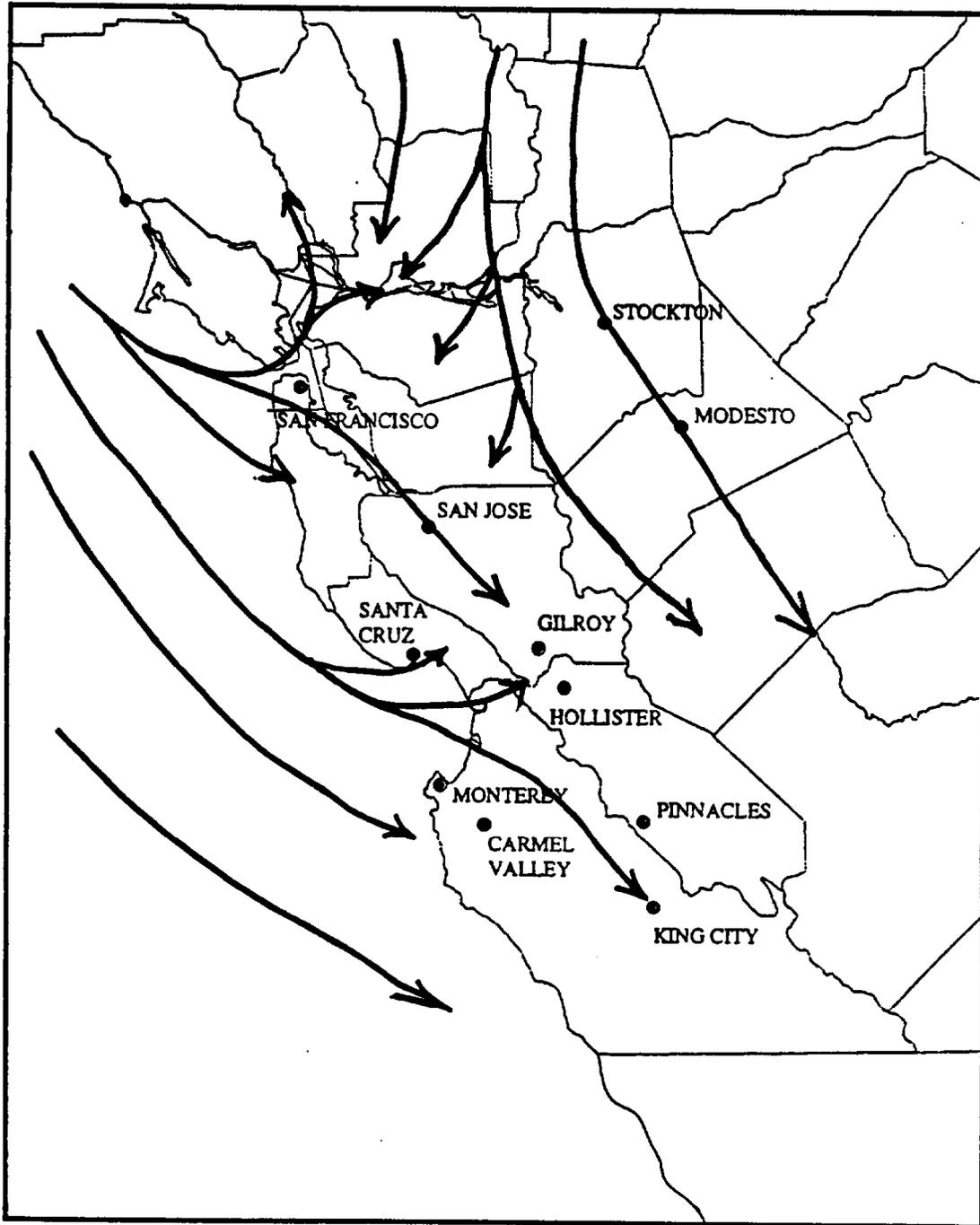


FIGURE 3-27a. Wind flow diagram based on supplementary data for 1-2 July 1991 (Bay Outflow): 1600 PST, 1 July 1991.

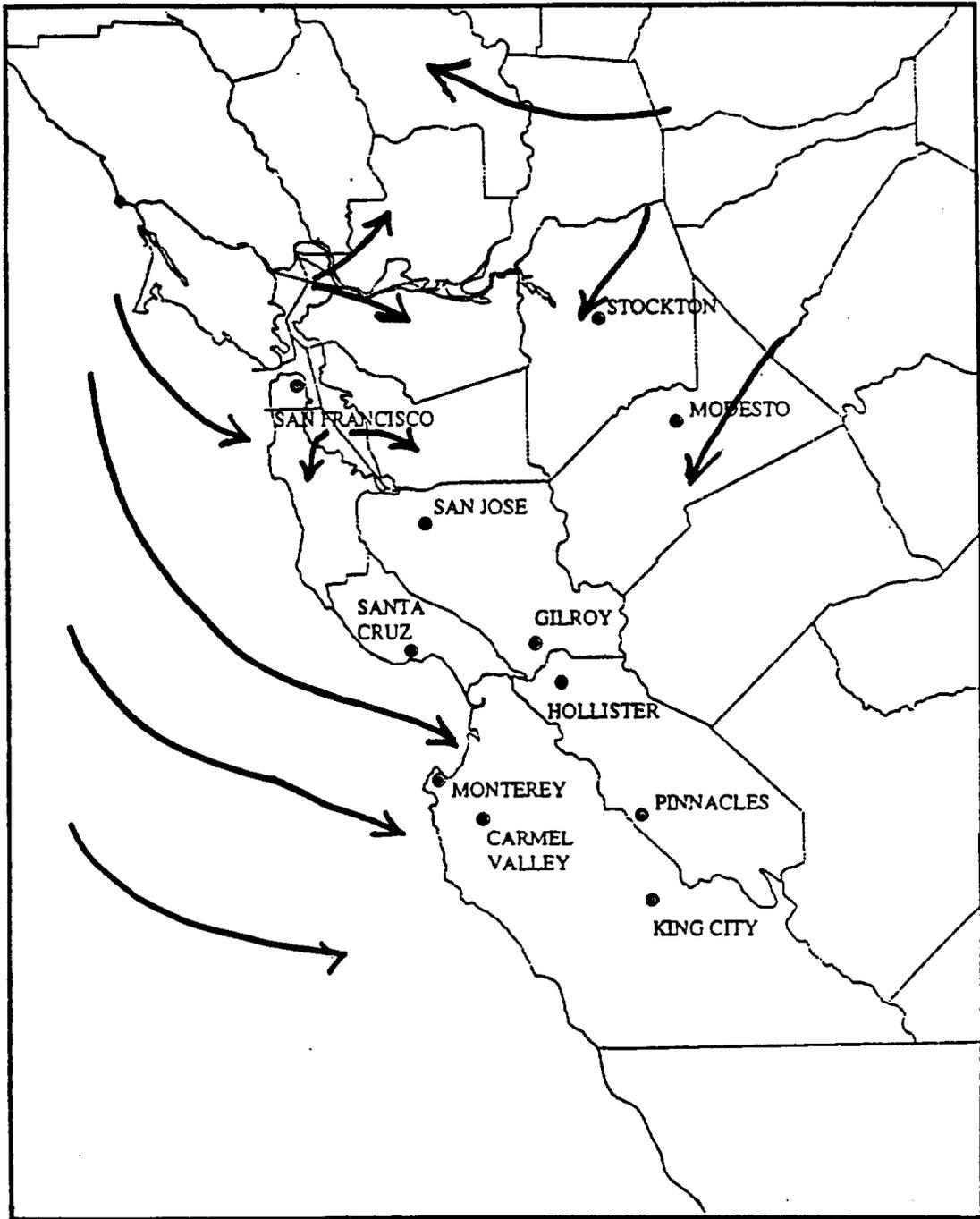


FIGURE 3-27b. Wind flow diagram based on supplementary data for 1-2 July 1991 (Bay Outflow): 0400 PST, 2 July 1991.

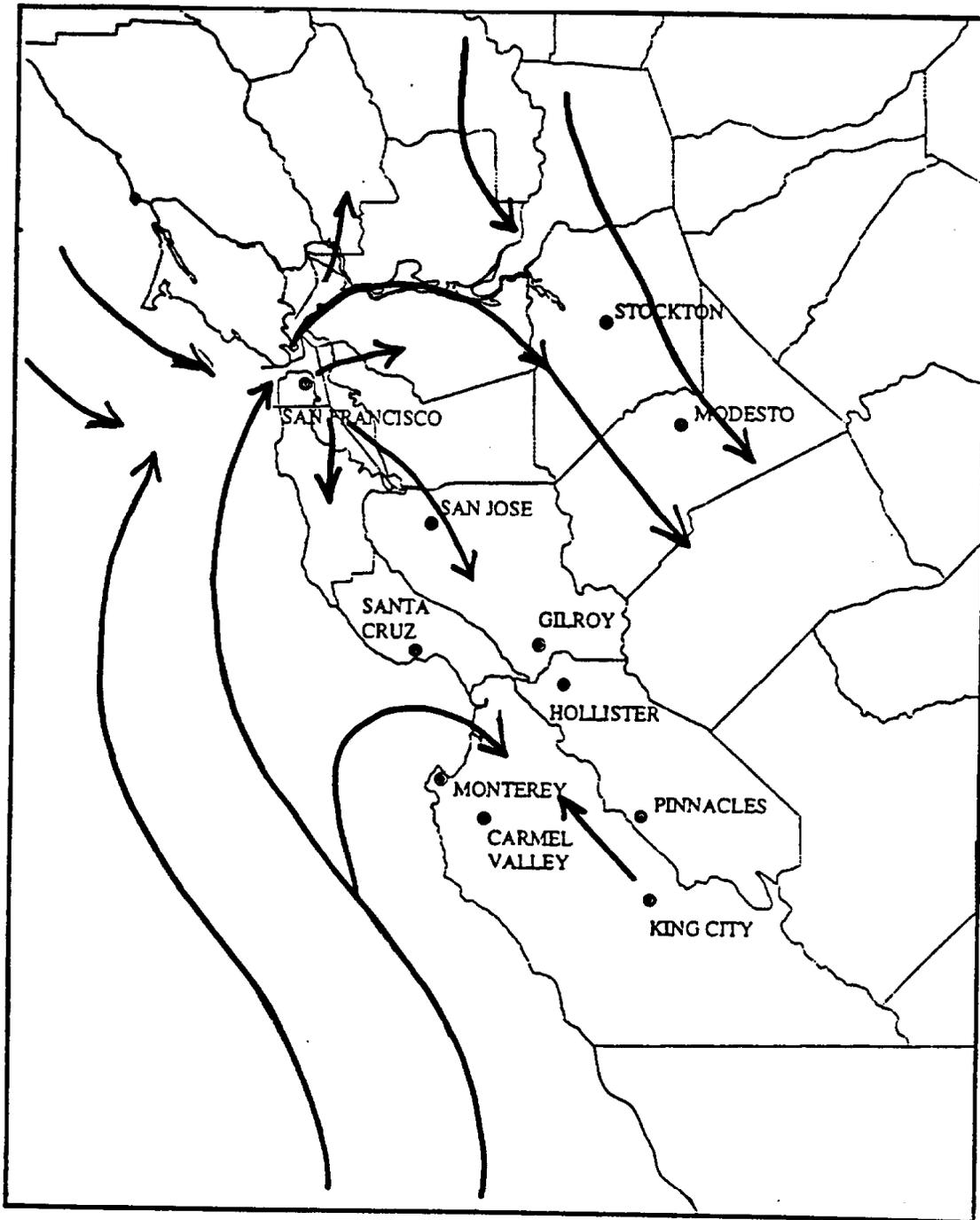


FIGURE 3-27c. Wind flow diagram based on supplementary data for 1-2 July 1991 (Bay Outflow): 1000 PST, 2 July 1991.

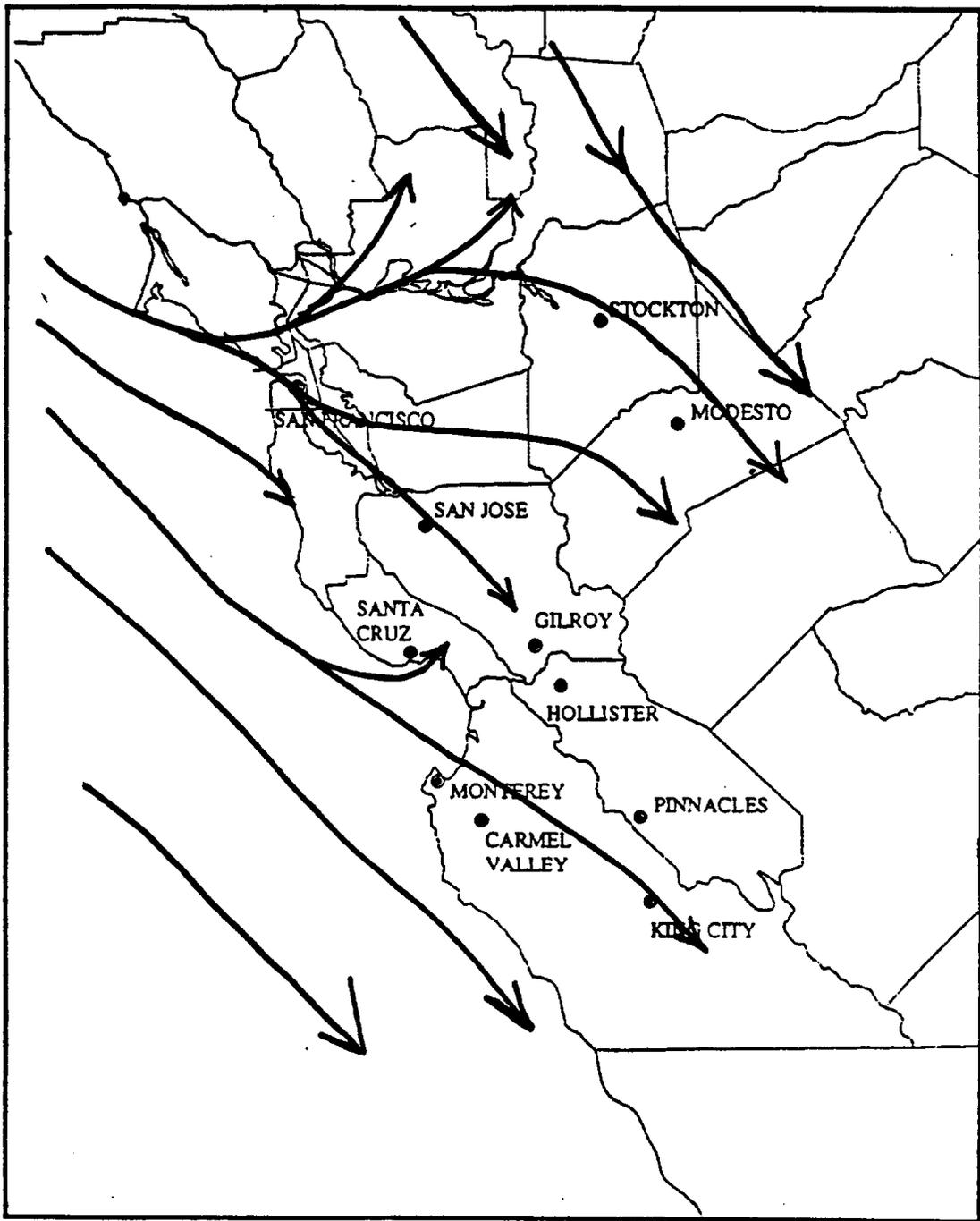


FIGURE 3-28a. Wind flow diagram based on supplementary data for 1-2 September 1991 (Northeasterly): 1600 PST, 1 September 1991.

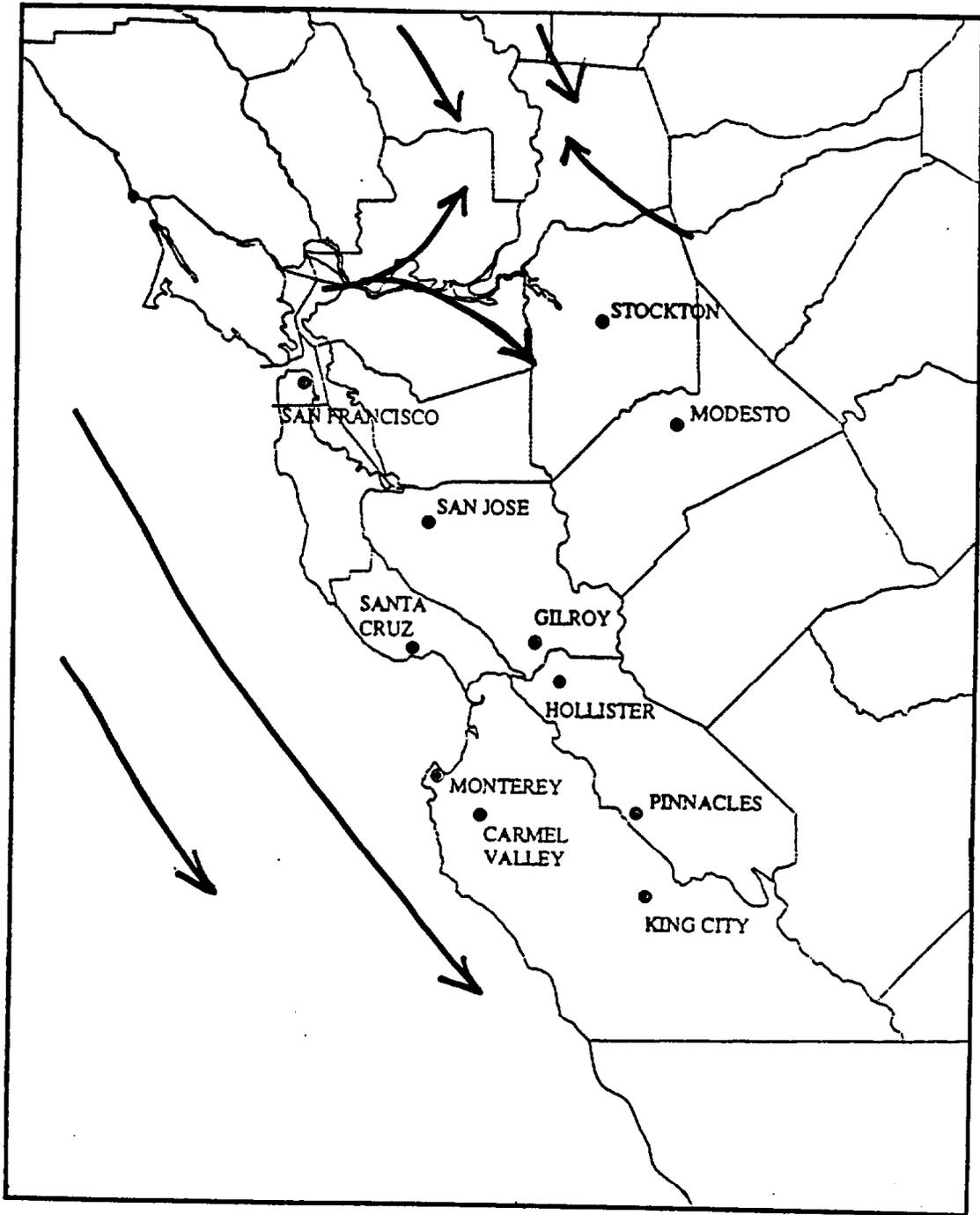


FIGURE 3-28b. Wind flow diagram based on supplementary data for 1-2 September 1991 (Northeasterly): 0400 PST, 2 September 1991.

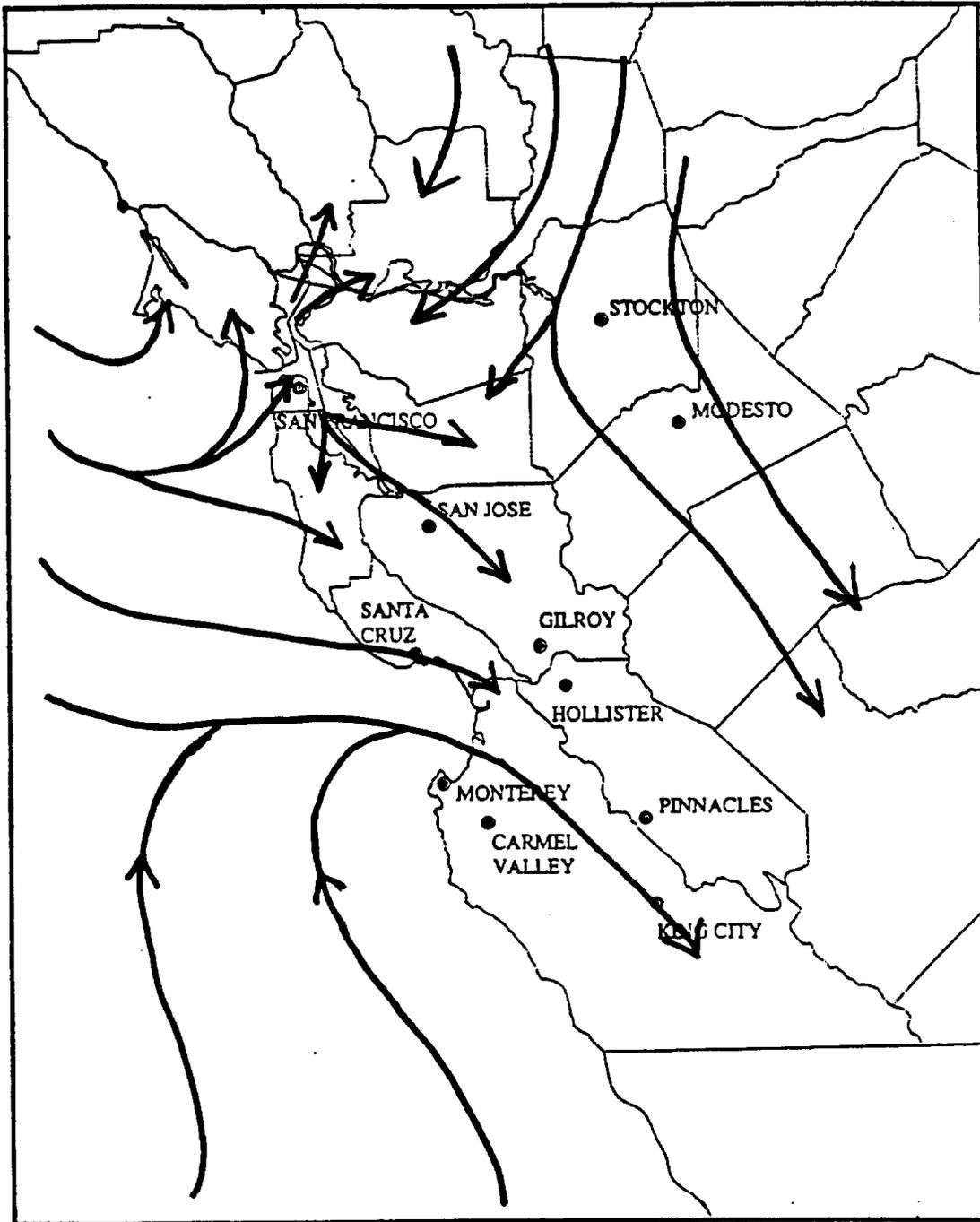


FIGURE 3-28c. Wind flow diagram based on supplementary data for 1-2 September 1991 (Northeasterly): 1000 PST, 2 September 1991.

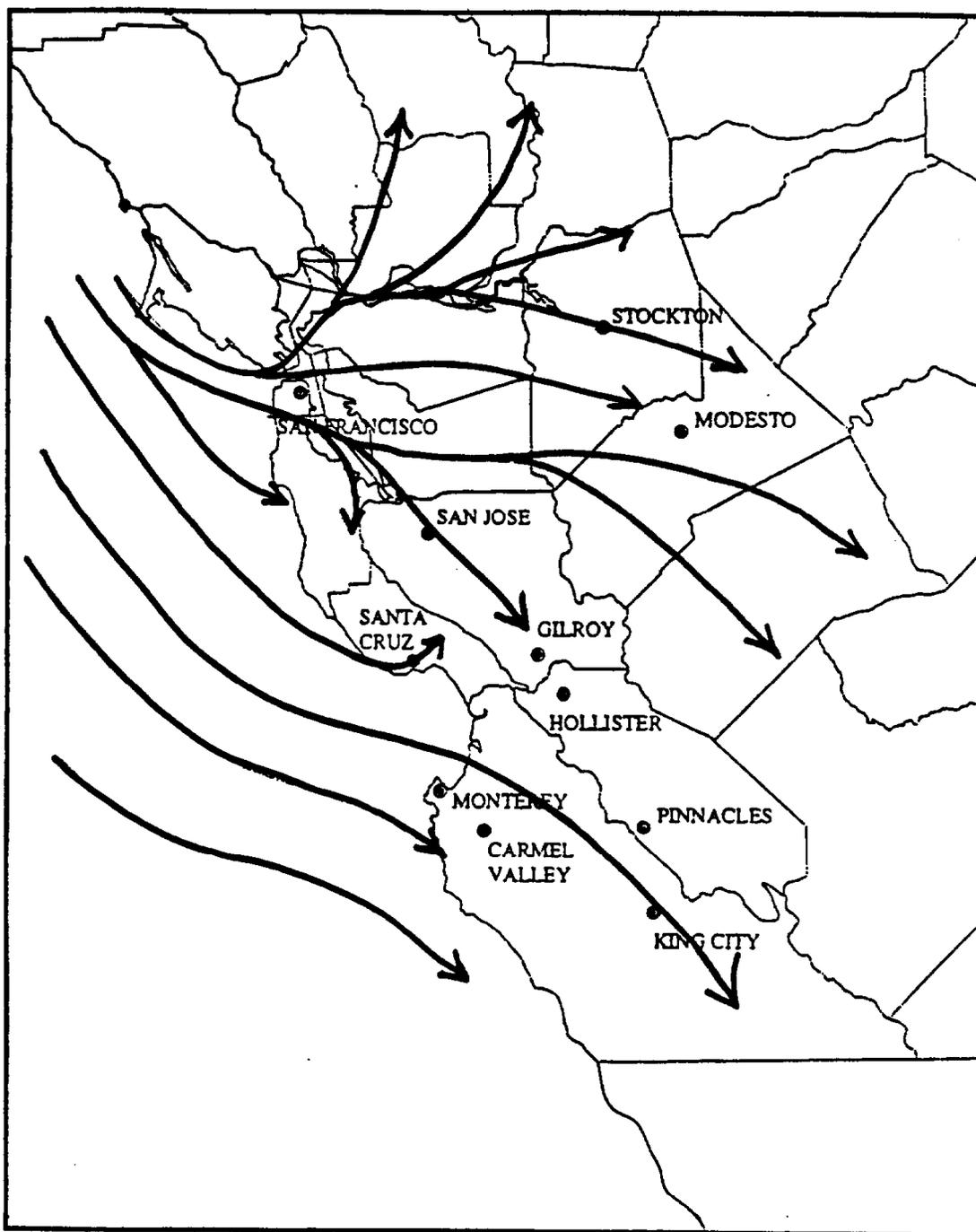


FIGURE 3-29a. Wind flow diagram based on supplementary data for 16-17 September 1991 (Bay Outflow): 1600 PST, 16 September 1991.

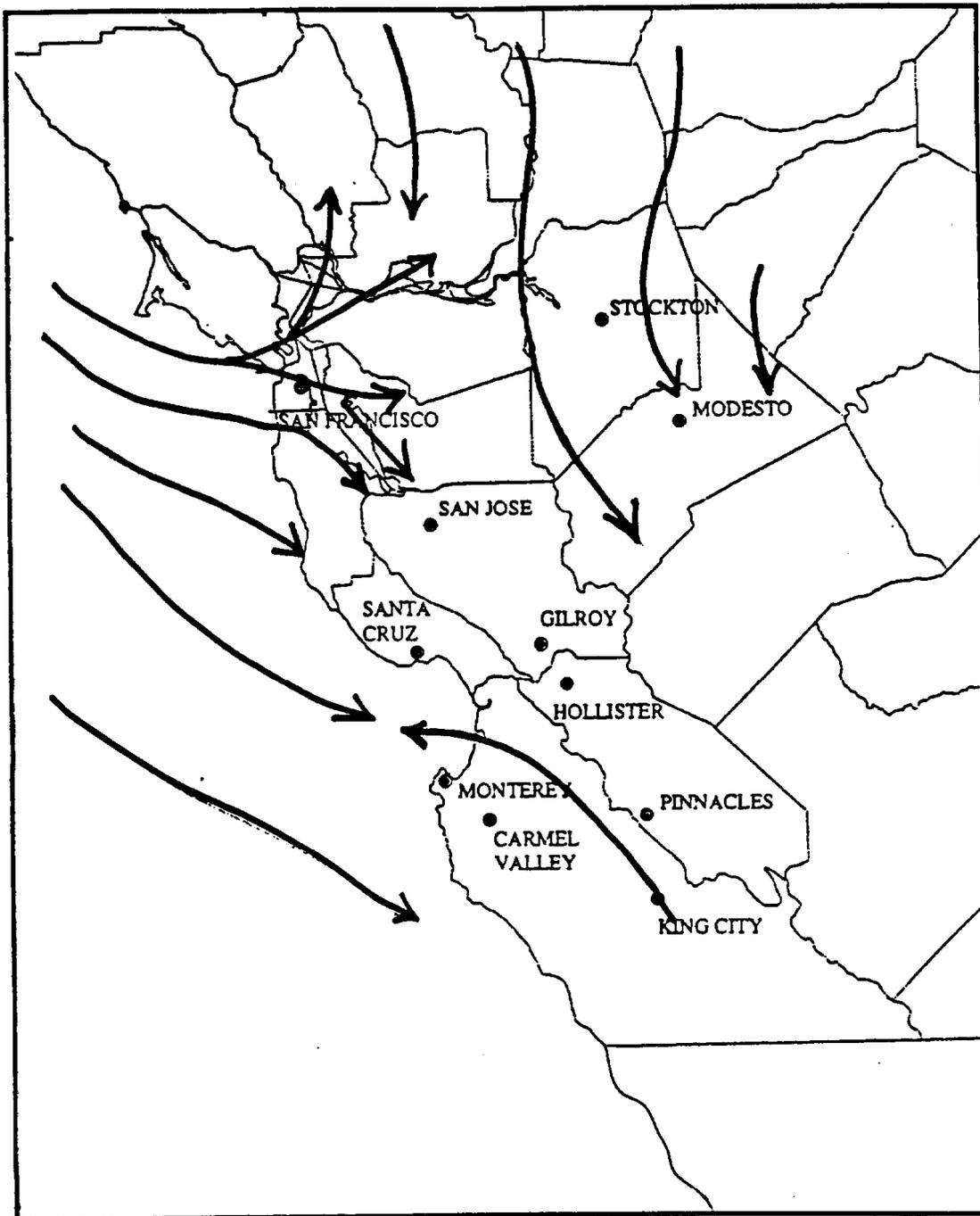


FIGURE 3-29b. Wind flow diagram based on supplementary data for 16-17 September 1991 (Bay Outflow): 0400 PST, 17 September 1991.

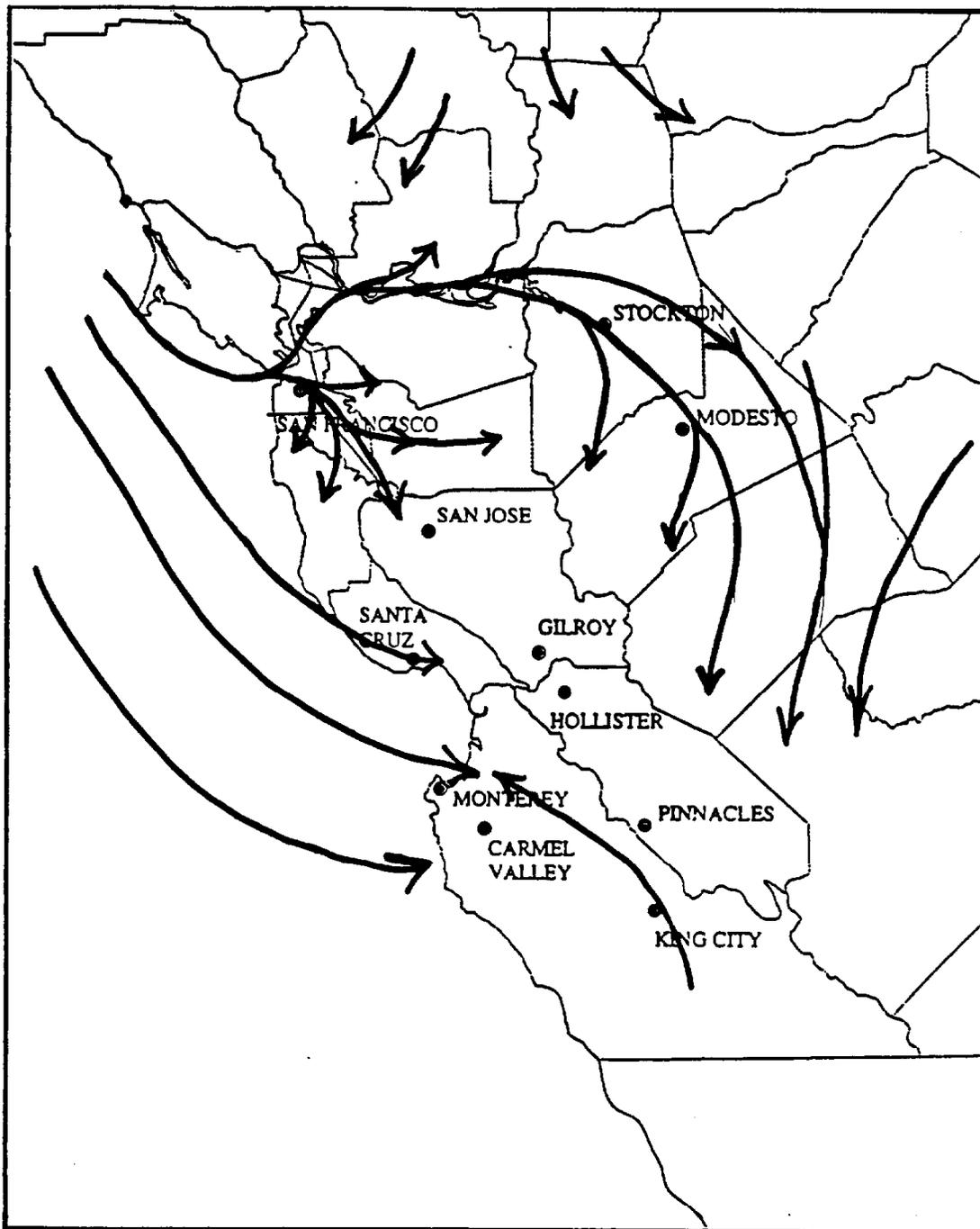


FIGURE 3-29c. Wind flow diagram based on supplementary data for 16-17 September 1991 (Bay Outflow): 1000 PST, 17 September 1991.

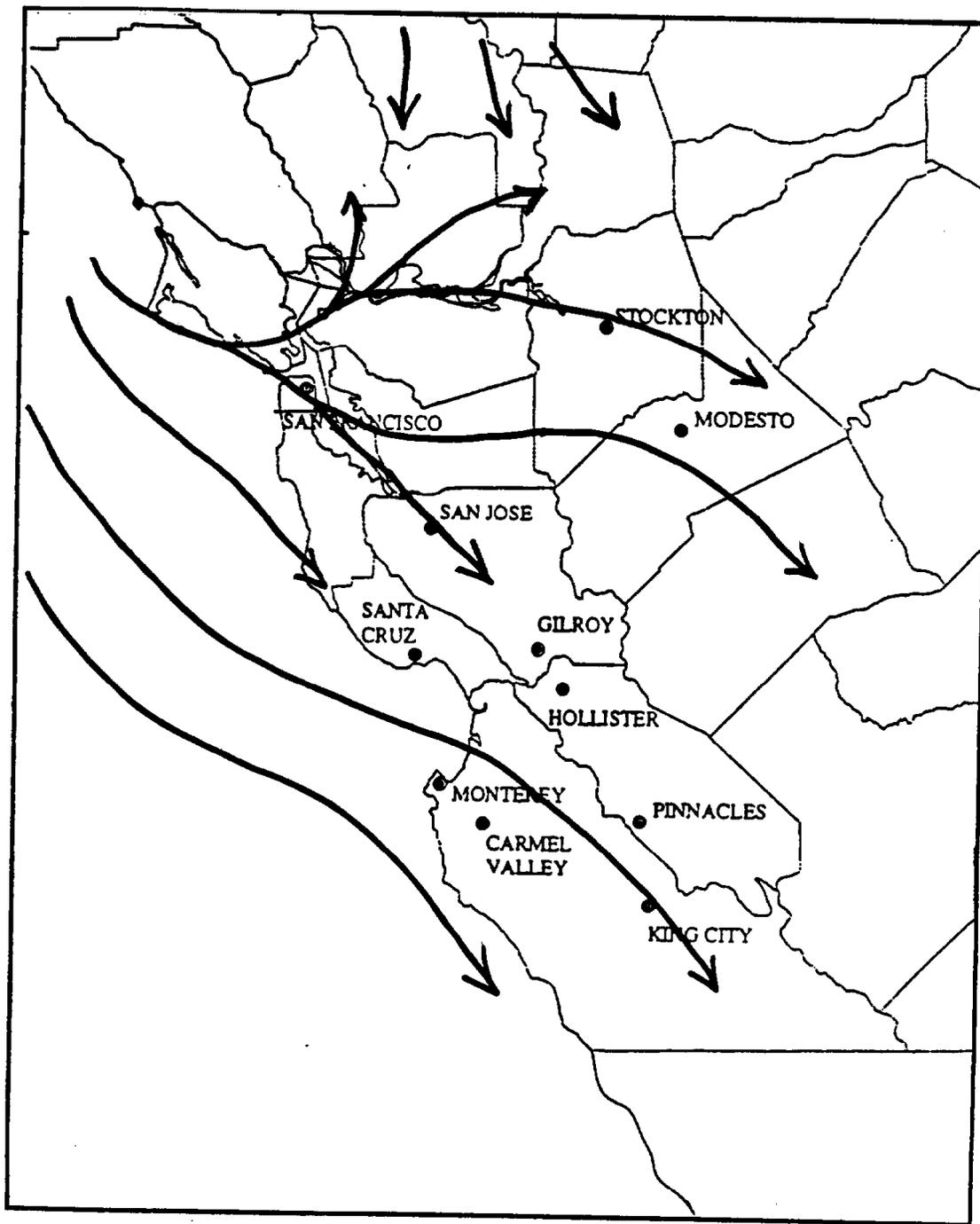


FIGURE 3-30a. Wind flow diagram based on supplementary data for 23-24 September 1991 (Bay Outflow): 1600 PST, 23 September 1991.

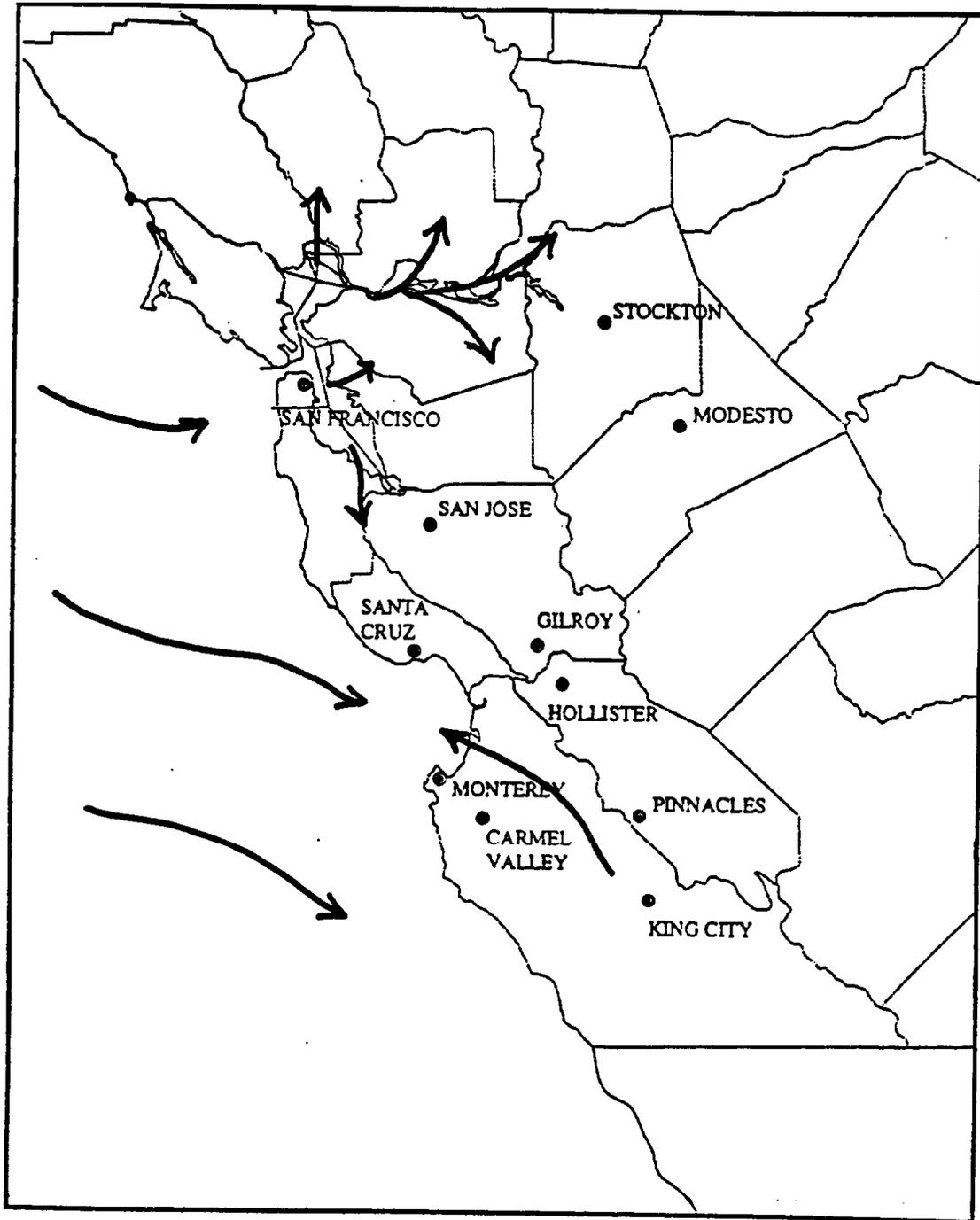


FIGURE 3-30b. Wind flow diagram based on supplementary data for 23-24 September 1991 (Bay Outflow): 0400 PST, 24 September 1991.

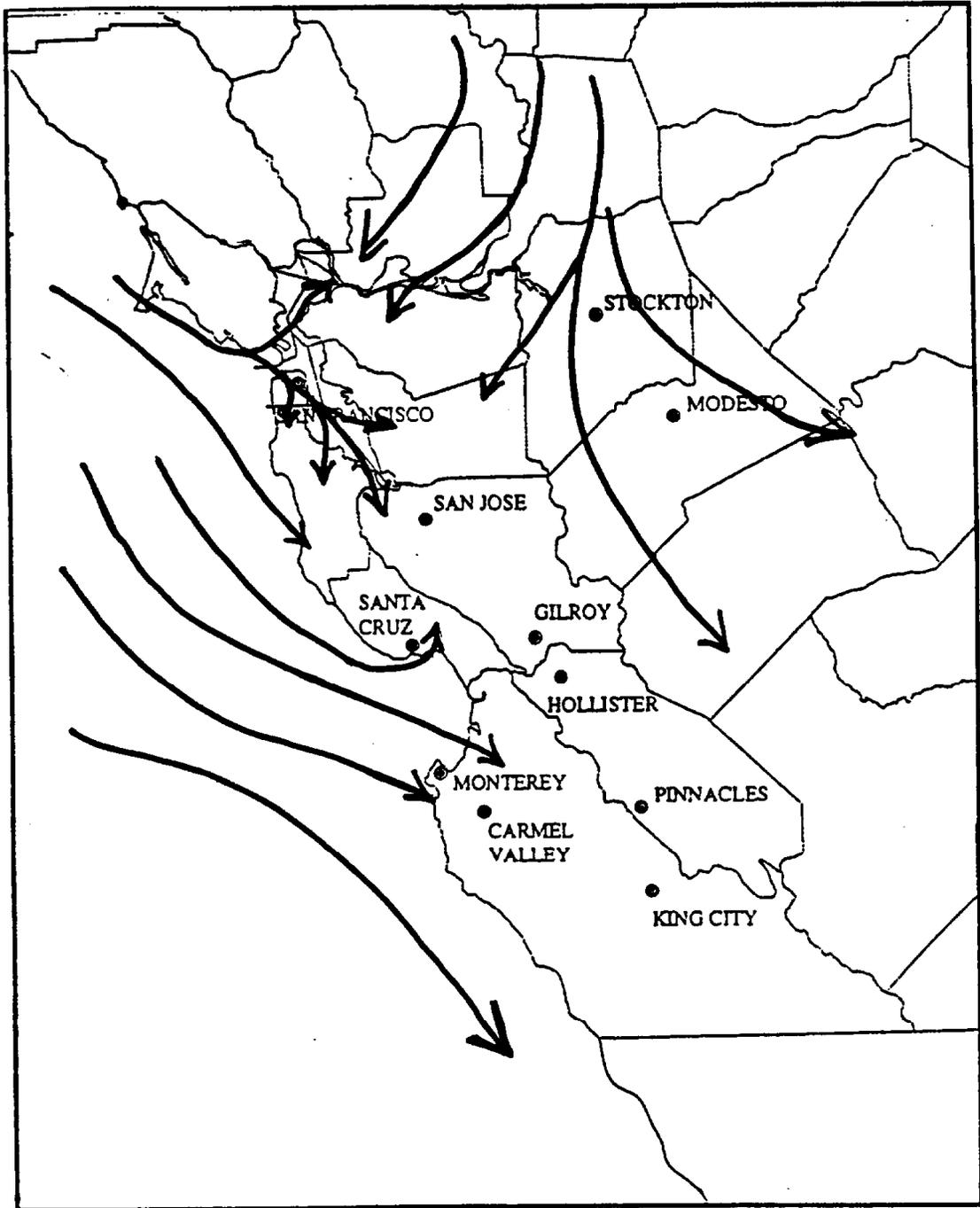


FIGURE 3-30c. Wind flow diagram based on supplementary data for 23-24 September 1991 (Bay Outflow): 1000 PST, 24 September 1991.

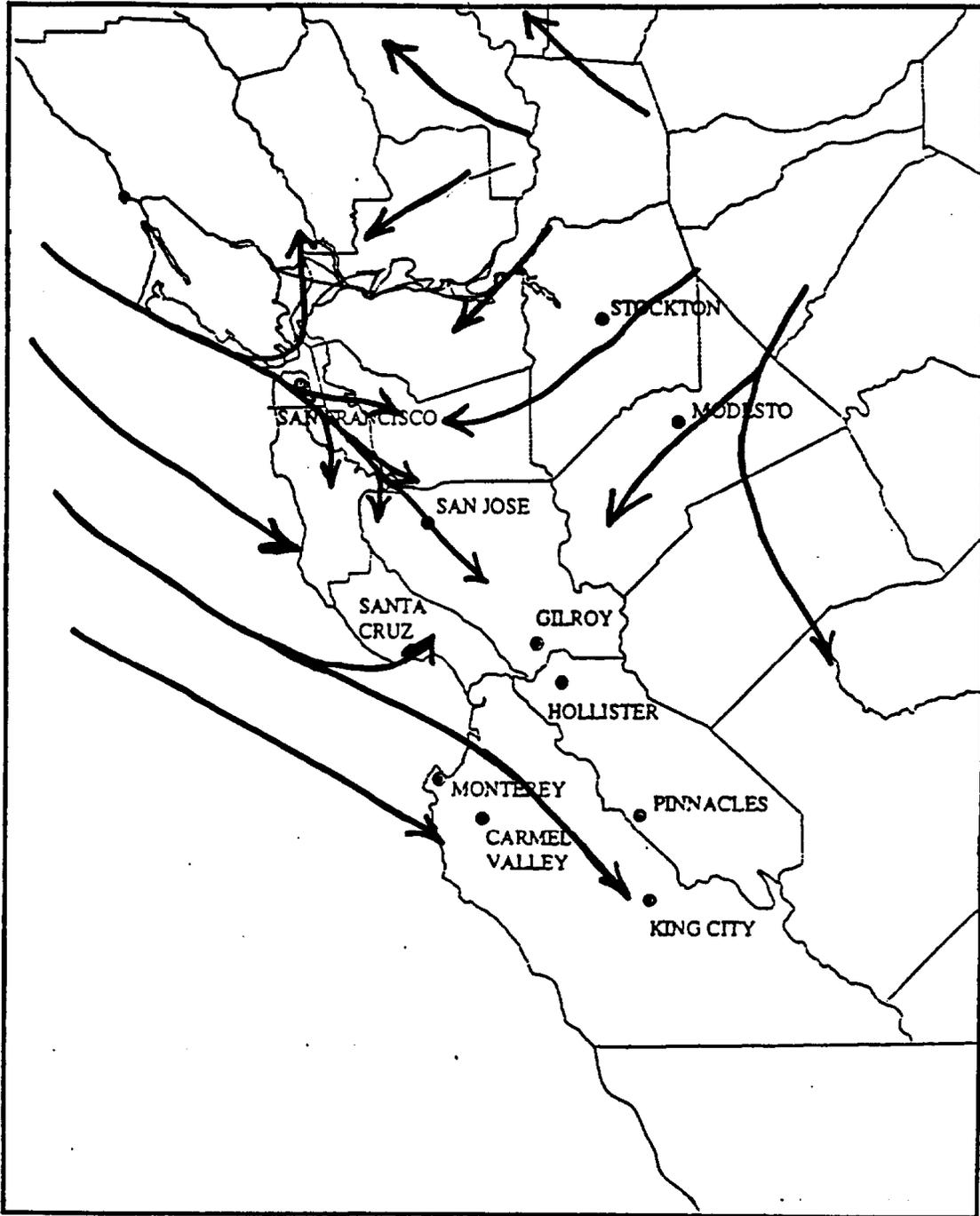


FIGURE 3-31a. Wind flow diagram based on supplementary data for 9-10 October 1991 (Northwest-South): 1600 PST, 9 October 1991.

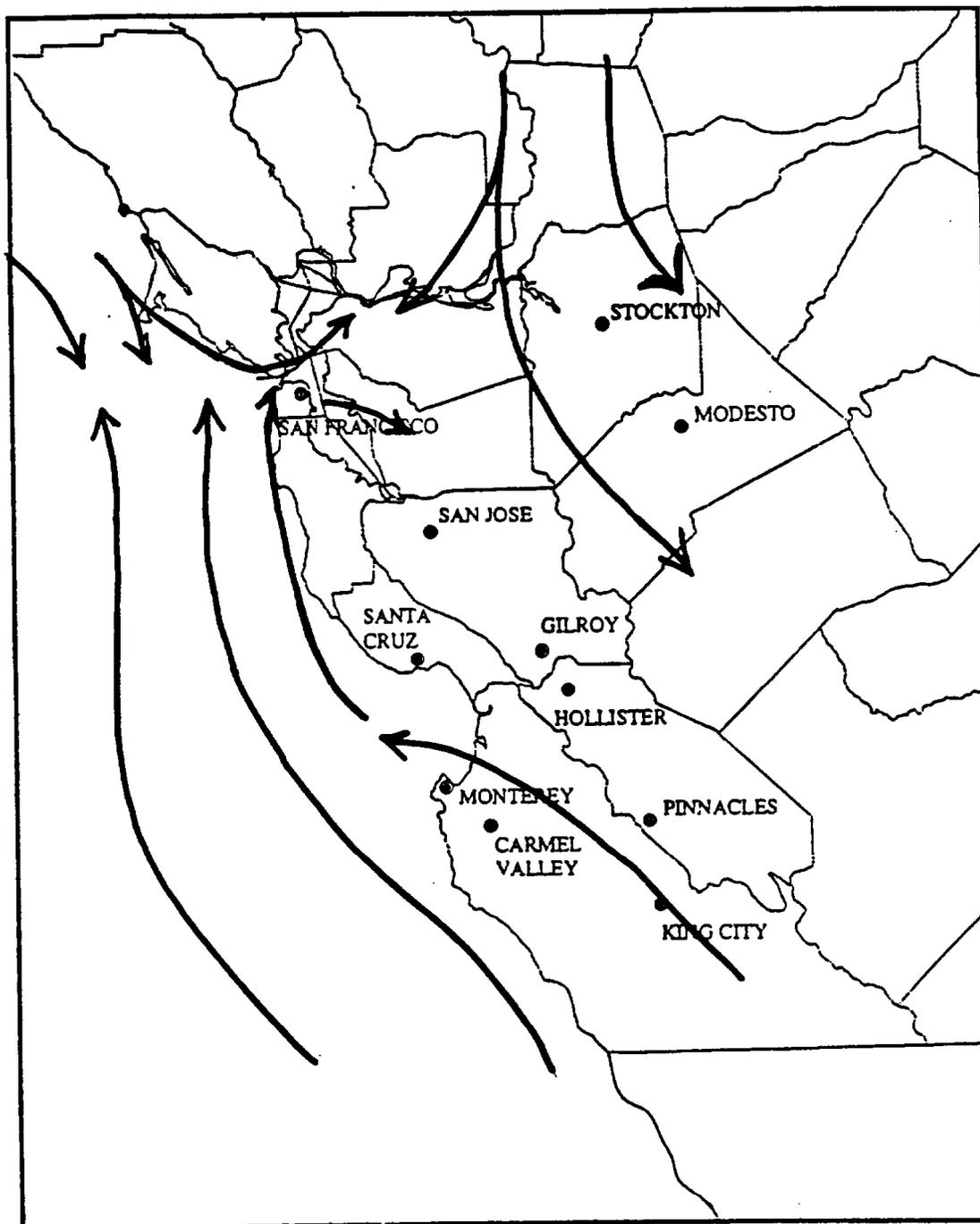


FIGURE 3-31b. Wind flow diagram based on supplementary data for 9-10 October 1991 (Northwest-South): 0400 PST, 10 October 1991.

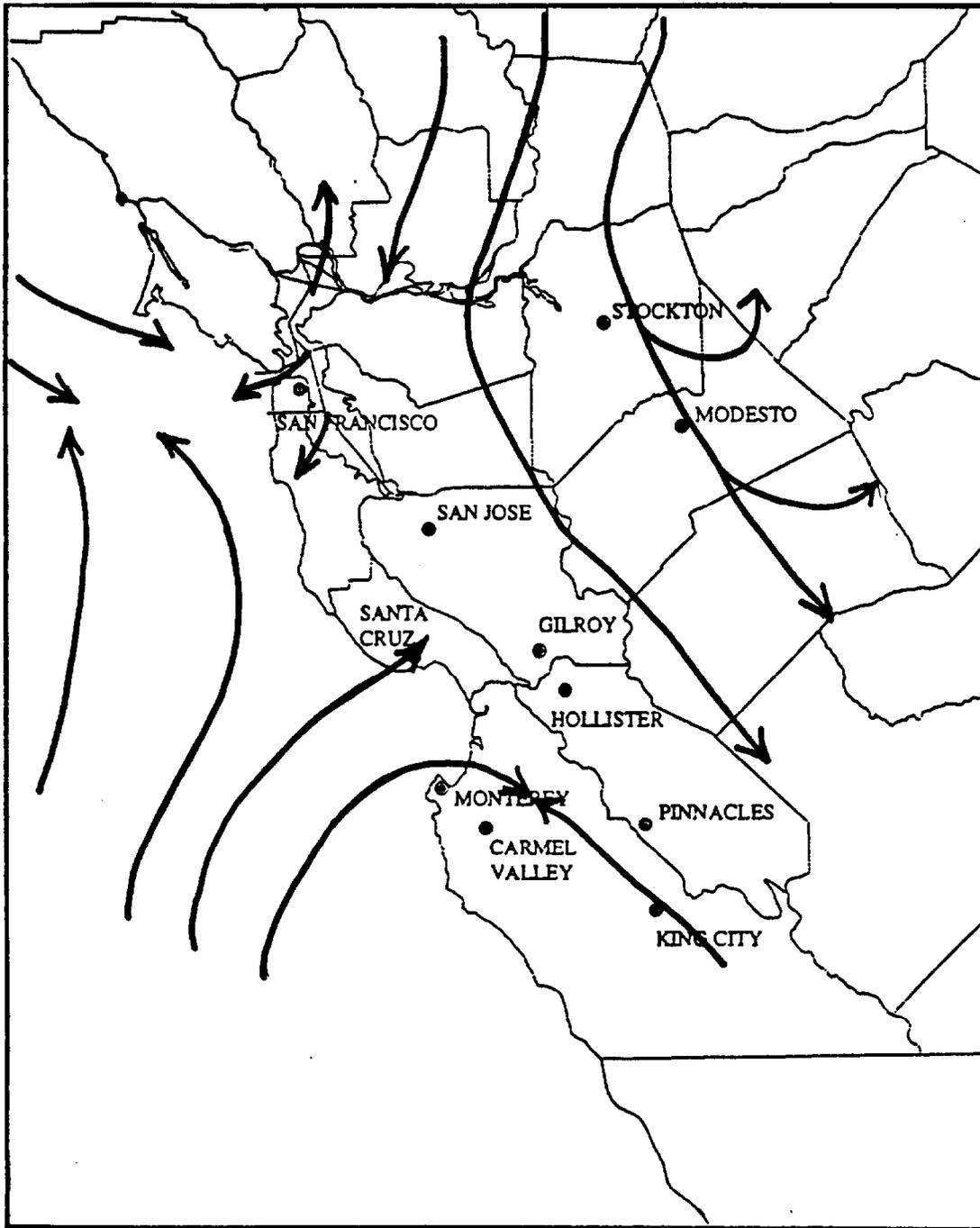


FIGURE 3-31c. Wind flow diagram based on supplementary data for 9-10 October 1991 (Northwest-South): 1000 PST, 10 October 1991.

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=OK4A850T 4AM Oak 850 mb temp

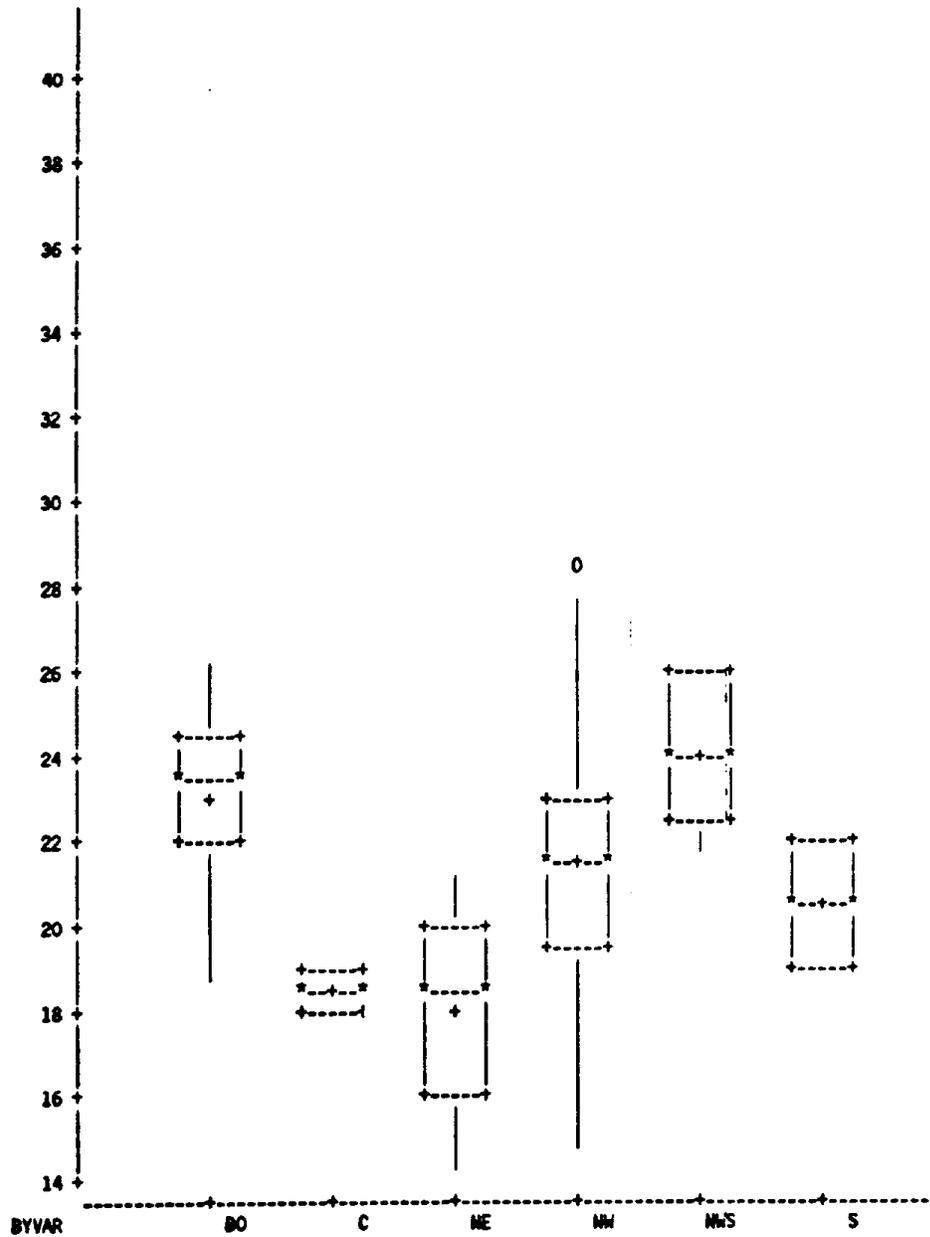


FIGURE 3-32a. Boxplots of key meteorological variables for days assigned to each flow pattern: 0400 PST, Oakland 850 mb temperature (°C).

UNIVARIATE PROCEDURE
Schematic Plots

Variable=OK4DELTA 4AM Oak Inv Del Temp

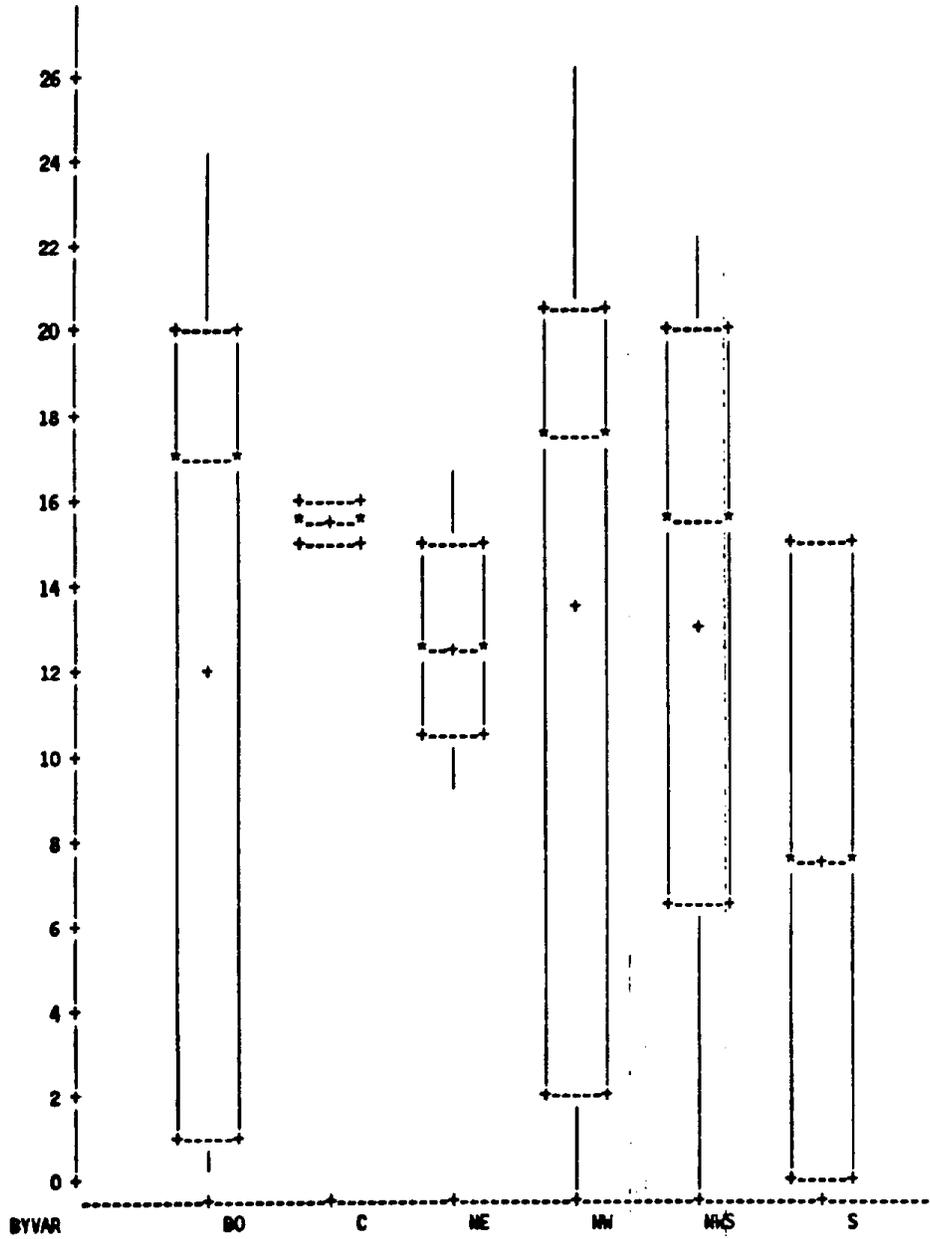


FIGURE 3-32b. Boxplots of key meteorological variables for days assigned to each flow pattern: 0400 PST, Oakland inversion top-base temperature difference ($^{\circ}\text{C}$).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=OK4AIBH 4AM Oak Inv Base Height

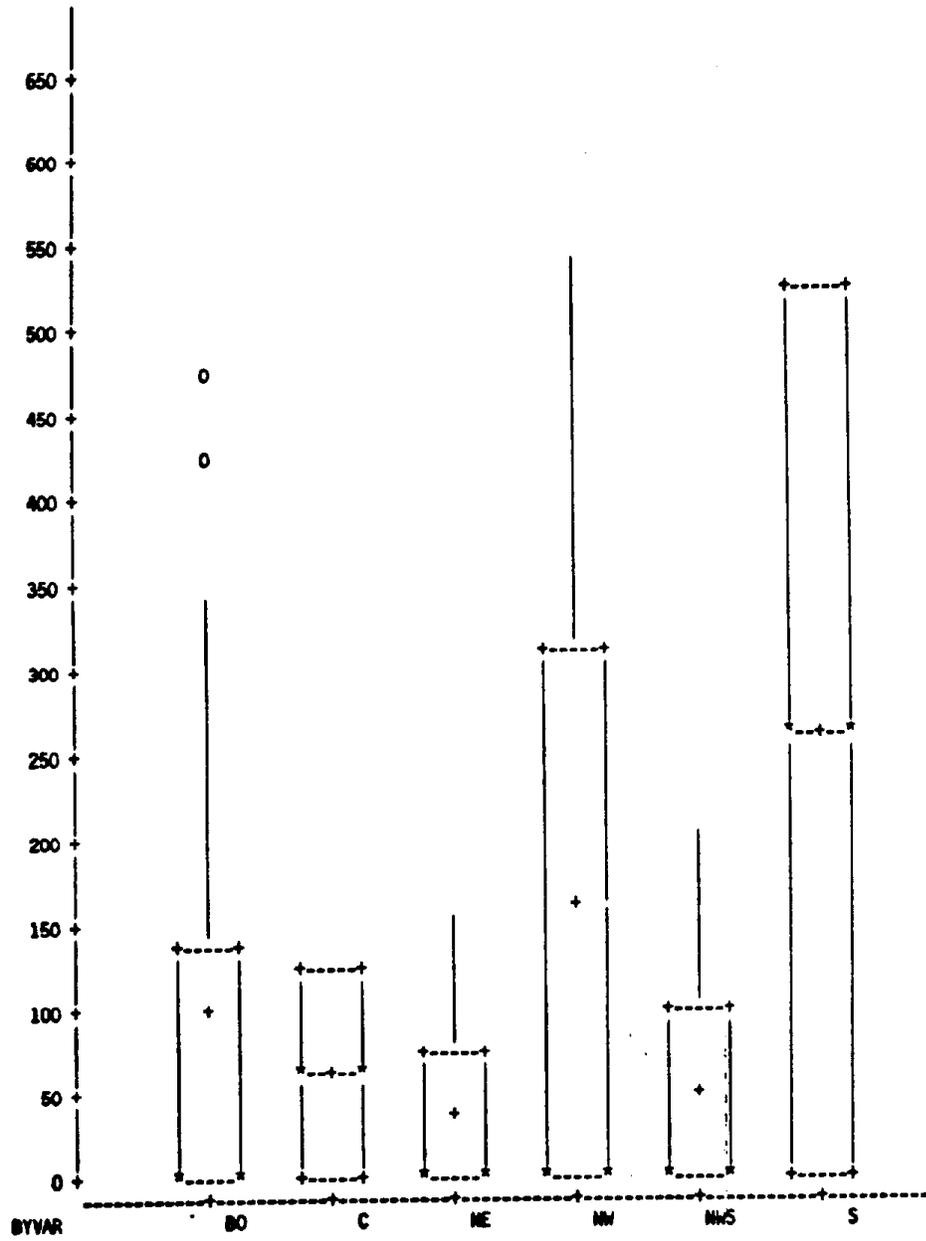


FIGURE 3-32c. Boxplots of key meteorological variables for days assigned to each flow pattern: 0400 PST, Oakland inversion base height (m).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=OK4PIBH 4PM Oak Inv Base Height

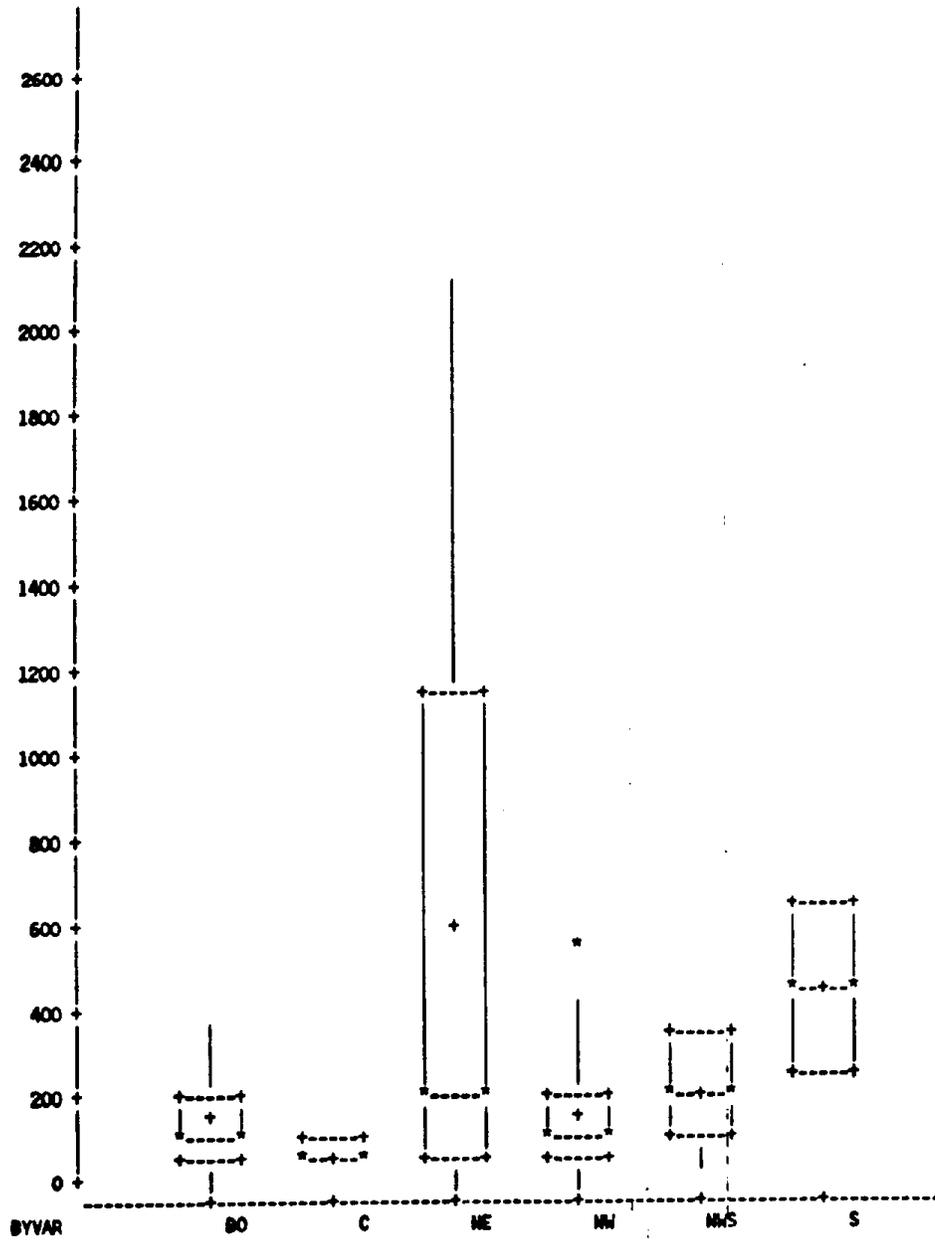


FIGURE 3-32d. Boxplots of key meteorological variables for days assigned to each flow pattern: 1600 PST, Oakland inversion base height (m).

Side by side box plots
 UNIVARIATE PROCEDURE
 Schematic Plots
 Variable=TMPDKSC Sacn max temp

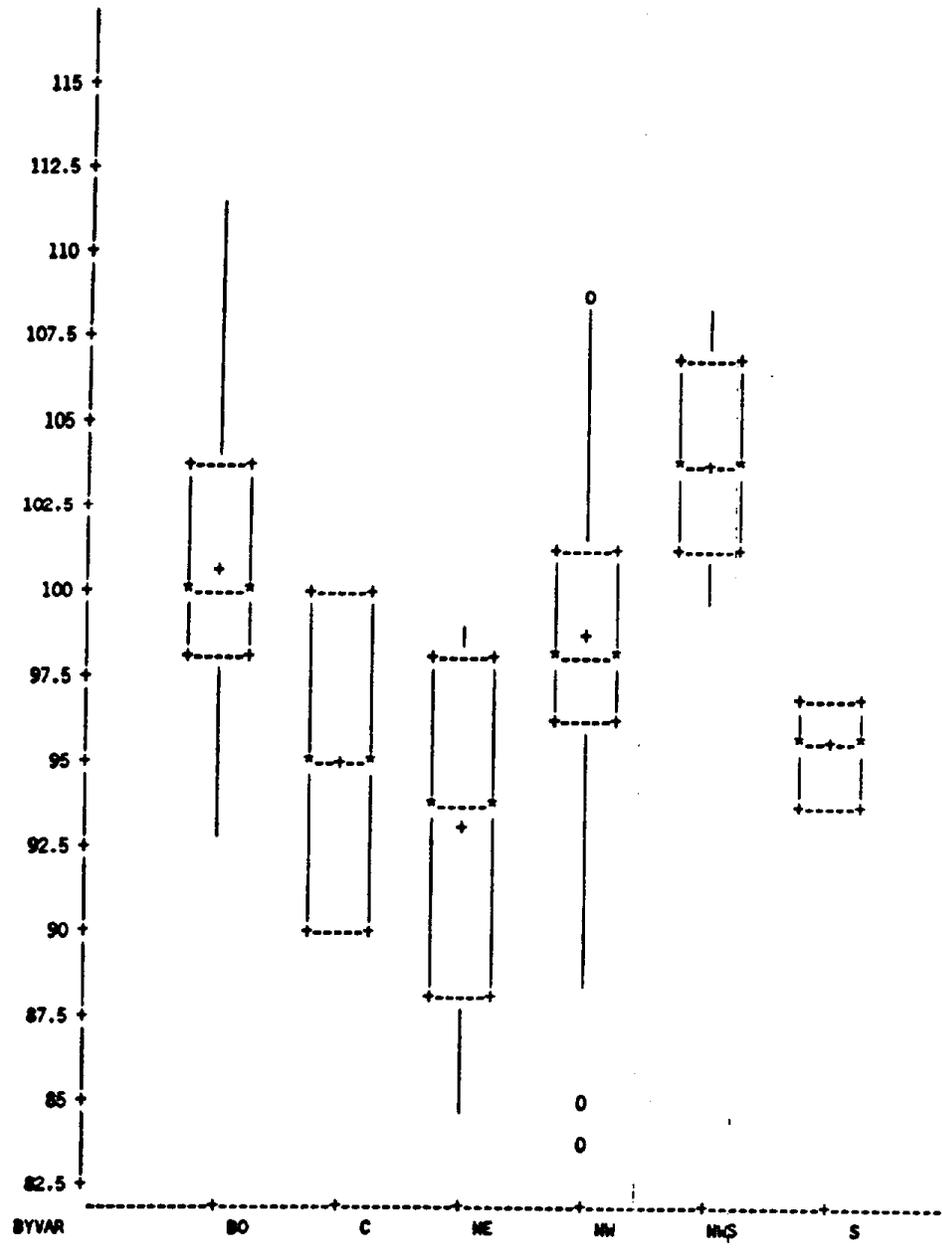


FIGURE 3-32e. Boxplots of key meteorological variables for days assigned to each flow pattern: Sacramento maximum temperature (°F).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=TMPD00FS Fresno max temp

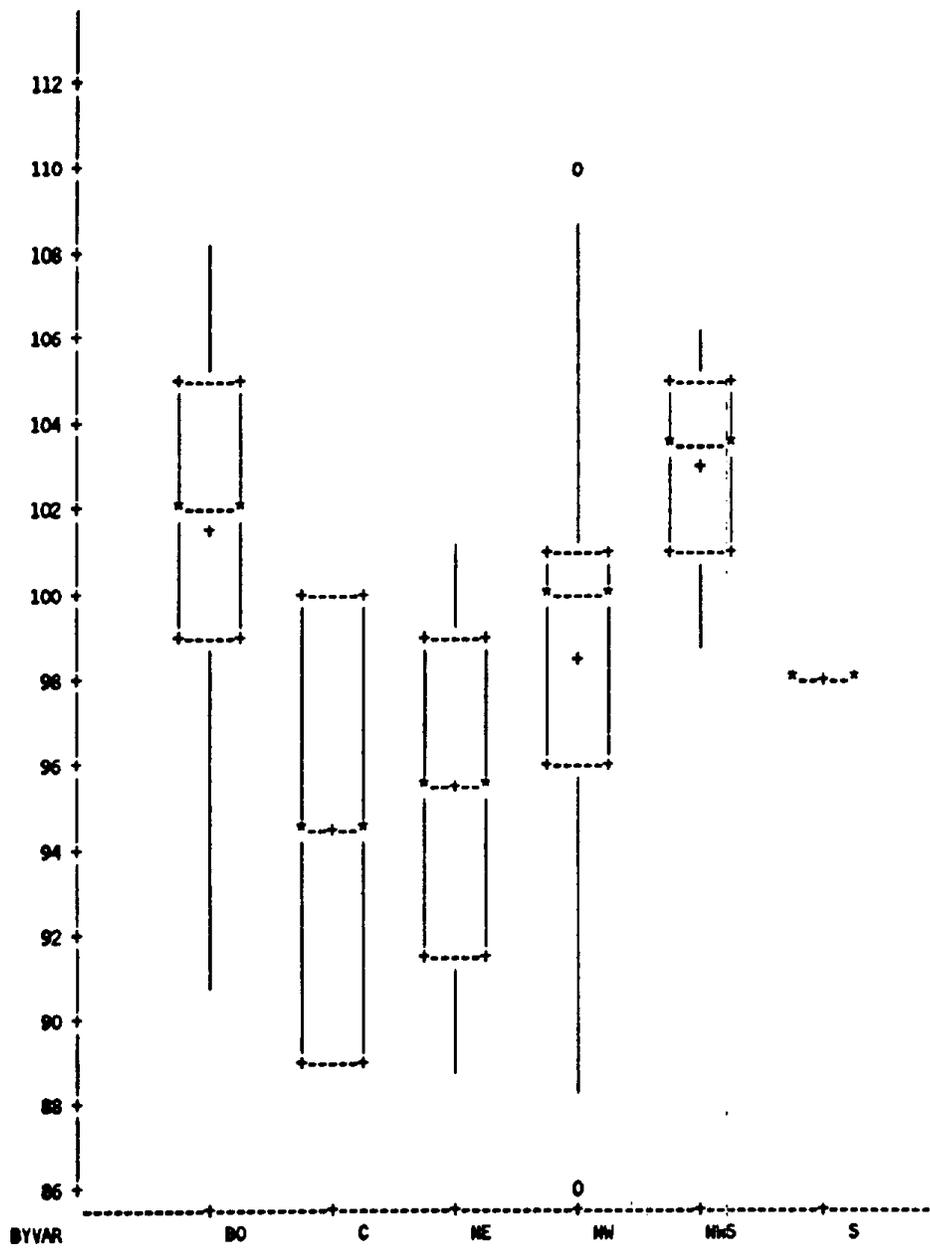


FIGURE 3-32f. Boxplots of key meteorological variables for days assigned to each flow pattern: Fresno maximum temperature (°F).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=SLVPSFRM SF-Reno press gradient

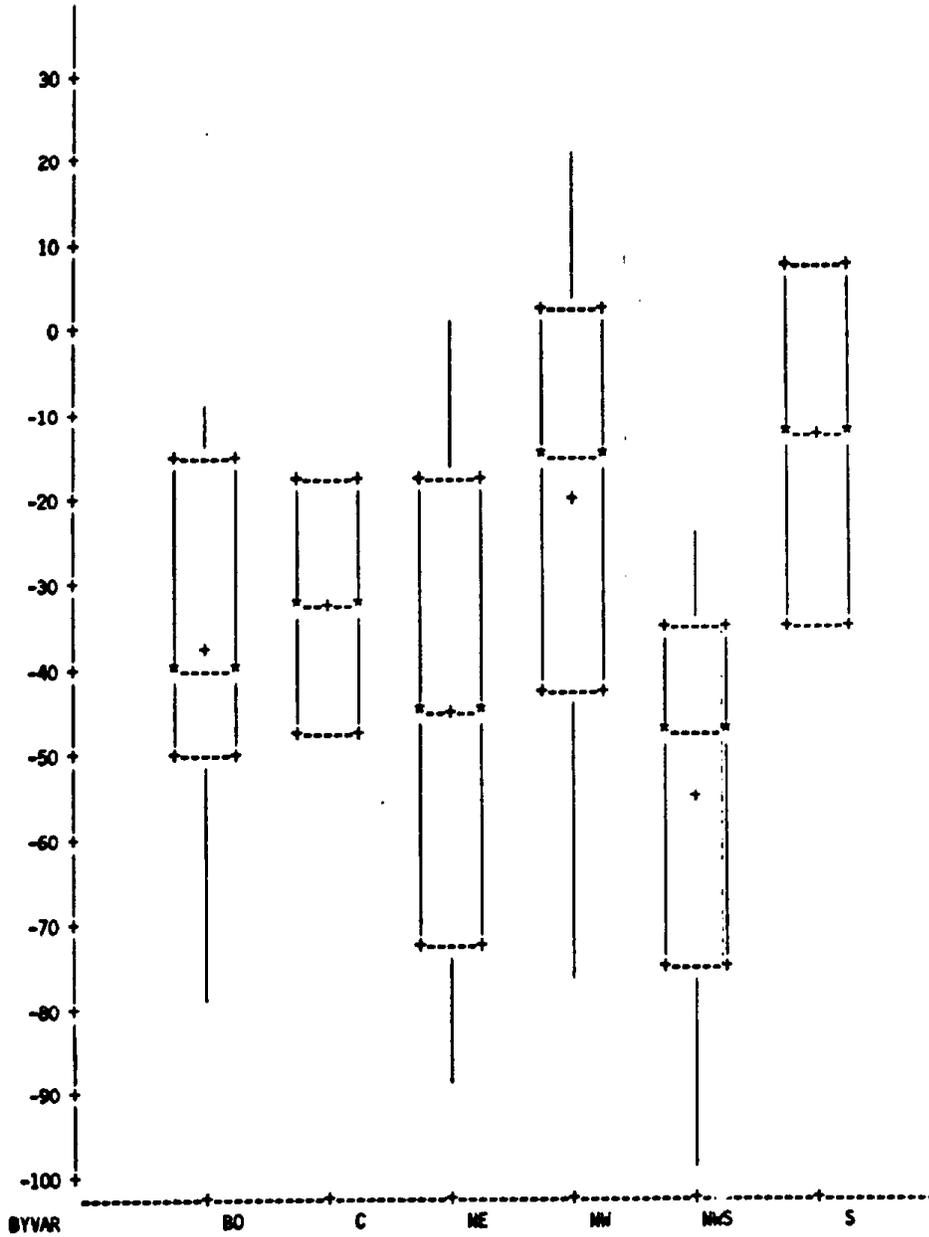


FIGURE 3-32g. Boxplots of key meteorological variables for days assigned to each flow pattern: SFO-Reno pressure gradient (mb).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=SLVPSFRD

SF-Redd press gradient

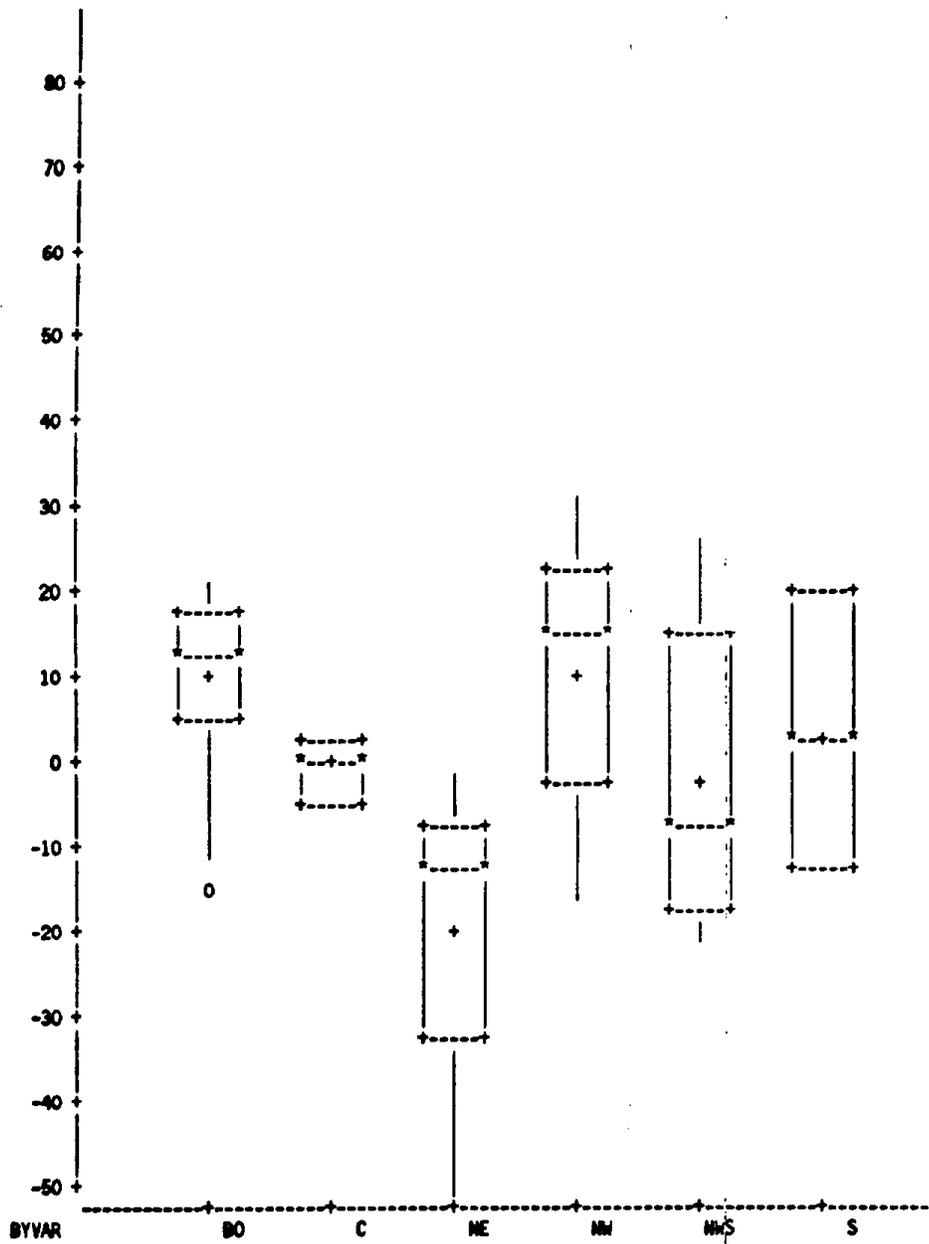


FIGURE 3-32h. Boxplots of key meteorological variables for days assigned to each flow pattern: SFO-Redding pressure gradient (mb).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=SLVPSFFS SF-Fres press gradient

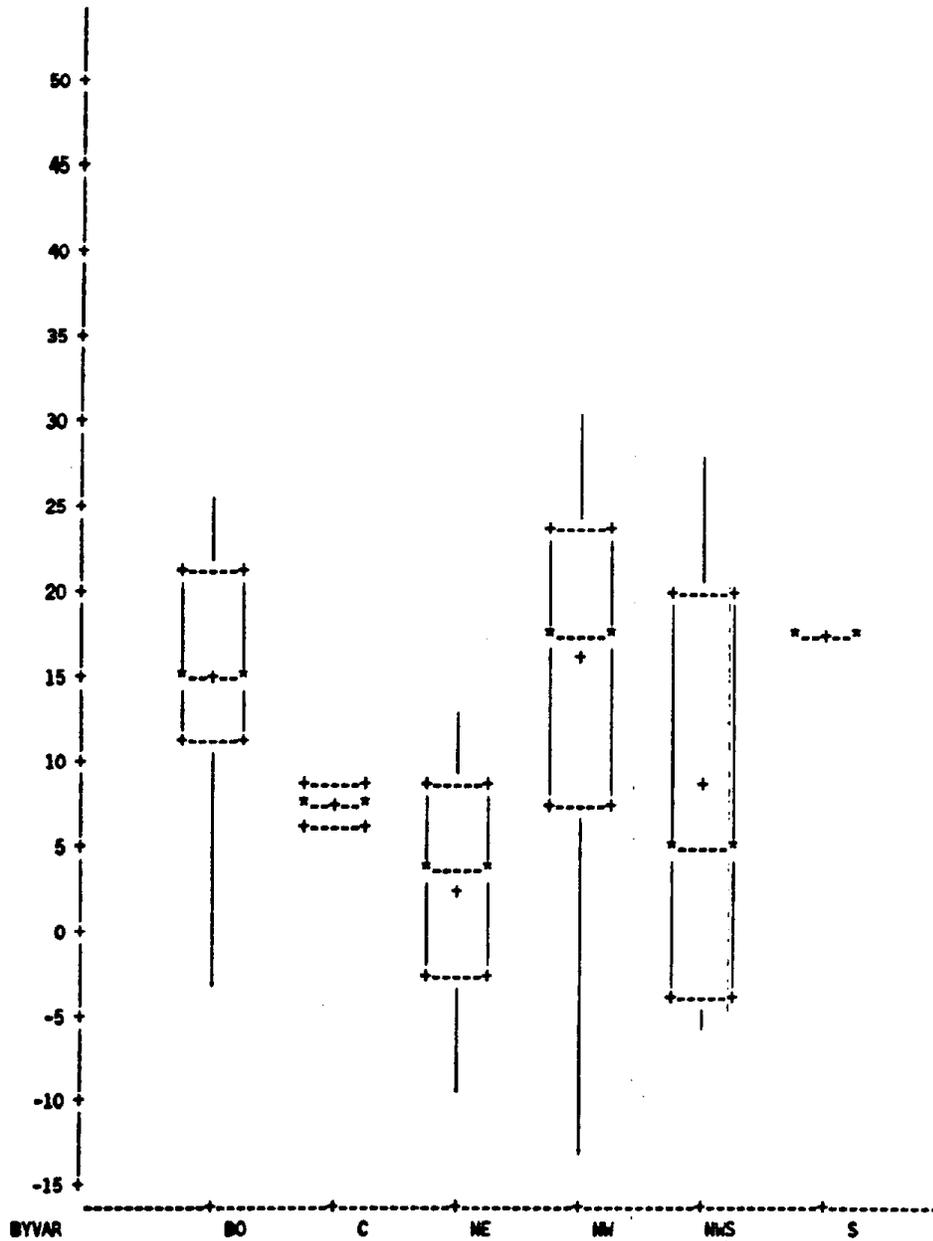


FIGURE 3-32i. Boxplots of key meteorological variables for days assigned to each flow pattern: SFO-Fresno pressure gradient (mb).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=TM90SFSC SF-Sacr max temp gradient

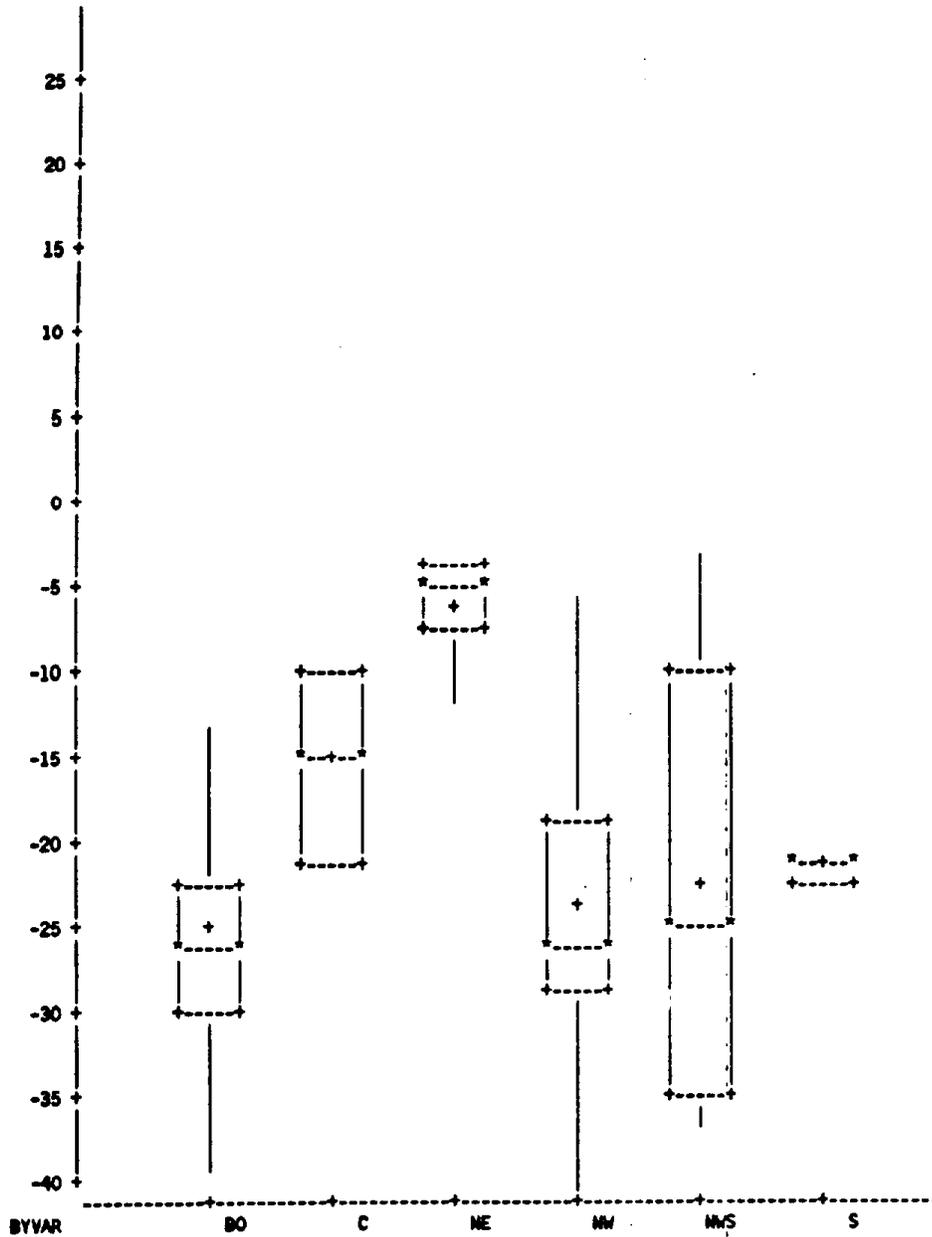


FIGURE 3-32j. Boxplots of key meteorological variables for days assigned to each flow pattern: San Francisco-Sacramento maximum temperature difference (°F).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=TMPSFSC SF-Sacr 4PM temp gradient

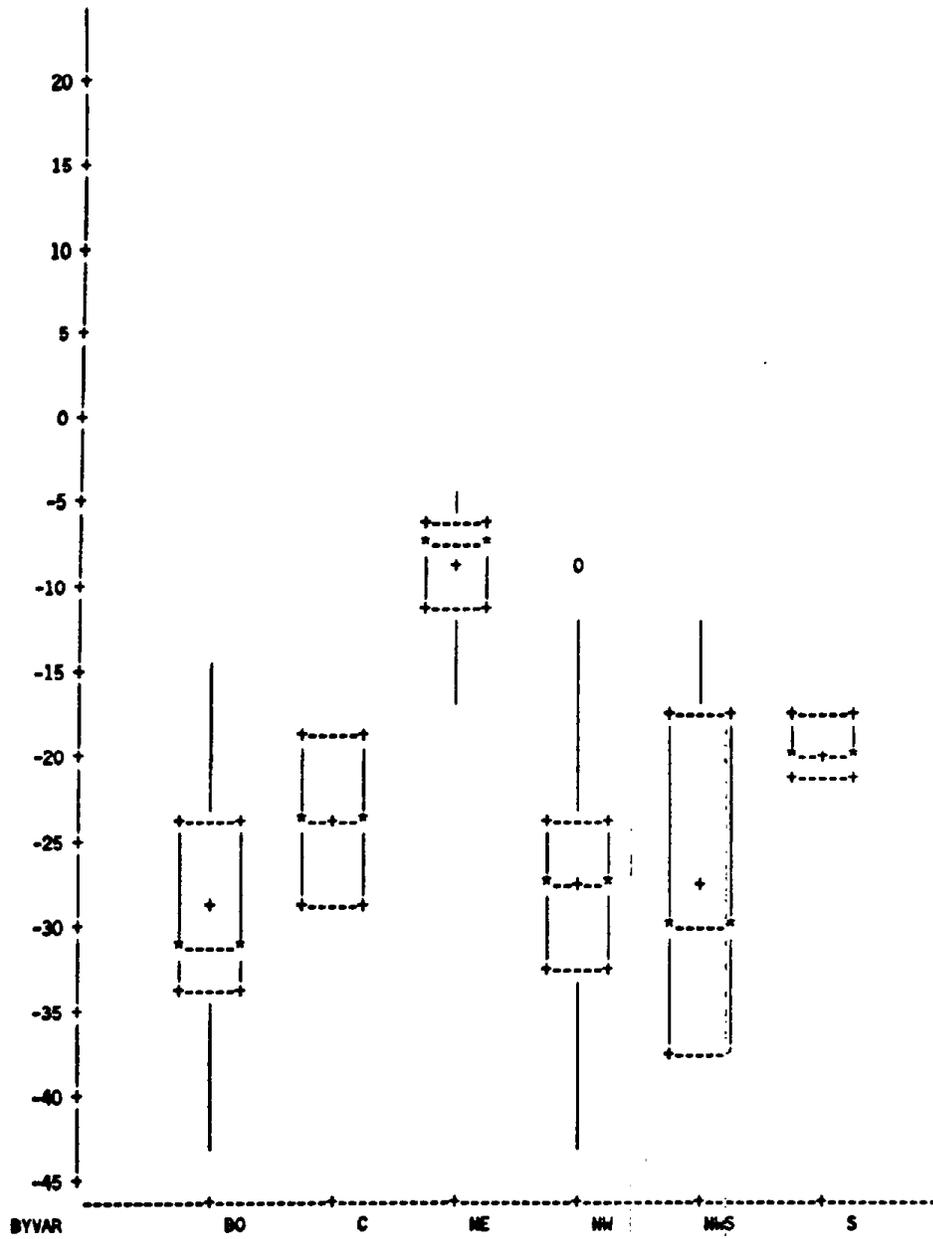


FIGURE 3-32k. Boxplots of key meteorological variables for days assigned to each flow pattern: San Francisco-Sacramento 1600 PST temperature difference (°F).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=TMDFSFC tmmxfsc-tm4psfsc

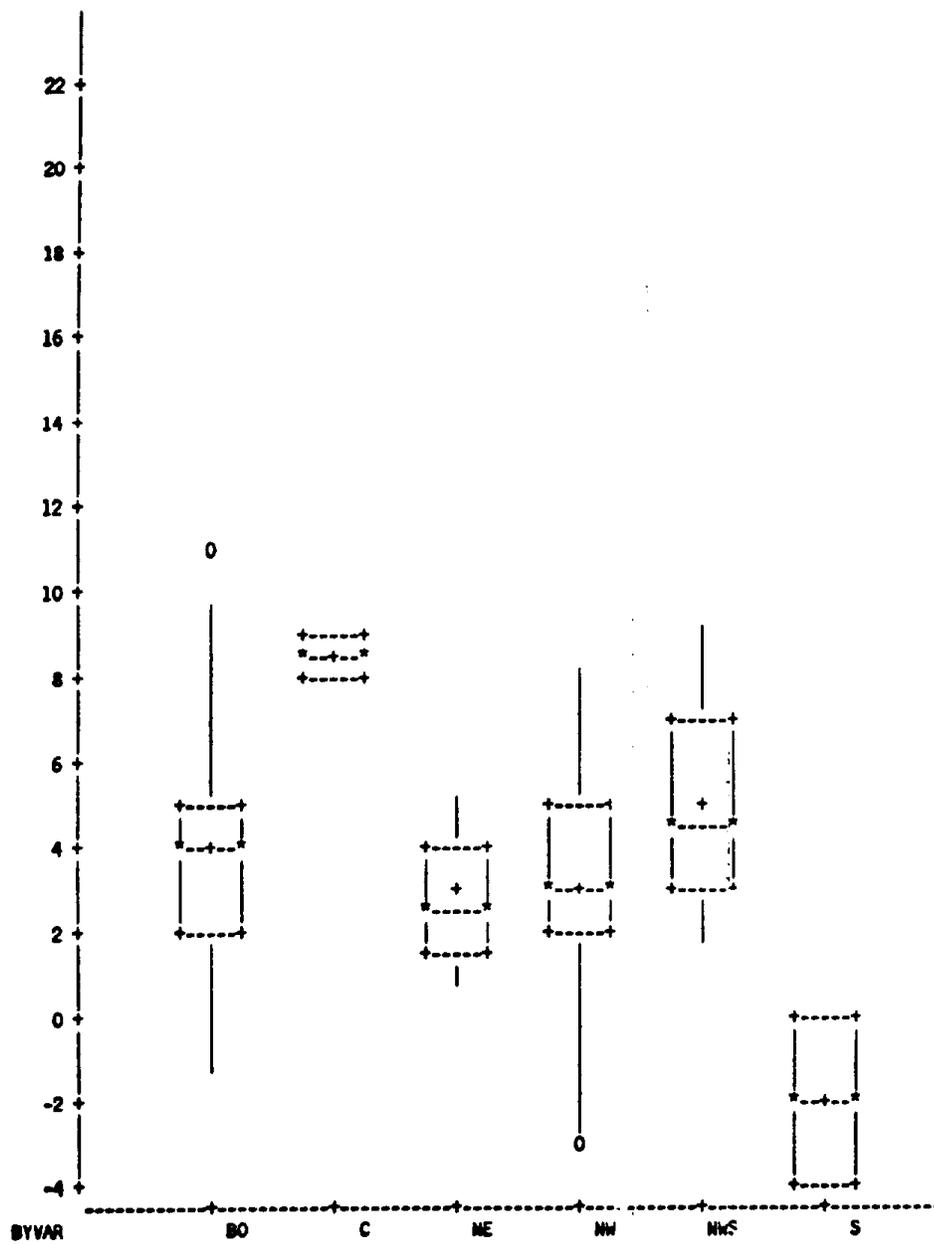


FIGURE 3-321. Boxplots of key meteorological variables for days assigned to each flow pattern: TMMXSFSC-TM4PSFSC .

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=05000KUM 4AM Oak-Winn 500mb height

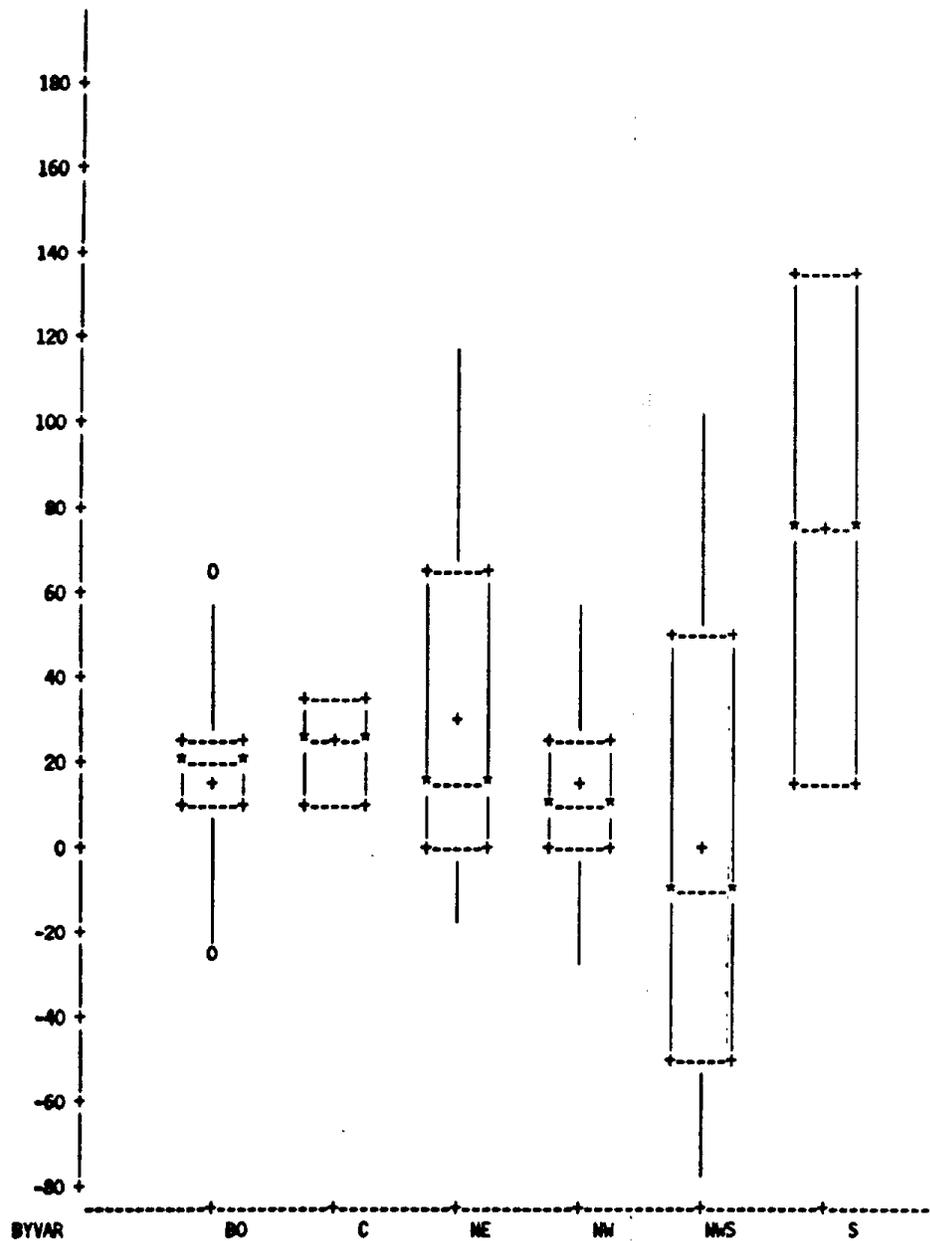


FIGURE 3-32m. Boxplots of key meteorological variables for days assigned to each flow pattern: 0400 PST 500 mb height gradient, Oakland-Winnemucca.

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=D5000KD 4AM Oak-Medf 500mb height

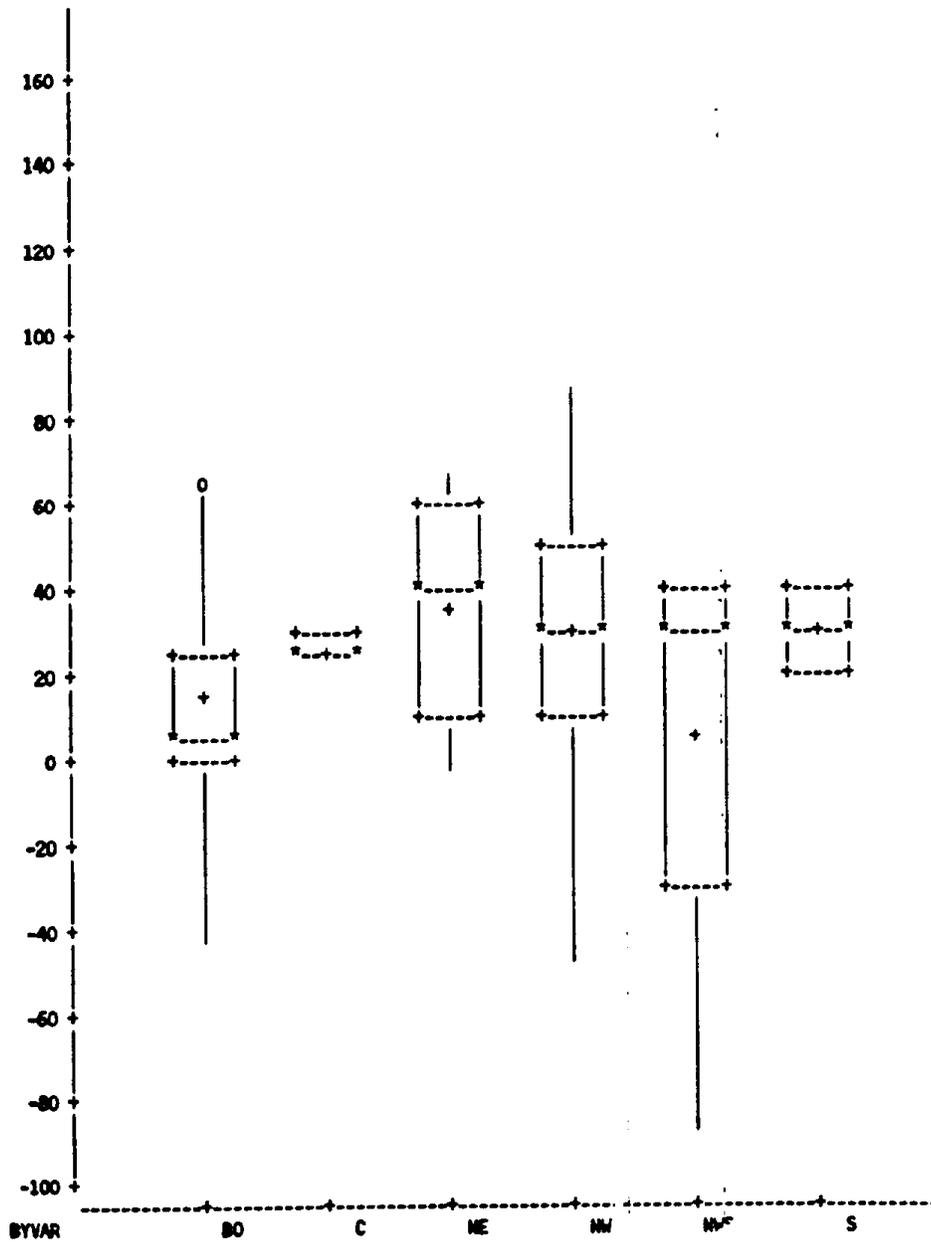


FIGURE 3-32n. Boxplots of key meteorological variables for days assigned to each flow pattern: 0400 PST 500 mb height gradient, Oakland-Medford.

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=D5000KLM 4AM Oak-LMU 500mb height

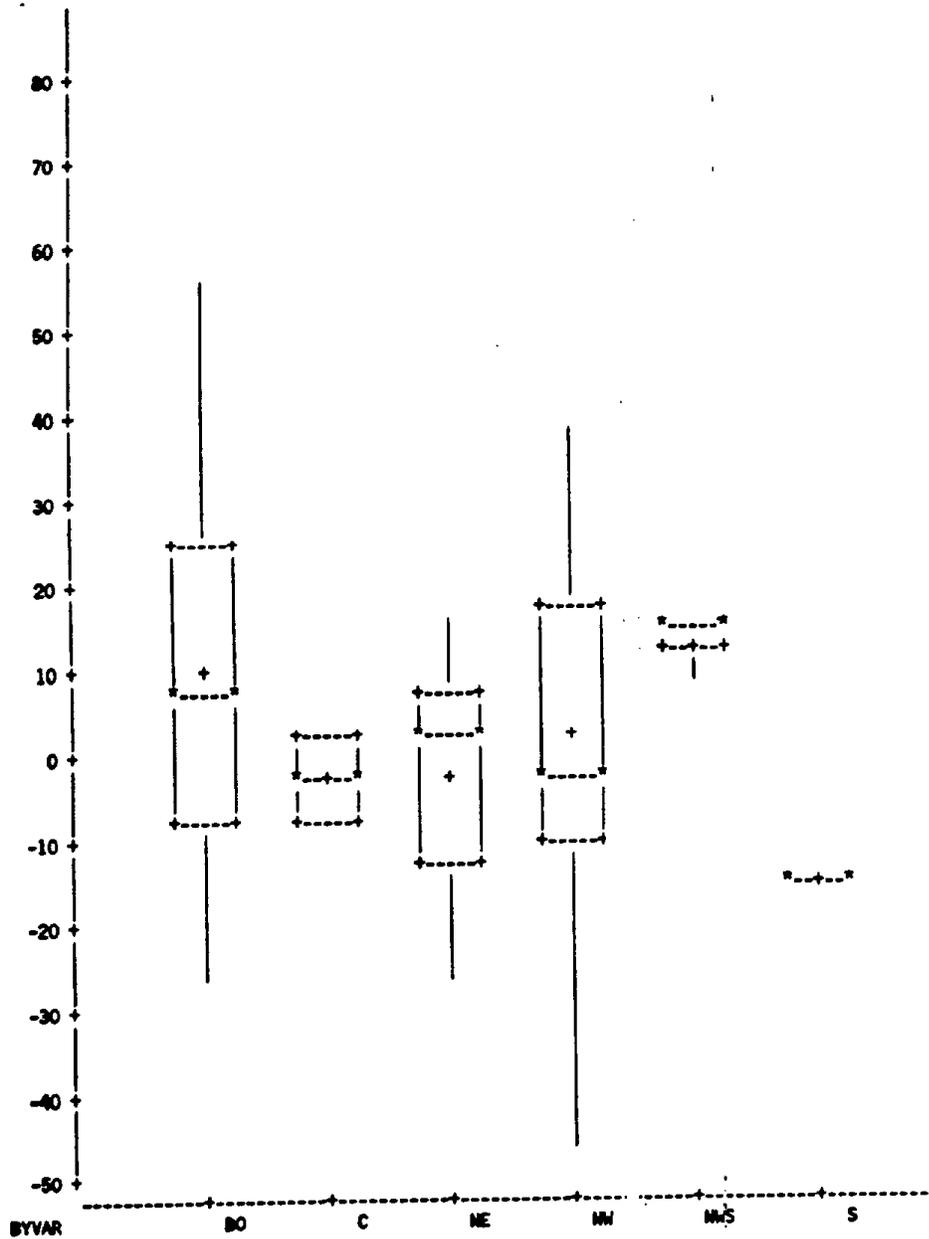


FIGURE 3-32o. Boxplots of key meteorological variables for days assigned to each flow pattern: 0400 PST 500 mb height gradient, Oakland-LMU.

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=D7000KM 4AM Oak-Minn 700mb height

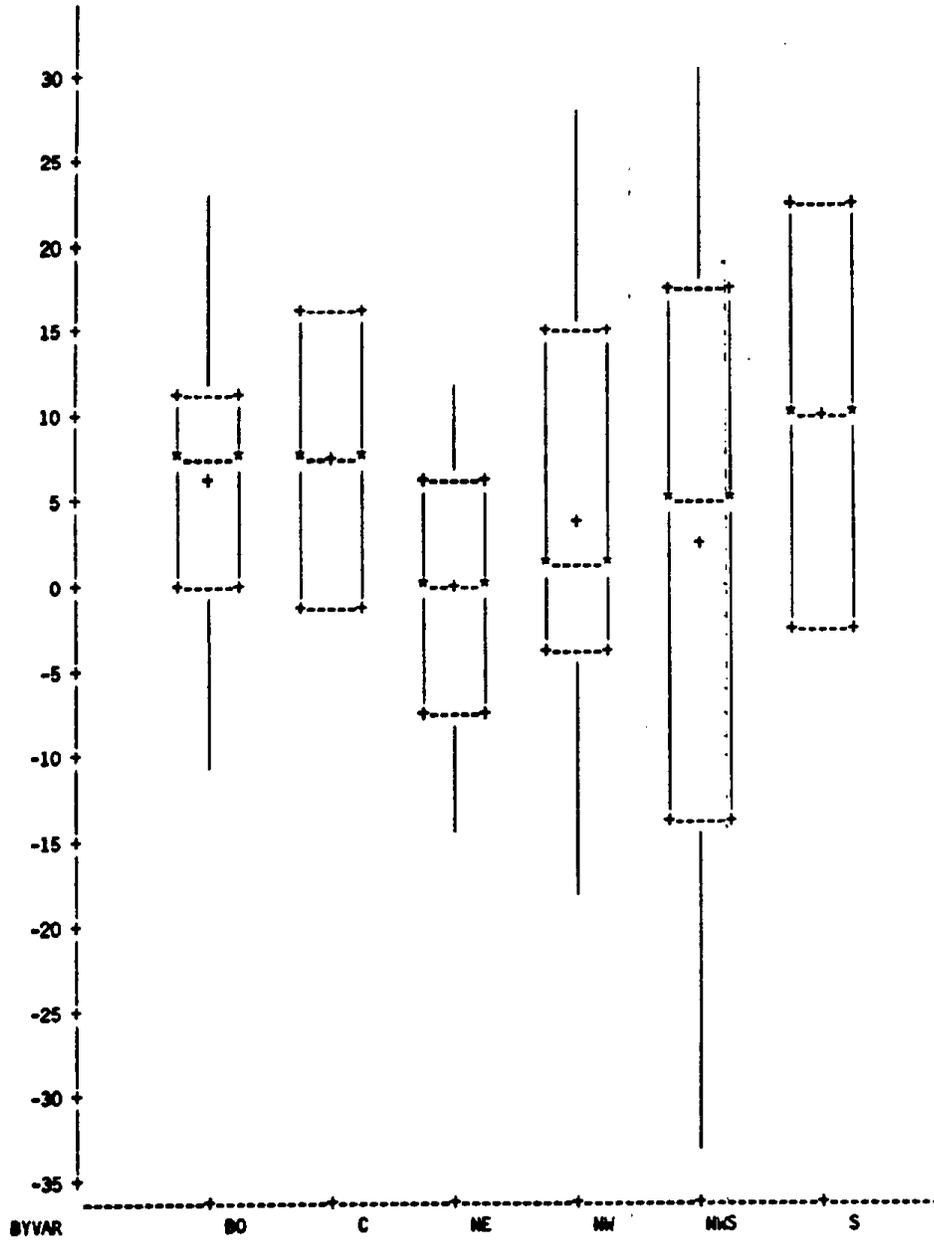


FIGURE 3-32p. Boxplots of key meteorological variables for days assigned to each flow pattern: 0400 PST 700 mb height gradient, Oakland-Winnemucca.

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=07000KD 4AM Oak-Medf 700mb height

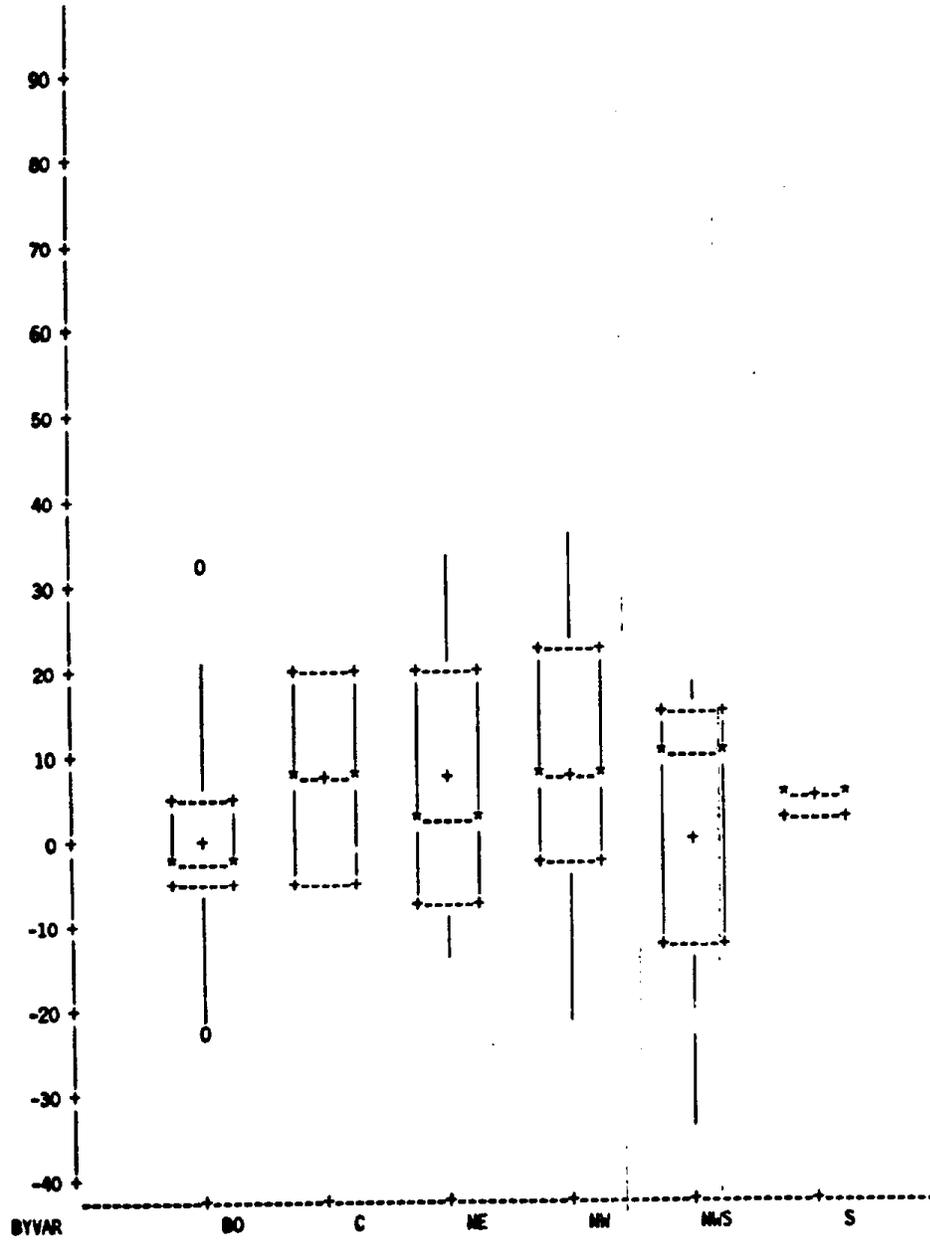


FIGURE 3-32q. Boxplots of key meteorological variables for days assigned to each flow pattern: 0400 PST 700 mb height gradient, Oakland-Medford.

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=OK4A850T 4AM Oak 850 mb temp

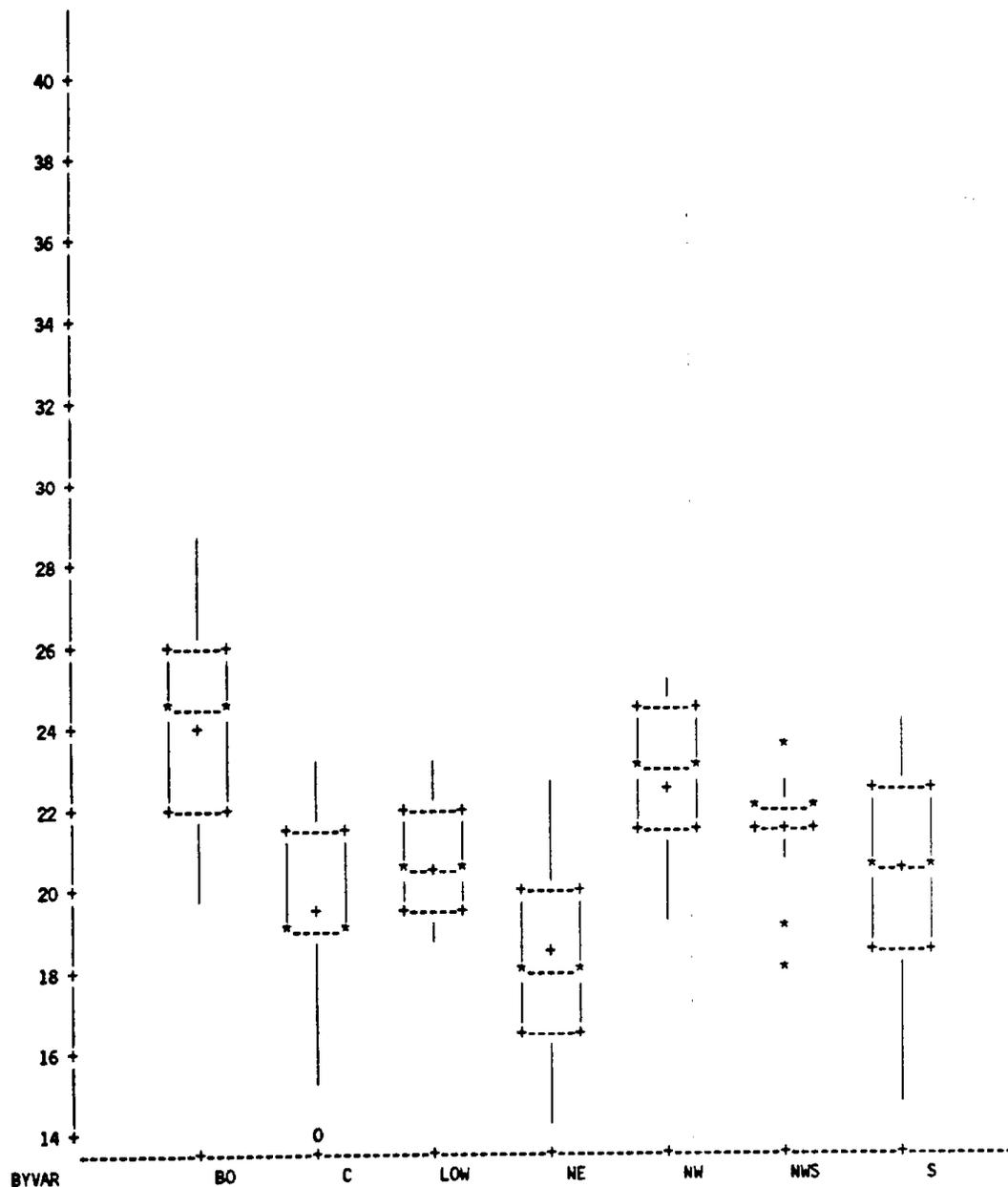


FIGURE 3-33a. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: 0400 PST, Oakland 850 mb temperature (°C).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=OK4ADELT 4AM Oak Inv Del Temp

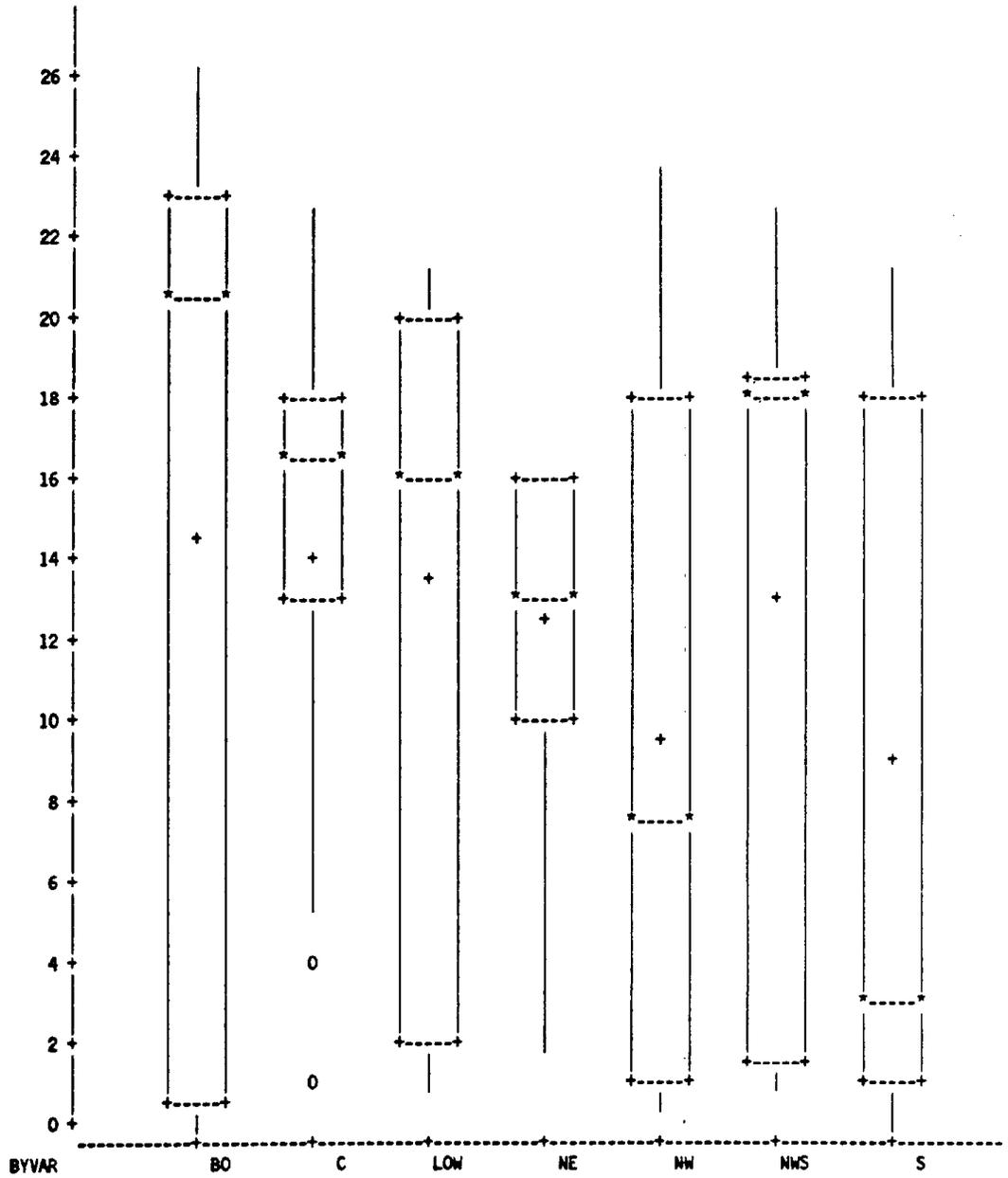


FIGURE 3-33b. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: 0400 PST, Oakland inversion top-base temperature difference (°C).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=OK4A1BH 4AM Oak Inv Base Height

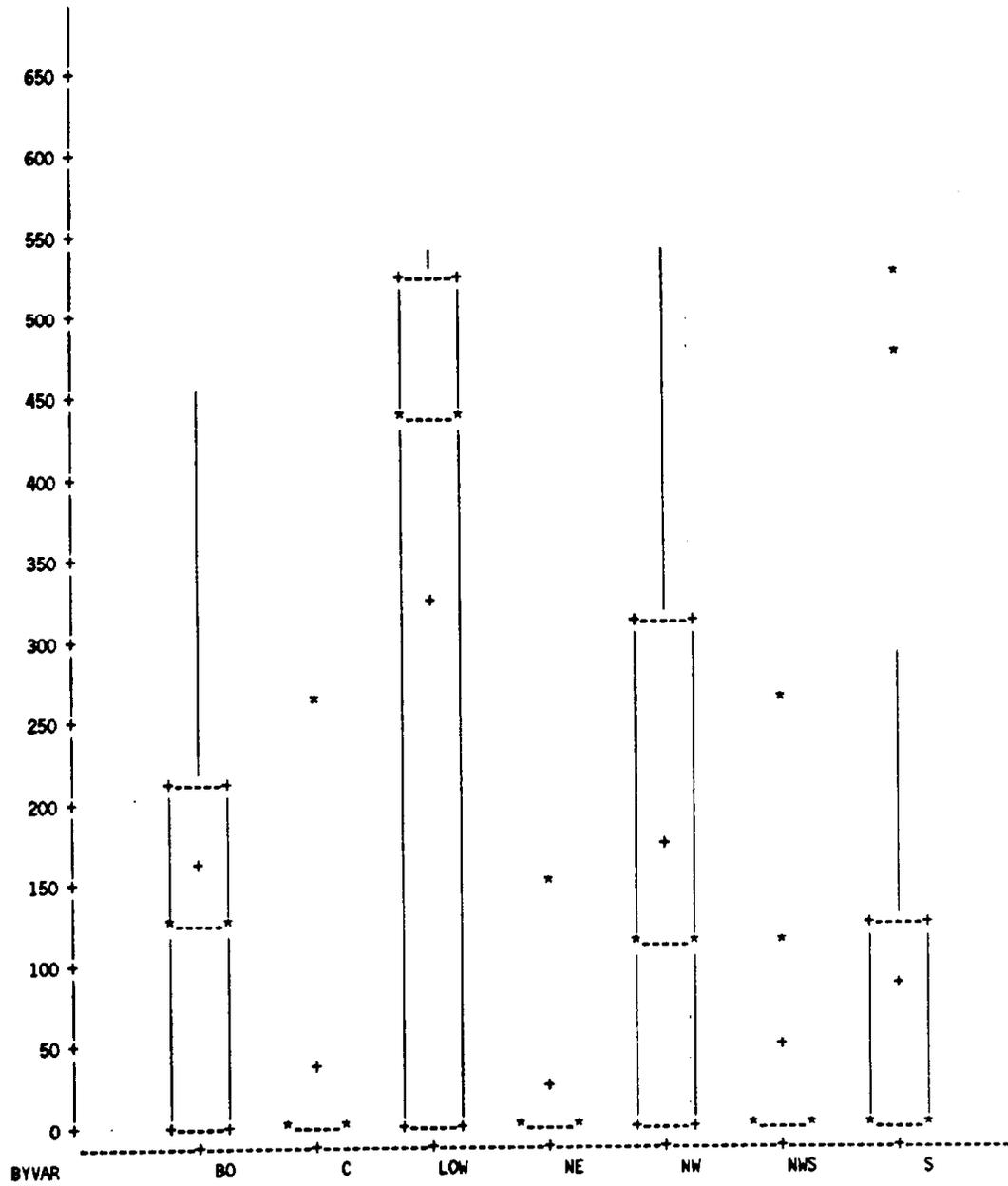


FIGURE 3-33c. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: 0400 PST, Oakland inversion base height (m).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=OK4PIBH 4PM Oak Inv Base Height

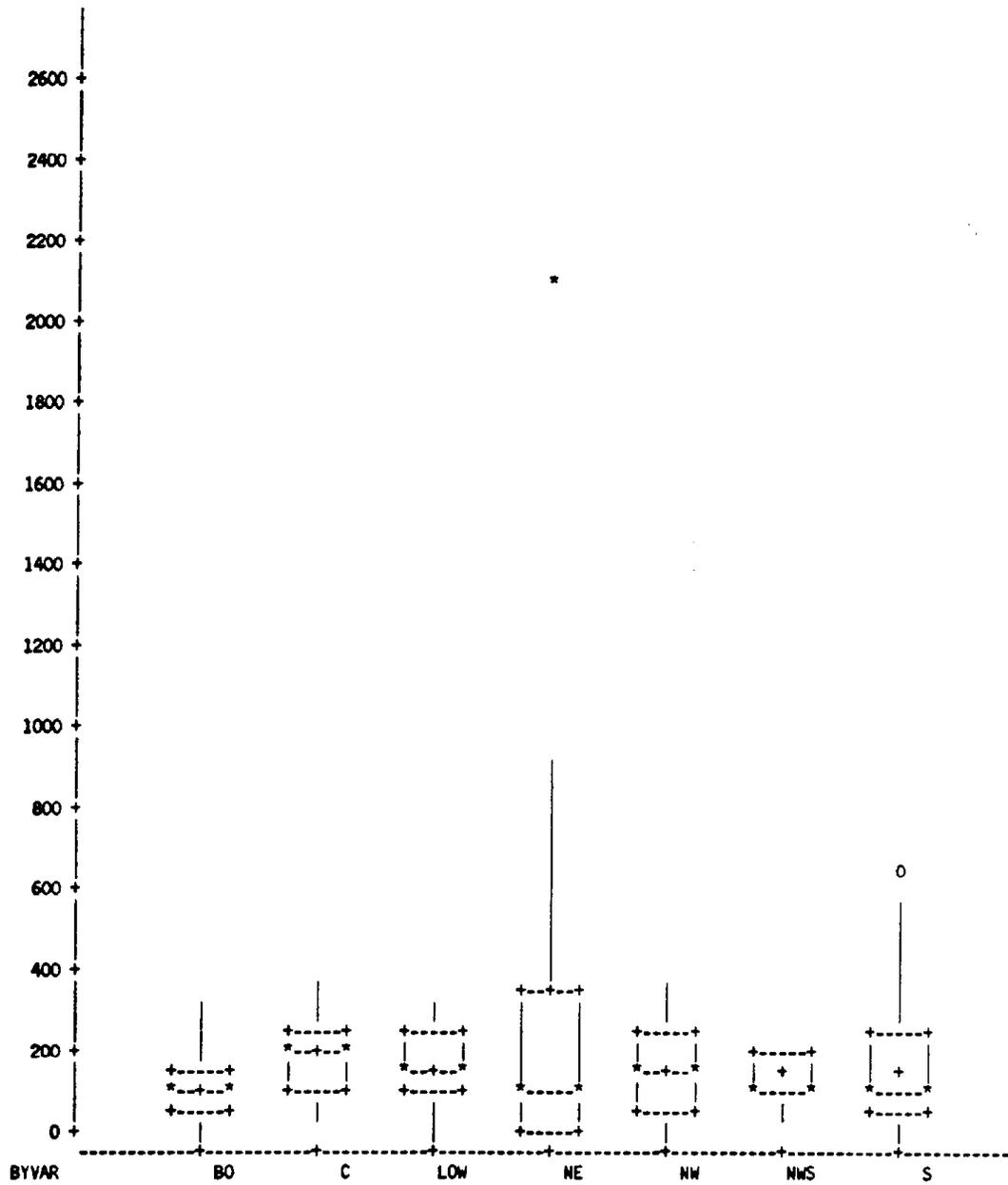


FIGURE 3-33d. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: 1600 PST, Oakland inversion base height (m).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=TMPDMSK Sacm max temp

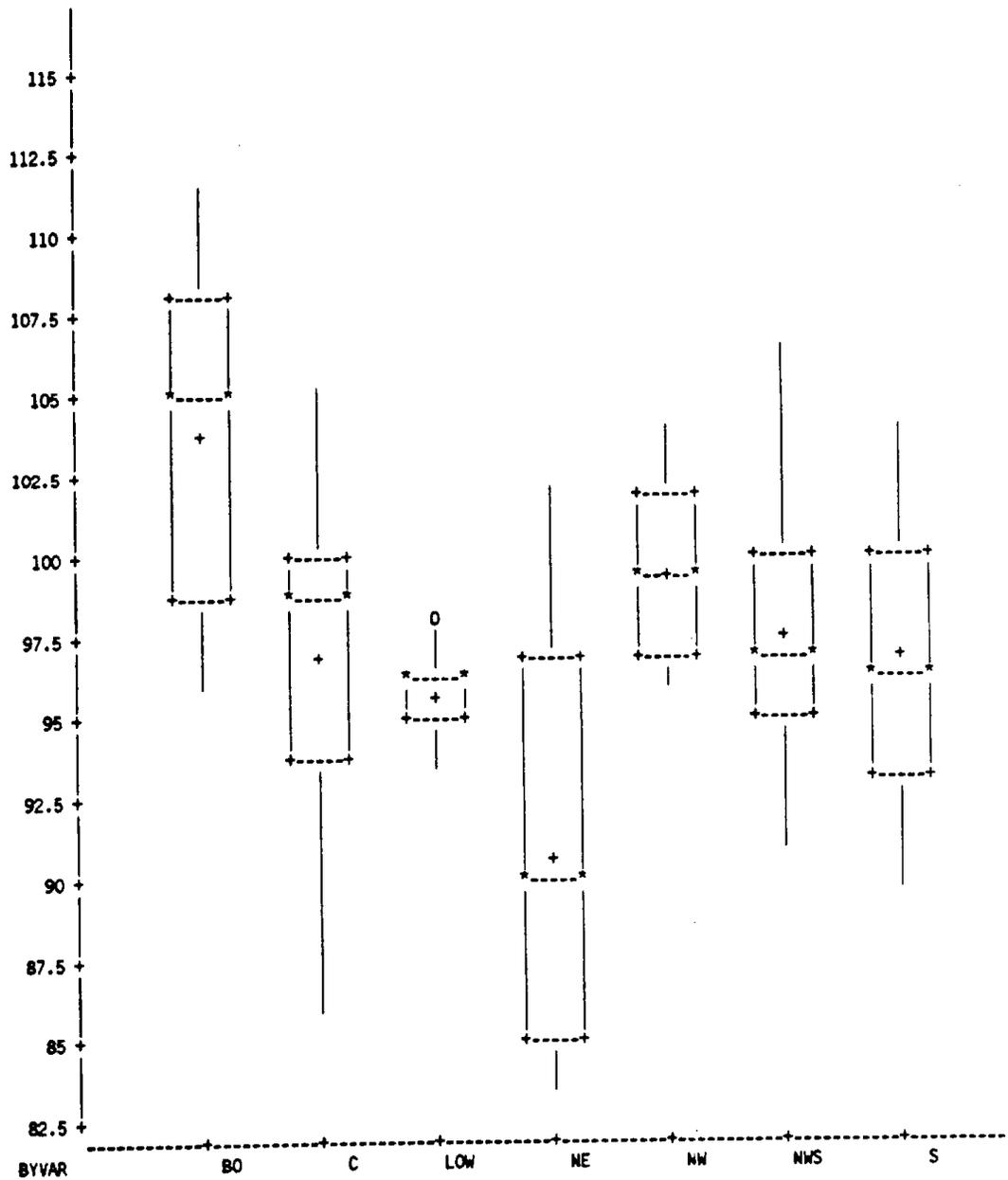


FIGURE 3-33e. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: Sacramento maximum temperature (°F).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=TMPDXXFS Fresno max temp

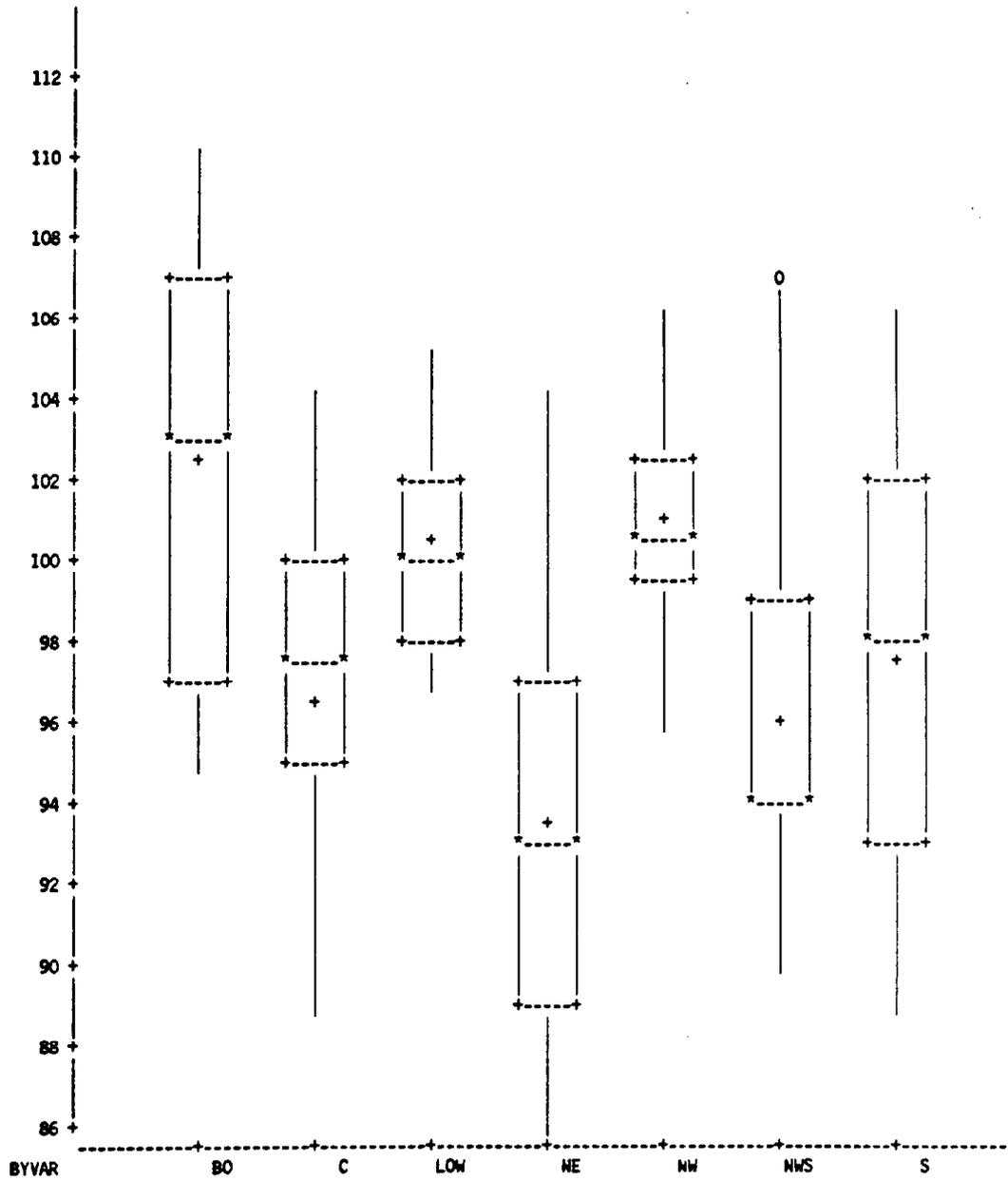


FIGURE 3-33f. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: Fresno maximum temperature (°F).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=SLVPSFRN SF-Reno press gradient

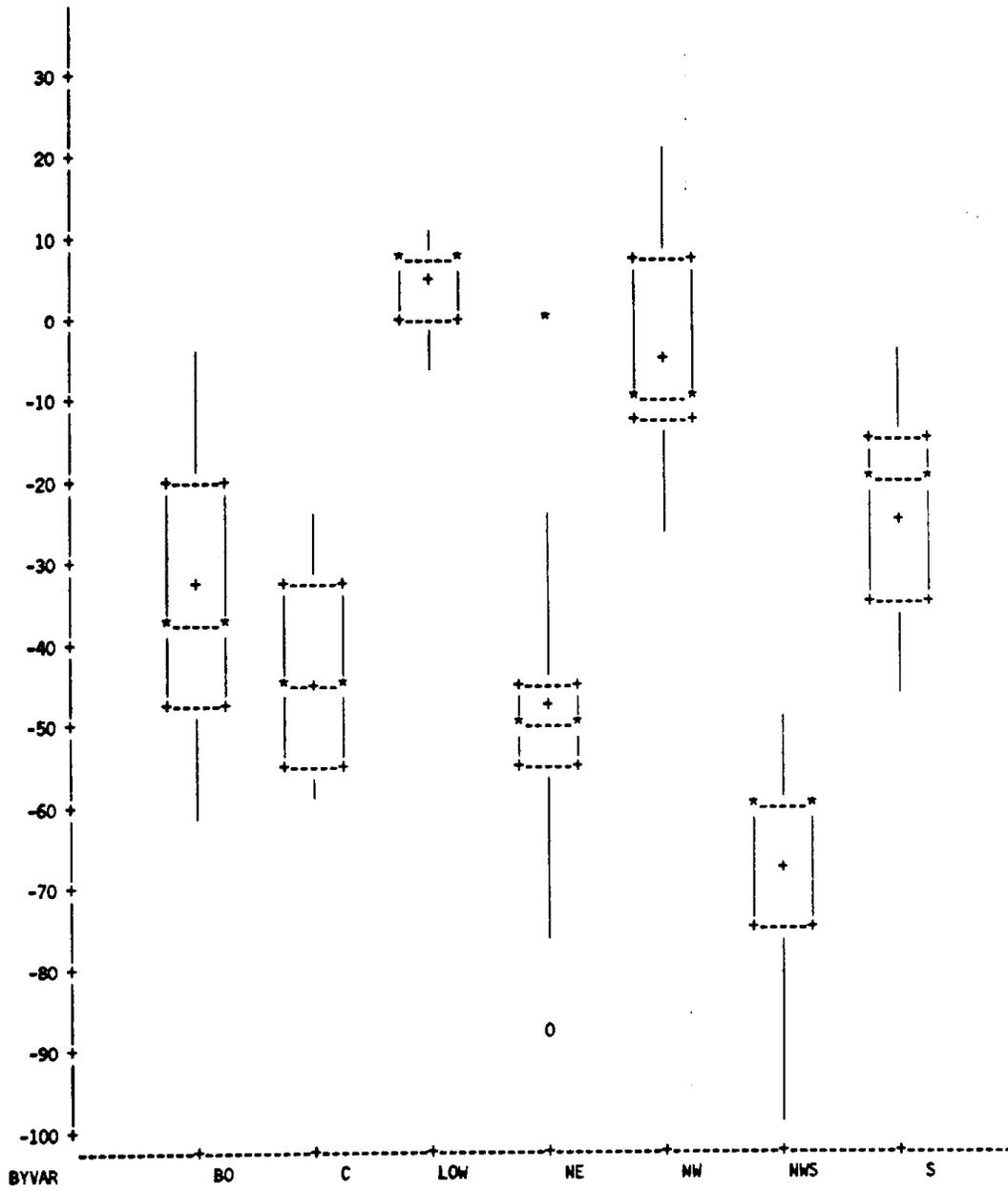


FIGURE 3-33g. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: SFO-Reno pressure gradient (mb).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=SLVPSFRD SF-Redd press gradient

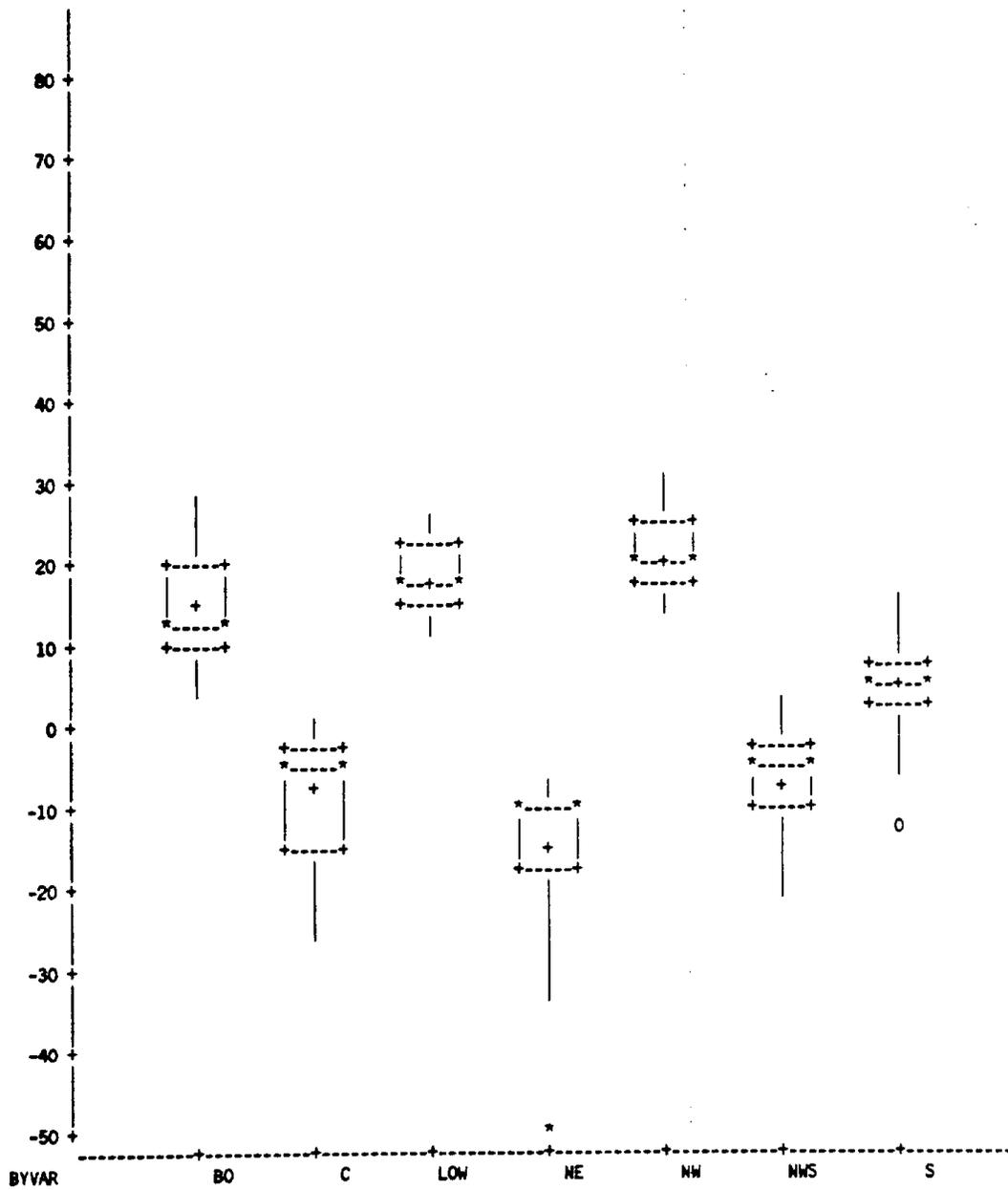


FIGURE 3-33h. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: SFO-Redding pressure gradient (mb).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=SLVPSFFS SF-Fres press gradient

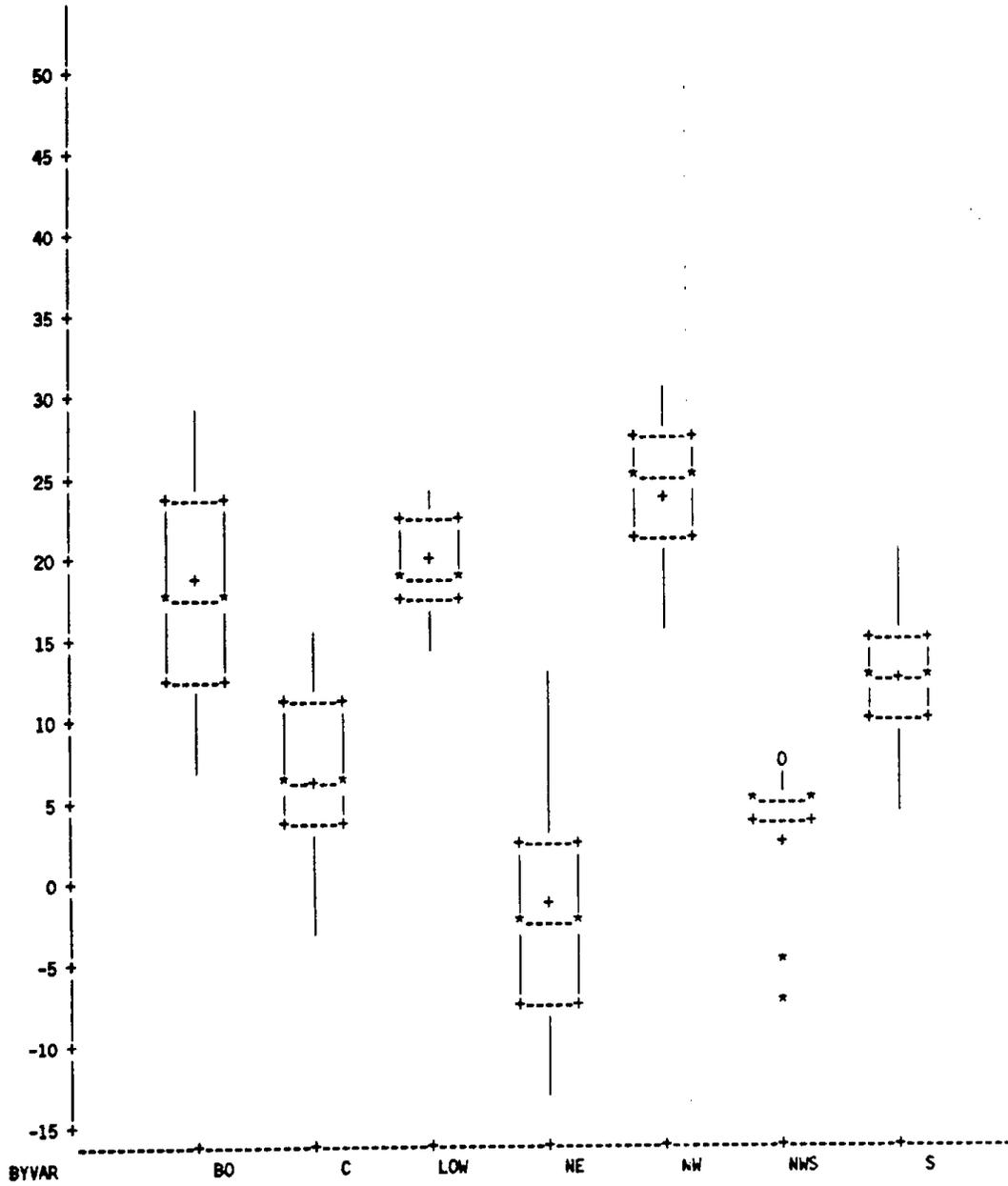


FIGURE 3-33i. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: SFO-Fresno pressure gradient (mb).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=TMMXSFSC SF-Sacr max temp gradient

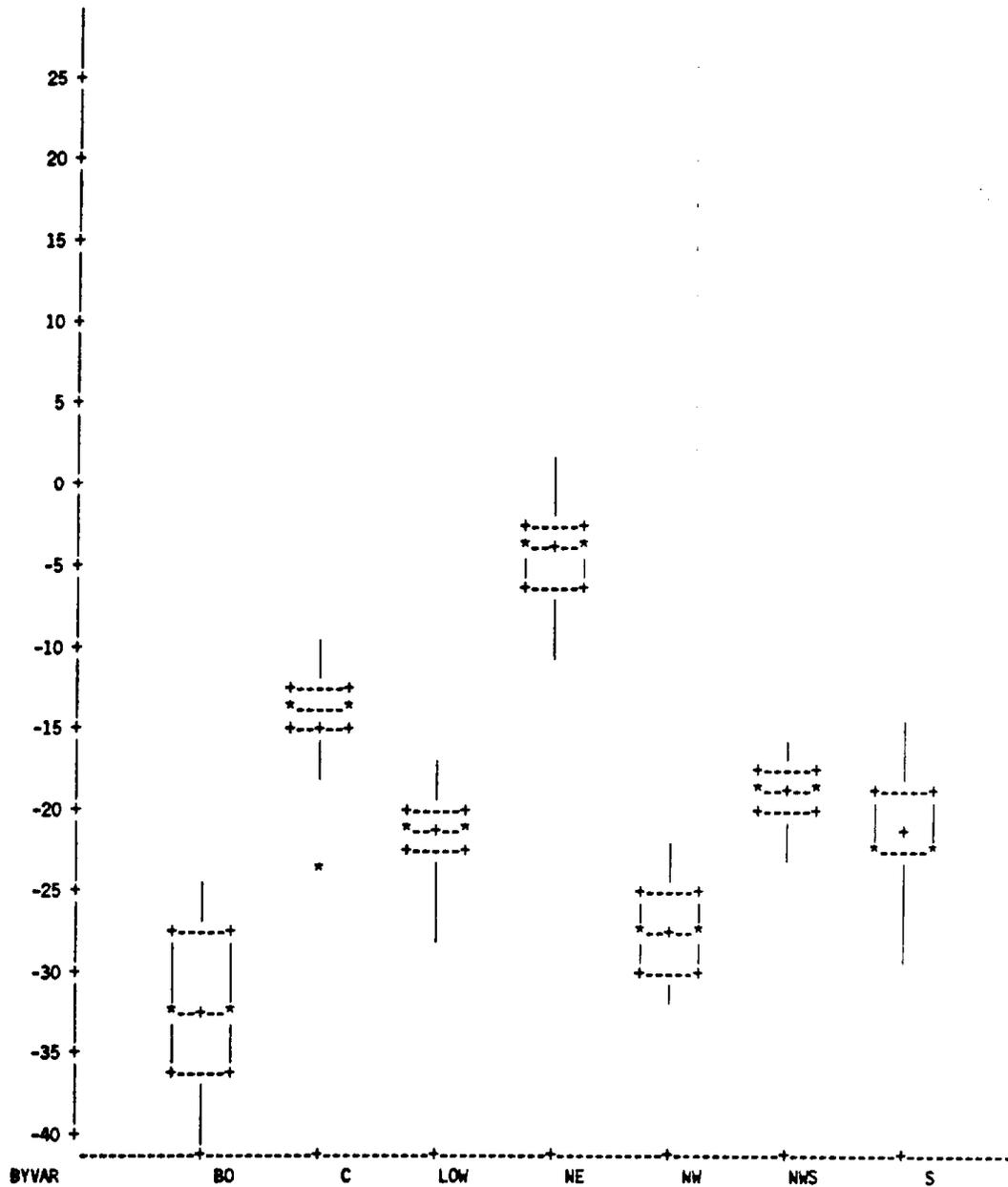


FIGURE 3-33j. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: San Francisco-Sacramento maximum temperature difference (°F).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=TMPSFSC SF-Sacr 4PM temp gradient

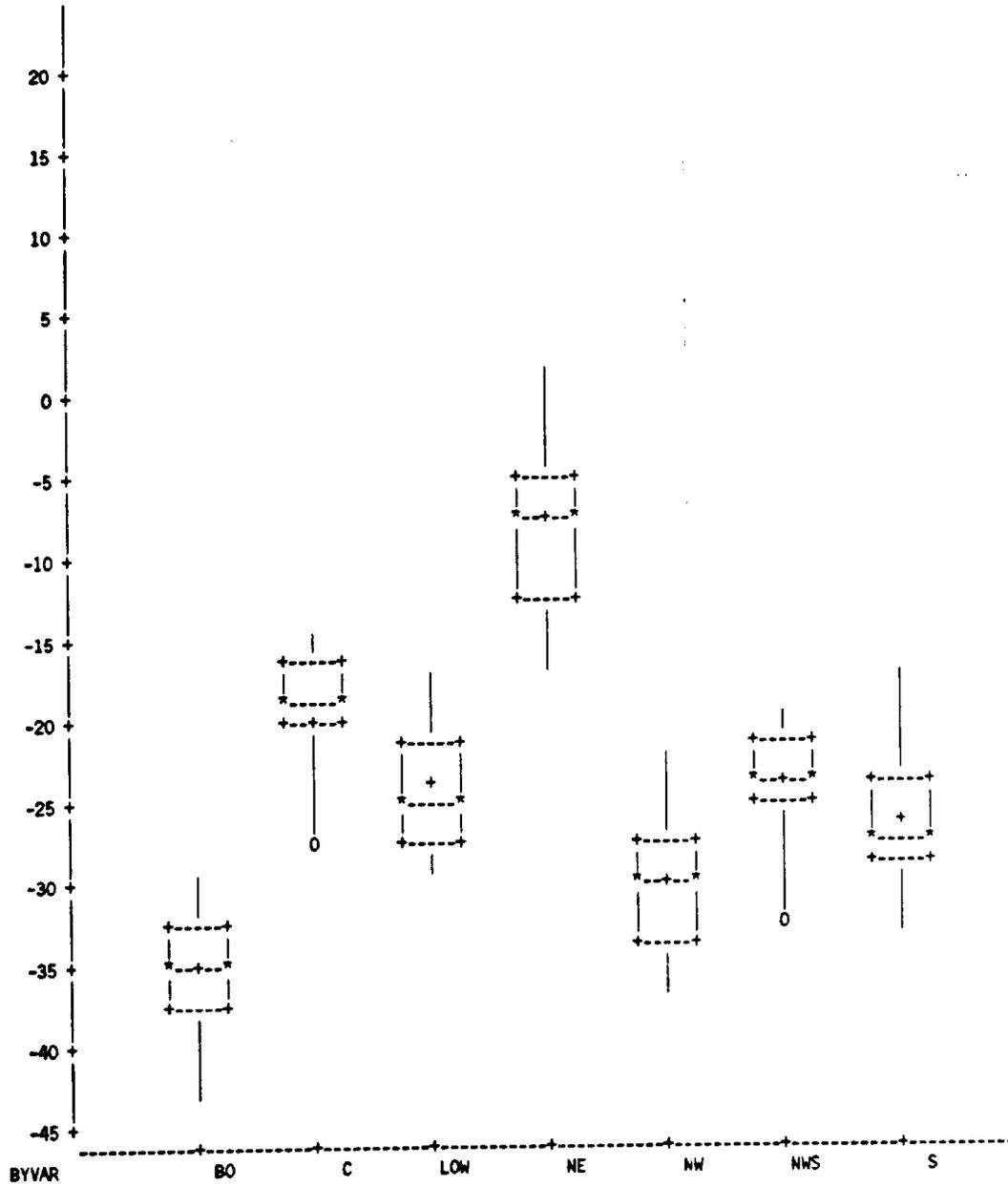


FIGURE 3-33k. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: San Francisco-Sacramento 1600 PST temperature difference (°F).

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=TMDFSFC tmmxfsc-tm4psfsc

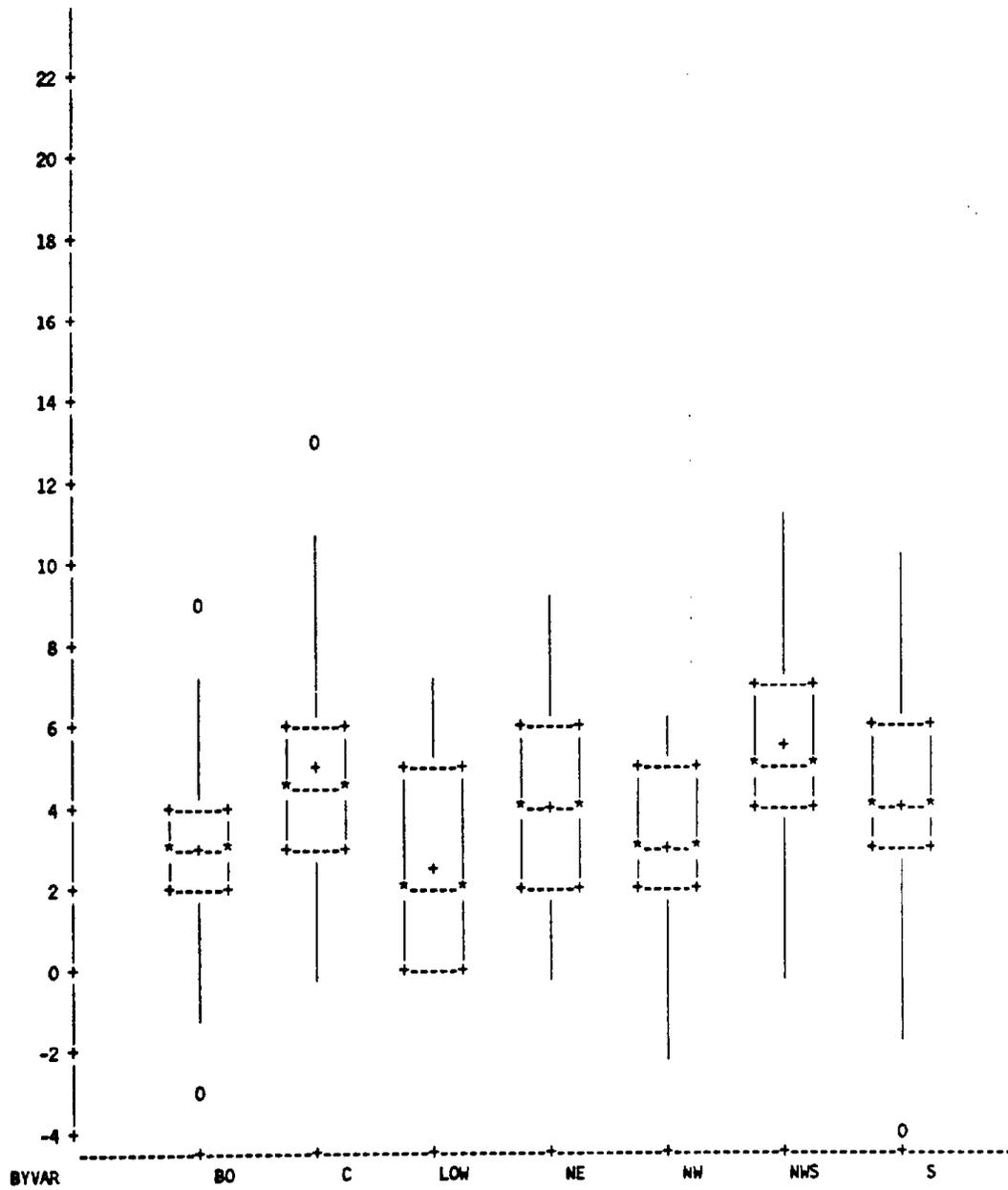


FIGURE 3-331. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: TMMXSFSC-TM4PSFSC.

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=D5000KWN 4AM Oak-Winn 500mb height

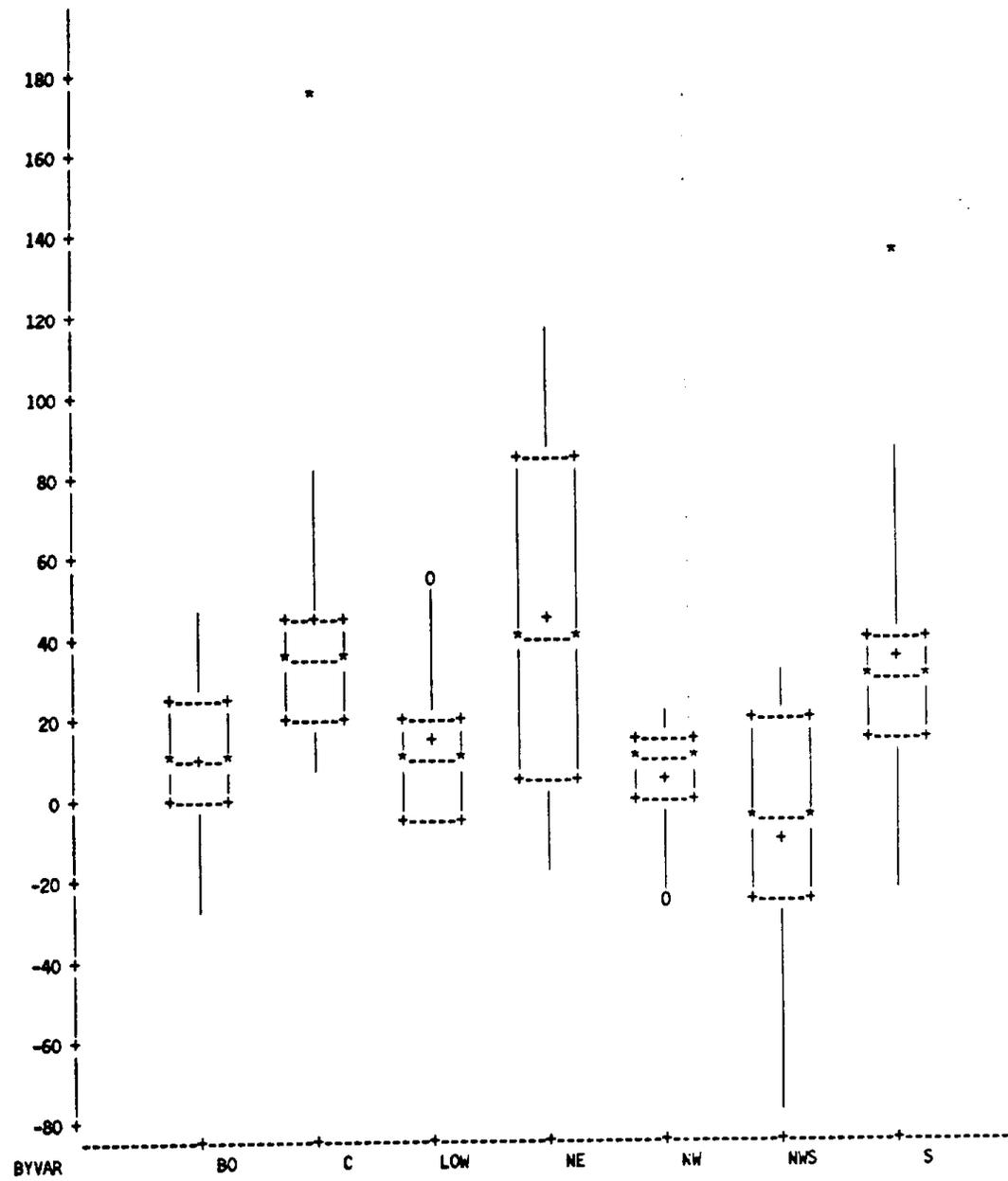


FIGURE 3-33m. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: 0400 PST 500 mb height gradient, Oakland-Winnemucca.

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=D5000KHD 4AM Oak-Medf 500mb height

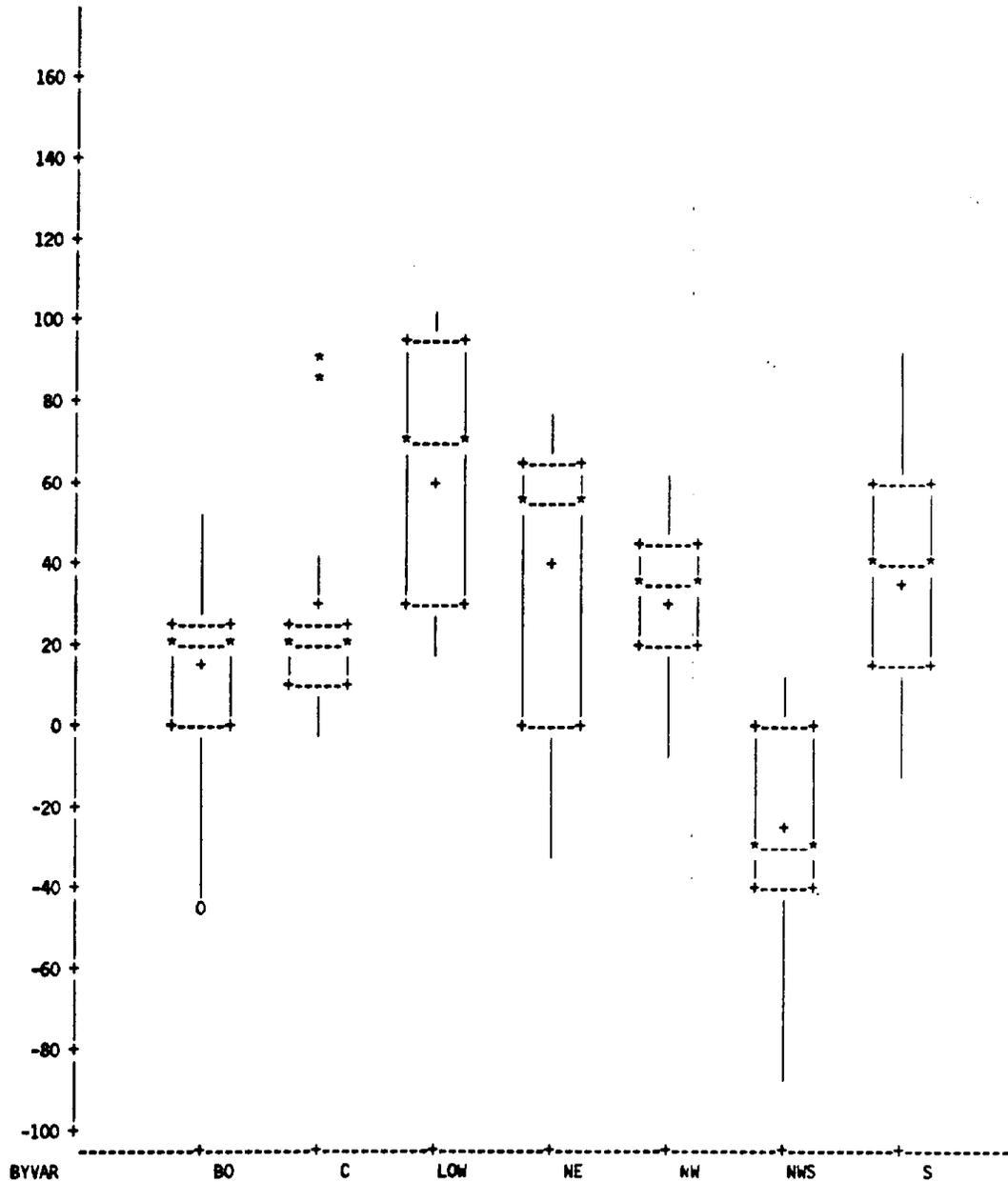


FIGURE 3-33n. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: 0400 PST 500 mb height gradient, Oakland-Medford.

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=D5000KLM 4AM Oak-LMU 500mb height

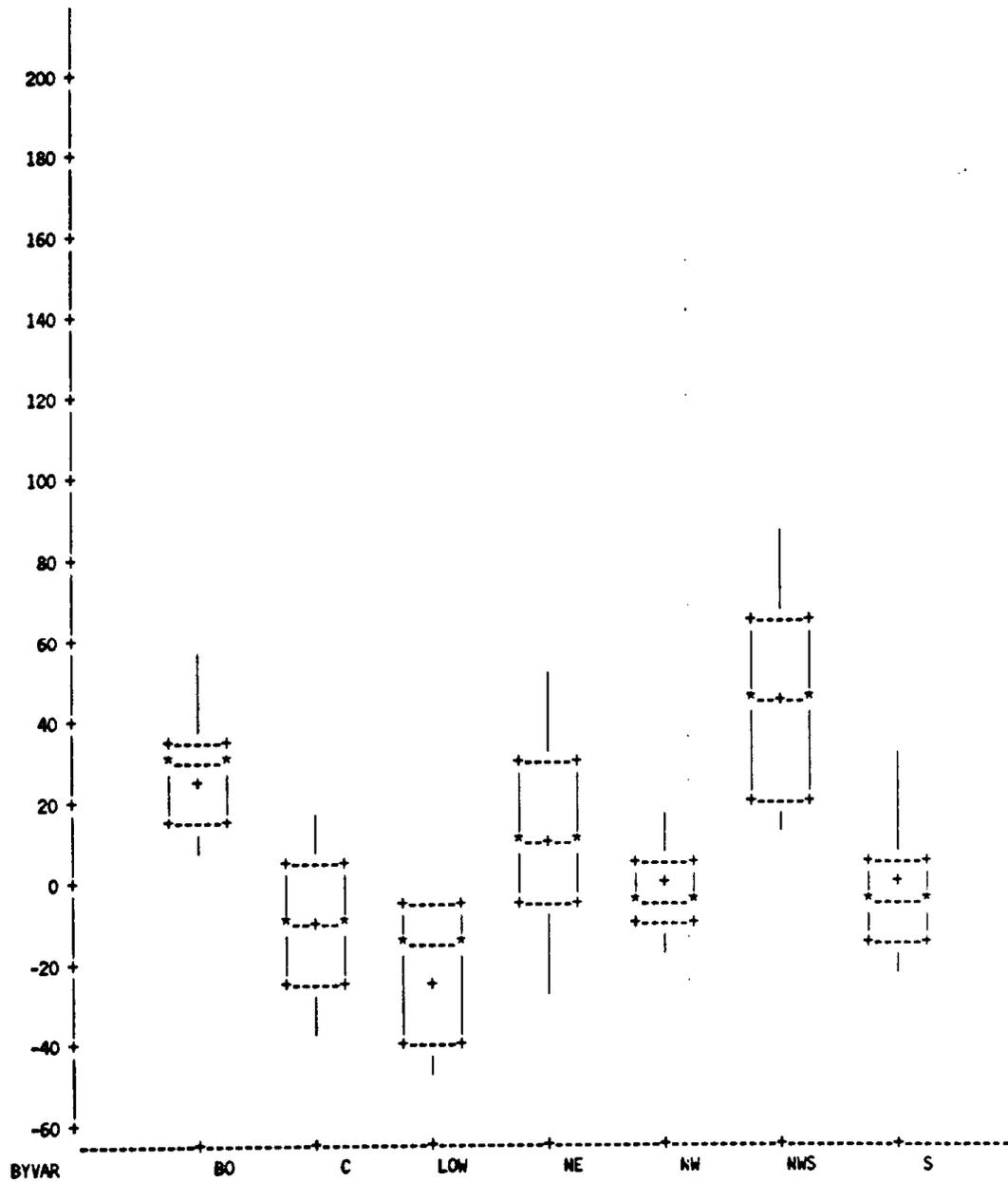


FIGURE 3-33o. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: 0400 PST 500 mb height gradient, Oakland-LMU.

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=D7000KIN 4AM Oak-Winn 700mb height

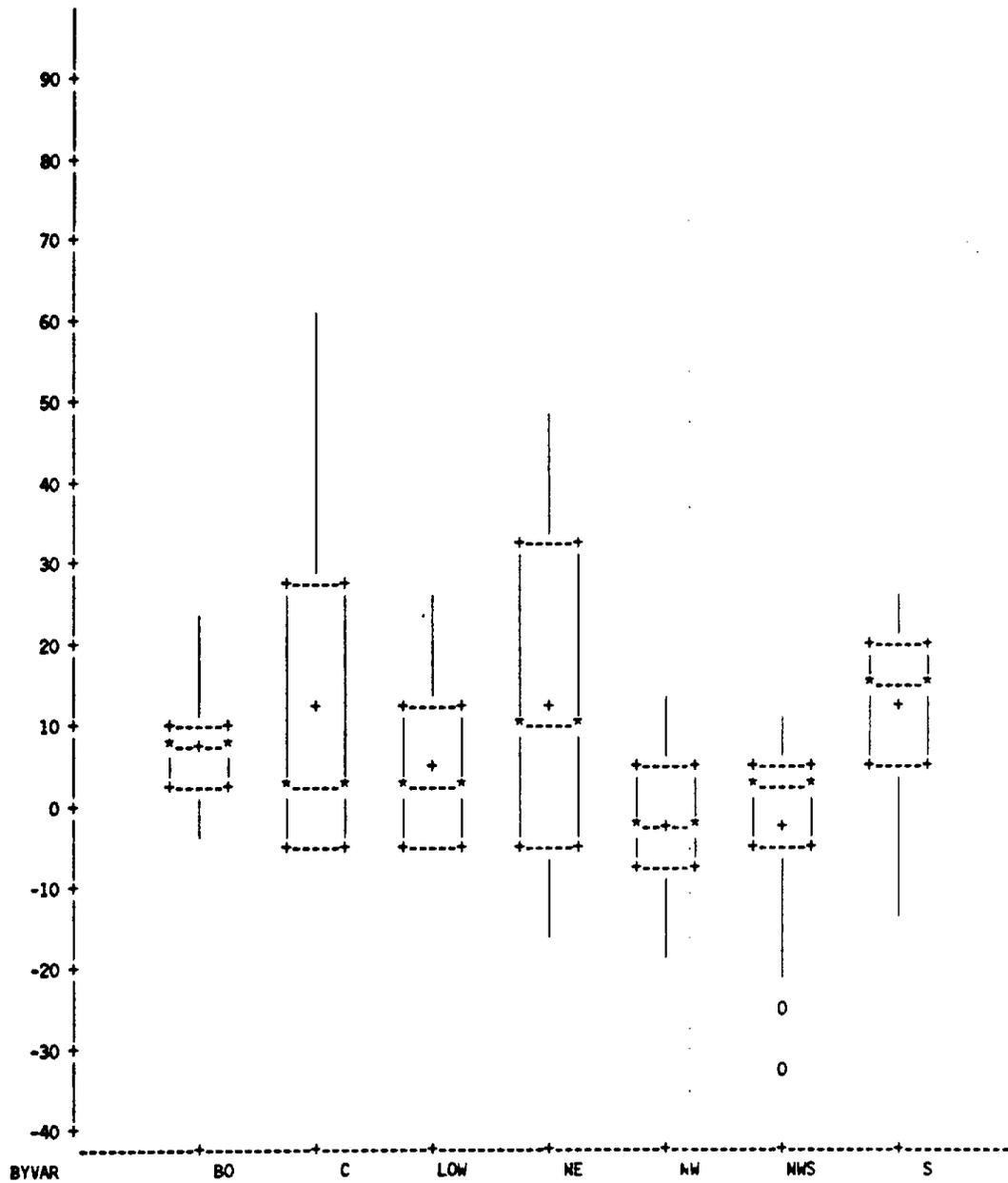


FIGURE 3-33p. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: 0400 PST 700 mb height gradient, Oakland-Winnemucca.

Side by side box plots

UNIVARIATE PROCEDURE
Schematic Plots

Variable=D70000MD 4AM Oak-Medf 700mb height

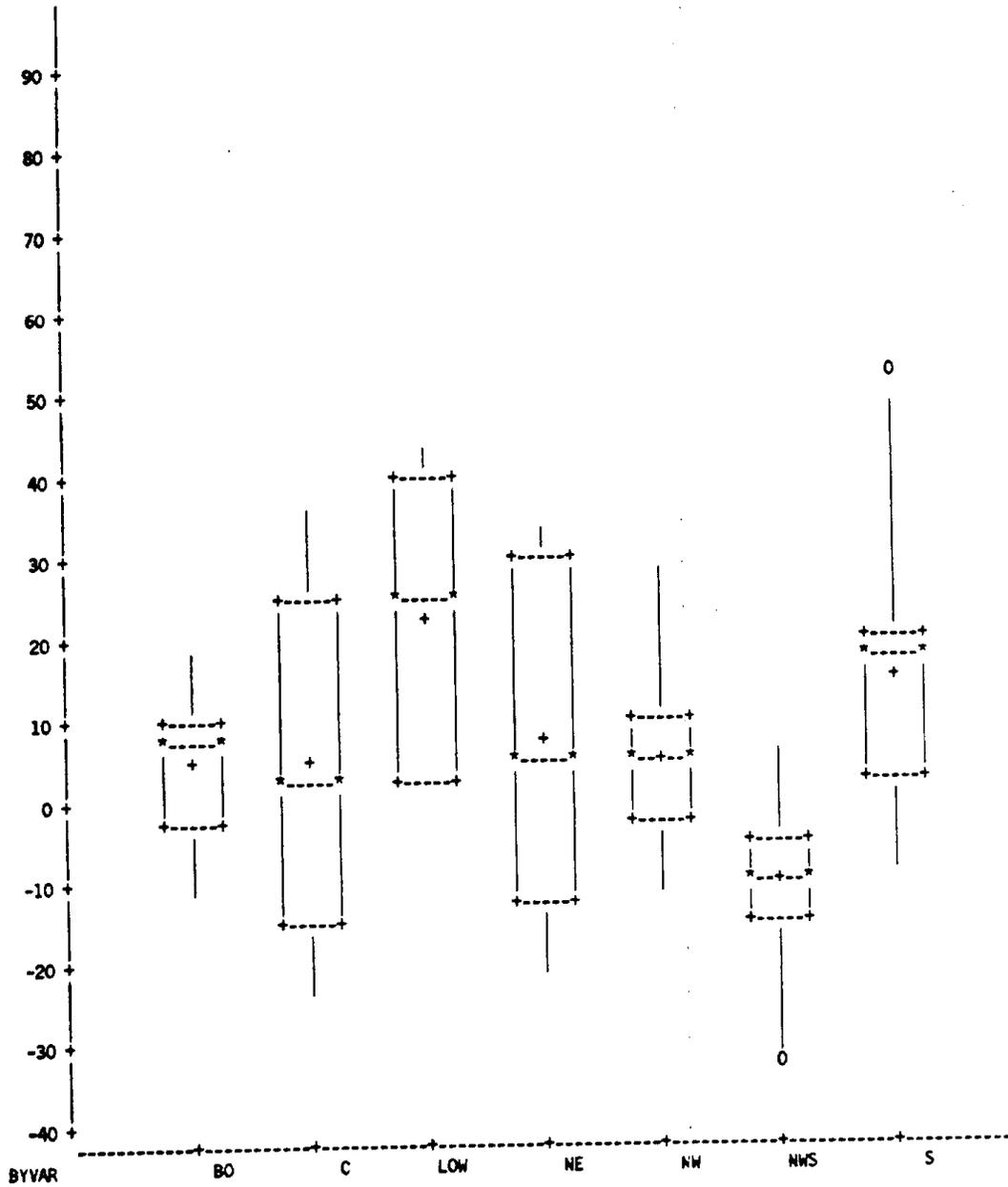


FIGURE 3-33q. Boxplots of key meteorological variables for days assigned to each cluster by the iterative clustering algorithm: 0400 PST 700 mb height gradient, Oakland-Medford.

4 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY OF ANALYSIS PROCEDURES

We conducted a detailed analysis of wind flow patterns and associated meteorological conditions during ozone episodes in the San Francisco Bay Area and surrounding air basins. As in previous studies of this region, we found that five of the seven principal flow patterns identified by Hayes et al. (1984) are associated with high ozone concentrations¹. Although the flow patterns evolve during the course of the day, our analysis and that of Douglas et al. (1989) indicate that mid-morning conditions, when precursor concentrations increase and rapid ozone formation begins, are closely related both to the magnitude and spatial distribution of afternoon maximum ozone concentrations in the study area and to meteorological conditions in the area. Thus, the 10:00 a.m. flow patterns provide a good indication of the most likely source-receptor scenario for the day.

The number of episodes on Northwest, Northeast, and Calm days is roughly in proportion to the overall frequency of occurrence of these flow types. The Bay Outflow pattern leads to a disproportionate number of episodes, with relatively frequent exceedances of the state ozone standard at Livermore. This pattern also favors high concentrations in the South Bay and in the Central Valley. Episodes are disproportionately infrequent on Southerly flow days, with only two episodes observed during the three-year study period; in both cases the only exceedances were values of 13 pphm in the Broader Sacramento Valley. Both the Northeast and Calm flow patterns are relatively rare, and only a few episodes of each type were observed. These conditions favor high concentrations within the Bay Area, especially at sites where such concentrations are not normally observed (e.g., around the Inner Bay).

Based on the analysis of onshore and nearshore flow patterns and the distributions of ozone concentrations associated with these patterns, a set of candidate source-receptor scenarios was defined. Each episode day during the study period for which wind fields were available was assigned to one of the scenarios. This tentative grouping of episodes was used to explore the principal features of each scenario through a series of analyses:

- A set of forward and backward surface air parcel trajectories were calculated on selected days representing each scenario. The trajectories provide an indication of the source regions impacting each downwind receptor area and the principal transport routes.

¹ The five flow patterns are Northwest, Northeast, Bay Outflow, Southerly, and Calm.

- Meteorological conditions associated with each candidate source-history scenario were analyzed to determine the principal features of each scenario. Box plots were used to compare the distributions of key meteorological variables between source-receptor scenarios on episode days and between episode and non-episode days.
- Exploratory cluster and discriminant analyses provided quantitative measures of the principal meteorological features of each source-receptor scenario and identified days that did not seem to fit well into their assigned scenario. Meteorological conditions on these days were examined, and days that appeared to be a better match with a different scenario were reassigned.
- Revised scenario assignments for episode days were used to develop a final set of linear discriminant functions. These functions form the basis of an objective source-receptor scenario classification procedure. A screening procedure was also developed to help identify days that meet the basic requirements for the formation of high ozone concentrations. The objective classification procedure is most appropriate for days that meet these requirements; other days may not match the general features of the source-receptor scenarios assigned by the procedure.

Results obtained from these analyses and from the application of the objective classification procedure are summarized below.

RESULTS

Trajectory analyses performed on days representing each candidate scenario confirm the principal relationships between source and receptor regions as suggested by the idealized flow diagrams in Figure 3-8. One exception is that the flow under the Northeast pattern on episode days is similar to the Bay Outflow pattern but with northeasterly winds in the Broader Sacramento Valley and Delta (i.e., offshore winds are not observed along the coast). Thus, the Northeast source-receptor scenario is not consistent with transport from the San Francisco Bay Area to the Broader Sacramento Valley. Trajectory analyses on Northwest days performed for this study indicate that the transport of material from the Bay Area through the Delta primarily moves material to the south of Sacramento and into the northern San Joaquin Valley due to the presence of a northerly wind component within the Central Valley. More significant transport to Sacramento may occur under a weak Northwest pattern, when northerly component winds are not present as far south as Sacramento, or a Bay Outflow pattern if southwest Delta winds build rapidly enough during the day.

Transport from the Bay Area into the North Central Coast is possible under all but the Northwest-South scenario. However, routinely available data do not allow for distinguishing between those scenarios in which a convergence zone is or is not present in the vicinity of Gilroy. When present, this convergence zone effectively blocks surface transport between the South Bay and receptors to the south in the North Central Coast air basin, although transport aloft may still occur.

The analysis of meteorological conditions reveals that ozone episodes in the San Francisco Bay Area and surrounding air basins generally occur under a variety of conditions; however, low, strong subsidence inversions—as evidenced by high 850 mb temperatures, low inversion base heights, high temperatures at inland locations, and higher sea-level pressures at Reno than at San Francisco—are a common denominator. In most cases, temperatures along the coast remain cool, indicating at least localized onshore flow that can transport material inland. All episode days examined have some or all of these characteristics. However, grouping episodes by source-history category reveals several unique features of each pattern:

- **Northwest** days are the most numerous and the most diverse group, representing a mix of conditions typical of episode days in general. Of all the episode days, this group has, on average, the least negative San Francisco-to-Reno surface pressure gradient (recall that the gradient is near zero or negative on nearly all episode days), suggesting a relatively vigorous sea breeze and a deeper marine layer that maintains low ozone concentrations along the coast and around the Bay but allows transport of precursor material inland where high concentrations can form.
- **Northeast** days are quite distinct with significantly higher pressure to the north and east of San Francisco (large negative San Francisco-to-Redding and San Francisco-to-Reno pressure gradients) resulting in a north to northeasterly flow in the southern Sacramento Valley and Delta region which can, but does not always, extend into the inland valleys of the Bay Area (e.g., Livermore). However, strong offshore winds are not present over the Bay Area under this scenario since the presence of such winds generally eliminates any high ozone concentrations.² This pattern is also identifiable by relatively warm temperatures along the coast.
- **Bay Outflow** days are similar in many respects to Northwest days, but with higher temperatures aloft and inland and weaker 700 mb and 500 mb height gradients. This indicates the presence of a broad, flat high pressure system with strong subsidence inversion and a weaker, primarily thermally driven surface circulation pattern that sets up in the absence of any synoptic-scale forcing.
- **Calm** days were only observed twice in conjunction with ozone episodes, making it difficult to generalize about their principal meteorological characteristics. However, both days were characterized by generally weak surface and aloft pressure gradients, as one would expect.
- **Southerly** days are not normally associated with ozone episodes. Two episodes with very different meteorological conditions were classified as having southerly flow. In both cases, the only ozone exceedances were 13 pphm concentrations in Sacramento.

² We note, however, that Douglas et al. (1989) studied a northeast flow event during 1980 during which the northeasterly winds penetrated into the Bay Area and produced exceedances in the South Bay. An event of this type was not observed during the 1989–1991 study period.

- **Northwest-South** days exhibited a variety of conditions similar to those associated with both Northwest and Bay Outflow patterns. Exceedances occurred at several monitors throughout the Bay Area on one of these days, but only at Livermore on another and only at Pinnacles on the remaining two. These results suggest that the characteristics of this flow pattern are quite diverse.

Taken together, the above results suggest that some of the candidate source-history scenarios, such as the Northeast scenario, are reasonably well defined while others, such as the Southerly and Northwest-South categories, require further refinement.

Attempts to develop a screening procedure to identify ozone episode days on the basis of meteorological conditions using discriminant analysis and classification trees (CART) were largely unsuccessful in that these procedures put many actual episode days in the non-episode category. Therefore, a simple conservative screening procedure was developed that categorizes days as "potential ozone days" or non-ozone days depending on the value of four key temperature and pressure gradient variables. The key feature of this procedure is that it successfully identifies nearly all (86 percent) of the actual episode days while at the same time eliminating most (85 percent) of the non-episode days. The objective source-receptor scenario classification procedure was then applied to the potential ozone days to determine the most appropriate scenario for each day. Daily maximum ozone concentrations for days assigned to each scenario were examined to evaluate differences in the spatial distribution of ozone concentrations between scenarios. In addition, diurnal profiles of average hourly ozone concentrations on episode days were computed for key monitoring sites to evaluate the potential for transport under each scenario. The principal features of spatial ozone distributions associated with each scenario, as revealed by these analyses, are these:

- Concentrations in the immediate vicinity of San Francisco Bay are generally highest under the Northeast and Bay Outflow scenarios, when the sea breeze is weakest. Similarly, concentrations in San Jose are highest under Northeast and Calm scenarios.
- Peak concentrations at Livermore are highest under Northwest and Bay Outflow scenarios, and exceedances of 9 pphm are most frequent under Bay Outflow conditions. Diurnal profiles show little difference between scenarios in the timing of the afternoon peak ozone concentration.
- Concentrations in the Sacramento area are lowest under the Northeast scenario, when transport from the Bay Area is cut off by northerly winds in the Central Valley and local emissions are transported away from the area. Much higher concentrations are observed under the Bay Outflow and Northwest scenarios and exceedances of 9 pphm are most common under Bay Outflow conditions, most likely as a result of increased stagnation, high temperatures, and reduced vertical mixing in both the Bay Area and Sacramento. Our trajectory analyses on Northwest episode days showed no evidence of transport from the Bay Area due to northerly component flow in the Broader Sacramento Valley. However, such transport may occur on some days included in the Northwest category when

conditions allow southwest Delta winds to extend into the Sacramento metropolitan area. Data on Bay Outflow days are insufficient for calculating reliable trajectories due to the light and variable winds characteristic of this scenario. Streamline analyses prepared for a few Bay Outflow days indicate northerly winds in the Sacramento area (which would prevent transport from the Bay Area) at least during the morning hours. Diurnal profiles show little difference between scenarios in the timing of the late afternoon ozone maximum in Sacramento.

- Highest ozone concentrations in the Northern and Central San Joaquin Valley regions are associated with the Bay Outflow scenario as in the Sacramento area. Diurnal profiles at Stockton and Modesto reveal higher late afternoon concentrations under this scenario, indicating possible transport from the Bay Area and, in some cases, Sacramento. This feature is not evident at Fresno.

RECOMMENDATIONS

Results presented in this report provide a good basic description of the major categories of meteorological conditions, including wind flow patterns most commonly associated with high ozone concentrations in the San Francisco Bay Area and surrounding air basins, and the resulting spatial and temporal distribution of ozone concentrations. Additional refinement of the unique meteorological and air quality features of each source-receptor scenario we have identified would enhance the usefulness of our results in air quality management tasks including transport assessment, trends analysis, and episode selection for modelling. Further study of transport between air basins under each scenario is especially needed. Currently available data are only sufficient to suggest the possibility of transport in some cases but not to confirm the occurrence or quantify the magnitude of transport. In particular, data needed to identify the existence or nonexistence of a convergence zone between Hollister and Gilroy (and therefore transport from the South Bay to the North Central Coast) under each scenario were not available. Some wind profiler data have been collected at key locations to help address this need; however, these data were not available in time for use in our study. Application of a more sophisticated, three-dimensional wind field model would also help identify transport patterns. However, such a model would have to be sufficiently efficient in its computations to be suitable for application to at least several days representative of each scenario and the data necessary to run the model on these days would have to be available.

Crossvalidation results of the objective source-receptor scenario classification procedure developed in this study indicate that improvements may be needed in the identification of Bay Outflow days. In addition, more examples of Northeast, Calm, and Northwest-South scenarios are needed to confirm the proper identification of these scenarios. Air quality and meteorological conditions on Northwest-South days in particular require further study. An independent data set could be developed for testing the classification scheme proposed here as an alternative to the use of crossvalidation. All of these activities require assembling additional air quality and meteorological data for analysis. Extending

the analysis to include at least an additional three years of data (say, 1992, 1993, and, when available, 1994) is recommended.

The objective classification procedure presented in this report is based on a set of 13 meteorological variables. Preliminary stepwise discriminant analyses indicate that a procedure based on just four of these variables would perform almost as well. Reducing the number of variables would simplify the procedure and reduce problems encountered when one or more of the variables are missing. This possibility should be explored in more detail.

5 REFERENCES

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Wilson, B. 1984. Personal communication with Bill Wilson of the California Air Resources Board, Technical Support Division.

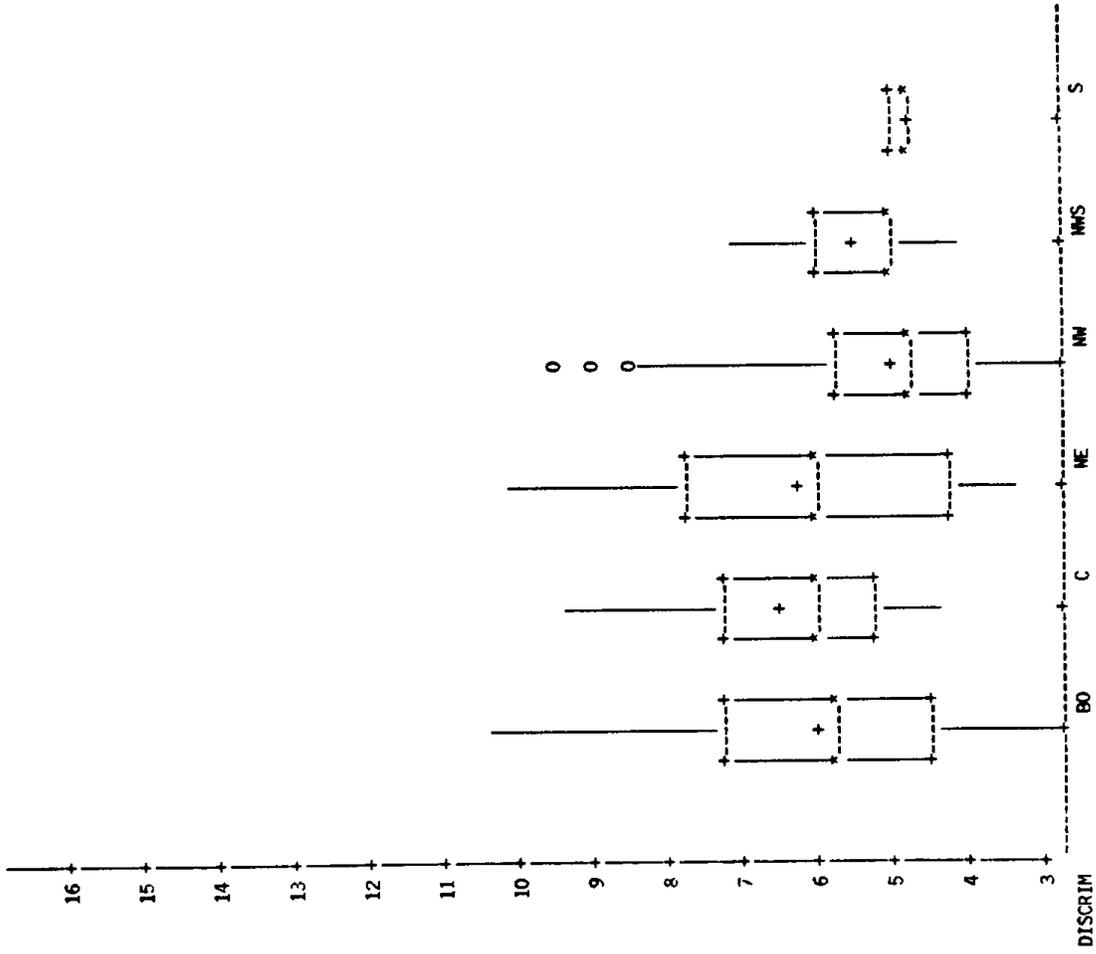
Appendix A

**BOX PLOTS OF DAILY MAXIMUM OZONE CONCENTRATIONS (PPHM)
BY SOURCE-RECEPTOR SCENARIOS (BO = BAY OUTFLOW, C = CALM,
NE = NORTHEAST, NW = NORTHWEST, NWS = NORTHWEST-SOUTH,
S = SOUTH)**

A key to the box plot symbols is presented in Figure 3-3.

Side by side box plots
 UNIVARIATE PROCEDURE
 Schematic Plots

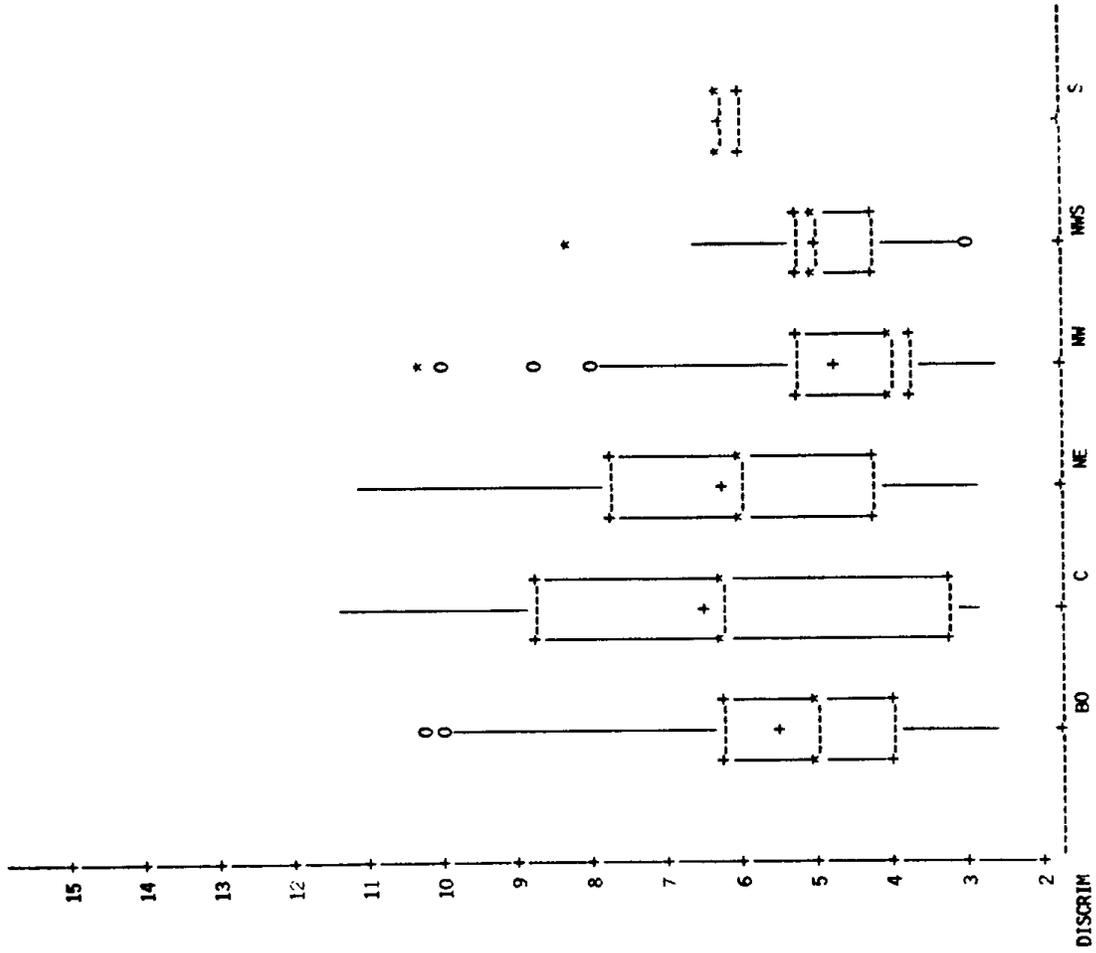
Variable=MBAY 03 Ave--North Bay



Side by side box plots
 UNIVARIATE PROCEDURE
 Schematic Plots

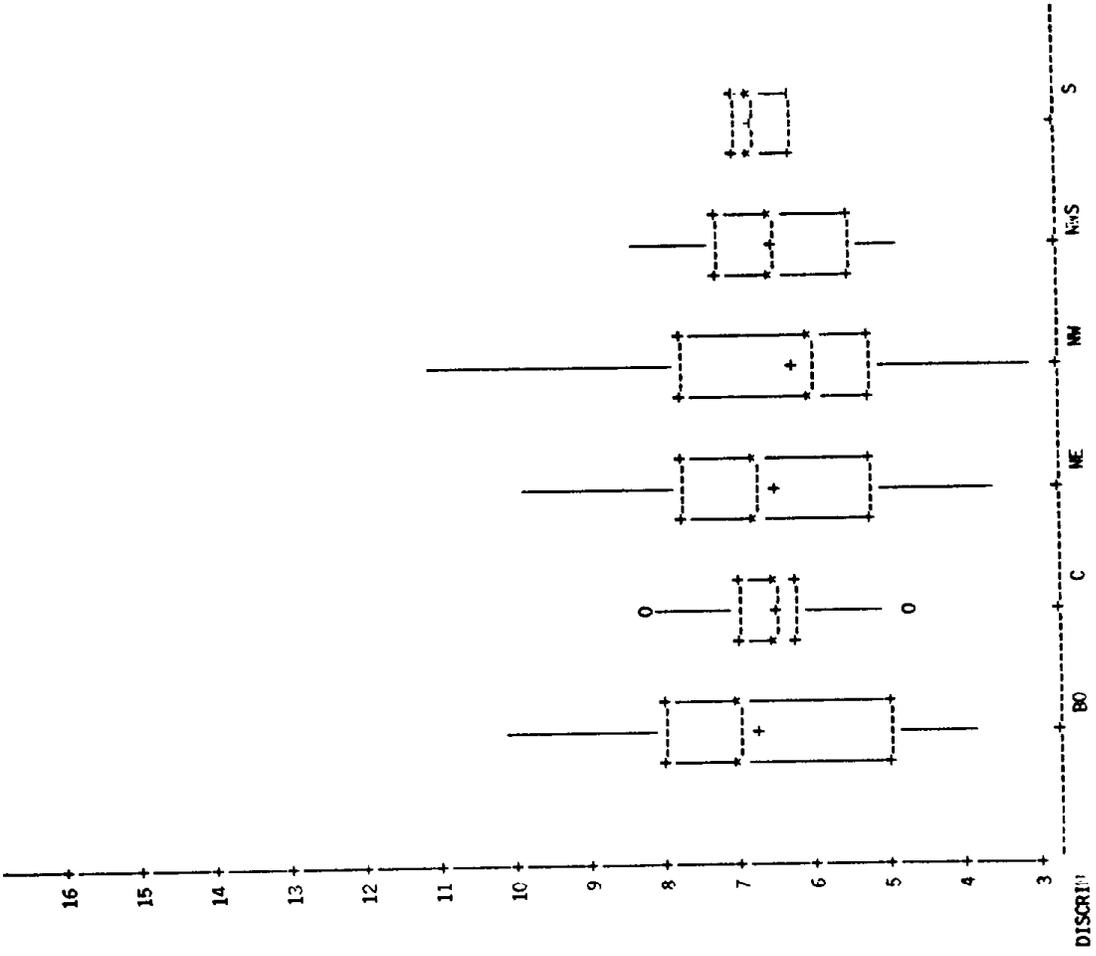
03 Ave--Western Alameda

Variab1ertHALA

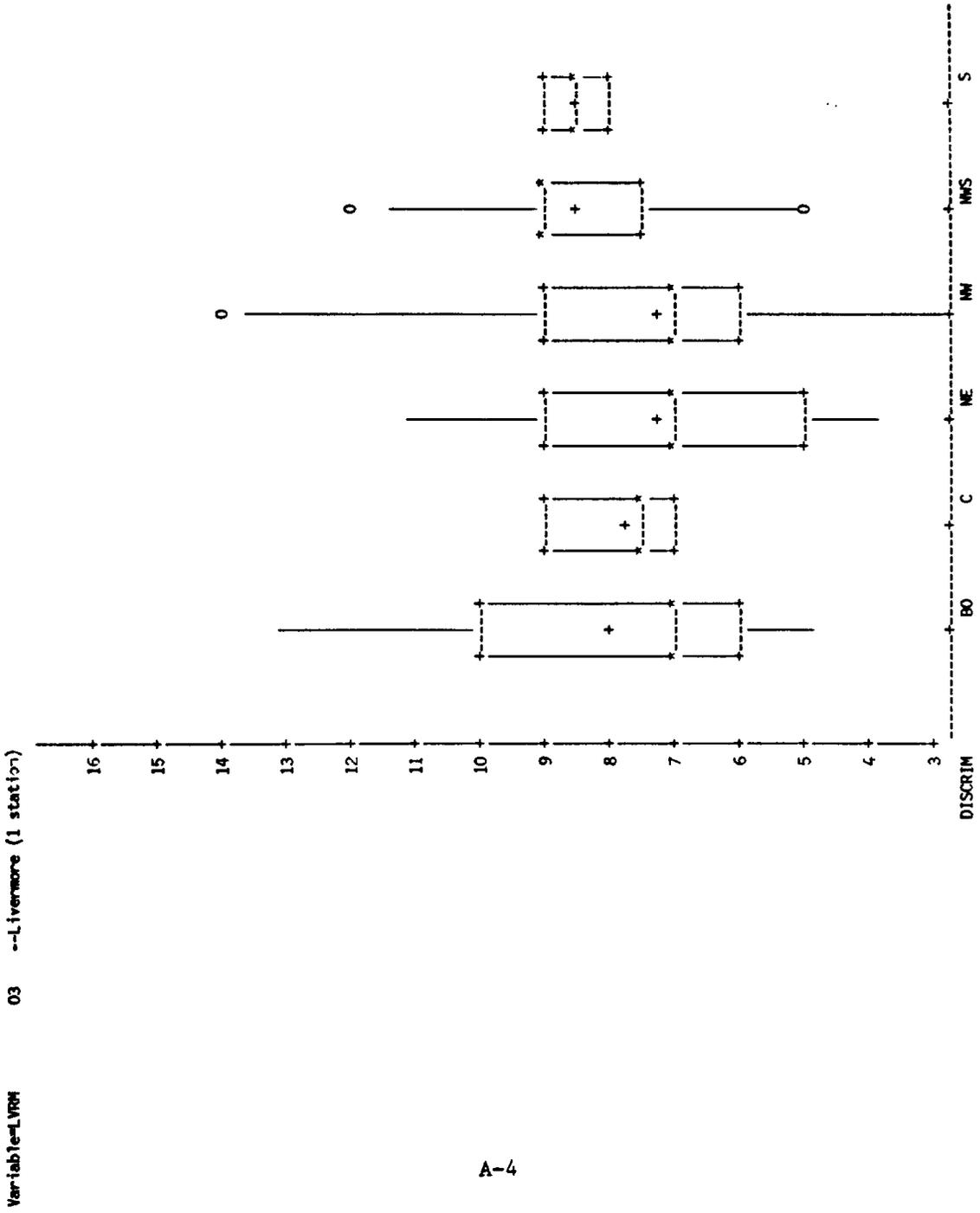


side by side box plots
 UNIVARIATE PROCEDURE
 Schematic Plots

Variable=CONT 03 Ave--Contra Costa

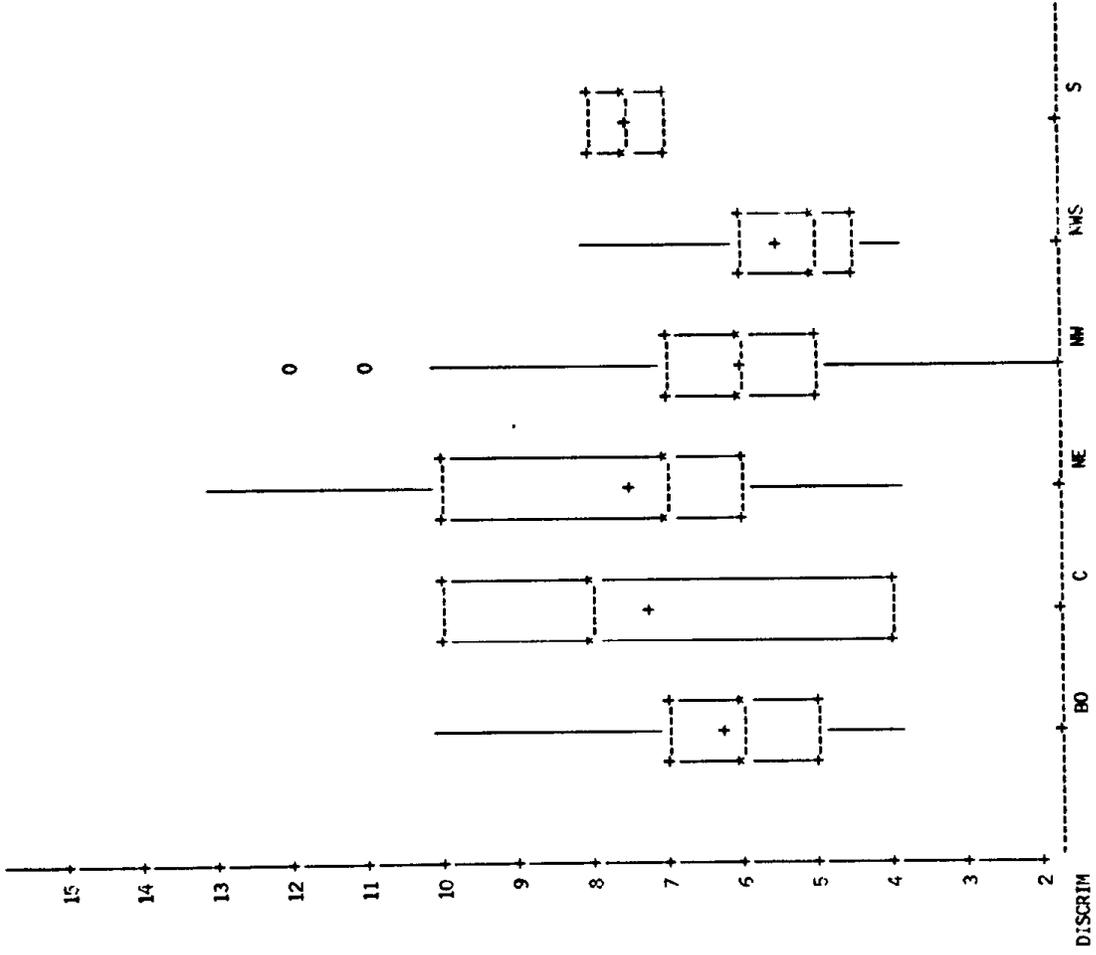


Side by side box plots
 UNIVARIATE PROCEDURE
 Schematic Plots



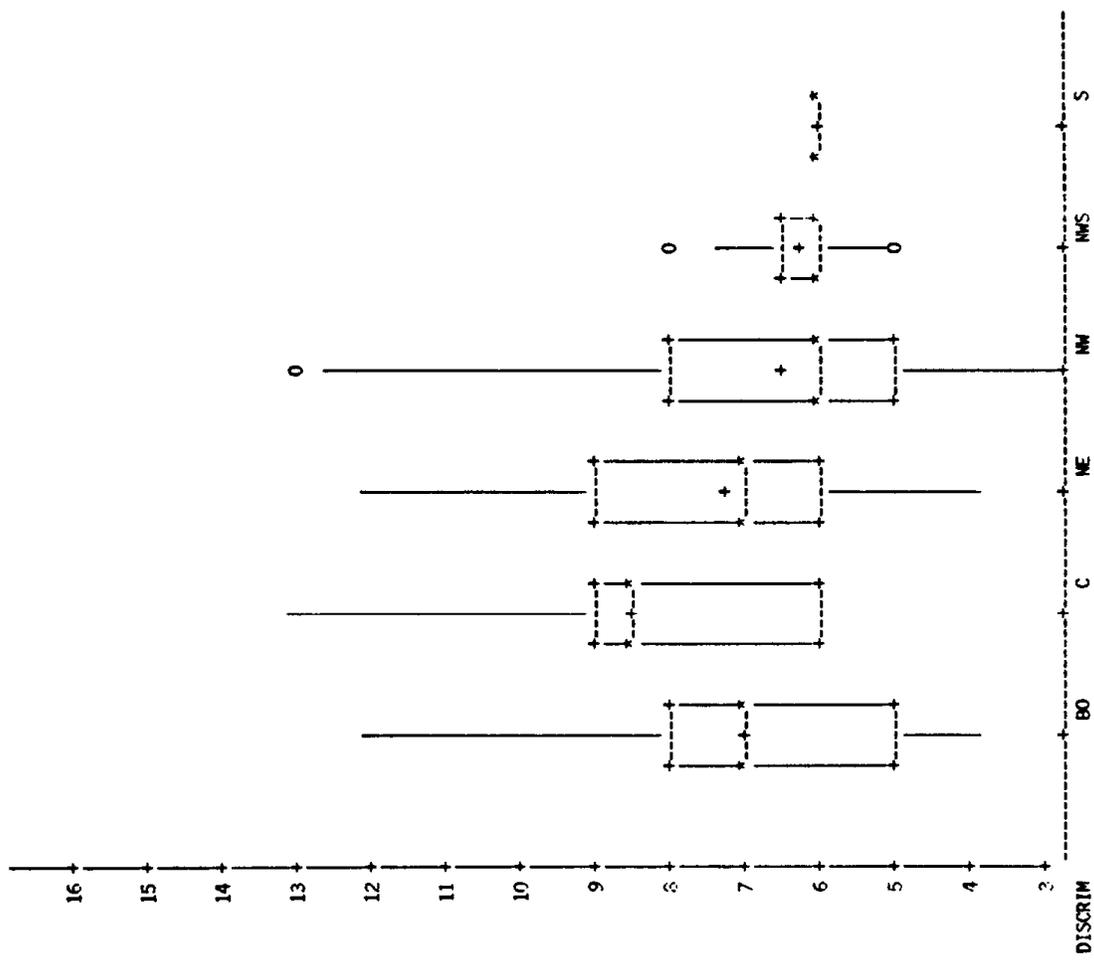
Side by side box plots
 UNIVARIATE PROCEDURE
 Schematic Plots

Variable=SAKJOSEA San Jose - 4th St



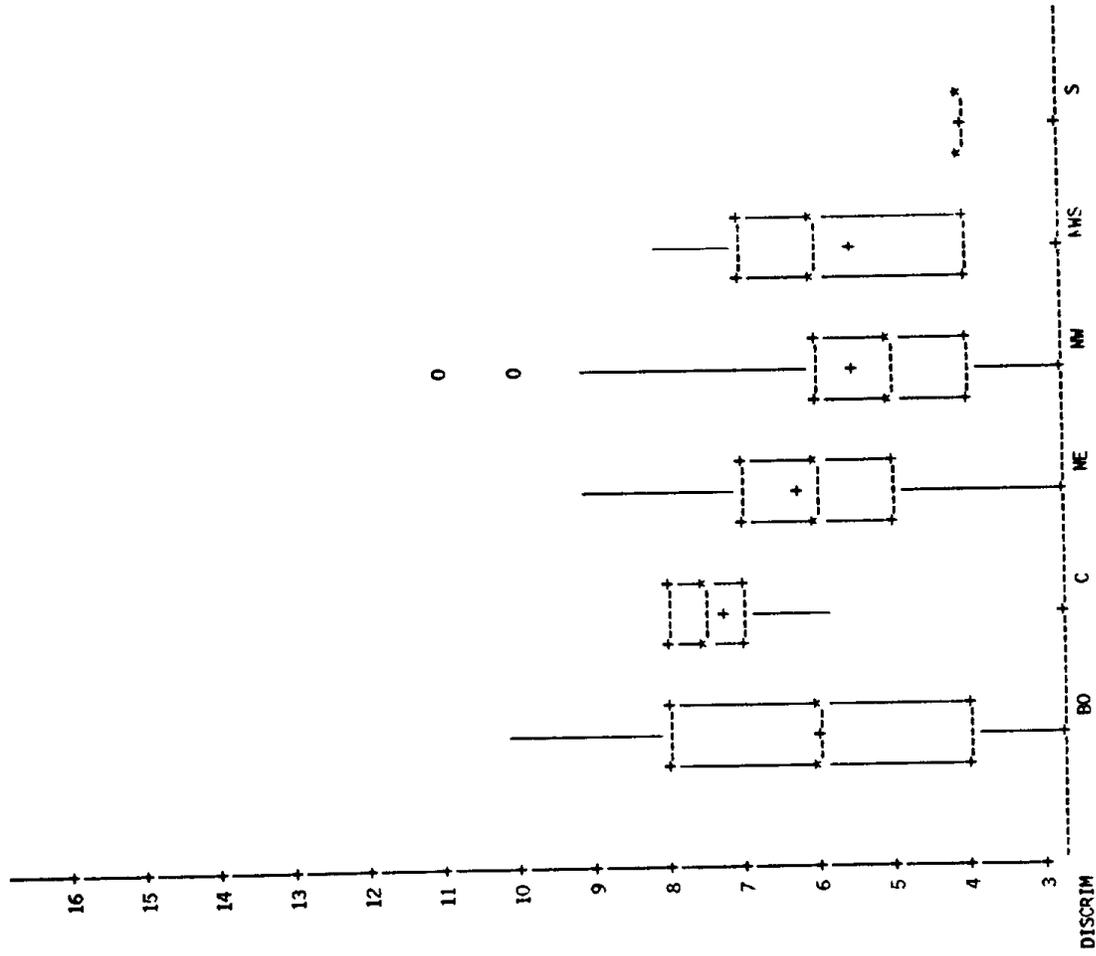
Side by side box plots
 UNIVARIATE PROCEDURE
 Schematic Plots

Variable=GILROY GILROY



Side by side box plots
 UNIVARIATE PROCEDURE
 Schematic Plots

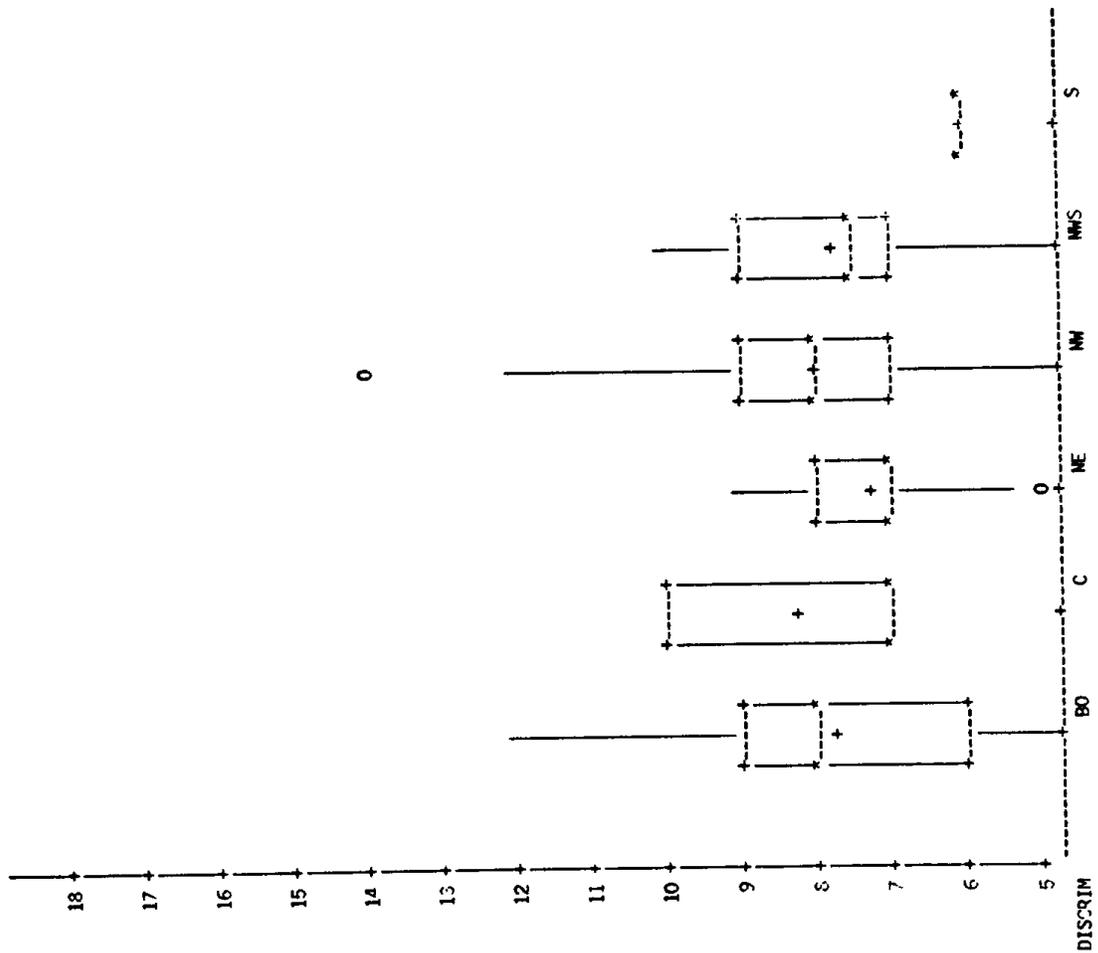
Variable=HOLLIS Hollister



Side by side box plots
 UNIVARIATE PROCEDURE
 Schematic Plots

Pinnacles

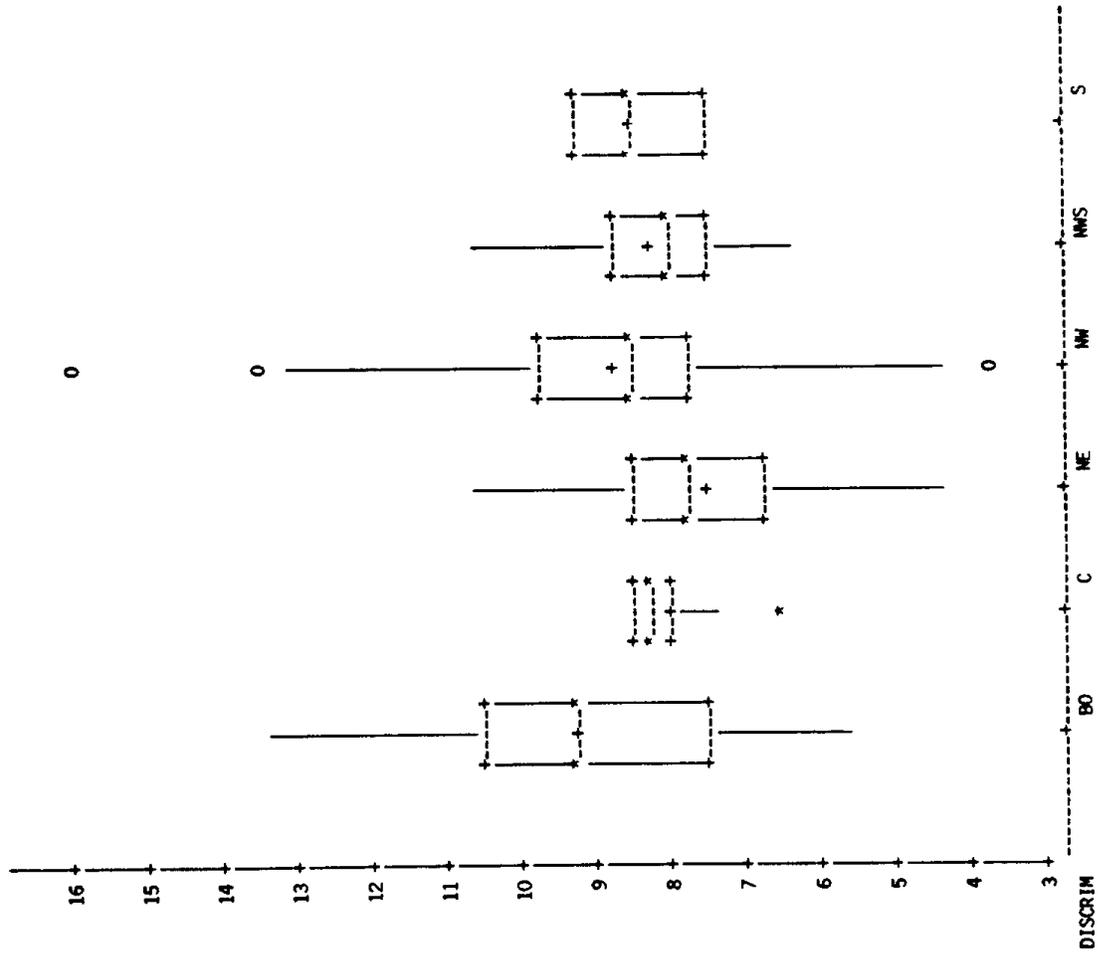
Variable=PINN



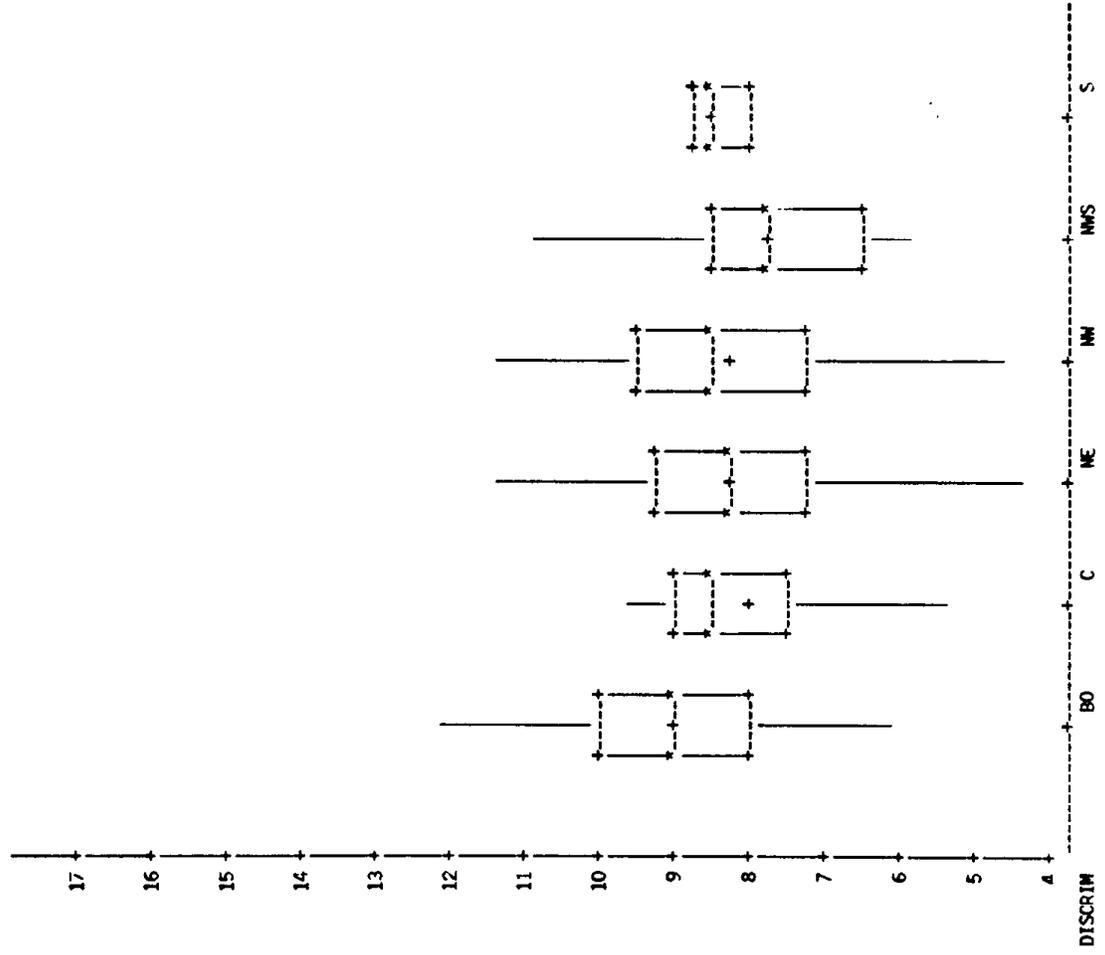
Side by side box plots
 UNIVARIATE PROCEDURE
 Schematic Plots

Variable=SACR

03 Ave--Sacramento



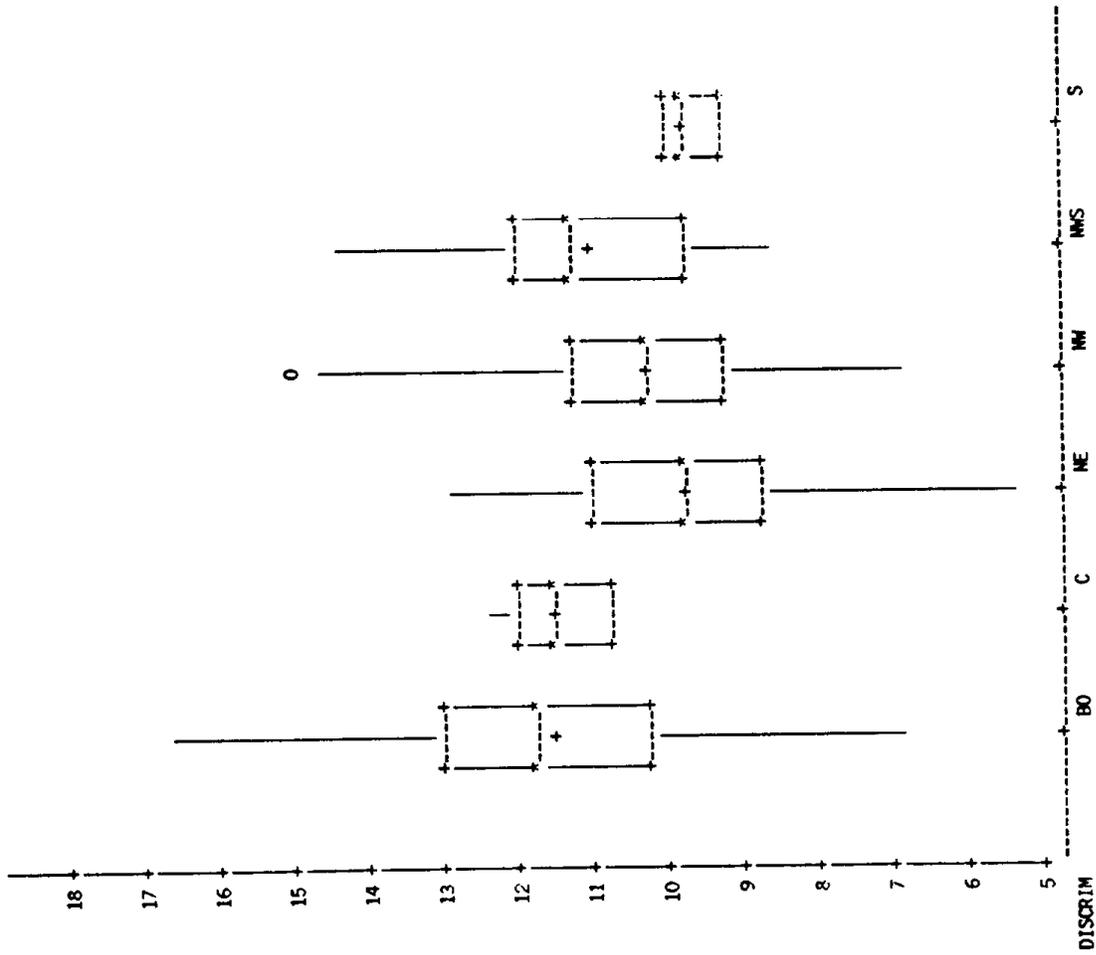
Side by side box plots
UNIVARIATE PROCEDURE
Schematic Plots



Side by side box plots
 UNIVARIATE PROCEDURE
 Schematic Plots

Variable=CSQ

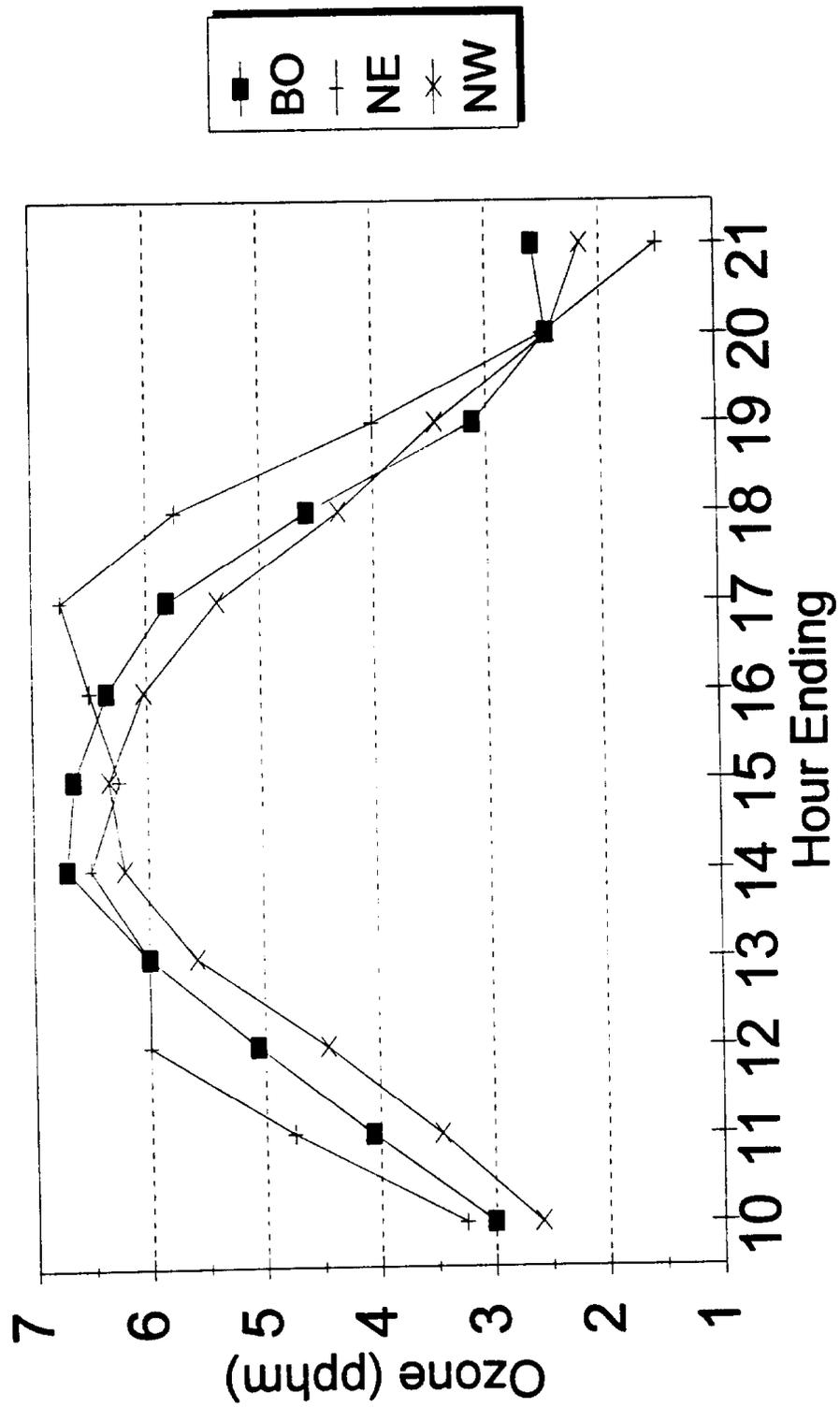
03 Ave--Cen San Joaquin



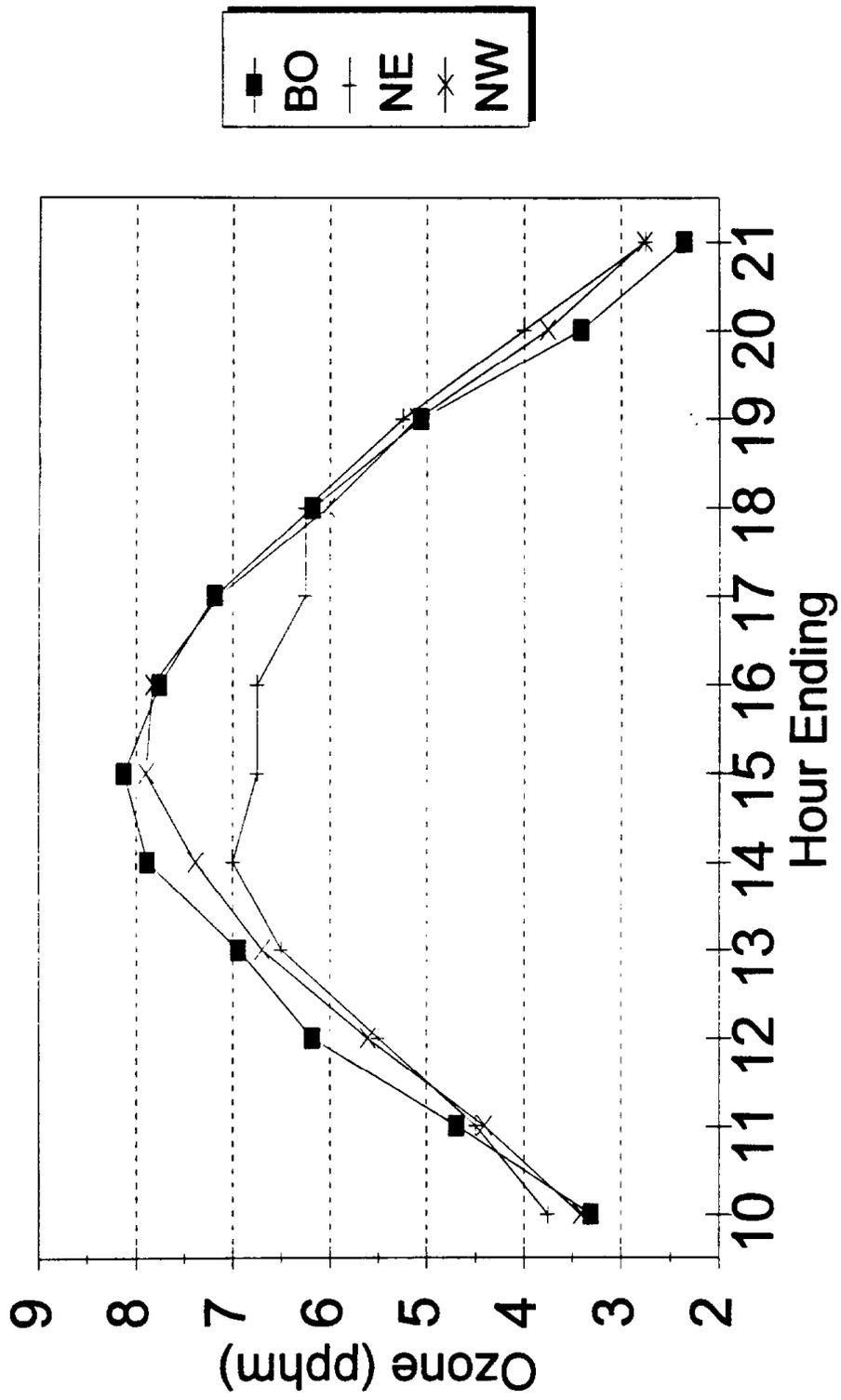
Appendix B

**AVERAGE DIURNAL PROFILES OF HOURLY OZONE CONCENTRATIONS AT
SELECTED MONITORING SITES FOR EACH SOURCE-RECEPTOR SCENARIO
(BO = BAY OUTFLOW, NE = NORTHEAST, NW = NORTHWEST)**

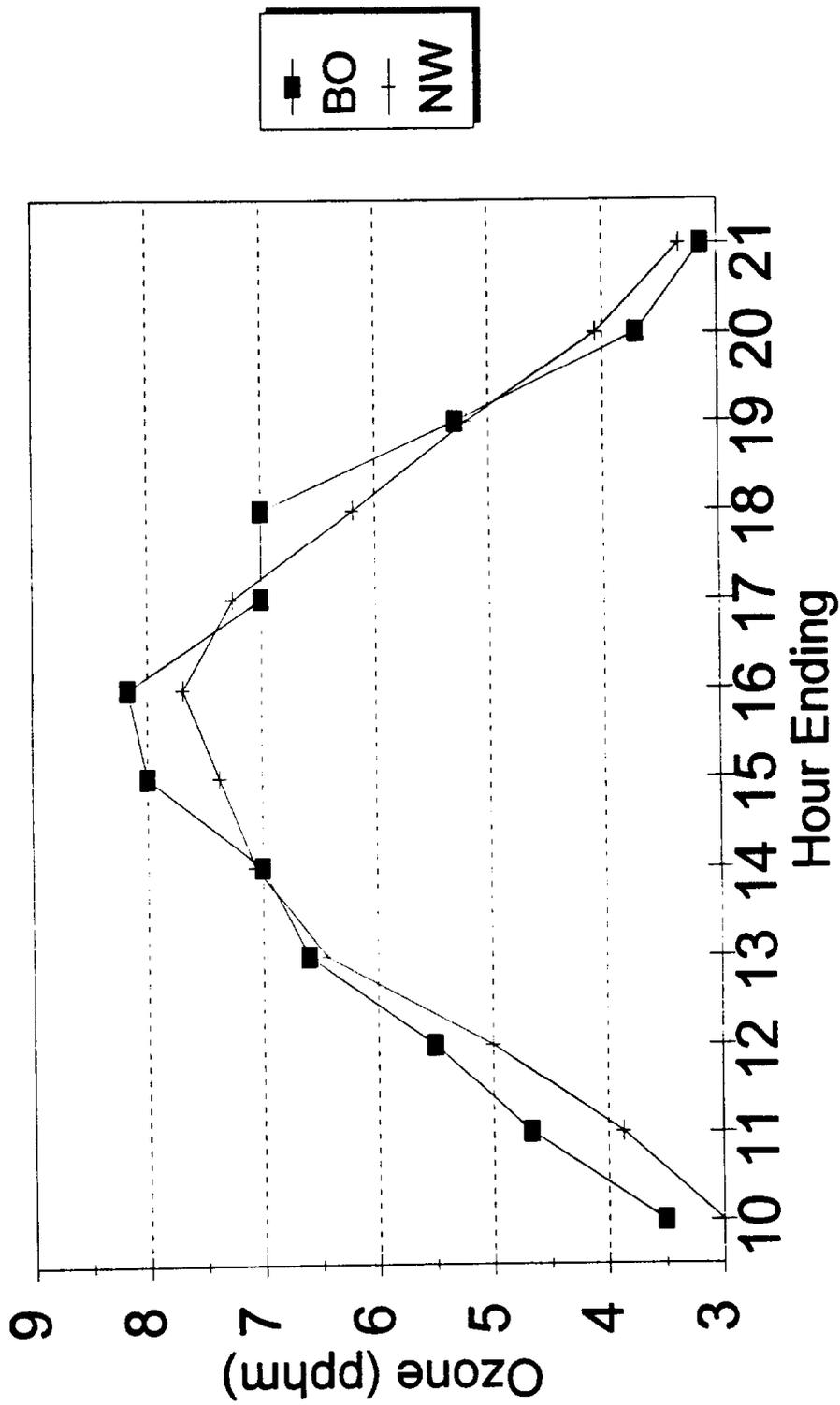
Hourly Average Ozone Concentrations For Fairfield



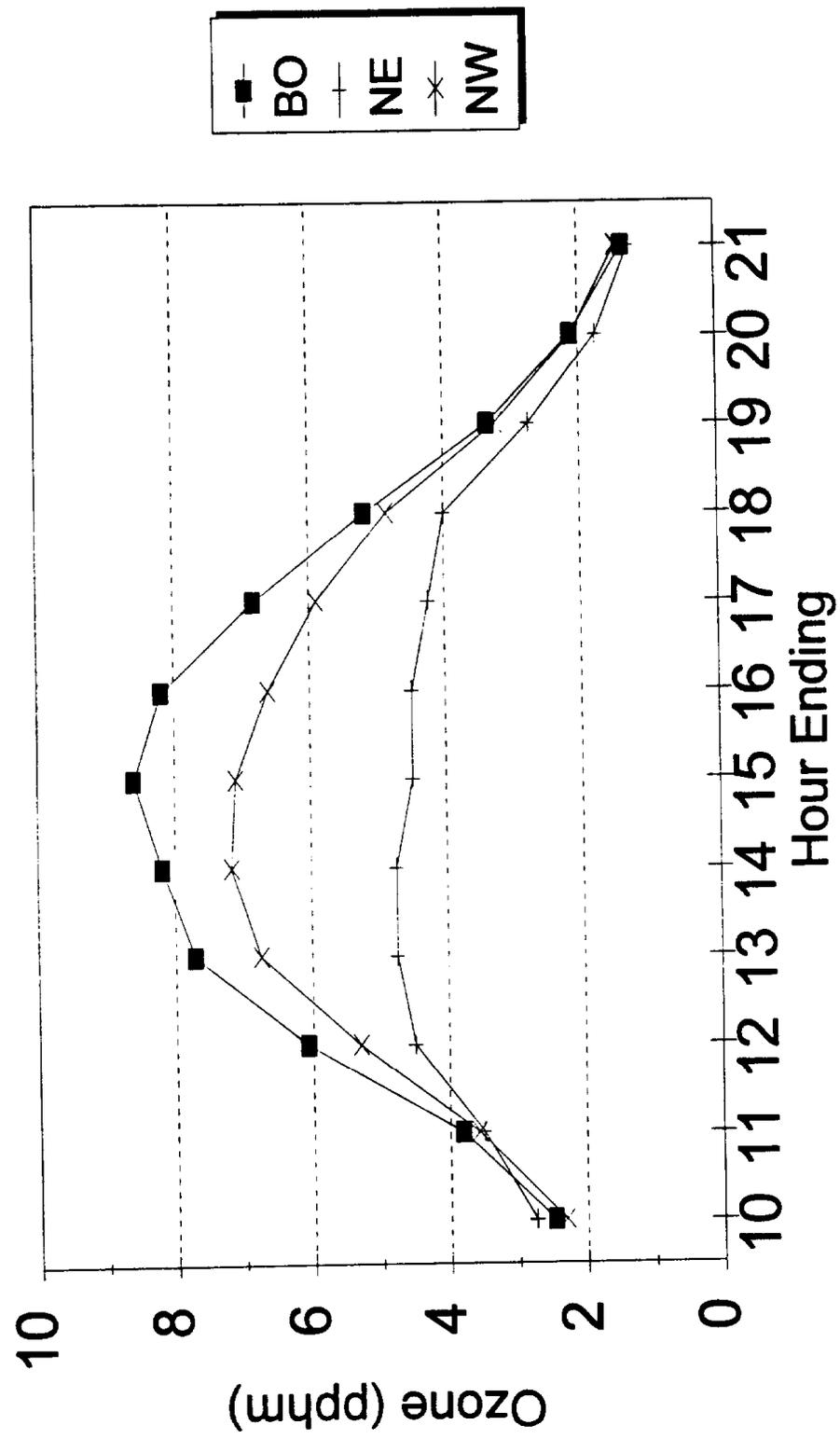
Hourly Average Ozone Concentrations For Bethel Island



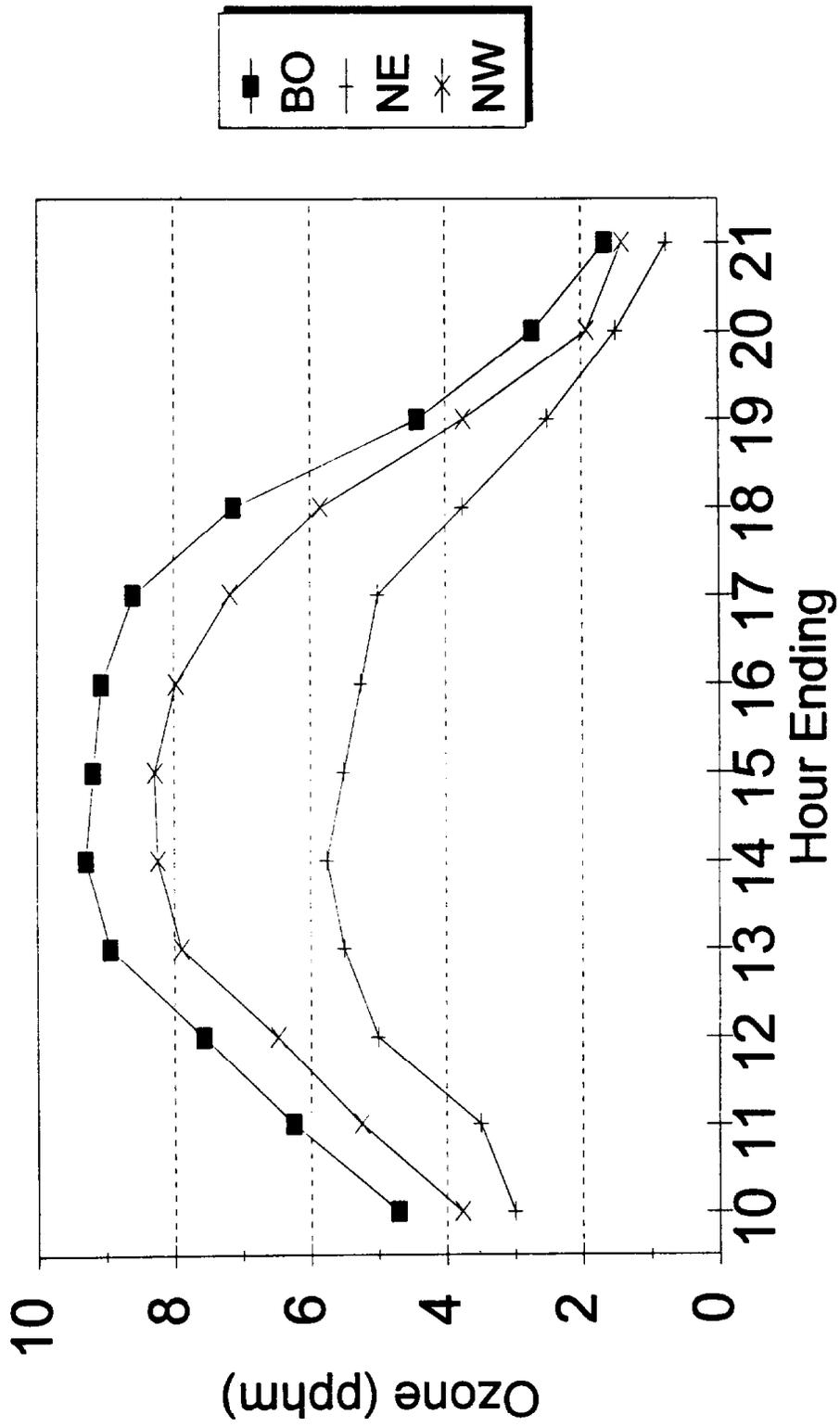
Hourly Average Ozone Concentrations For Lambie Road



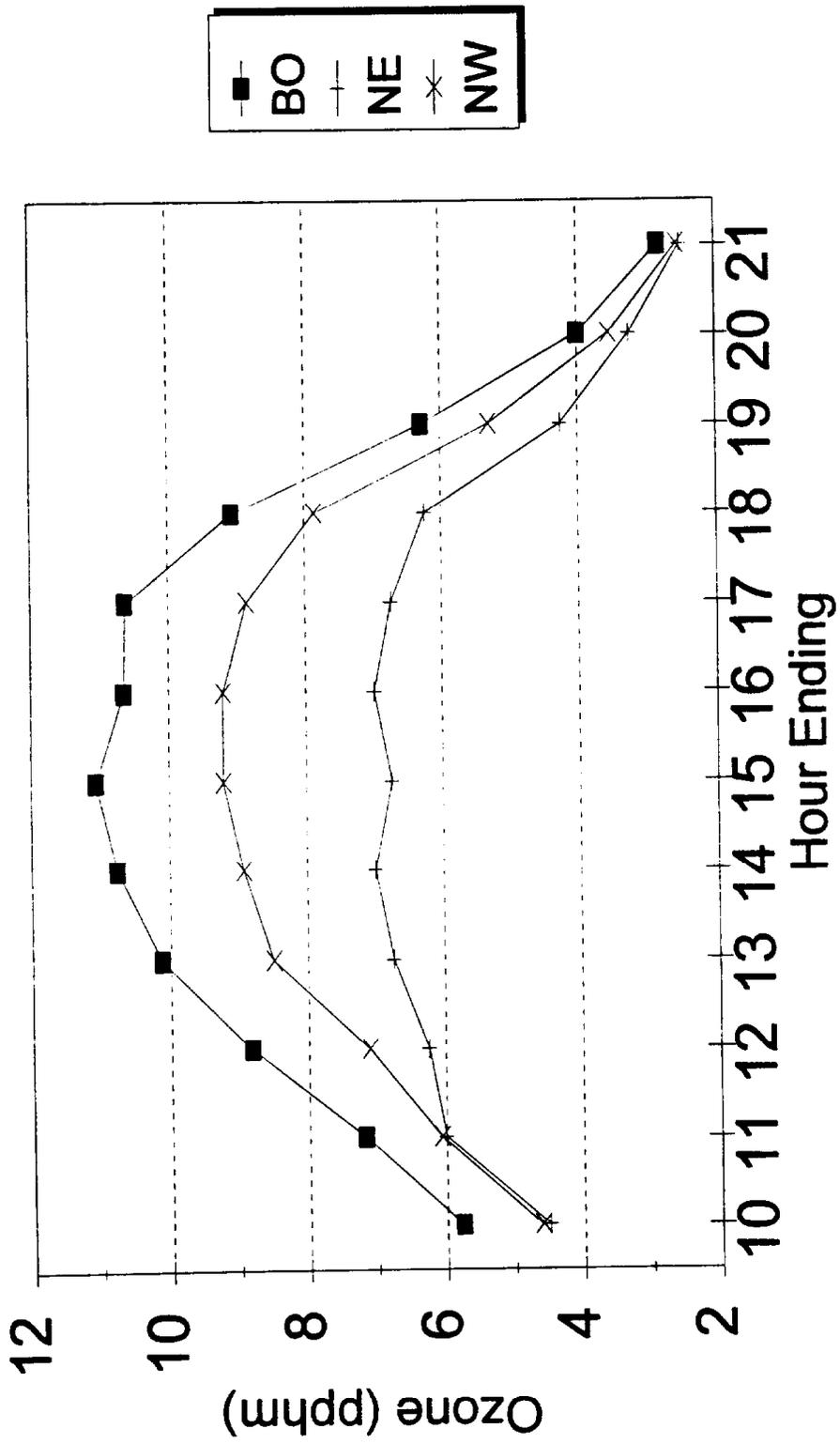
Hourly Average Ozone Concentrations For Sacramento



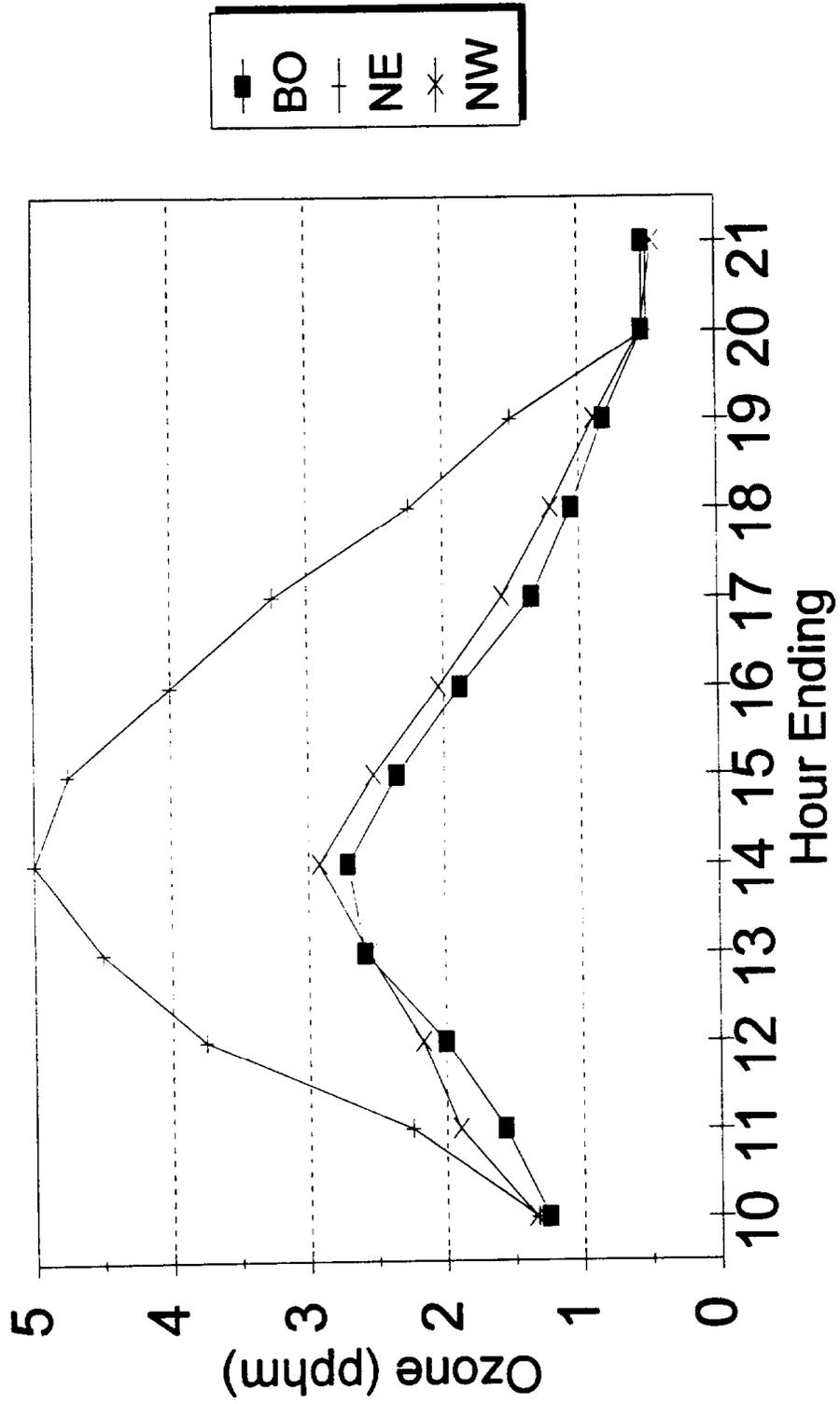
Hourly Average Ozone Concentrations For Citrus Heights



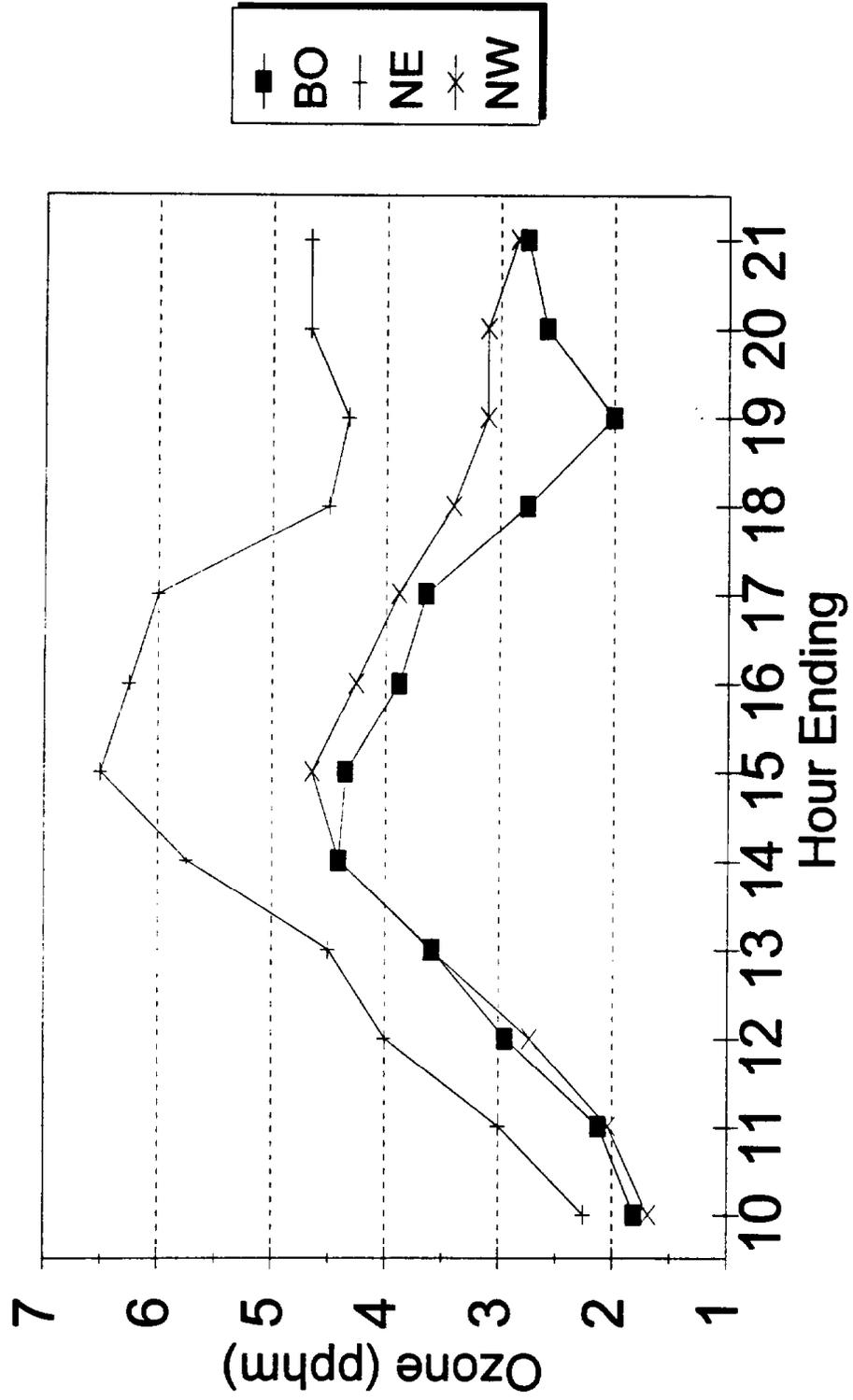
Hourly Average Ozone Concentrations For Folsom



Hourly Average Ozone Concentrations For Oakland

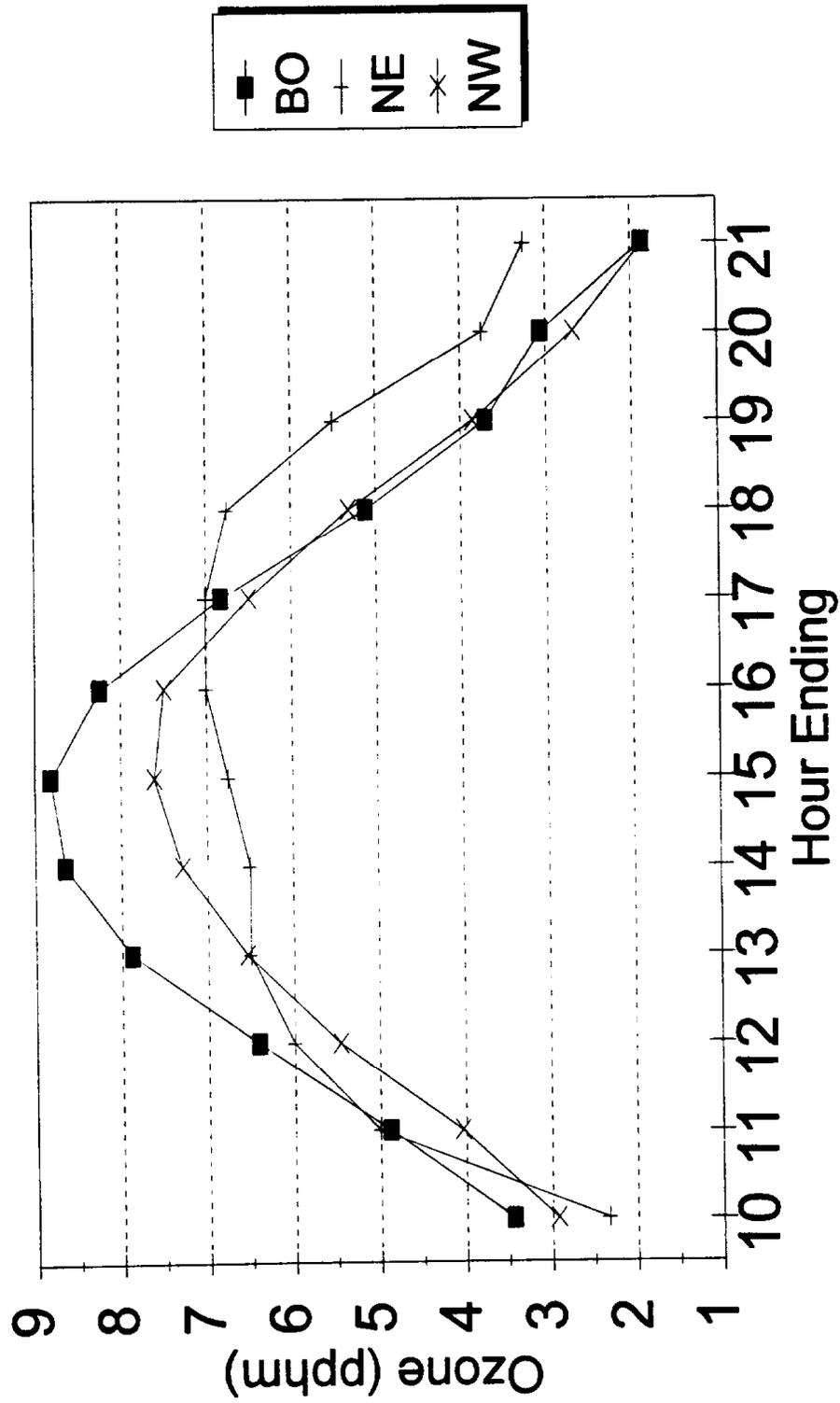


Hourly Average Ozone Concentrations For Hayward

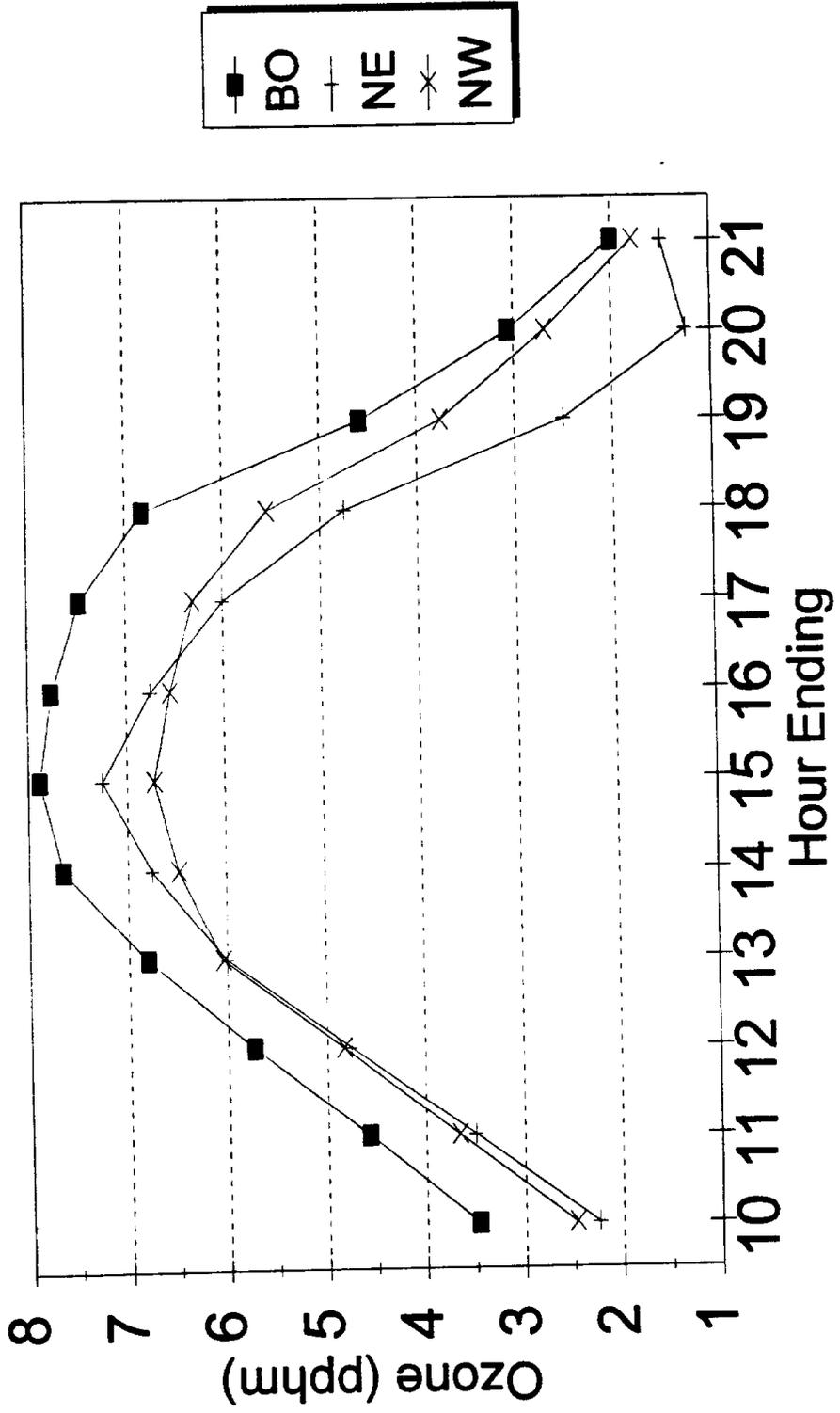


Hourly Average Ozone Concentrations

For Livermore

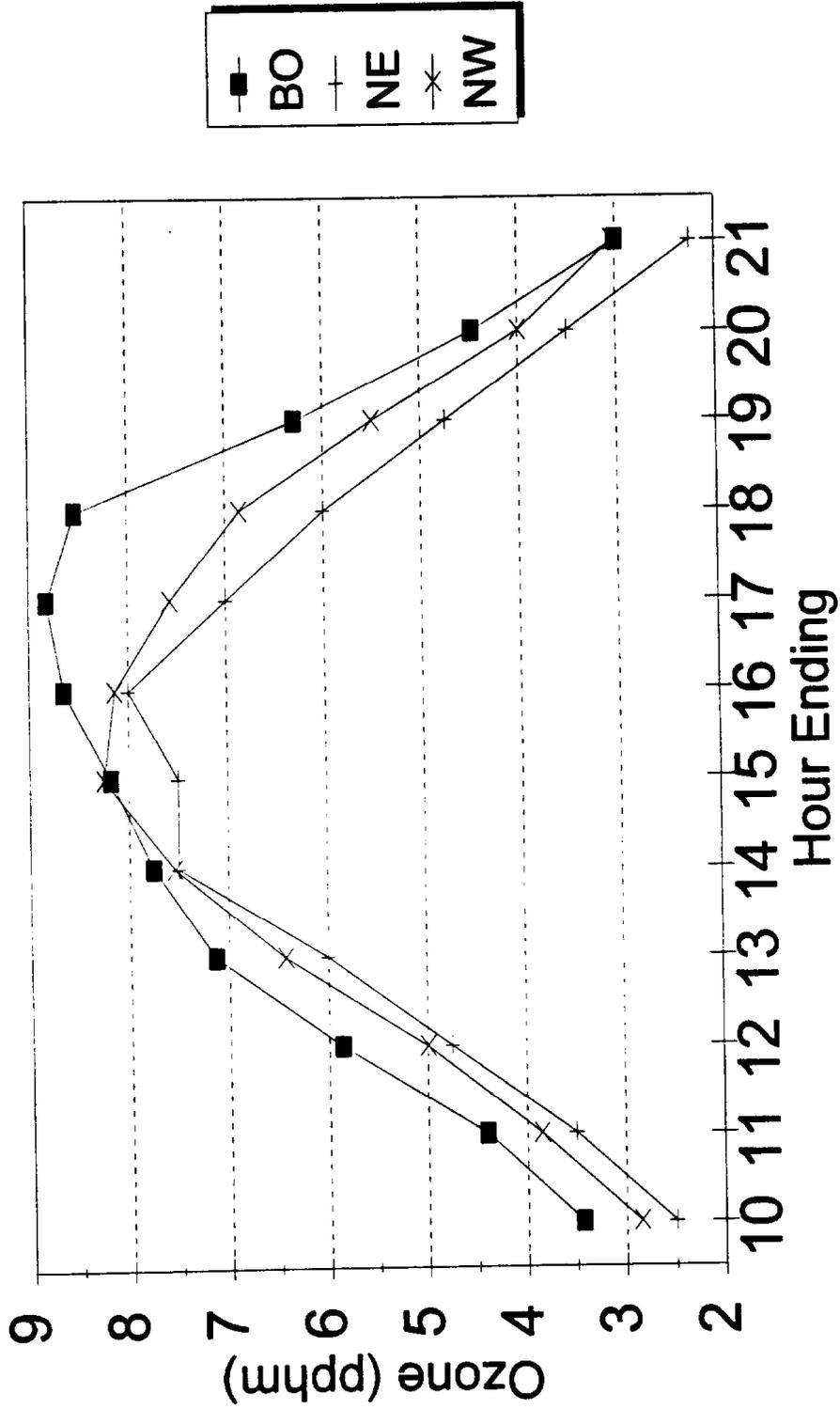


Hourly Average Ozone Concentrations For Stockton

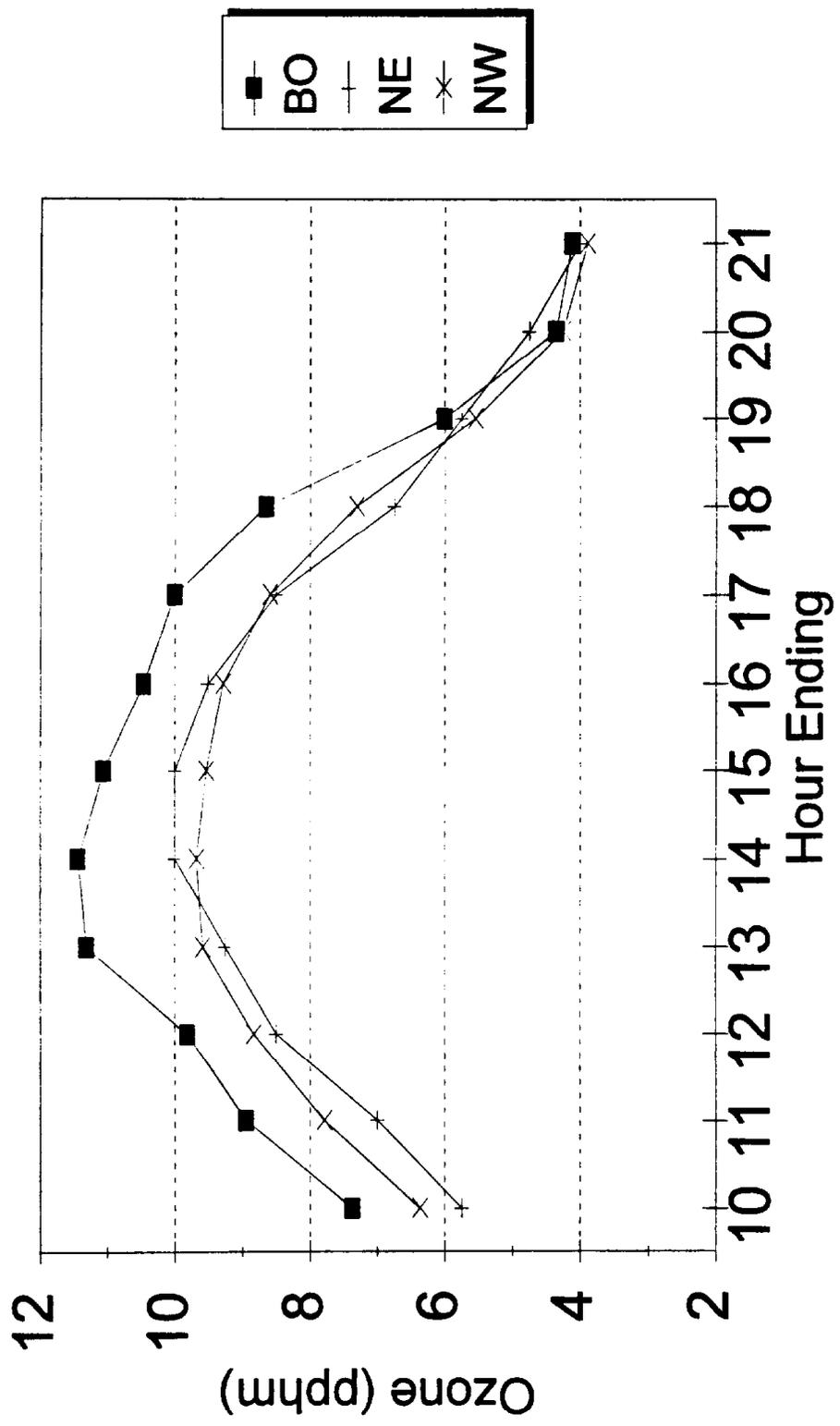


Hourly Average Ozone Concentrations

For Modesto

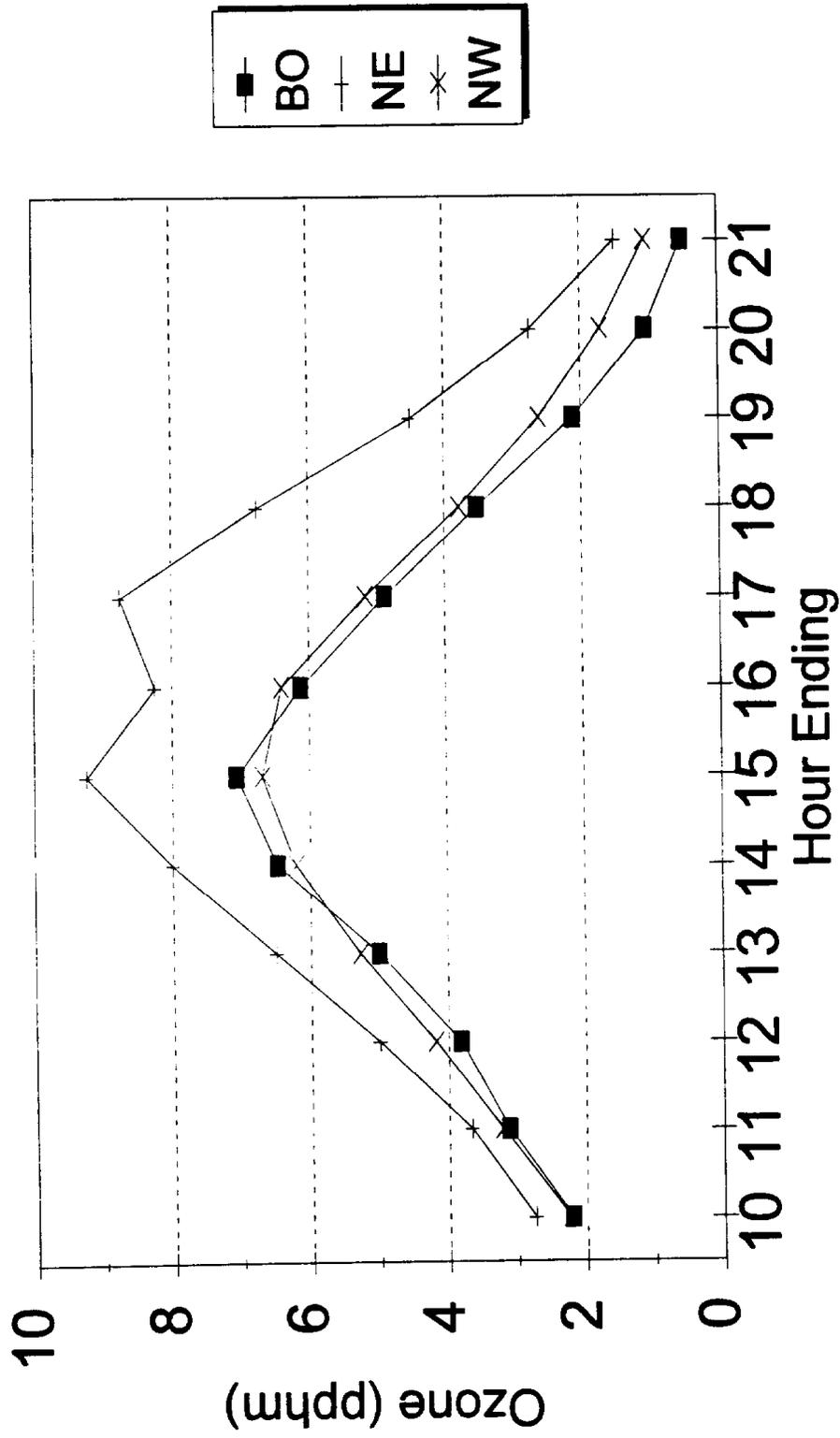


Hourly Average Ozone Concentrations For Fresno

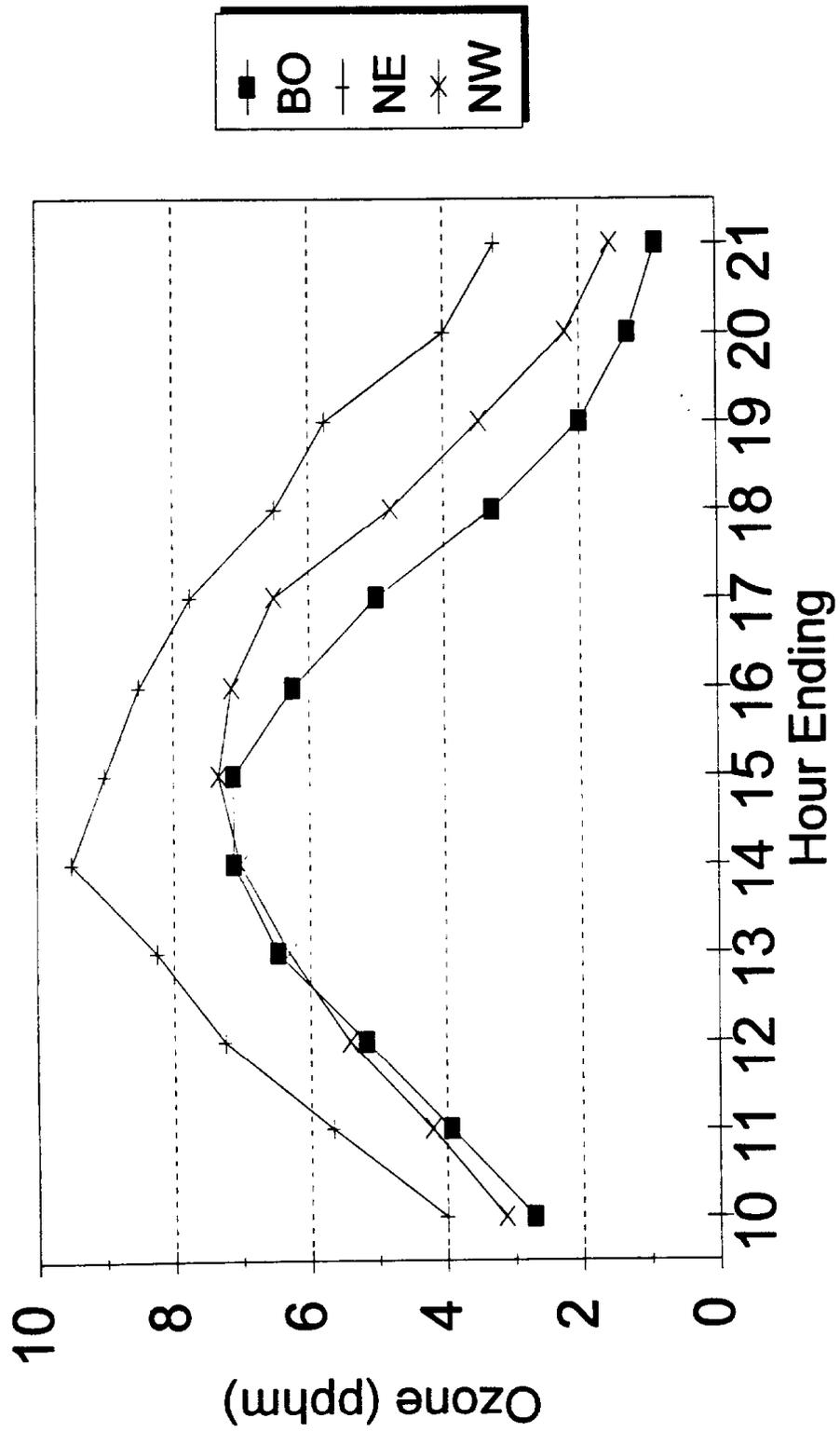


Hourly Average Ozone Concentrations

For San Jose

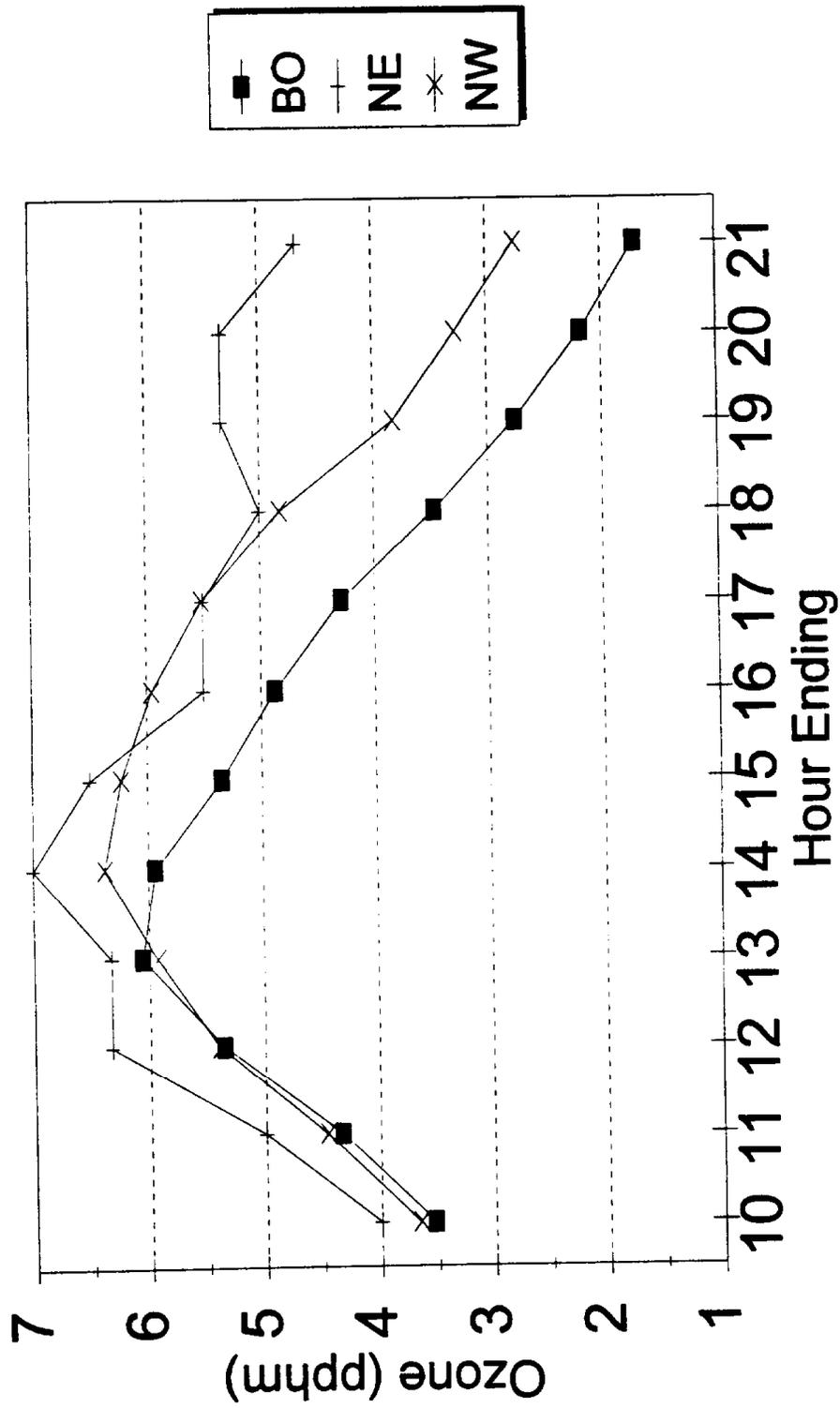


Hourly Average Ozone Concentrations For Gilroy

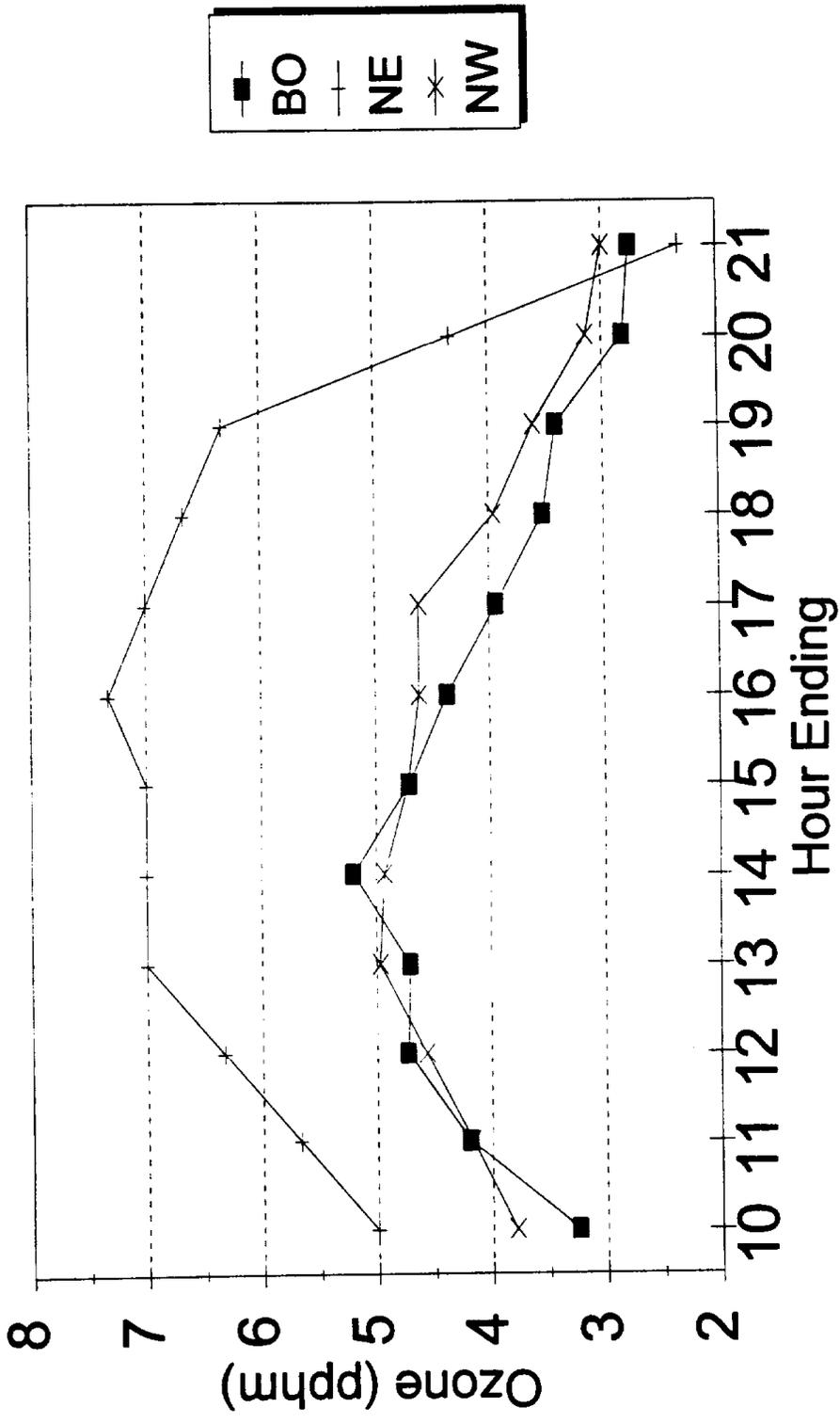


Hourly Average Ozone Concentrations

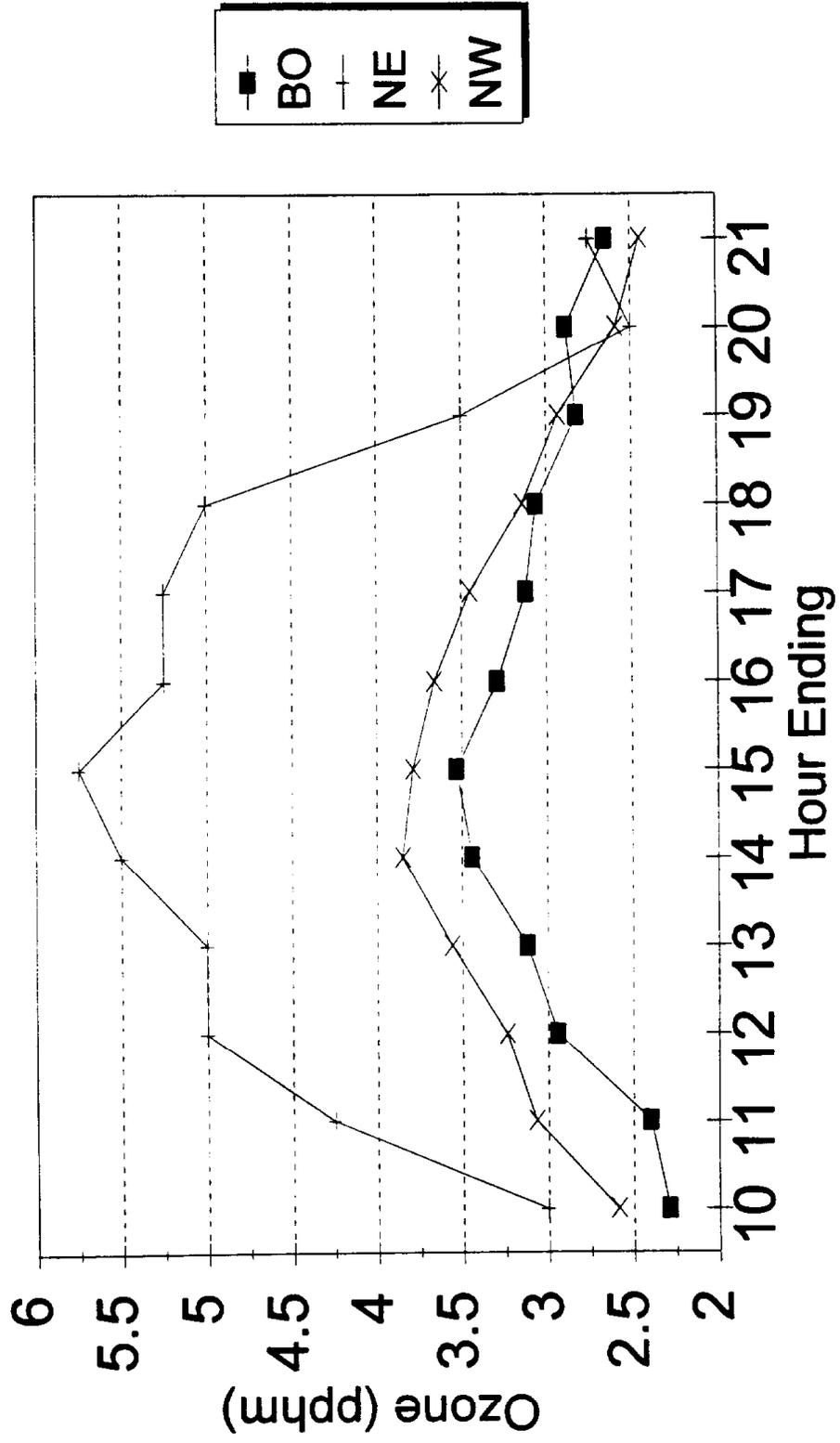
For Hollister



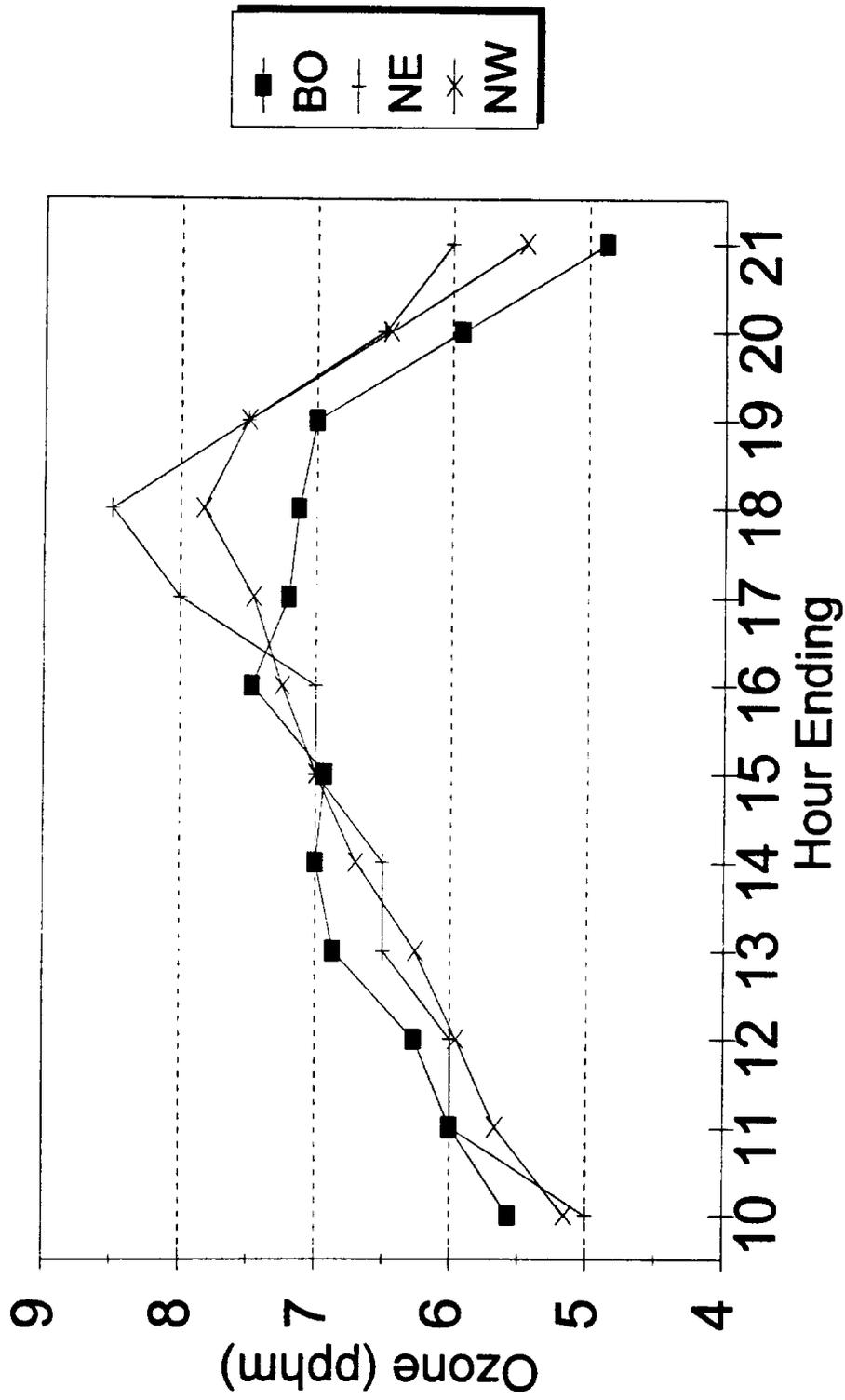
Hourly Average Ozone Concentrations For Carmel Valley



Hourly Average Ozone Concentrations For Salinas



Hourly Average Ozone Concentrations For Pinnacles



REPORT DOCUMENTATION PAGE

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13. ABSTRACT <i>(Maximum 200 Words)</i> Air quality and meteorological data collected during a three-year period (1989-1991) in the San Francisco Bay Area and surrounding air basins (North Central Coast, southern portion of the Sacramento Valley and northern and central portions of the San Joaquin Valley) were analyzed to determine air flow patterns and accompanying meteorological conditions associated with high ozone concentrations in the region. A set of six unique "source-receptor scenarios" were identified. The distinguishing meteorological features of each scenario were explored and used as the basis for the development of an objective procedure for identifying the most appropriate scenario for any given day based on the values of key routinely collected meteorological variables. Trajectory analyses were performed for selected days representative of the more common scenarios to determine the principle source-receptor relationships. These results provide an improved understanding of the mechanisms that control ozone concentrations in various portions of the study region. The results are particularly useful for the analysis of interbasin transport, air quality trends, and the selection of episodes to be used for photochemical modeling studies.				
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