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Sierra Cooperative Ozone Impact Assessment Study: Year 3

Volume 1

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

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Final Report

Contract No. A132-188

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ABSTRACT:

The purpose of the Sierra Cooperative Ozone Impact Assessment Study (SCOIAS) is to document the degree to which sensitive pine species in Sierran forests are exposed to ozone and the amount of injury the exposed trees exhibit. The major cooperators are the U.S. Forest Service (USFS), the California Air Resources Board (ARB) and the University of California, Davis (UCD). This document reports progress made by the UCD cooperators during the third year of the project (June 7, 1992 to October 30, 1993). The major tasks performed were the following: the continued operation of the six sites established in the previous years' efforts, tree water potential measurements, and data quality control, analysis and archiving. The six stations are Mountain Home within the Sequoia, Shaver Lake and Jerseydale in the Sierra, Five-Mile Learning Center in the Stanislaus, Sly Park Learning Center in the Eldorado and White Cloud in the Tahoe National Forests. The ozone monitoring season is the warm part of the year, from about April 15 to October 15, although actual station operating dates depend on accessibility in the spring. At all but one site, the targeted 80% data coverage was attained or exceeded during 1992. At one site, a combination of computer system problems and ozone monitor and temperature sensor malfunctions caused data voids totaling almost 35% of the operational period. However, valid ozone data is available for about 80% of the season at this station. These problems appear to have been solved by mid-season. At three of the sites, data coverage was better than 99%. Measured ozone concentrations were typically highest in the afternoon hours, and tend to increase toward the southern end of the network. Stations located on well defined steep slopes show a very strong diurnal variation in ozone concentration and meteorological conditions. Hourly peak ozone concentrations from June through September were greater than 60 ppbv at all sites nearly every day, in excess of 80 ppbv at most sites more than half the days and in excess of 100 ppbv at least a few days a month at all sites and nearly half the days at the most impacted sites (Mountain Home and Shaver Lake). At several sites, ozone concentrations were frequently high several hours after sunset. At White Cloud, the highest concentrations occurred between 10 pm and midnight.

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SUMMARY AND CONCLUSIONS:

The purpose of the Sierra Cooperative Ozone Impact Assessment Study (SCOIAS) is to document the degree to which sensitive pine species in Sierran forests are exposed to ozone, the meteorological processes that coincide with high ozone concentrations and the amount of injury the exposed trees exhibit. The major cooperators are the U.S. Forest Service (USFS), the California Air Resources Board (ARB) and the University of California, Davis (UCD). This document reports progress made by the UCD cooperators during the third year of the project (June 7, 1992 to October 30, 1993). The primary tasks pursued were the continued operation of the six measurement sites established in the previous years, retrieval of the instrumentation in late fall, maintenance and recalibration of these over the winter, reinstallation of the stations as they became accessible in the spring and operation of the stations through the summer of 1993. The USFS cooperators have conducted training classes (July, 1992 and July, 1993) and continued scoring of ozone injury in plots of pine trees located near the monitoring sites.

The six sites were originally selected to satisfy both the needs of the biological effects researchers and meet the meteorological criteria necessary to characterize exposure of pine species to ozone in the immediate vicinity of the sites (Carroll, 1991; 1992). The sites range in elevation between 3550 and 6000 feet above mean sea level. Measurements of ozone concentration (differential UV absorption) and meteorological conditions (temperature, humidity, wind speed, wind direction and solar radiation) were recorded with a PC-based data acquisition system. The system also monitored several additional variables such as the A/D reference voltage and enclosure temperature. The stations were visited by project personnel approximately biweekly, at which time instrument maintenance was performed, as necessary, and the recorded data retrieved via diskette. Two stations, located at learning centers, were operated year round except for a short period in winter used for maintenance and recalibration. Although this exceeds the contract requirements, these stations are used by the learning centers as part of their educational programs and this use is part of our agreements with them. The remaining four sites were deactivated in late fall and will be reinstalled beginning in mid-April as the sites become physically accessible.

Tree water potential measurements were performed in order to calculate the available soil moisture at each of the sites. The testing was done at each of the six sites, once a month, from August through October, 1993. Actual values for soil moisture have not been calculated yet, but the initial results indicate that available soil moisture decreased during the observation period.

Quality assessment and quality control were performed both by UCD and a subcontractor from San Jose State University (SJSU). UCD maintains transfer standards for ozone, temperature and humidity and performs periodic checks of the wind sensors and radiation instruments. Based on these calibration checks and other data recorded in the monitoring systems and from field logs, data quality information is encoded into the archived records. In addition, the SJSU subcontractors perform two independent audits of each of the stations each year and have the ozone transfer standard checked yearly by the Standards Laboratory of the ARB. The calibration of the ozone transfer standard has changed less than 1.5% over the last 2.5 years.

All of the major objectives have been met -- with the exception of 80% data recovery at all sites. During 1992 at Shaver Lake, data were lost for intermittent periods totaling 34.7% of the season due to a series of problems with the computer systems, ozone monitor and ambient temperature sensor. The problems with the ozone monitor and temperature sensor at Shaver Lake were successfully resolved by the end of July. Problems with the computer systems at Jerseydale and Five-Mile caused losses of up to 13% of the data. At Mountain Home, Sly Park and White Cloud, data recovery exceeded 99%.

Available literature indicates that needle injury occurs from exposure to ozone concentrations of 60 ppbv, and is significant at and above 80 ppbv (e.g., Hogsett et al., 1985; Miller and Millecan, 1971; Skarby et al., 1987; Williams et al., 1977; Woodman, 1987). The recorded data suggest that serious to severe exposure (> 80 ppbv) of pines to ozone is likely. The data show that ozone concentrations were typically highest in the afternoon hours, and tended to increase toward the southern end of the network. Stations located on well defined steep slopes show a very strong diurnal variation in ozone concentrations and meteorological conditions. Hourly peak ozone concentrations from June through September were greater than 60 ppbv at all sites nearly every day, in excess of 80 ppbv at most sites more than half the days and in excess of 100 ppbv at least a few days a month at all sites and nearly half the days at the most impacted sites (Mountain Home and Shaver Lake). At the two sites in the middle of the network (Jerseydale and Five-Mile Learning Center) the diurnal variations in ozone were not very well pronounced and nighttime values remained relatively high. At White Cloud, the highest concentrations occurred at night when winds were from the NNE.

The stations at the southern end of the network appear to have higher peak ozone concentrations than those in the north. This latitudinal gradient may also be a result of altitude differences among the sites. The southernmost site, Mountain Home, is also the highest elevation site. It is also not clear whether these observations were due to the trapping of pollutants within or between inversion layers that intersect the slopes, the net accumulation of pollutants as the air traverses the San Joaquin Valley before turning upslope, or due to higher emission rates of primary pollutants in the southern part of the Valley.

Striking differences in the diurnal pattern of ozone concentration at White Cloud, Jerseydale and Five-Mile on the one hand, and the other stations are receiving further study. The differences in the diurnal pattern among sites raises questions about spatial variability and the nature of three dimensional pollutant transport. The high nighttime high ozone concentrations at White Cloud occur with winds having a significant northeasterly component. For this material to reach this site from that direction, it must follow a circuitous route and remain well away from the ground during its travel.

RECOMMENDATIONS:

While the primary measurements described here are sufficient to document environmental conditions and ambient air quality, the actual exposures experienced by the trees may not be accurately defined. The literature suggests that injury to plant tissues is due to the flux of ozone into leaves (Coyne and Bingham, 1981; Yang et al., 1983). While ambient air quality can be documented by measurements of ozone concentration, a better indicator of tree exposure is the flux of ozone into the leaves (i.e., the product of ambient ozone concentration and stomatal conductance). Stomatal conductance is a function of air temperature, humidity, available sunlight, moisture status, age and other physiologic factors. Davis (1992) developed a method for estimating stomatal conductance in pine species using meteorological data such as those being collected at the SCOIAS sites. Although data are needed to verify Davis' model, it is recommend that tree exposures be calculated using hourly stomatal conductance estimated by Davis' model and hourly average ozone concentrations. Estimates of tree exposure calculated in this way should better describe the potential for ozone injury than ambient ozone concentration alone.

Striking differences in the pattern of diurnal ozone concentration at White Cloud, Jerseydale and Five-Mile compared to the other stations needs further study. Van Ooy (1993) examined statistical patterns of the measured variables during 1992. As the data base expands to contain multiple observational periods, the repeatability and detailed nature of these differences can be examined more carefully. We will investigate the practicality of performing conductance measurements in 1994.

The differences in the diurnal pattern among sites raises questions about spatial variability and the nature of three dimensional pollutant transport. Observations over the Central Valley have frequently shown a strong vertical layering of ozone, with elevated layers of high ozone concentrations (> 80 ppbv) persisting through the night (Carroll and Dixon, 1989). These layers can impact the slopes of major topographic features. Given the complexity of the topography at and near the sites being studied, it is strongly recommended that portable ground unit(s) and aircraftborne systems be used to supplement the fixed site measurements and assess whether three dimensional spatial variability is significant in these areas. The airborne observations would also be needed to assess three dimensional transport issues.

INTRODUCTION:

It has been established in laboratory conditions that ponderosa and Jeffrey pines are susceptible to injury when exposed to ozone (Coyne and Bingham, 1981). Ozone affects various parts of the plant adversely, including specific forms of needle injury observable at the end of a growing season. Chronic exposure and the accompanying injury and stress is believed to be a major threat to the viability of forests in California, including those along the western slopes of the Sierra. The United States Forest Service (USFS), National Parks Service (NPS), University of California, Davis (UCD) and the Air Resources Board (ARB) have established a cooperative study to document ozone exposure and any accompanying injury to selected stands of trees as a means of assessing the impact of ozone on naturally growing trees. The measurement of local concentrations of ozone and meteorological conditions near these stands of trees is the responsibility of the UCD group, and is the subject of this report.

During the summer and fall of 1990 a network of five stations was installed along the foothills of the Sierra Nevada. A sixth station was installed at Shaver Lake in July, 1991. The locations of the sites are shown in Figure 1. Additional information about the sites, including dates of operation, are listed in Table 1. The first five stations were operated in the fall of 1990 and were reinstalled in the spring of 1991 to begin the first full year's operation. Since the observable injury is cumulative, a key requirement of the measurement systems is that they be fully operational at least 80% of the duration of the growing season, which lasts from late April until the end of September. Beginning in late summer, USFS employees and other cooperators, not funded by this project, quantitatively score ozone specific needle injury, if any, and record other information on the health and vitality of the selected groups of trees located near each of the sites.

When the current funding began, all sites were in full operation. The instrumentation at the two learning centers (Five-Mile and Sly Park) were operated through the winter in support of educational programs given at those locations, in accordance with our agreements with the school districts. However, data recovery and quality control procedures are somewhat relaxed during winter periods. Instrumentation from all sites is withdrawn and refurbished prior to the start of the primary data acquisition season.

In addition to the operational tasks required to run the network, the project Staff Research Assistant and one graduate student attended the meeting led by Judy Rocchio held in July, 1992 to familiarize cooperators with the injury assessment procedures. They also attended training sessions on how to assess tree vitality and identify and score ozone specific needle injury. The principal investigator participated in this meeting in June, 1993, and also attended the annual meeting for Project FOREST in December, 1992.

INSTRUMENTATION:

The list of currently recorded variables is contained in Table 2. The initial set of sensors were the wind systems mounted at the top of the towers and the temperature and relative humidity sensors mounted about two meters above the surface. The ozone monitors were located with the data acquisition equipment in weather protected environments. Input to the monitors was through 0.25 inch diameter teflon tubes mounted outdoors, two to three meters aboveground and at least 0.5 meters from extended surfaces such as roofs or walls. Photometric light sensors, sensitive to solar radiation, were installed at the top of the each instrument tower in 1991. These instruments were added to measure solar radiation reaching the trees. This, in addition to the air temperature and humidity data, can be used to estimate stomatal conductance and ozone uptake by the trees (Davis, 1992).

All instruments are calibrated in-house through the data acquisition systems used in the field. The wind speed sensors were calibrated using fixed RPM synchronous motor calibrators corresponding to two wind speeds. Starting thresholds and the resistance of the wind direction sensors were checked using a torque watch. The temperature sensors were checked using a secondary standard, liquid in glass thermometer. The humidity sensors are calibrated in the laboratory with a high quality dew point hygrometer and a psychrometer. An electronic temperature and humidity transfer standard was used for in situ calibration checks during the monitoring season. The ozone monitors were calibrated in the laboratory and in situ using both their internal self-checks and by use of an ozone calibrator/transfer standard checked yearly by the ARB. These checks along with cleaning and filter changes are part of the routine maintenance procedures. The solar radiation instruments were calibrated at the laboratory using an Epply precision pyranometer.

SOFTWARE DEVELOPMENT AND DATA HANDLING:

Flexible, user friendly, data acquisition software have been developed at UCD. The program allows for listing recent data (the last 12 five minute averages or the last 16 hourly averages) to the screen with no interruption of the data acquisition function. This allows convenient access to the data by on-site personnel as well as by service technicians. The software has error trapping capabilities and restarts itself following power failures as well as miscues or unauthorized keyboard requests. The output of the data acquisition system consists of three types of files. The first contains five minute averages of the data sampled at one second intervals and the standard deviation of these data. The second contains a joint distribution table of the number of observations and the average of each variable by octant of wind direction. The third is a log file in which automatic and manual entries can be made describing significant events related to the data logging function such as restarts after power interruptions, use of user interactive features (hot keys) and the like. The format of these files is shown in Table 3. These data are copied onto diskettes for transfer to UCD. The last data copied to the diskette is also saved in a backup directory on the on-site system's hard disk and not deleted until the retrieved raw data has been successfully reduced. The data acquisition program also writes pertinent information to a log file which keeps track of various types of activities on the system.

Data acquired at the sites are processed at UCD using the procedures outlined in

Figure 8. Data quality control was assessed from scanning the data themselves, log book entries, interpretation of the on site log files and from periodic calibration checks. The raw data were transferred to a permanent archive which included a data quality word, as described below. The archive contains both the five minute data and the hourly, event-rose summaries. Each data record or set of records is marked by a data quality word. This word is set up so that each digit represents the data quality code for a particular instrument, as shown in Table 4. For example, if there were seven instruments, there would be seven digits in the quality control word (QCW). For the five minutes of data and its derivatives, there is one QCW per record. For the event data there is one QCW per grouped record. For the event data, if an instrument malfunctions for any part of the time, the whole period is flagged with the most critical code for that instrument. In addition to the data files themselves, summaries of the data quality assessments are kept as individual files at UCD. These are created as input files for programs that create archive files which include the appropriate quality control words.

High resolution digitized topographic data have been obtained from the United States Geological Survey (USGS) and three dimensional plots of the topography near each site are being generated. An example is shown for the Shaver Lake site in Figure 16. The high resolution data use an unusual coordinate system. As the coordinates of the sites are converted into this system, additional plots will be made. These will greatly aid the interpretation of data vis-a-vis local slope winds.

PRIMARY RECORD KEEPING:

Several written records of operating procedures, instrument use, and calibration histories are maintained. One is the TRAVELING LOG, in which information on site visits, problems encountered, maintenance performed, calibration data and other pertinent information is recorded. At each station, there is a STATION LOG in which UCD, the SJSU auditors and on site personnel make entries. The STATION LOG contains a detailed operational history, records of instruments in use (by serial number), calibrations performed, repair and maintenance data, systematic corrections made to the data and periods of applicability. Finally, a MASTER BINDER is maintained at UCD in which instrument calibration summaries and results, printouts of station on-line log files and QCW applicability files, time plots of raw data for multi-day periods, and summaries of significant events transcribed from the STATION LOG are recorded. This binder contains explanations of QCW non-zero values added to the archived data sets.

SUBCONTRACTOR ACTIVITY:

The primary functions of the subcontractor at SJSU were to provide independent quality assurance audits, to develop a separate data archive and tabulated summaries of hourly data, and to arrange for the certification of the transfer standard. A summary of their activities is contained in Appendix B.

The subcontractors conducted two field audits (June 16-19 and 26 and October 16-18, 1992) in 1992 and one (June 14-18 and July 13-15, 1993) in 1993. A second audit was in progress on October 30, 1993. The results of these audits were all generally positive. Except for a small disparity in the air temperature at Mountain Home and Jerseydale in 1992 and Five-Mile in 1993, no calibration disparities or other problems were identified. Calibrations of all instruments have remained constant except for the ozone monitors. These have shown small changes in the slope of their responses, but all remain within 9% of the calibrations established at the start of the season. The data processing programs apply the small observed corrections to the ozone calibrations as well as the 9 ppbv offset deliberately set into the units' outputs.

INSTRUMENTATION PERFORMANCE:

The instrument performance is summarized in Table 5 for the primary observation period ending October 15, 1992. The information is given in terms of the percent of the available hours during which data were lost. These statistics are subdivided in terms of which part of the system failed. At all but one station, we were able to achieve the targeted 80% data recovery. The problems at Shaver Lake were complex and varied (two different instruments and the computer system). The temperature sensor problem was solved by replacement of the temperature sensor (in July) and the ozone monitor problems were only solved by replacing all of the internal boards in the monitor (in July). The computer problem was never resolved, it simply went away. The computer difficulties at Five-Mile and Jerseydale were one-time computer hang-ups which have not been duplicated in the laboratory. Preliminary analysis of the effect of lost data on seasonally averaged exposure suggest that even with 15 missing days, the seasonal averages vary less than 8% (Van Ooy, 1993).

The last column of the table lists the percent of the time that the instrument enclosure temperature was greater than 30 °C or less than 20 °C, the values at which the United States Environmental Protection Agency (EPA) warns that the measured ozone concentrations no longer conform to EPA designation requirements (Dasibi, 1990). Tests of these systems in our laboratory to temperatures of 45 °C showed no dependence of the calibration slope or zero on the measuring unit's temperature.

MONITORING RESULTS:

The Sierran sites displayed pronounced differences in both ozone and meteorological patterns throughout the 1992 season. Seasonal diurnal patterns of temperature and relative humidity are shown in Figures 9 and 10. Shaver Lake experienced the strongest diurnal ranges, with nighttime temperatures cooler and humidities higher than Mountain Home. Jerseydale, Five-Mile and White Cloud had the weakest diurnal variations in temperature and relative humidity. These last three sites also experienced relatively warmer nighttime temperatures and lower nighttime humidities.

Figure 11 shows the seasonal resultant wind direction by hour of the day for the sites. In order to see the constancy of the wind patterns, the resultant wind speed (dashed line), as well as the averaged wind speed (solid line) for each hour is depicted in Figure 12. Winds which are constant will have resultant wind speeds similar in magnitude to average wind speeds, whereas highly variable winds will have resultant wind speeds significantly smaller than average speeds. Mountain Home and Sly Park both have well defined diurnal patterns in wind speed and direction. These patterns are typical of upslope-downslope mountain wind patterns. White Cloud, located on a ridge, has the least amount of variability in wind direction. With the exception of Sly Park, wind speeds are low at night and increase during the day at the sites.

Figure 13 shows the seasonal average ozone concentrations by hour for June to September, 1992. The Mountain Home and Shaver Lake sites have the greatest average diurnal variation, whereas Jerseydale, Five-Mile and White Cloud have little average diurnal variation. These last three sites, which also experience relatively warmer nighttime temperatures, have high nighttime ozone concentrations.

Ozone frequency distributions for June through September, 1992 are shown in

Figure 14. Mountain Home and Shaver Lake have the largest range of ozone concentrations including higher concentrations than are found at the remaining sites. This broad range of ozone concentrations is the result of greater diurnal variation at these two site. Jerseydale and Five-Mile had a high percentage of observations in a few ozone concentration ranges, indicative of a more constant diurnal ozone concentration pattern. Sly Park and White Cloud had an intermediate level of variation in diurnal ozone pattern. The data plotted in Figure 14 are tabulated in Table 6. In this table, the frequency distribution of hourly ozone concentrations is expressed in terms of percent of available data for each station by month. There are two trends discernable from this table. The first is that higher concentrations occurred more often at the southern end of the network than at the northern or central part. The second is that at most sites, the occurrence of higher concentrations was greatest in the months of June and August. Since the air reaching the southern Sierra has a long fetch through the San Joaquin Valley (which contains an number of urban areas and transportation corridors), it is expected that latitudinal differences are representative and likely to occur every year. So far, this has occurred in both 1991 and 1992.

In Figure 15, hourly averaged resultant wind directions (black squares) are plotted with event distributions. The event distributions are the fraction of observed hours when hourly averaged ozone concentrations are greater than 60 ppbv (white bar) and 90 ppbv (black bar). Both Mountain Home and Sly Park showed evidence to support the hypothesis that ozone, rather than it's precursors, is transported to remote regions. Since most of the peak concentrations appear well past noon, the time of greatest ozone production, it appears the ozone is transported. Shaver Lake demonstrates a similar, though less pronounced, pattern. The remaining three sites do not have any noticeable relationship between high ozone events and wind direction. However, Jerseydale, Five-Mile and White Cloud showed unexpected high concentrations through the late night hours. In fact, the highest frequency of exceedances and the highest values measured at White Cloud occurred several hours after sunset when local ozone production had ceased.

Hourly averaged data for each site, for the months of May through October, are plotted in Appendix A. Tabulated hourly data are contained in Volume 2. The typical diurnal pattern of upslope (westerly) winds during the daytime hours and downslope (easterly) winds at night is quite apparent at Mountain Home, Shaver Lake and Sly Park. Diurnal variations in the meteorological variables are moderately well defined at Jerseydale and Five-Mile but not very apparent in the ozone data. At White Cloud, only air temperature shows a well defined diurnal pattern. While there are differences among stations, peak ozone concentrations usually occur in the afternoon hours when the upslope flows are well established, winds are strongest and temperatures are highest.

Nighttime minima in ozone concentrations were also different among the stations. Shaver Lake and Sly Park typically dropped the most at night, frequently reaching minima of 20 ppbv. Conversely, the other sites frequently had nighttime minima in excess of 60 ppbv. The highest concentrations of ozone observed at White Cloud were found between 8 p.m. and 1 a.m. This pattern appears regularly enough to suggest that the trajectory from the Sacramento valley is not directly from the Sacramento area to White Cloud. During travel ozone is formed, but not destroyed, indicating no nitric oxide (NO) emissions along the path and only limited contact with the ground occurs.

Clearly, several of the sites experienced ozone concentrations that can be injurious to vegetation. What is somewhat surprising is that in some cases, ozone concentrations remained high at night, while others did not, even with downslope flows. Given the distance these sites are from NO emission sources, the nocturnal ozone concentrations appear to be controlled by transport processes rather than by chemical processes (Lefohn and Pinkerton, 1988). These observations point to the need to examine fairly complex three dimensional transport hypotheses and appropriate three dimensional sampling to verify those selected.

COMPARISONS WITH OTHER DATA:

An analysis was completed to determine if there was a correlation between high concentrations of ozone ($\geq$ 100 ppbv) at Central Valley ozone monitoring stations and at Sierra sites during the months of June through September, 1992. High ozone concentrations at air monitoring stations located within 100 miles upwind from the Sierra sites were identified. The air monitoring stations considered in the analysis (Table 8) are operated by the ARB, local air pollution control districts, the National Parks Service and private firms. Data from these stations was obtained from the 1992 ARB publication "California Air Quality Data," in which maximum daily ozone concentrations at each station are listed. The ozone data for each Sierra site was used to determine the times (day and hour) when high ozone concentrations occurred.

Two wind roses were created per ten day period for each Sierra site, one for the hours between 9 a.m. and 8 p.m. and the other for the hours between 9 p.m. and 8 a.m. For each twelve hour time period, the wind rose contained the percentage per sector of wind direction observations over the ten day period. The average wind direction does not vary greatly between days during a ten day period, therefore the wind roses determined the primary wind direction at a site for a day on which high ozone concentrations were observed. Data from the valley stations located upwind from the site were then examined to determine if high ozone concentrations were also observed on that day.

This analysis has been completed for the Mountain Home, Jerseydale, Five-Mile, Sly Park, and White Cloud sites. The following percentage of wind data was available for each site:

Mountain Home (98%)
Jerseydale (97%; Julian days 153-182 were not used)
Five-Mile (96%; Julian days 212-233 were not used)
Sly Park (98%)
White Cloud (98%).

Only daytime episodes of high ozone (between 9 a.m. and 8 p.m.) were included in the analysis. The primary wind direction during these episodes did not change at each site, thus the number of upwind stations used in the comparisons remained the same and was as follows:

Mountain Home (6)
Jerseydale (2)
Five-Mile (2)
Sly Park (8)
White Cloud (9).

The total number of days per site for which ozone concentrations reached at least 100 ppbv were as follows:

Mountain Home (58)
Jerseydale (13)
Five-Mile (9)
Sly Park (12)
White Cloud (10).

For all Sierra sites, the number of monitoring stations upwind that reported high ozone concentrations on the same day was greater than 50%. For Jerseydale, Five-Mile, and Sly Park the percentage was greater than 75%. Therefore, the primary results of the analysis show a moderate to strong correlation between episodes of high ozone concentrations at the Sierra sites with same day episodes of high ozone concentrations at stations upwind from the sites.

Beginning in July, 1993, tree water potential measurements were performed. Trees were sampled at each site once a month during the remainder of the growing season using the Scholander pressure-chamber technique (Koide et al., 1991). The pressure-chamber technique measures the tree's hydrostatic pressure which is approximately equal to the water potential when the tree is in equilibrium. The samples taken at each site were done during the two hours preceding sunrise since this is when the tree is in equilibrium. At individual sites, five trees were selected and one twig (about 1 cm in diameter) from each tree was used for measurement. Prior to removing the sample twig from the tree, the needles were enclosed in a plastic bag to prevent water loss during the measurement period. Once excised with a sharp razor blade, the sample was placed in the chamber with only the stem protruding from a rubber gasket which sealed the chamber. The chamber was then pressurized with nitrogen, and the exposed surface of the twig was examined with a dissecting microscope. The pressure was recorded when water first appeared on the cut surface. The results of these pressure-chamber measurements appear in Table 7. Since transpiration is influenced by available soil moisture (Rundel and Jarrell, 1991) and ozone injury results from ozone uptake through stomata during transpiration, a more accurate estimate of ozone uptake could be obtained by using measured values of available soil moisture, instead of a fixed estimate, in stomatal conductance models (e.g., Davis et al., 1993).

While the air monitoring data provide a measure of ozone concentrations in forests, they do not provide a measure of ozone uptake by trees. The ozone taken up by trees is responsible for tree injury (Miller and Millecan, 1971). By knowing the rate of absorption of ozone by the trees (ozone flux), an ozone exposure can be calculated for a given period of time: the growing season, for example. An exposure so calculated should give a better indication of the actual effect of the ozone on the trees than just using ambient ozone concentrations. The ozone flux is dependent on atmospheric conditions in addition to ozone concentration. A stomatal conductance model has been developed which incorporates air temperature, relative humidity, solar radiation and wind speed, as inputs to estimate the flux of ozone to trees. However, at this time the values generated by the model are not consistent with conductance measurements measured in a managed ponderosa pine stand in Chico (Draft final report for ARB Contract No. A132-101). These apparent discrepancies are currently being investigated.

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TABLE 1
SIERRA OZONE ASSESSMENT SITE CHARACTERISTICS

NO.	NAME	NATIONAL FOREST	ELEV. (FEET)	COOPER-ATOR	WIND TOWER HEIGHT	OPERATING DATES
1.	MOUNTAIN HOME	SEQUOIA	6000	CDF	17m (56')	10/10/90-11/12/90 5/25/91-11/07/91 5/14/92-11/12/92 5/10/93-10/29/93
2.	SHAVER LK.	SIERRA	5650	SCE	12m (40')	7/24/91-11/08/91 5/13/92-11/11/92 5/11/93 - pres.
3.	JERSEYDALE	SIERRA	3750	USFS	17m (56')	9/21/90-12/18/90 5/09/91-11/08/91 4/23/92-11/11/92 4/28/93 - pres.
4.	FIVE-MILE LEARNING CENTER	STANIS-LAUS	4000	CLOVIS SCH. DISTRICT	12m (40')	12/05/90-11/21/91 1/07/92-12/22/92 1/26/93 - pres.
5.	SLY PARK	ELDORADO	3550	SACRA. SCH. DISTRICT	17m (56')	10/30/90-12/22/92 1/15/93 - pres.
6.	WHITE CLOUD	TAHOE	4350	USFS	12m (40')	9/26/90-11/28/90 4/23/91-11/14/91 4/27/92-11/19/92 4/27/93 - pres.

TABLE 2
INSTRUMENT AND EQUIPMENT VENDORS:

Vendor	Equipment	Model
Met-One	Temperature, Humidity	083-1,1760TS-1760G
	Wind Speed	014-1,1680-1812
	Wind Direction	024-1,1690-2106
DASIBI	Ozone Monitor	1008 AH
	Ozone Calibrator	1008 PC
LI-COR	Solar Radiation	200-SZ
DCL Computers	Data acquisition	DFID11XT
Tri-Ex Tower Corp,	50' Telescoping Tower	W7-51
	33' Telescoping Tower	MW-33
Keithly/Metrabyte	8 channel MUX-A/D	STA-8PGA

TABLE 3
DATA FILE STRUCTURES:

Definitions:

DD = Wind direction	FF = Wind speed
RH = Relative humidity	Ta = Temperature
O_3 = Ozone concentration	Tb = Enclosure temperature
v = South to north wind component	u = West to east wind component
S = Solar radiation	R = Reference 5 volts

LOG FILES:

- Date and time of program restarts (e.g. after operational maintenance, or power failures); of data acquisition interruptions due to use of "hot keys"; counts of instrument's error flag and manually entered notes.

ON-LINE FIVE MINUTE FILES

- Month, day, year, hour, minute, station number
- Number of obs., DD, FF, u, v, Ta, RH, O_3, Tb, S, R
  Rms (DD, FF, u, v, Ta, RH, O_3, Tb, S, R)

Twelve entries per hour, 24 hours per day. Data appended to these files every five minutes.

TABLE 3 (CONTINUED)

ON-LINE HOURLY SUMMARY WIND & EVENT FILES:

- Month, day, year, hour, minute, station number
- Event distribution by octants in the wind direction:

Wind Dir. (Deg.)	Number of Obs. (count)	Average FF (m/s)	Average RH (%)	Average Ta (°C)	Average O_3 (ppbv)
CALM	71	0.0	42	12.5	55
22.6 - 67.5	1647	1.9	38	13.6	59
67.5 - 112.5	1231	1.6	38	13.5	59
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
292.6 - 337.5	36	1.9	37	13.5	57
337.6 - 22.5	179	1.8	38	13.6	58

ARCHIVED FIVE MINUTE AVERAGE FILES:

-- Date (julian day), year, number of records, station
-- Time, Ave (DD,FF,u,v,Ta,RH,O,S), RMS (DD,FF,Ta,RH,O,S), QCW

UP TO 24 HOURS WORTH

ARCHIVED HOURLY EVENT DATA:

-- Julian day, year, number of data blocks, station.

-- Decimal hour, and QCW for the hour.
-- # of observations by wind direction.
-- Average wind speed "
-- Average humidity "
-- Average temperature "
-- Average ozone "

Repeat for each hour of the day for which data are available.

TABLE 4
SCOIAS DATA QUALITY CODES.

The values for the codes are as follows:

- 0 No known problems. Calibration corrections have been applied. Data should be fine.
- 1 No calibration corrections have been applied or no calibration correction available.
- 2 Systematic error adjustments applied or data corrected for noisy signal.
- 3 Data not representative, non-standard exposure (test).
- 4 Data not representative, cold start/warm up period.
- 5 Data questionable, malfunction suspected.
- 6 Data is no good, instrument malfunction.
- 7 Data is no good, instrument not connected or inoperative.
- 8 Used for TBOX only, means shelter temperature is outside EPA specified limits for the DASIBI monitors.
- 9 N/A

Digit:	1	2	3	4	5	6	7
QCW =	S	DD	FF	RH	TEMP.	OZONE	TBOX

NOTE: Due to instrument warm up requirements, ozone data are flagged "4" for one-half hour following restarting after a power failure.

TABLE 5
Summary of operational performance for 1992 observing season.

No.	Name	Dates of Operation	Percent of time data missed due to: I	II	III	IV	V	Total	% time $T \neq EP$
1	Mtn Home	5/14 - 10/15	0.0	0.0	0.1	0.0	0.3	0.4	2
2	Shaver Lk	5/13 - 10/15	4.2	0.7	15.2	14.3	0.3	34.7	27
3	Jerseydale	5/01 - 10/15	11.0	0.8	0.4	0.0	0.3	12.5	78
4	Five-Mile	5/01 - 10/15	12.3	0.3	0.0	0.0	0.4	13.0	64
5	Sly Park	5/01 - 10/15	0.0	0.1	0.0	0.0	0.3	0.4	37
6	White Cld.	5/01 - 10/15	0.0	0.2	0.0	0.0	0.4	0.6	83

I = Computer system failures. IV = Meteorological instrument failures.
II = AC power failures. V = Operational maintenance.
III = Ozone monitor problems. EP = EPA temperature range of 20 to 30 °C.

TABLE 6
Percent of hourly average ozone concentrations by month (1992) and station for concentration ranges shown.

Month	Ozone Concentrations (ppbv) < 50	50-59	60-69	70-79	80-89	90-99	100-109	110-119	> 119
MOUNTAIN HOME:									
May	12.7	12.7	15.8	17.2	17.2	11.8	9.4	2.4	0.9
June	19.4	12.2	13.0	16.1	14.2	11.2	5.9	6.0	2.1
July	30.2	10.7	15.8	11.5	11.6	8.9	7.3	3.5	0.5
August	5.4	6.6	16.0	19.6	21.7	15.6	9.9	4.1	1.2
September	21.1	14.8	19.1	13.8	11.7	11.0	6.0	2.0	0.6
October	44.8	13.8	16.8	11.4	7.3	3.7	1.4	0.9	0.0
SHAVER LAKE:									
May	56.4	8.6	6.1	9.6	10.7	4.8	2.4	1.1	0.3
June	44.1	13.8	10.5	9.6	10.1	4.8	5.3	1.8	0.0
July	81.0	5.2	5.2	1.7	2.3	1.7	2.9	0.0	0.0
August	41.4	12.8	9.4	11.7	9.3	7.8	4.6	1.9	1.1
September	51.0	12.1	12.8	10.6	7.2	3.6	2.1	0.3	0.3
October	65.4	11.4	11.0	4.2	6.1	1.9	0.1	0.0	0.0
JERSEYDALE:									
May	8.5	16.8	31.4	25.9	12.9	4.2	0.3	0.0	0.0
June	20.0	7.8	16.3	26.7	19.3	4.8	5.2	0.0	0.0
July	24.3	16.8	22.3	22.1	10.6	3.1	0.7	0.0	0.0
August	9.2	20.2	25.1	25.0	14.6	4.7	1.1	0.0	0.0
September	15.0	13.6	24.5	20.1	18.5	7.1	1.1	0.0	0.0
October	24.8	8.0	18.1	21.2	19.3	6.2	2.1	0.2	0.0
FIVE-MILE:									
May	13.6	16.9	29.7	27.0	10.2	2.2	0.4	0.0	0.0
June	25.9	5.9	17.2	30.3	13.9	5.5	1.0	0.3	0.0
July	25.5	22.7	20.9	21.2	8.3	1.2	0.1	0.0	0.0
August	11.1	20.2	19.5	12.5	22.9	10.1	3.7	0.0	0.0
September	17.0	17.2	20.0	25.1	14.8	5.3	0.6	0.0	0.0
October	33.8	15.5	15.7	16.9	13.2	4.7	0.1	0.0	0.0
SLY PARK:									
May	46.6	16.8	16.7	11.2	7.0	1.1	0.3	0.3	0.0
June	49.2	12.8	13.6	15.0	6.5	1.7	0.7	0.4	0.0
July	44.3	18.6	17.5	10.8	6.0	1.8	0.7	0.1	0.3
August	36.9	19.4	18.9	11.9	7.4	3.8	1.2	0.4	0.0
September	36.7	23.6	20.7	10.8	4.9	2.2	0.6	0.4	0.0
October	61.5	13.5	13.1	7.1	3.4	1.4	0.1	0.0	0.0
WHITE CLOUD:									
May	11.7	15.5	27.8	34.2	8.1	2.3	0.1	0.3	0.0
June	28.0	9.3	17.9	26.6	11.3	4.1	1.6	1.0	0.3
July	23.7	19.5	20.7	19.3	13.2	3.1	0.5	0.0	0.0
August	12.5	18.9	27.1	19.6	15.8	4.9	0.8	0.1	0.1
September	19.8	19.9	24.6	22.8	9.8	2.7	0.4	0.0	0.0
October	41.0	20.3	20.4	10.3	6.6	1.5	0.0	0.0	0.0

TABLE 7

Results of tree water potential measurements (bars).

Site	Reading 1 (Jul-Aug) Mean	stdv	Reading 2 (Sep) Mean	stdv	Reading 3 (Oct) Mean	stdv
White Cloud	-5.54	0.67	-6.84	0.81	-6.14	0.65
Sly Park	-6.78	0.82	-8.18	1.27	-7.58	0.78
Five-Mile	-5.64	0.80	-6.90	1.35	-7.14	1.13
Jerseydale	-5.34	0.68	-8.08	0.70	-8.36	0.75
Shaver Lake	-4.16	0.55	-6.00	2.08	-5.50	1.62
Mountain Home	-5.08	0.54	-5.56	0.51	-5.30	0.80

TABLE 8

Central Valley air monitoring stations used in the correlation analysis.

Sierra Site	Central Valley Station	ID Code	County
MOUNTAIN HOME	Clovis	00248-I11	Fresno
	Sierra Skypa	00245-I11	Fresno
	Fresno	00246-A11	Fresno
	Fresno	00244-I11	Fresno
	Parlier	00230-I11	Fresno
	Visalia	00568-I11	Tulare
JERSEYDALE	Madera	00003-I11	Madera
	Merced	00528-I11	Merced
FIVE-MILE	Madera	00003-I11	Madera
	Merced	00528-I11	Merced
SLY PARK	Citrus Heights	00293-A11	Sacramento
	Folsom	00287-I11	Sacramento
	Sacramento	00295-I11	Sacramento
	Sacramento	00307-I11	Sacramento
	Sacramento	00305-A11	Sacramento
	Davis	00577-A11	Yolo
	Auburn-Dewitt	00813-I11	Placer
	Rocklin	00820-A11	Placer
WHITE CLOUD	Citrus Heights	00293-A11	Sacramento
	Folsom	00287-I11	Sacramento
	Sacramento	00295-I11	Sacramento
	Sacramento	00307-I11	Sacramento
	Sacramento	00305-A11	Sacramento
	Auburn-Dewitt	00813-I11	Placer
	Rocklin	00820-A11	Placer
	Pleasant Grove	00897-A11	Sutter
	Yuba City	00898-A11	Sutter

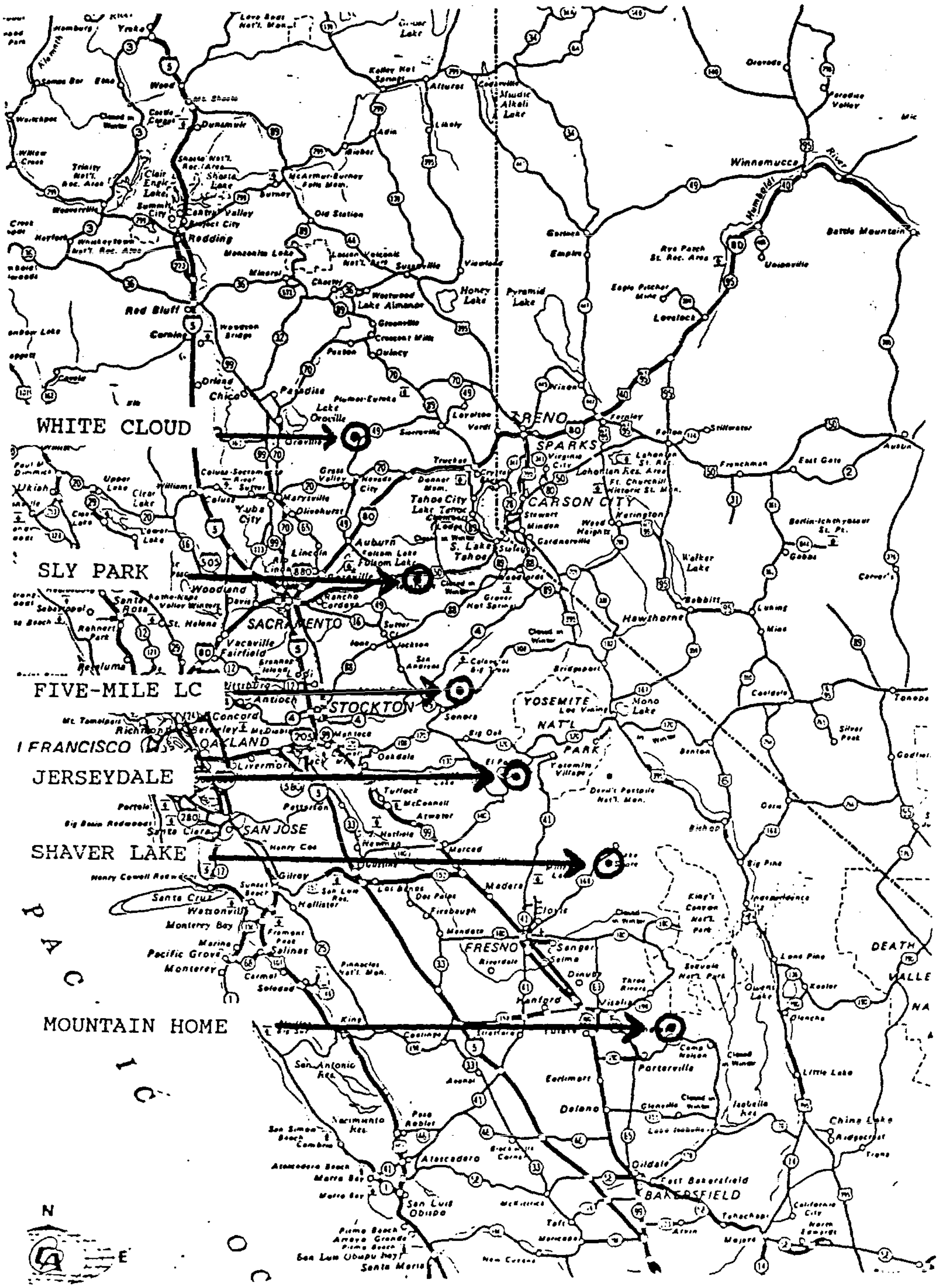


Figure 1. Map of central California showing the approximate locations of the ozone monitoring sites.

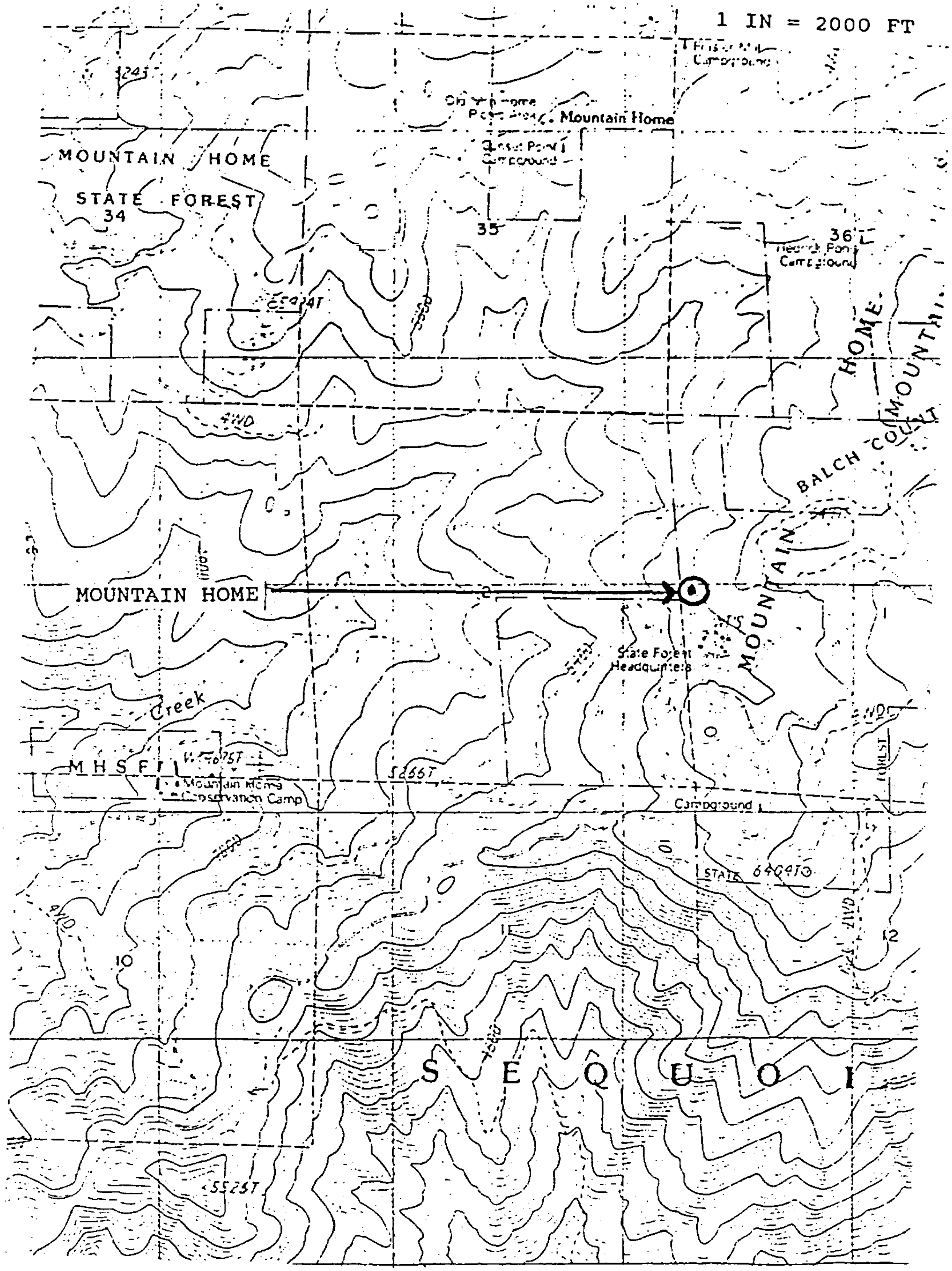


Figure 2. Detailed map of the Mountain Home area showing the location of the UCD - SCOIAS instrumentation.

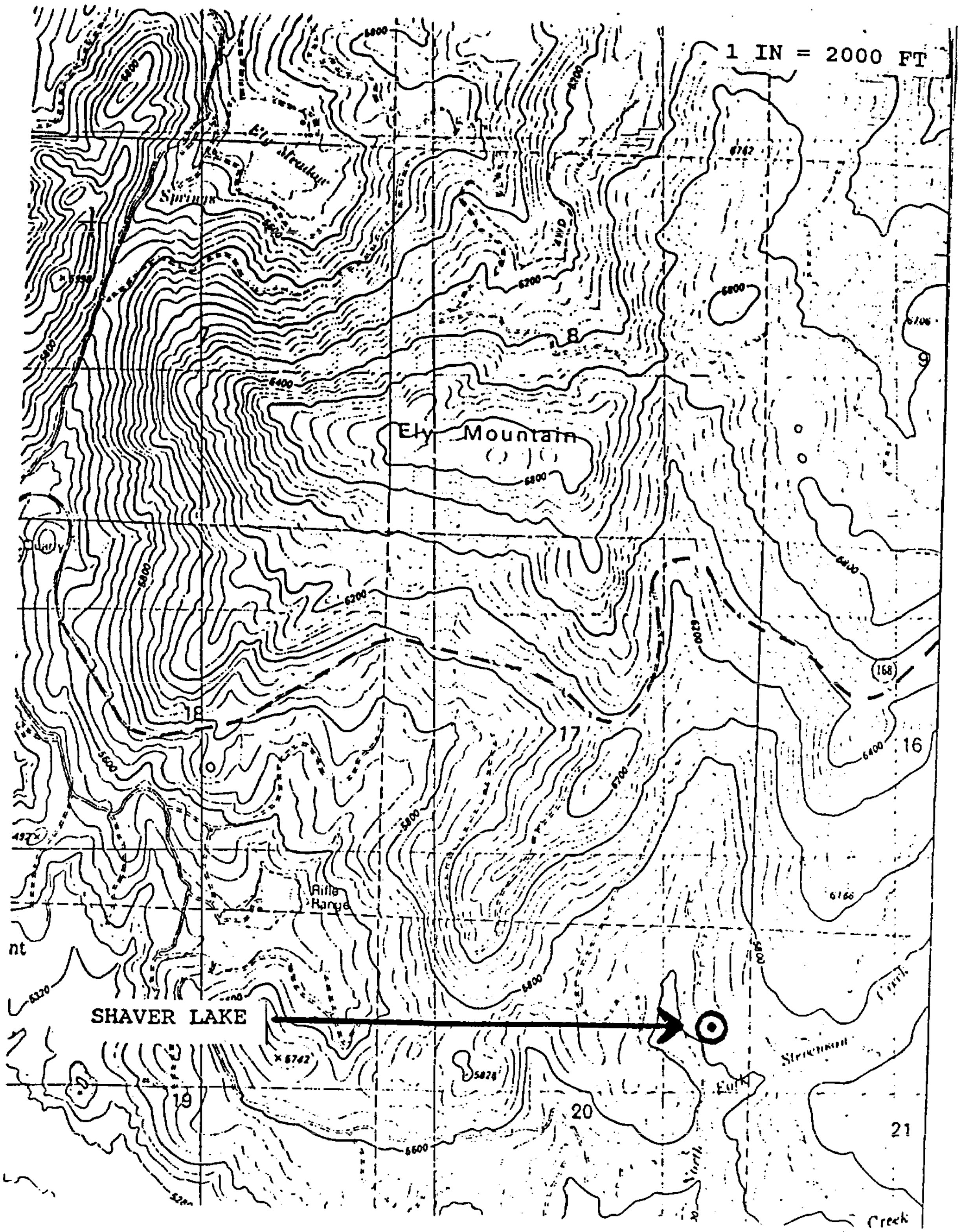


Figure 3. Detailed map of the Shaver Lake area showing the location of the UCD - SCOIAS instrumentation.

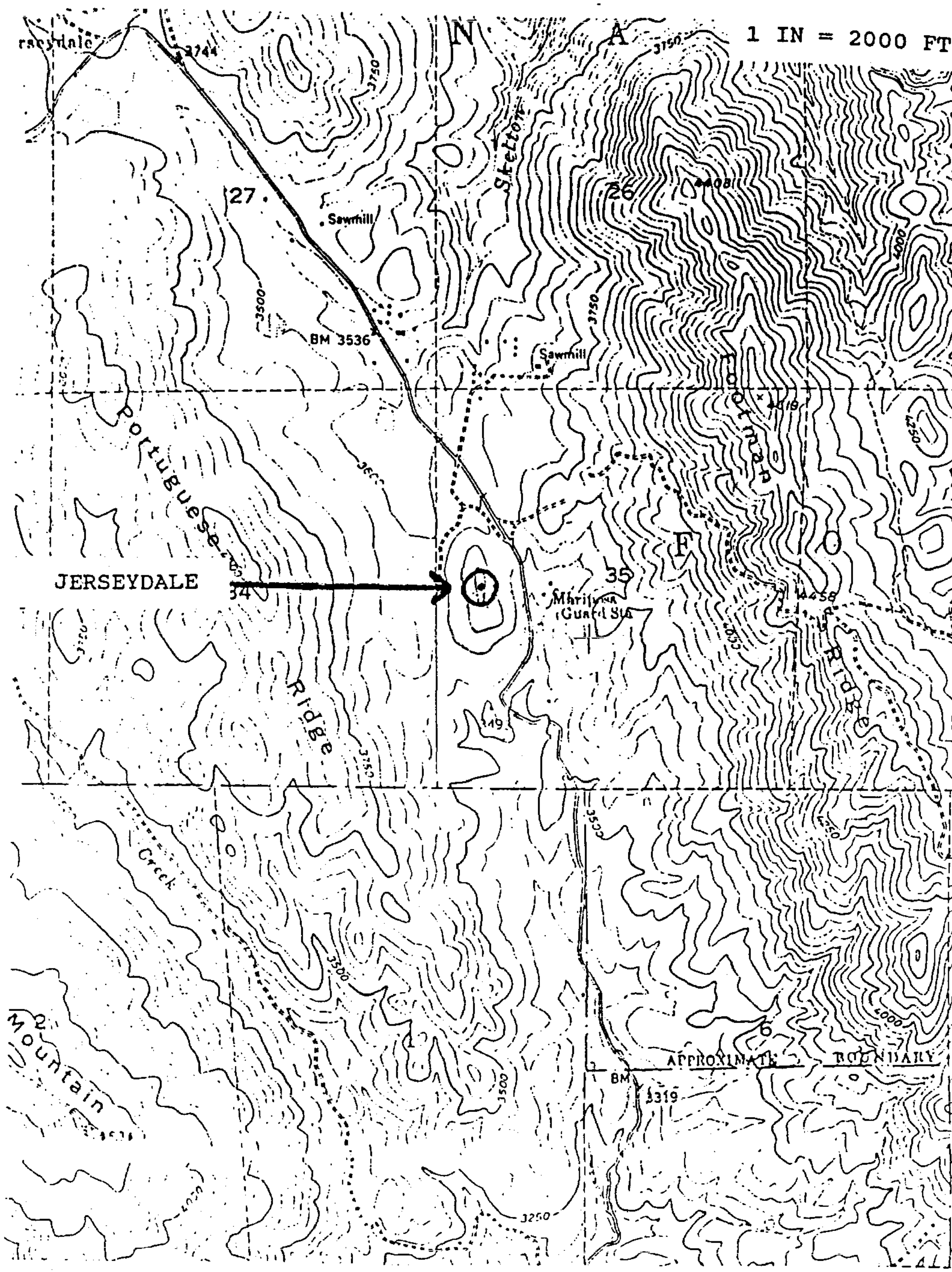


Figure 4. Detailed map of the Jerseydale area showing the location of the UCD - SCOIAS instrumentation.

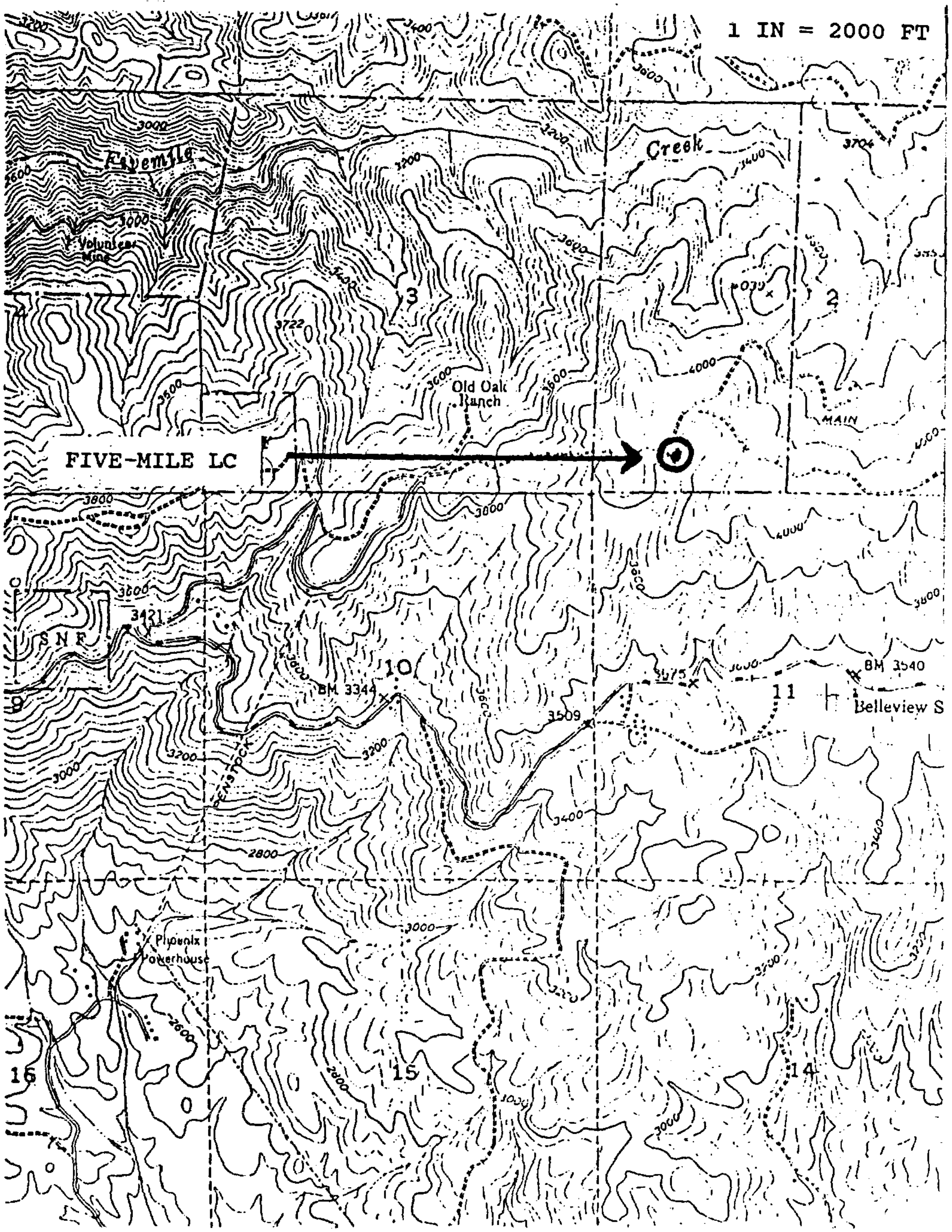


Figure 5. Detailed map of the Five-Mile Learning Center area showing the location of the UCD - SCOIAS instrumentation.

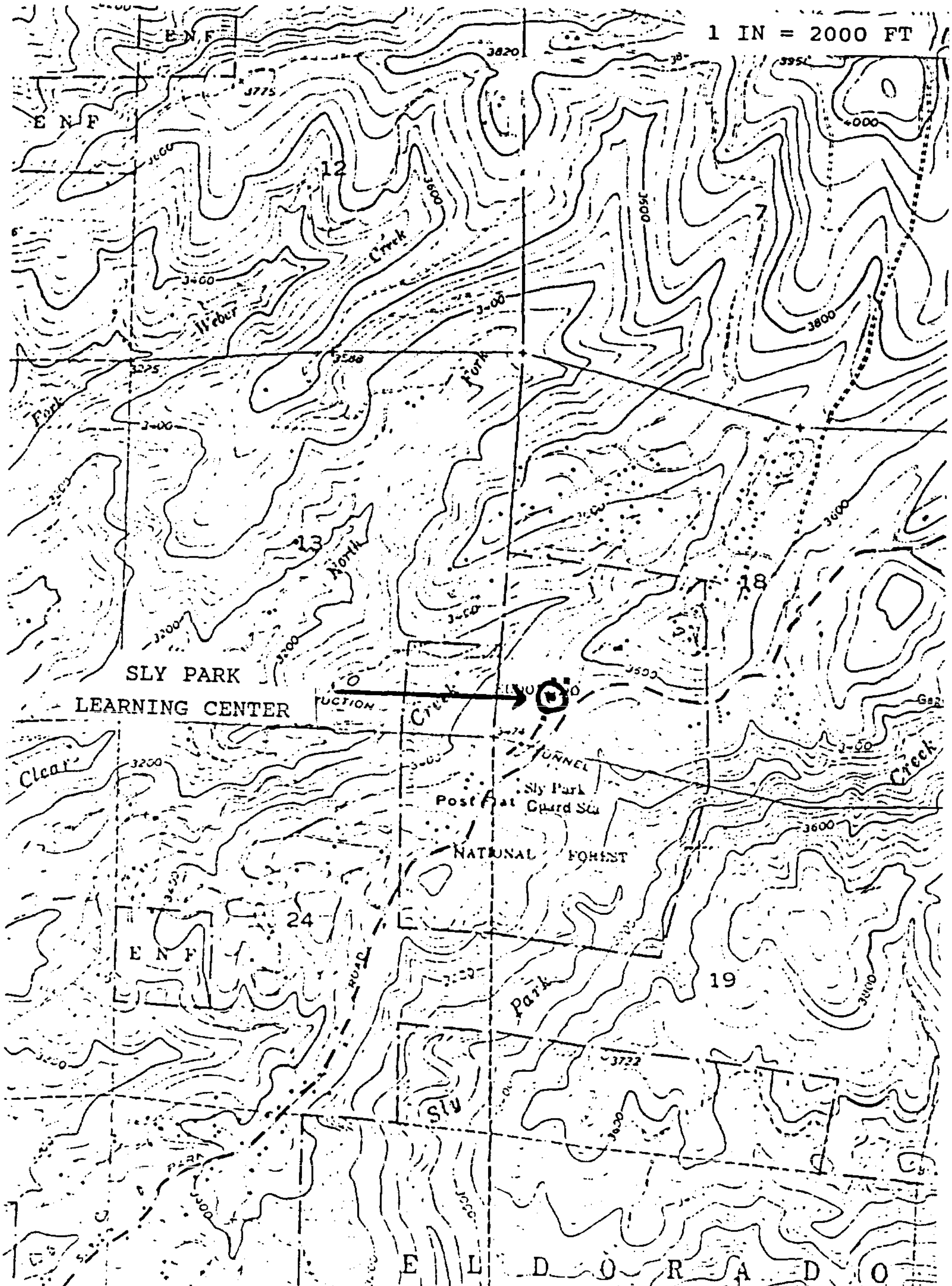


Figure 6. Detailed map of the Sly Park Learning Center area showing the location of the UCD - SCOIAS instrumentation.

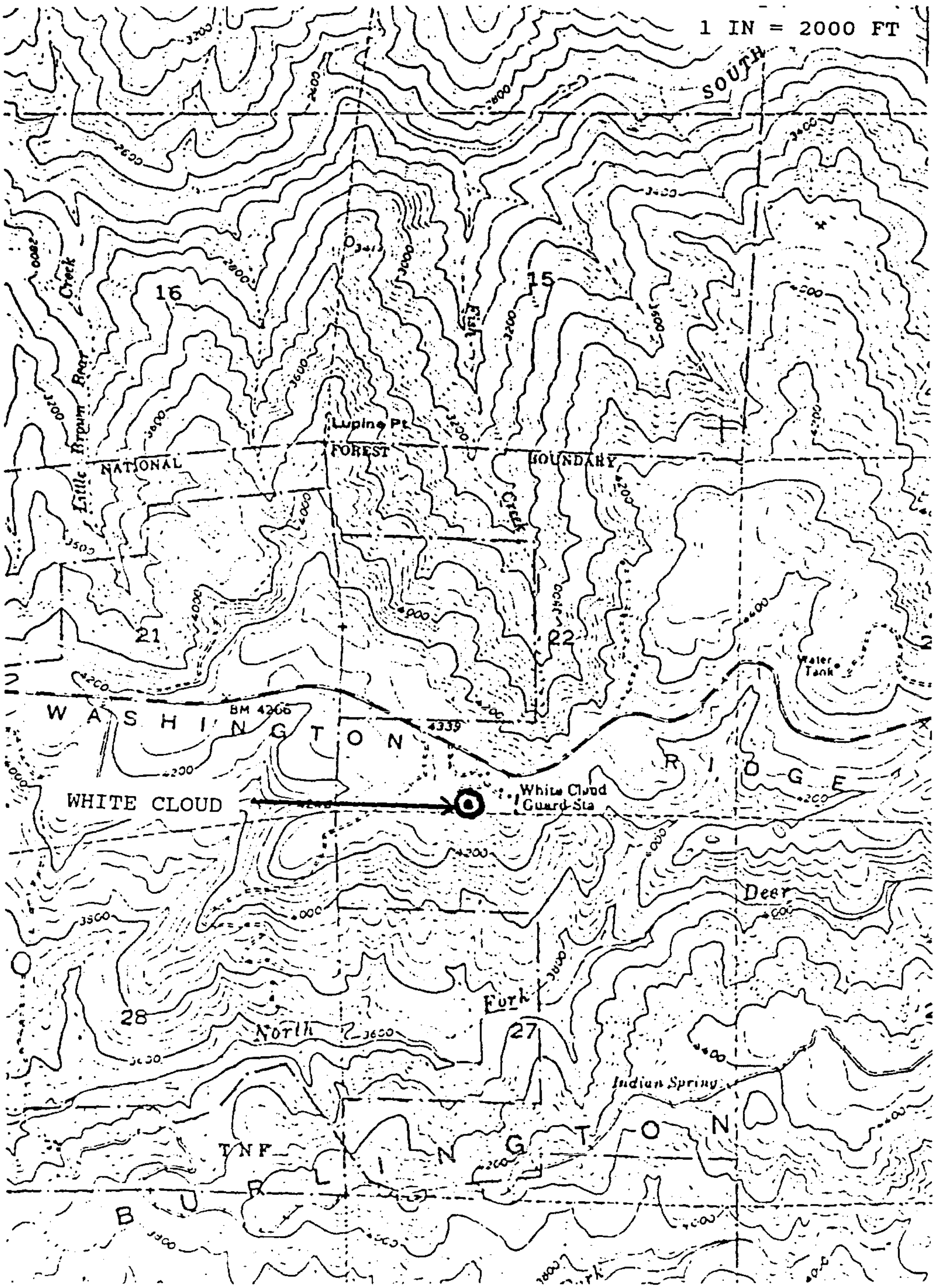


Figure 7. Detailed map of the White Cloud area showing the location of the UCD - SCOIAS instrumentation.

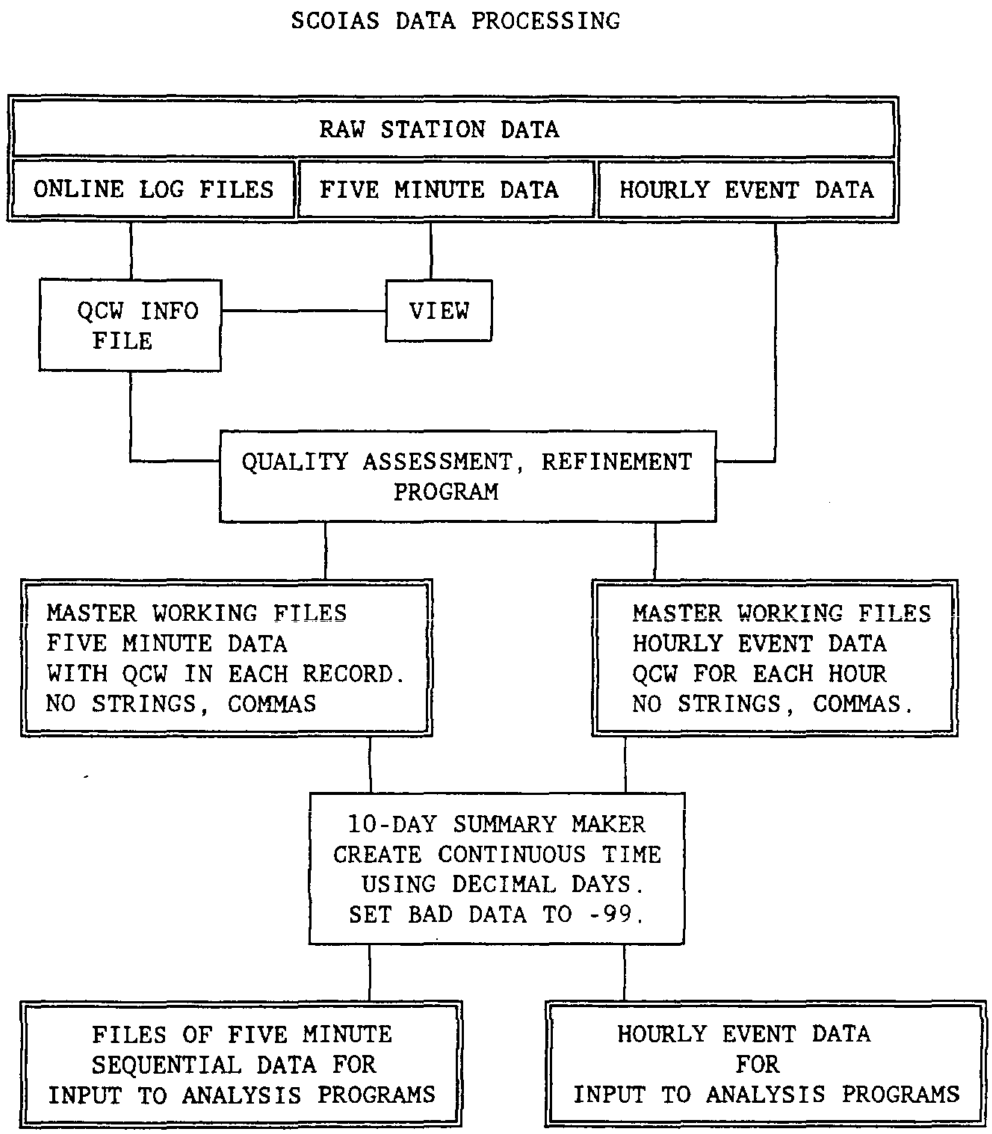


Figure 8. Summary of the SCOIAS data processing procedures. Boxes with double outline indicate data files. Boxes with single outlines represent data processing programs.

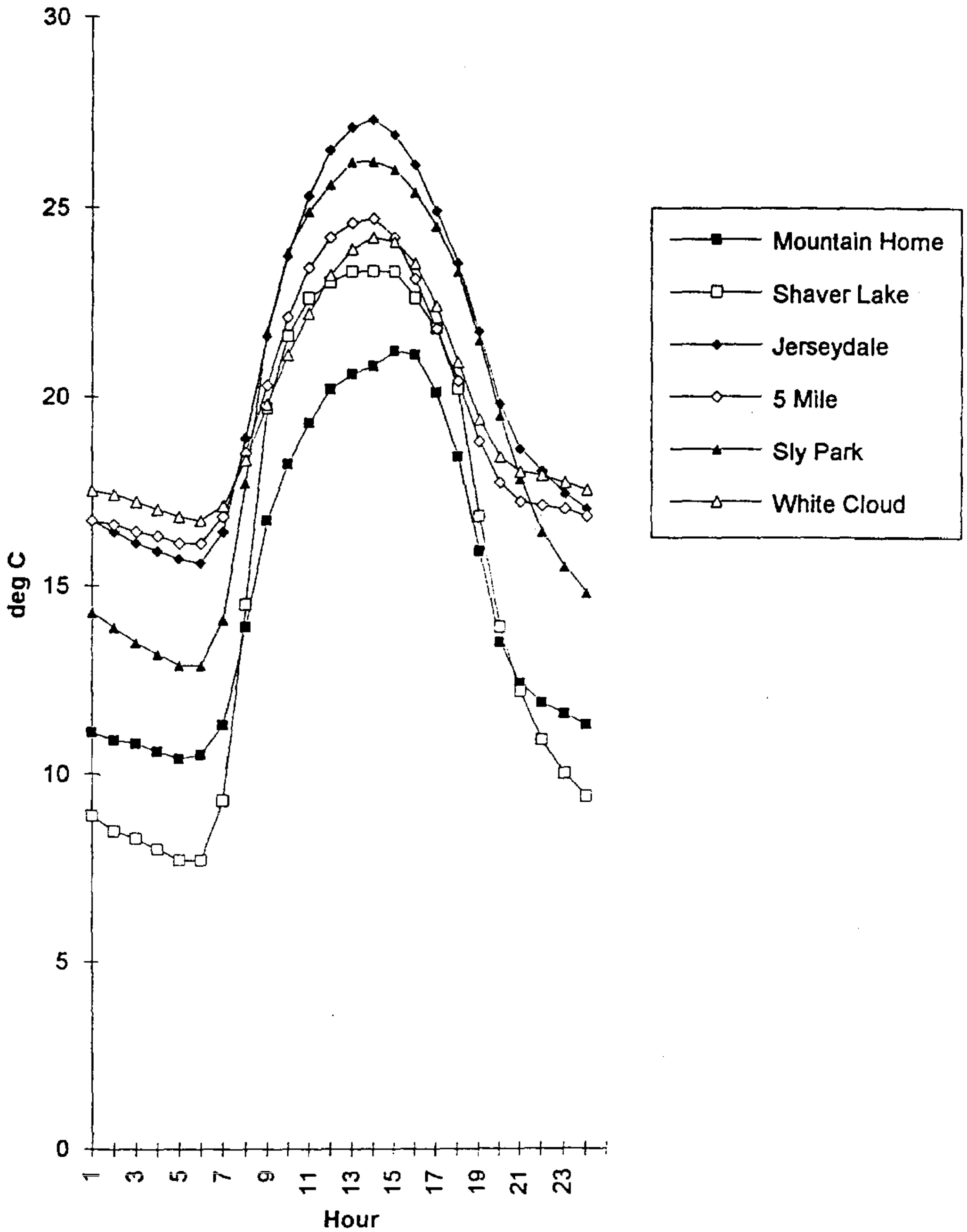


Figure 9. Seasonal average temperature by hour of day, June to September, 1992.

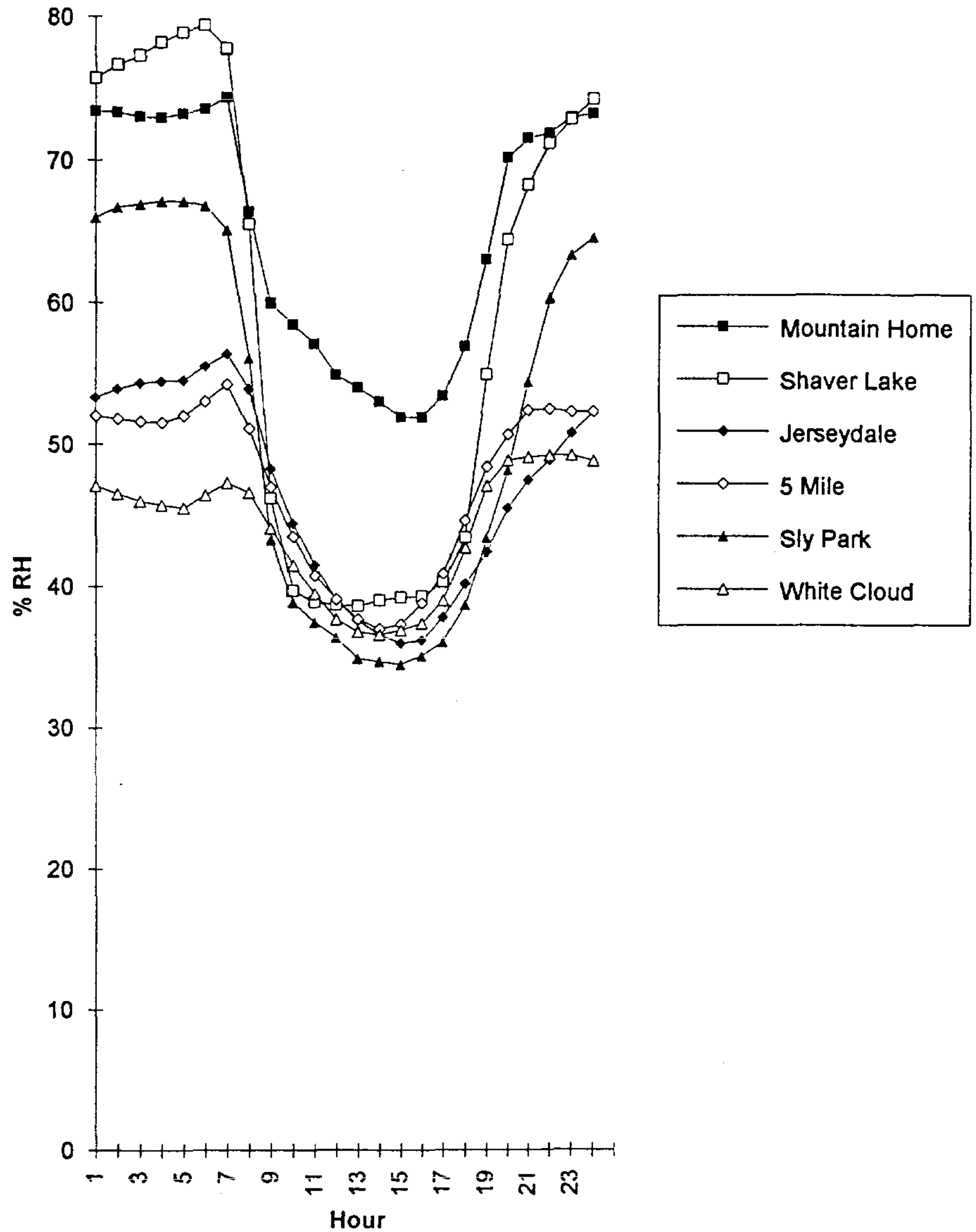


Figure 10. Seasonal average relative humidity by hour of day, June to September, 1992.

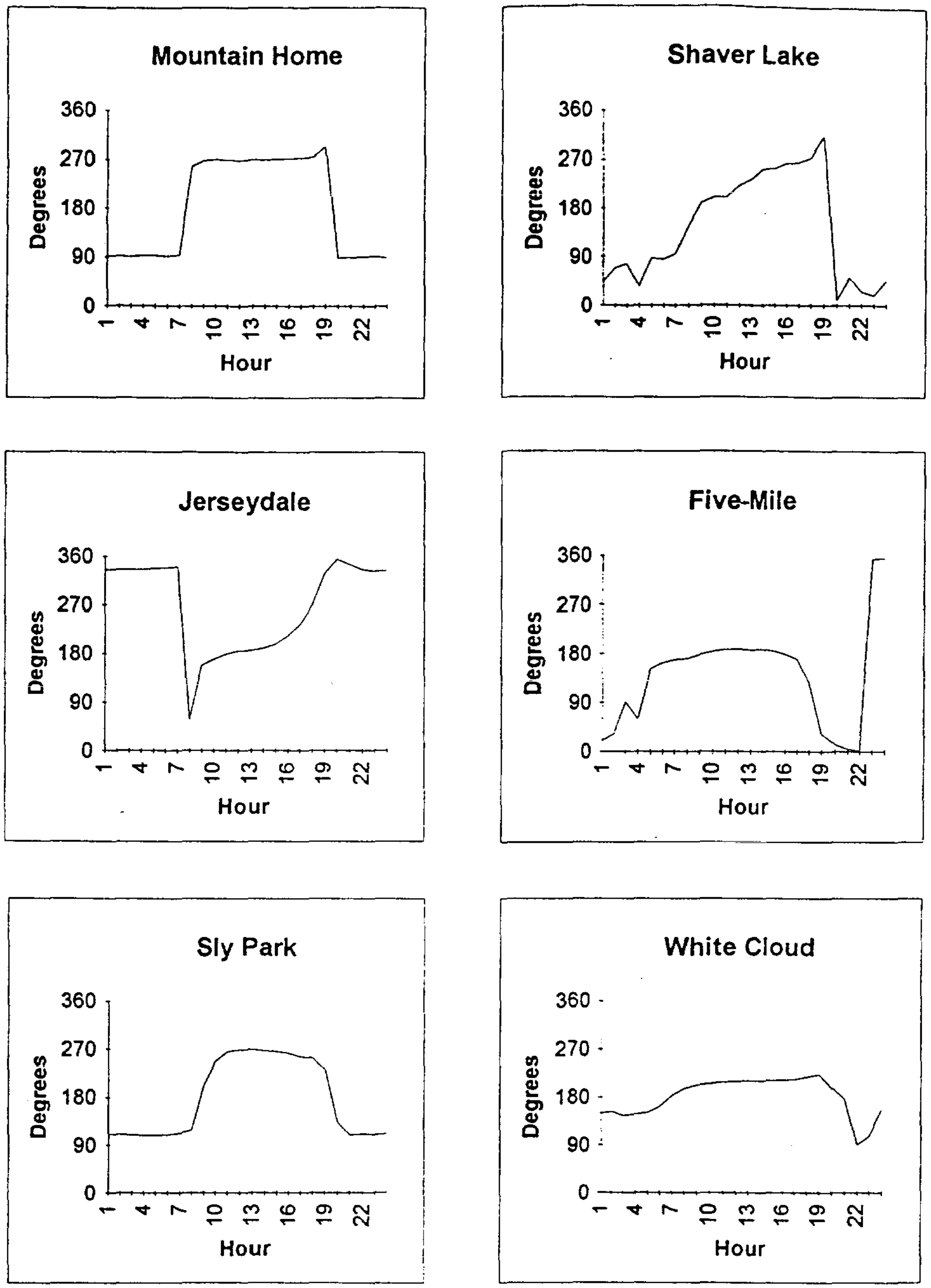


Figure 11. Seasonal resultant wind direction by hour of day, June to September, 1992.

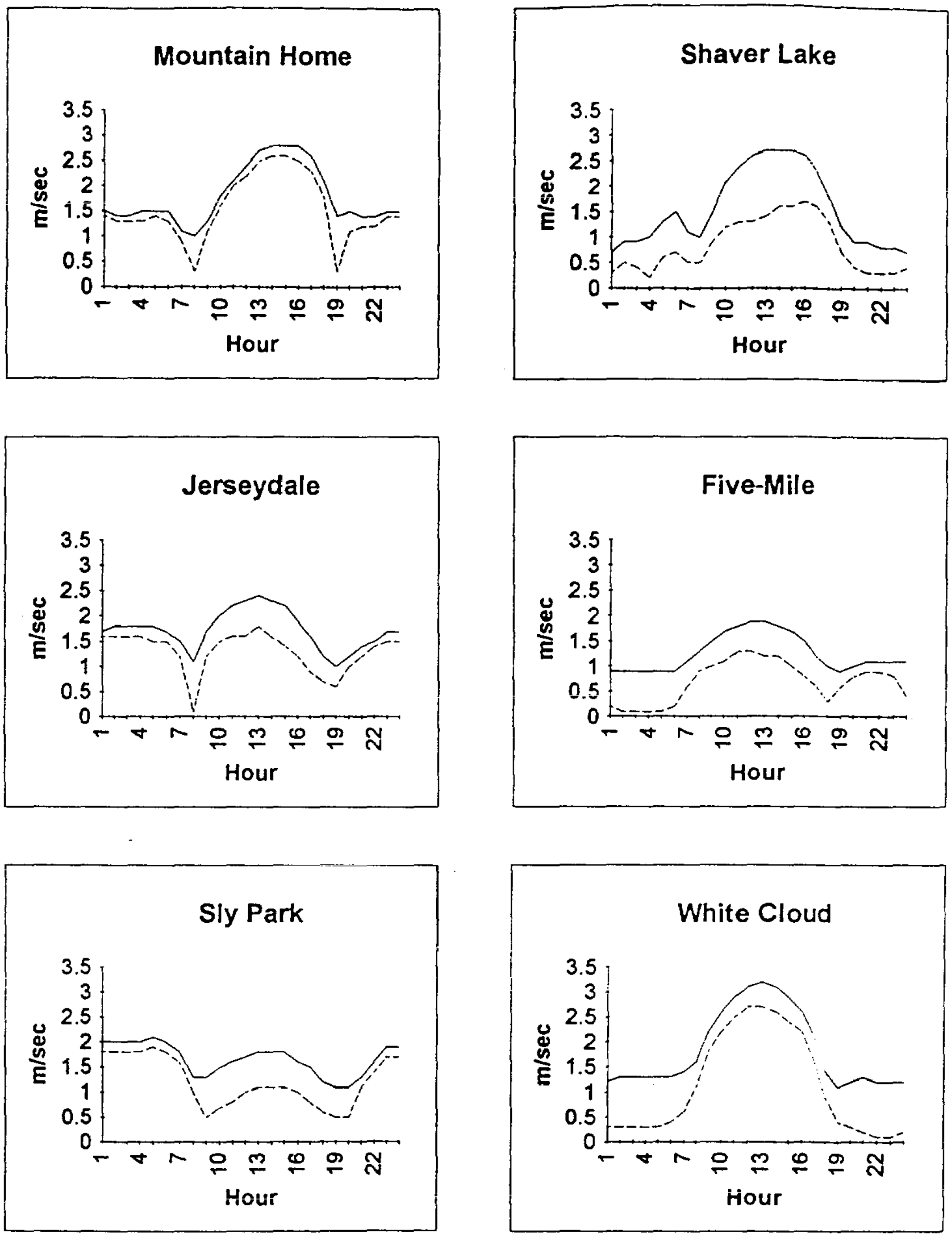


Figure 12. Average and resultant wind speeds by hour of day, June to September, 1992.

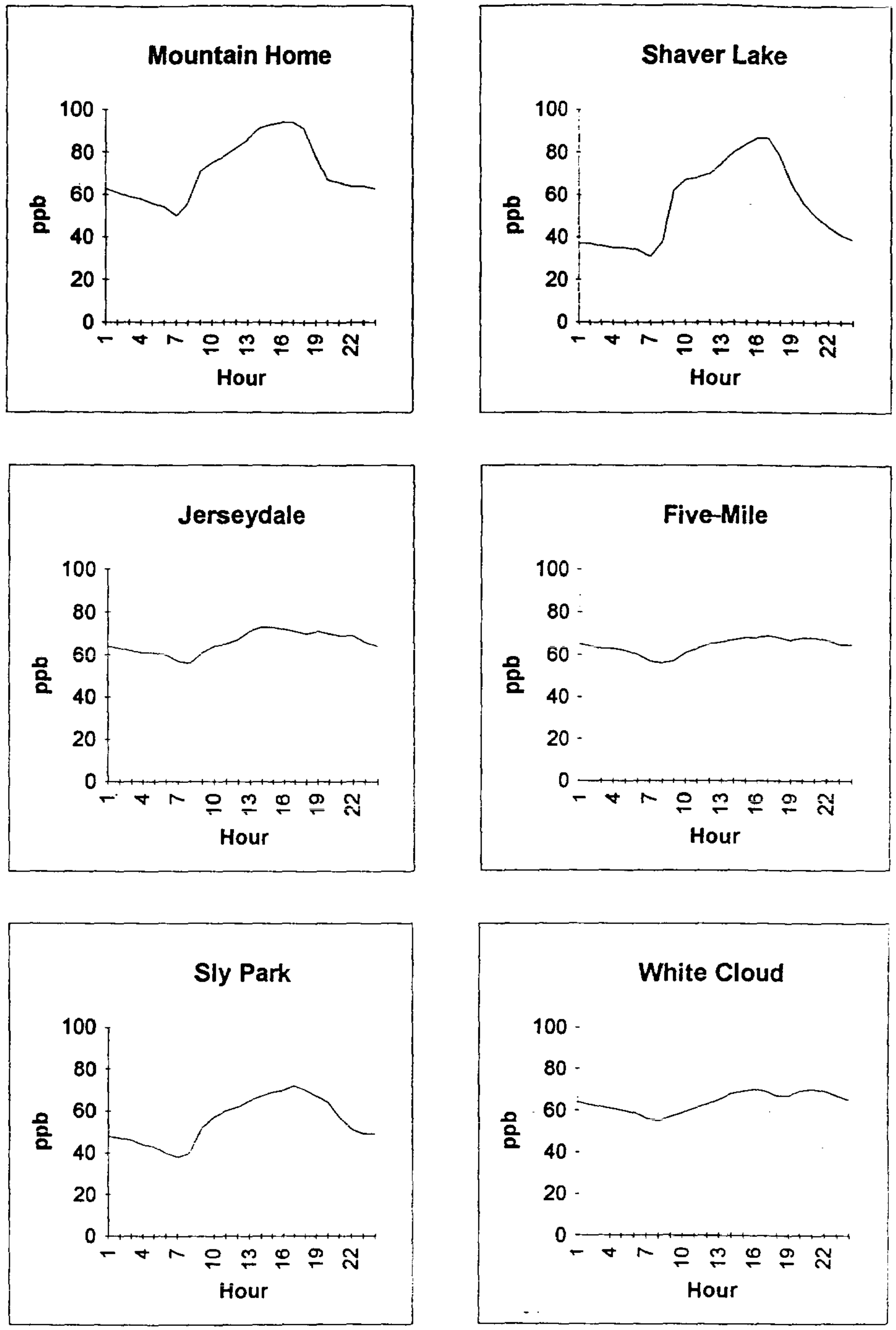


Figure 13. Seasonal average ozone concentrations by hour of day, June to September, 1992.

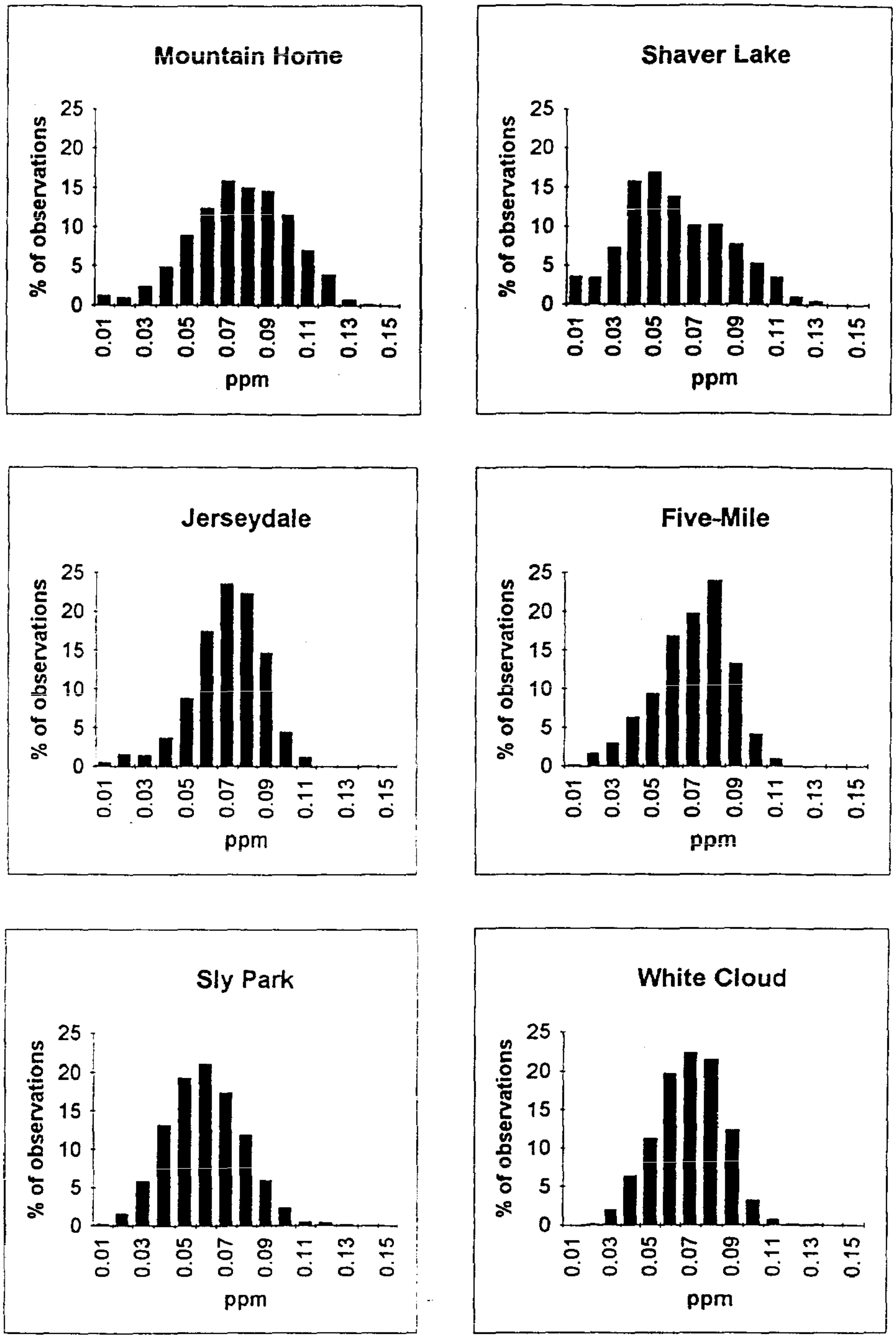


Figure 14. Ozone frequency distributions, June to September, 1992.

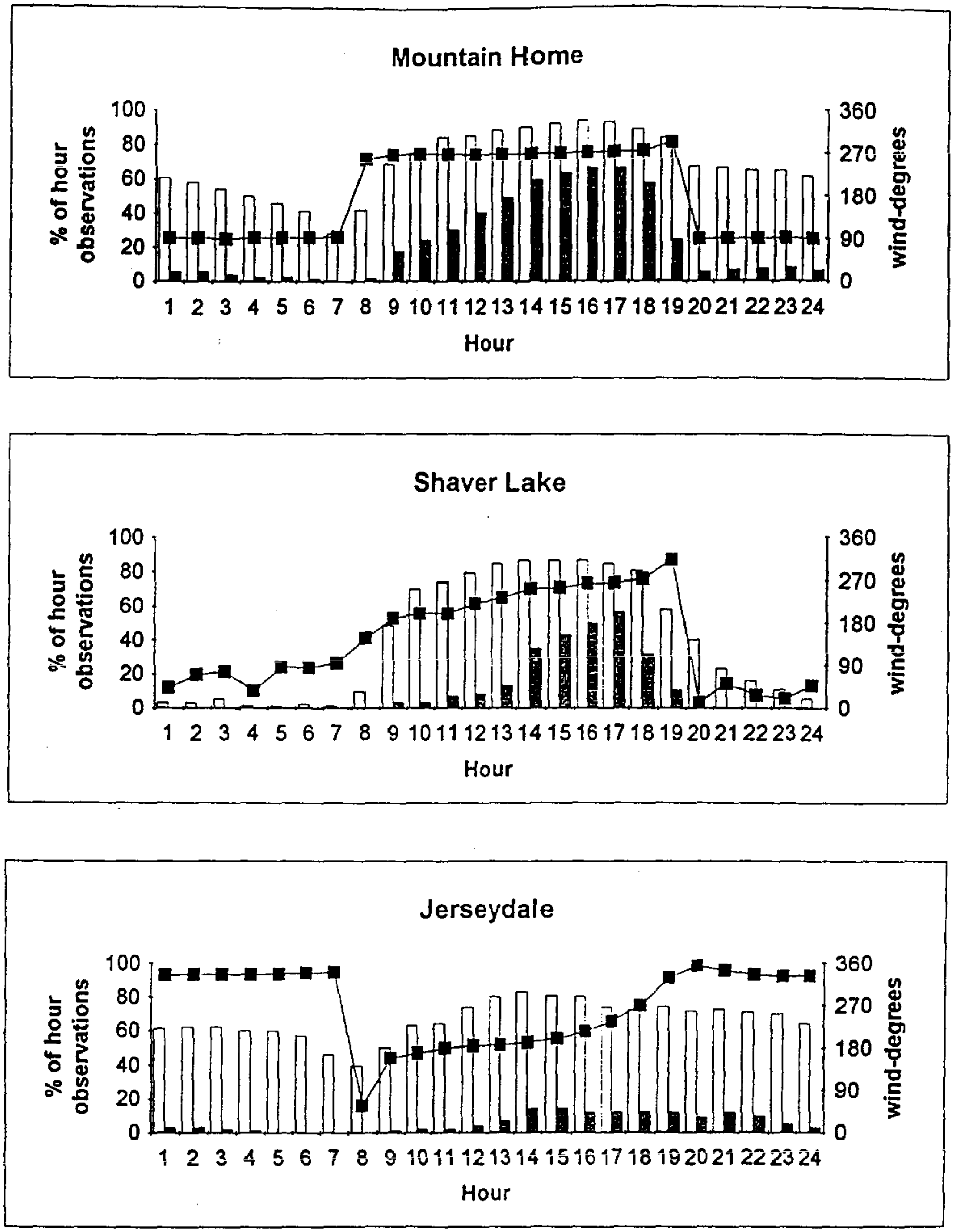


Figure 15(a). Seasonal resultant wind direction and events by hour of day for Mountain Home, Shaver Lake and Jerseydale.

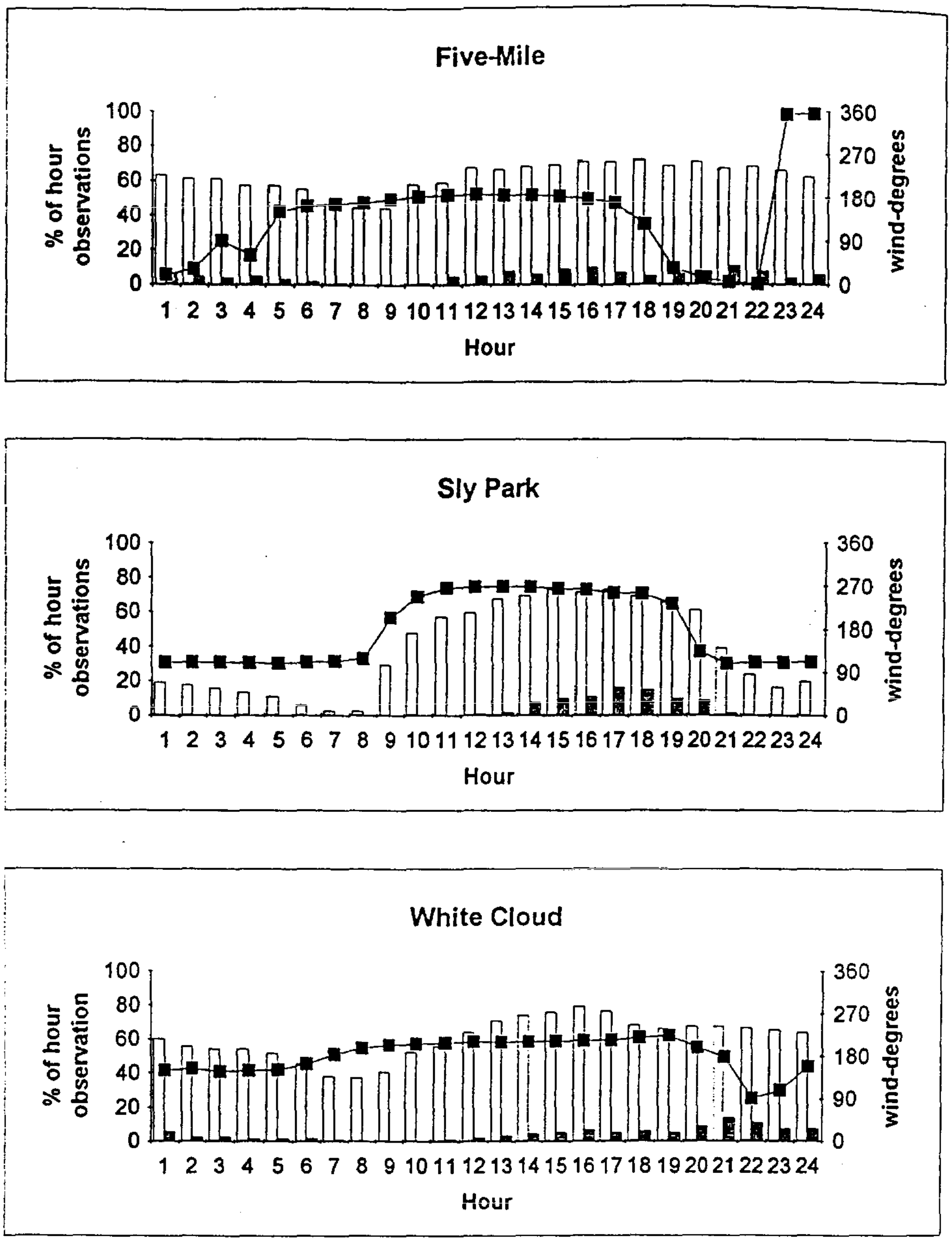


Figure 15(b). Seasonal resultant wind direction and events by hour of day for Five-Mile, Sly Park and White Cloud.

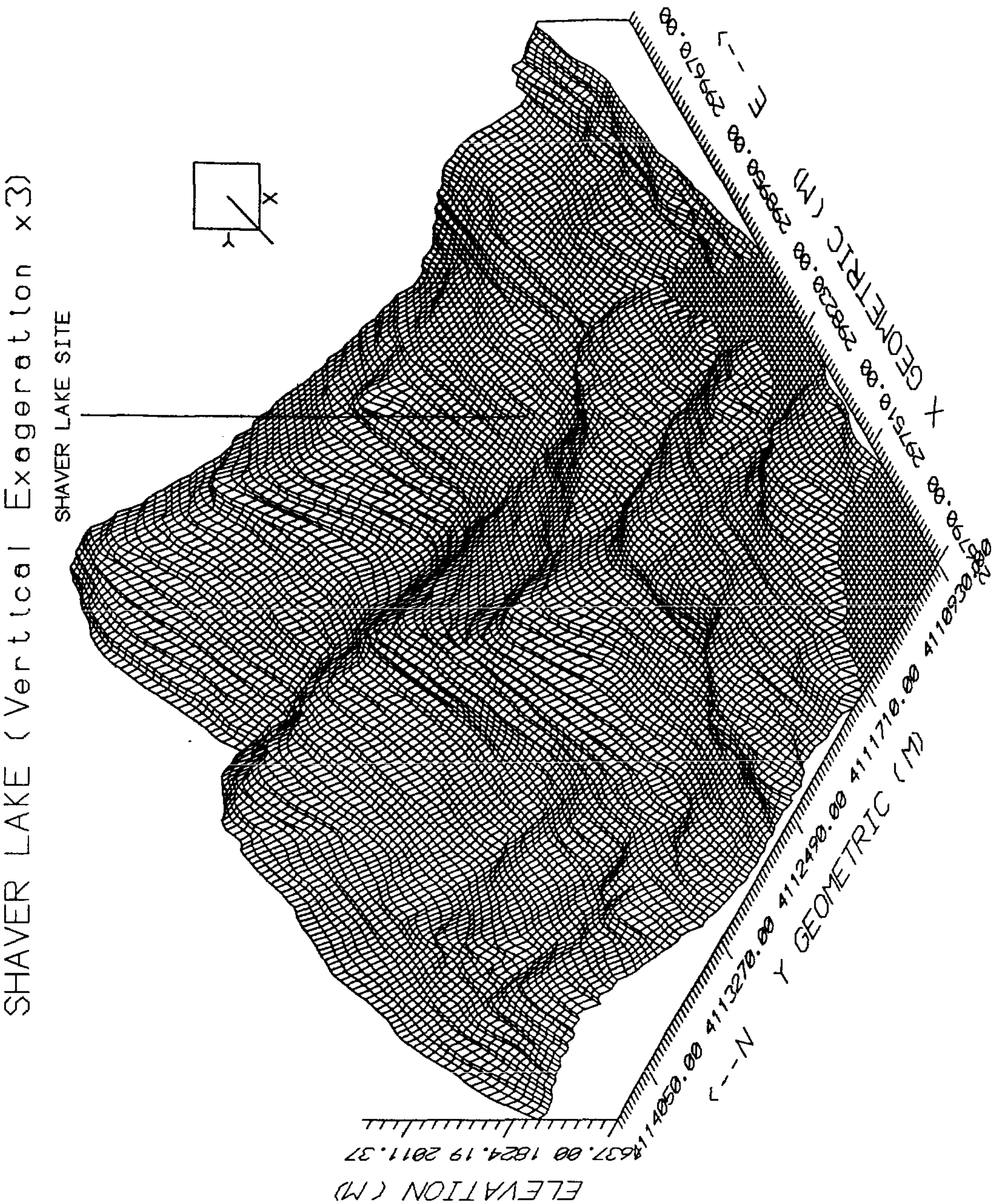


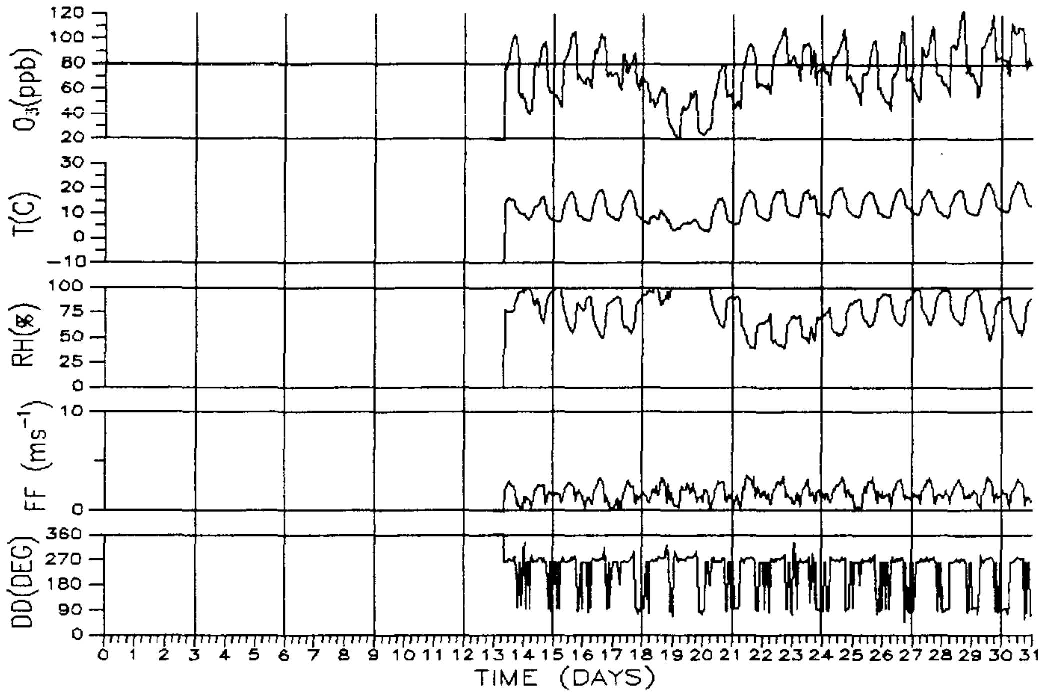
Figure 16. Three dimensional plot of the Shaver Lake site.

APPENDIX A:

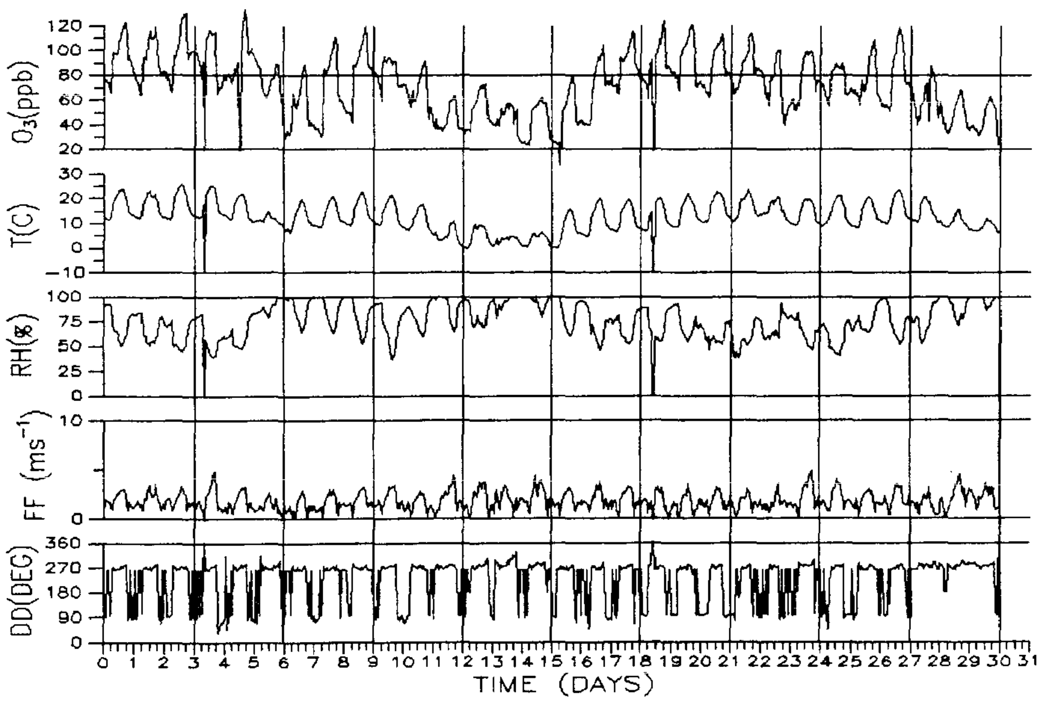
TIME PLOTS

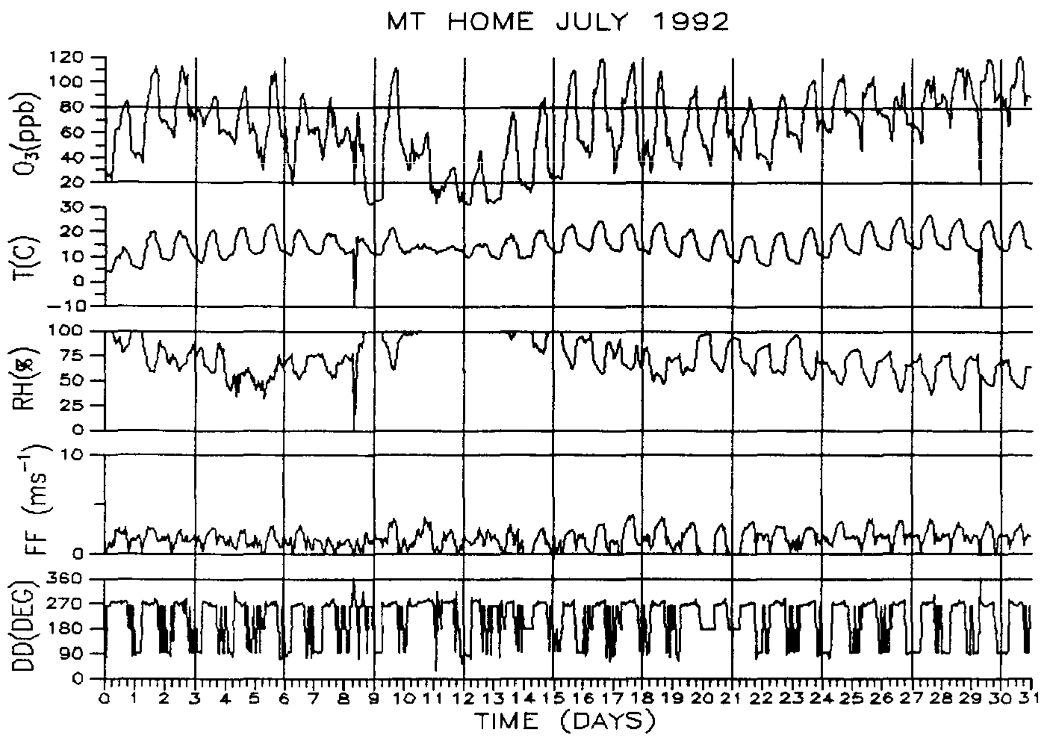
This appendix contains the time plots of the recorded variables for the 1992 data. Time plots of hourly averaged wind direction (DD), wind speed (FF), relative humidity (RH), air temperature (T) and volumetric ozone concentration (O3) normalized to standard conditions of temperature and pressure at the sites for the months of May through October. Wind direction values greater than 360 indicate calm conditions. Values of any variable less than 0 indicate missing or bad data.

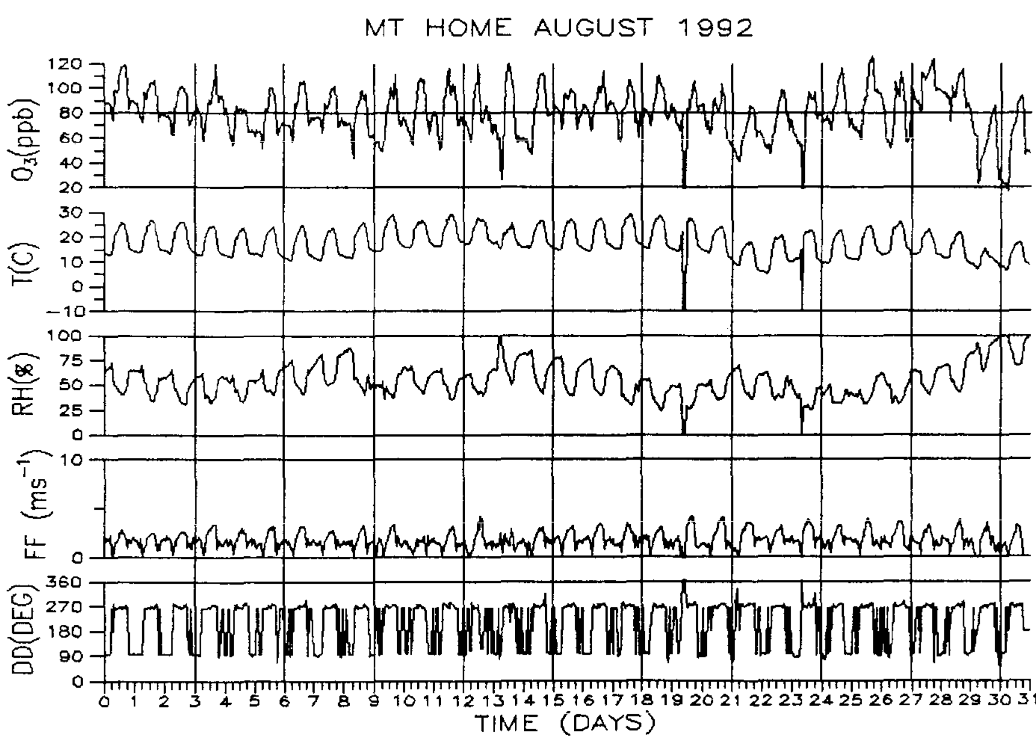
MT HOME MAY 1992

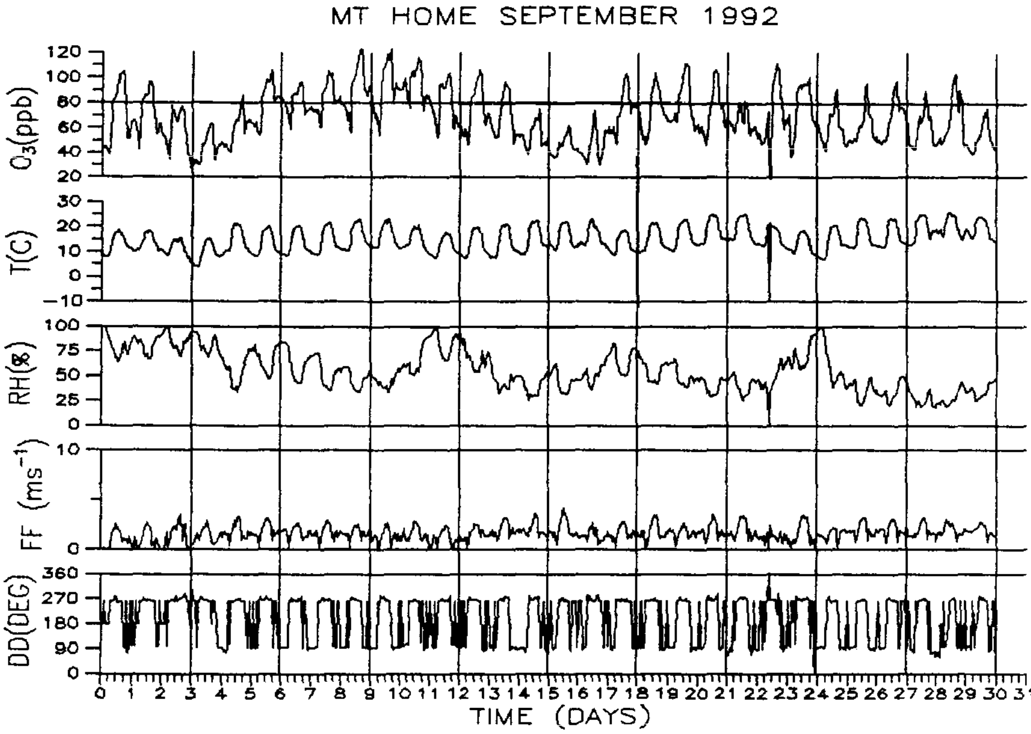


MT HOME JUNE 1992

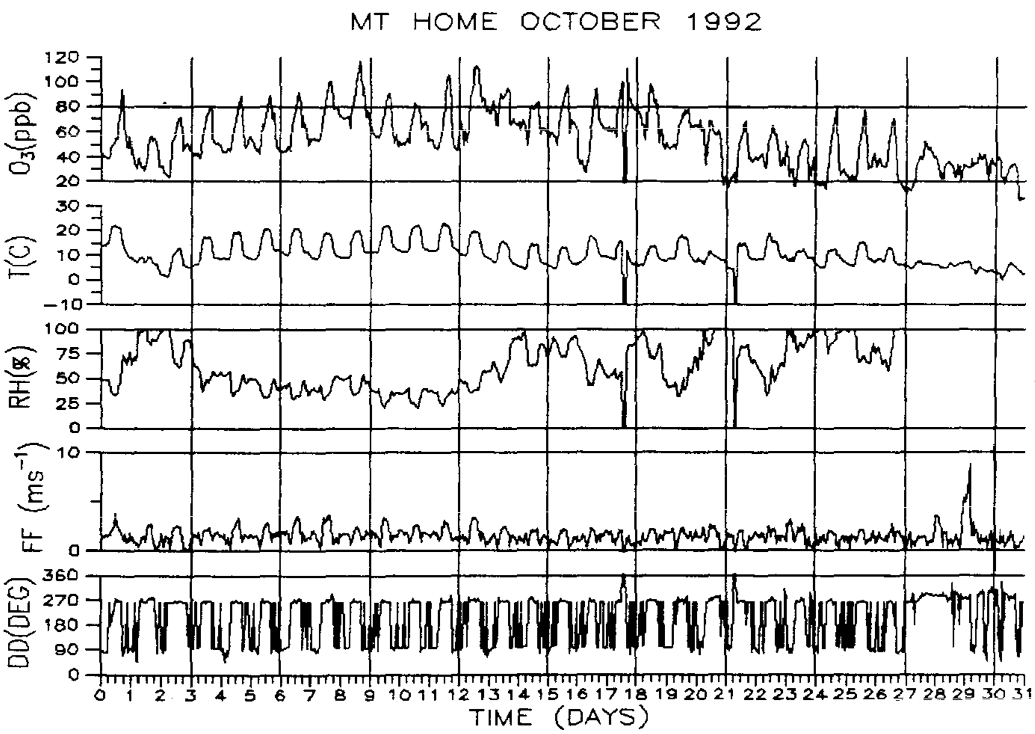



MT HOME JULY 1992
O3(ppb)
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)

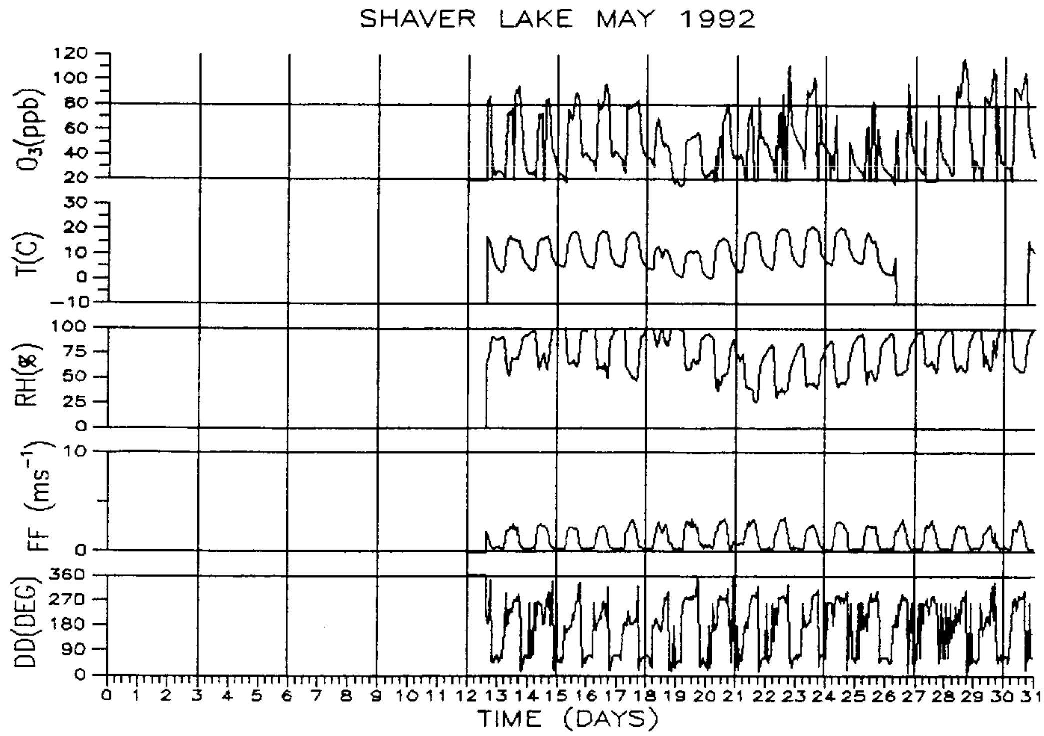

MT HOME AUGUST 1992
O3(ppb)
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)

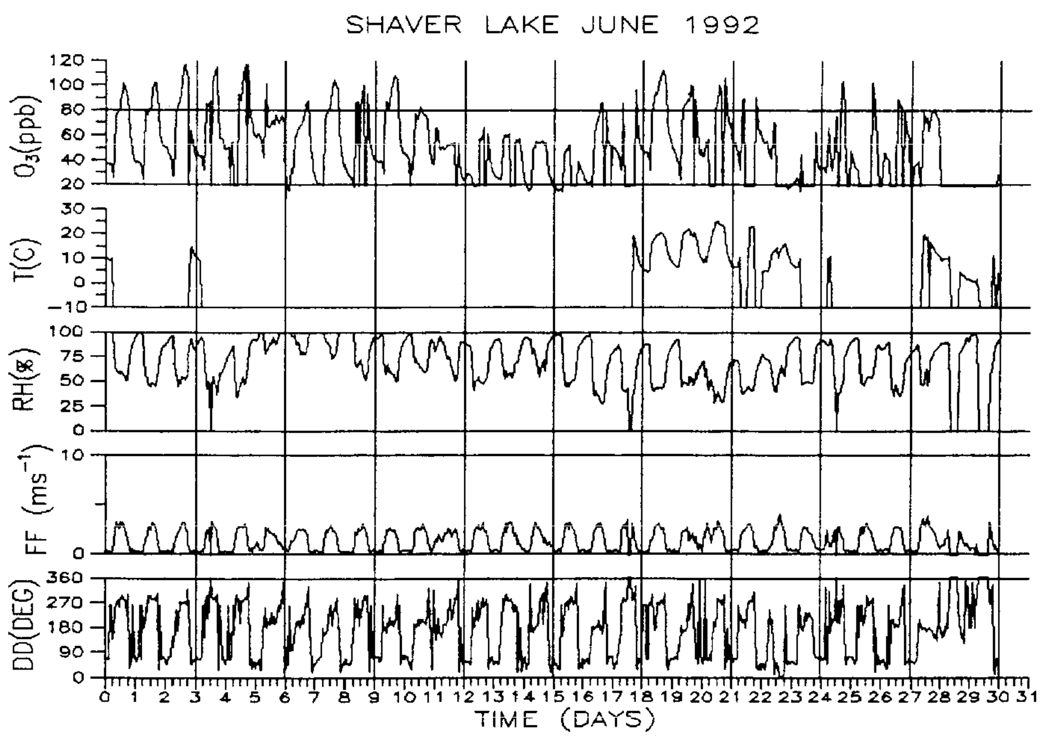


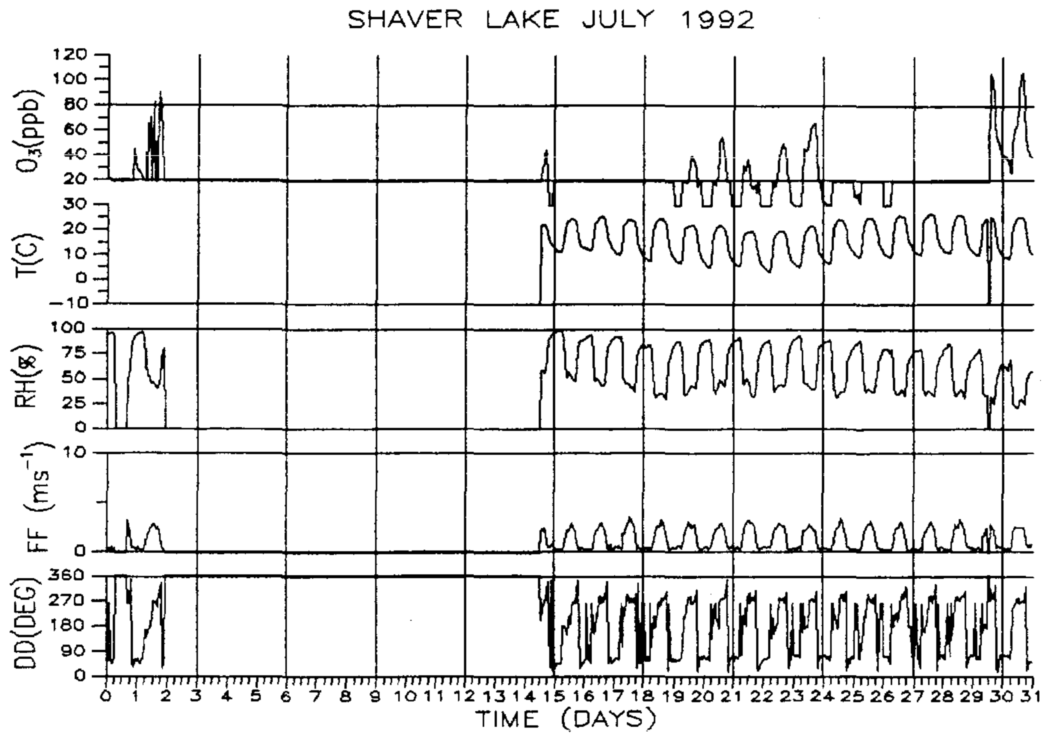
MT HOME SEPTEMBER 1992
O3(ppb)
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)

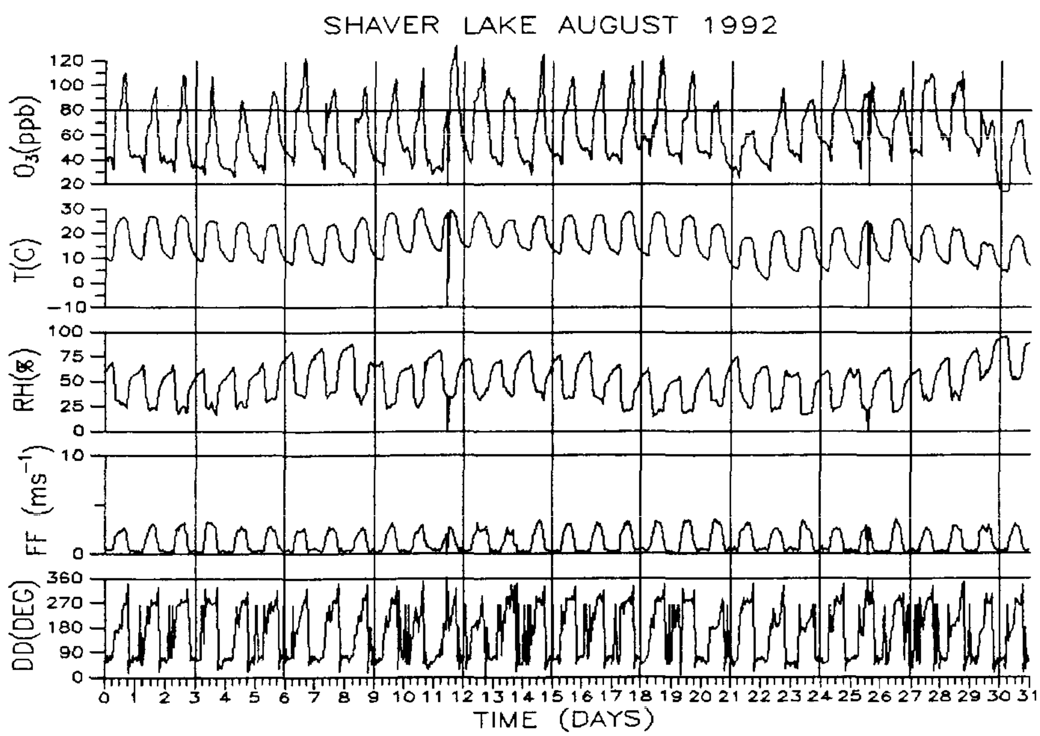


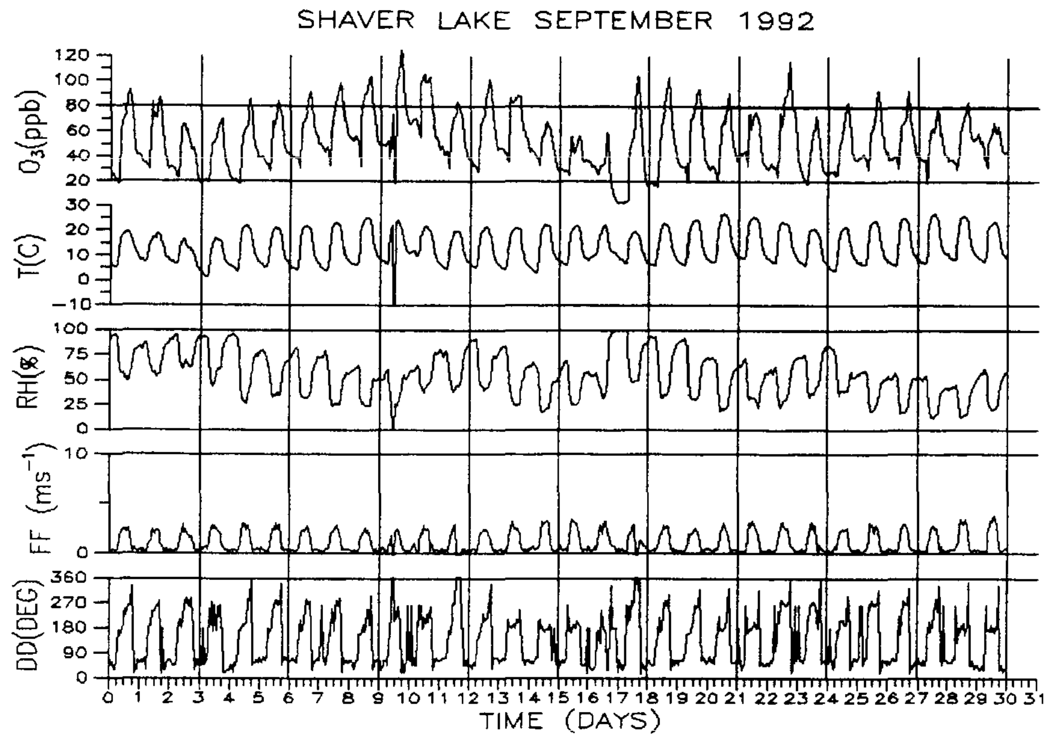
MT HOME OCTOBER 1992
O3(ppb)
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)


SHAVER LAKE MAY 1992
O3(ppb)
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)


SHAVER LAKE JUNE 1992
O3(ppb)
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)


SHAVER LAKE JULY 1992
O3(ppb)
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)


SHAVER LAKE AUGUST 1992
O3(ppb)
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)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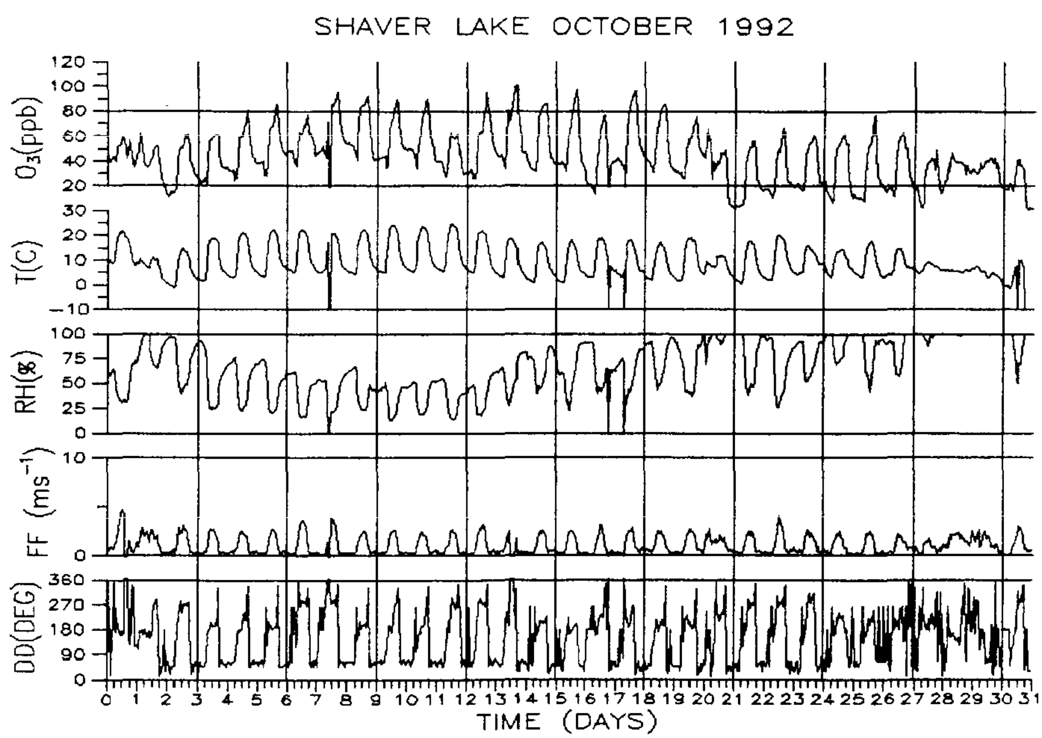
O3(ppb)
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)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T(C)
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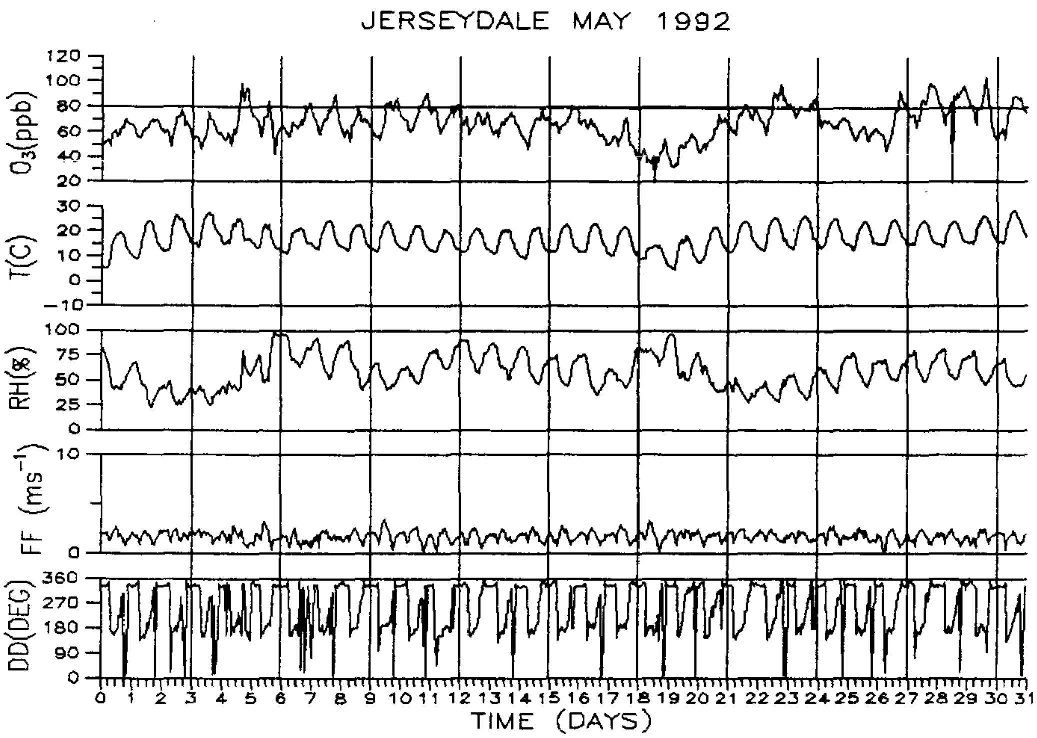
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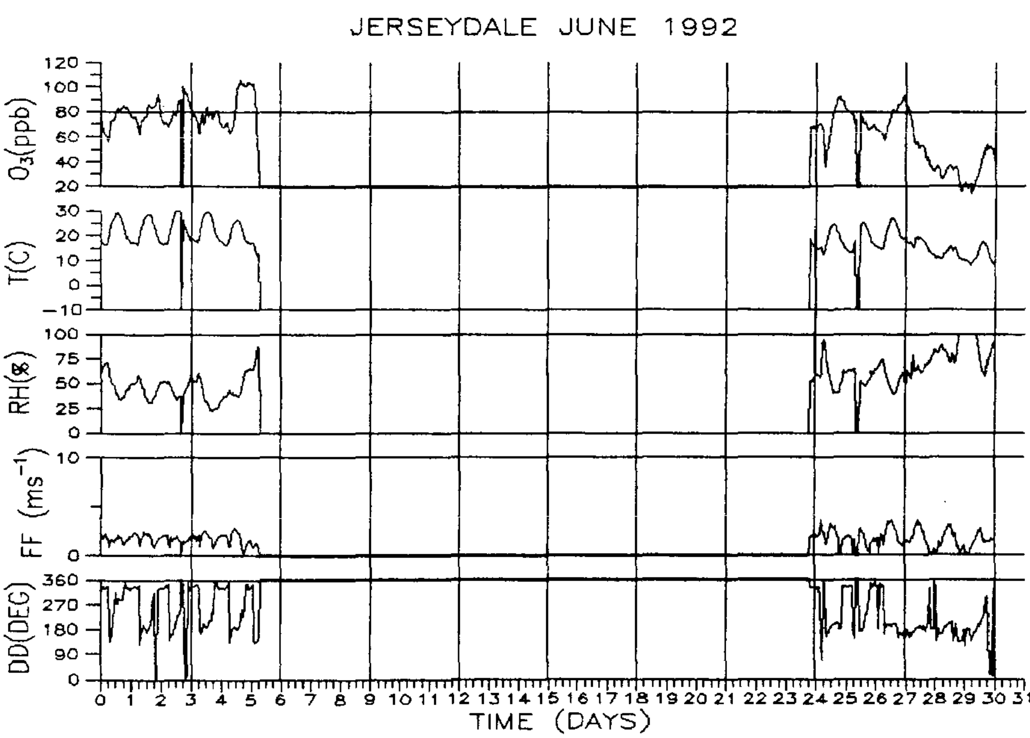
T(C)
RH(%)
FF (ms^{-1})
DD(DEG)
TIME (DAYS)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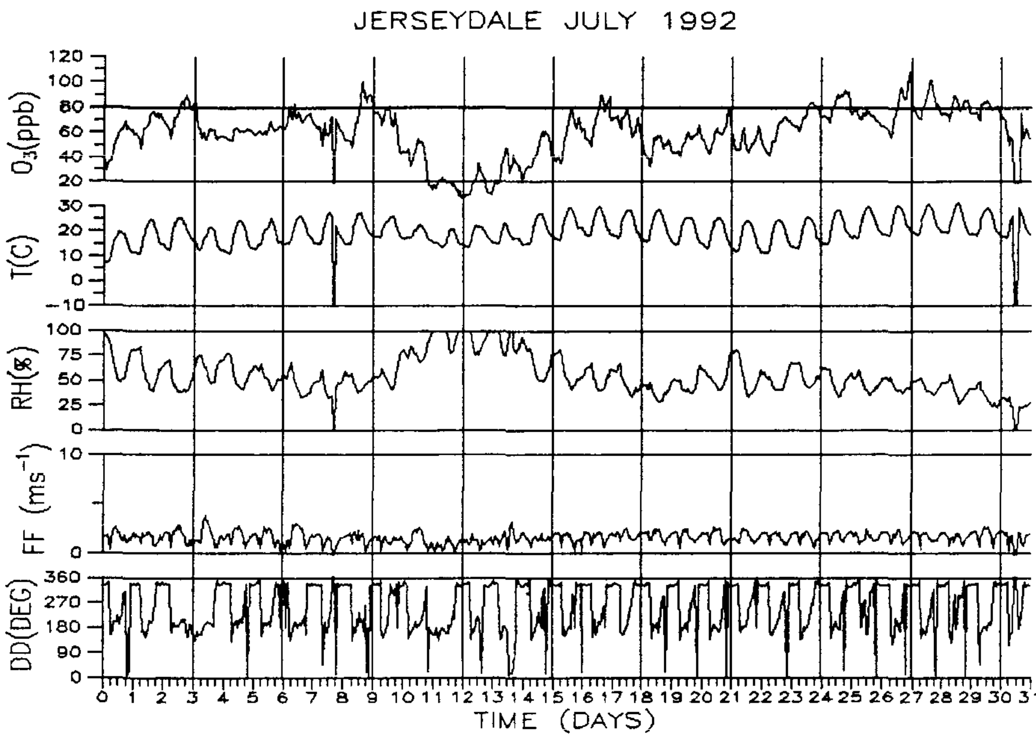
O_3(ppb)
T(C)
RH(%)
FF (ms^{-1})
DD(DEG)
TIME (DAYS)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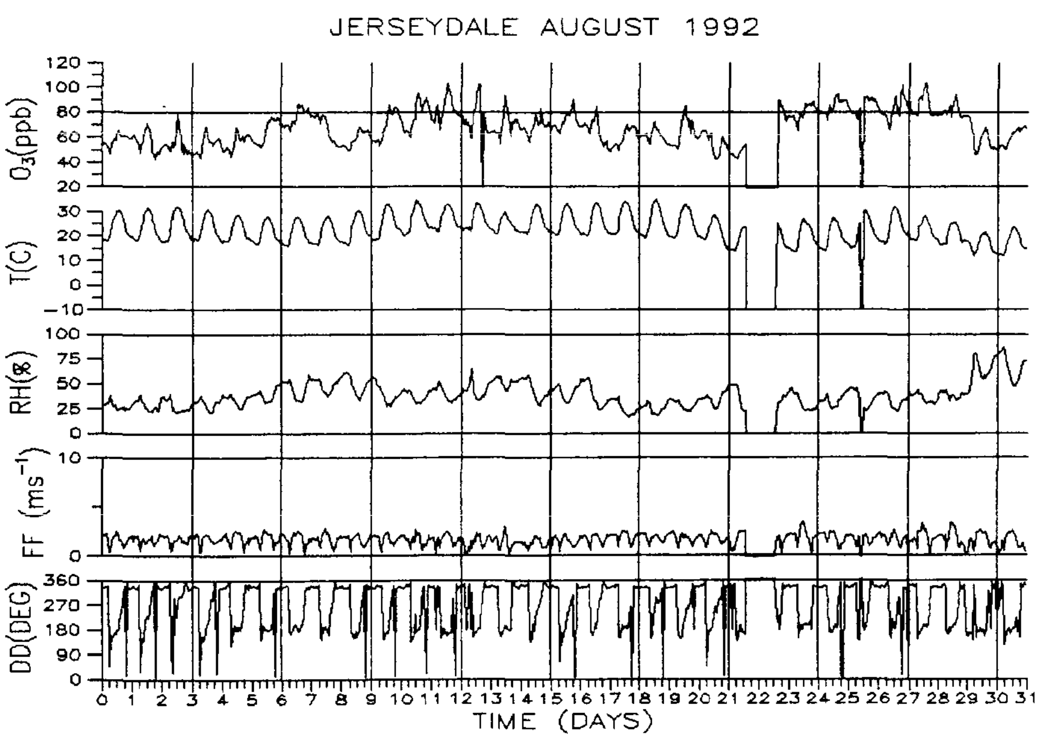
O3(ppb)
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)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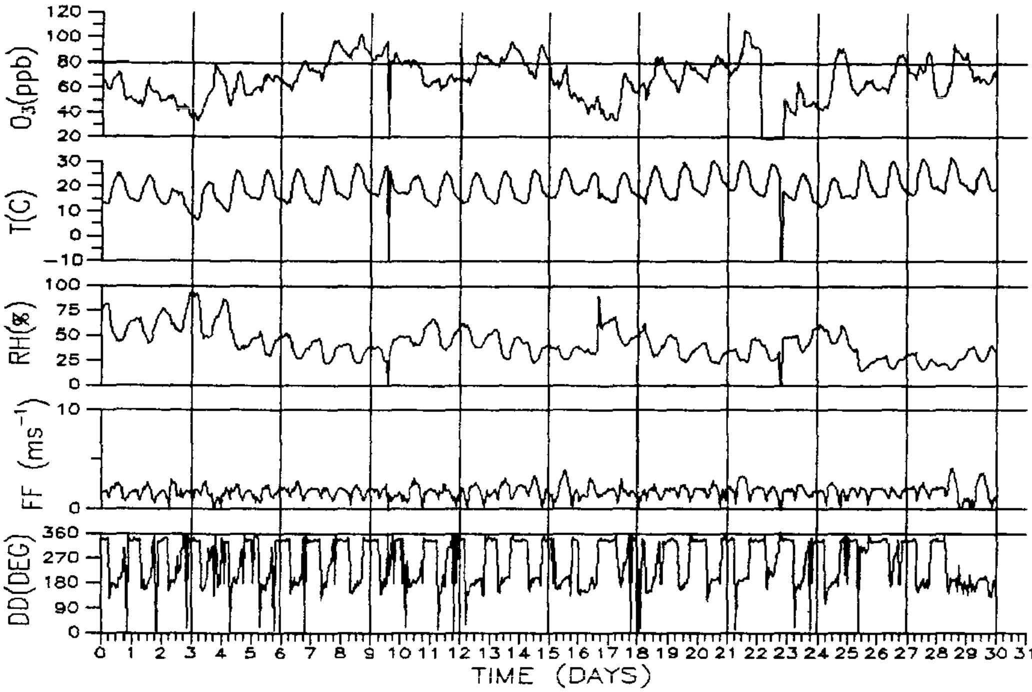
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)

JERSEYDALE SEPTEMBER 1992



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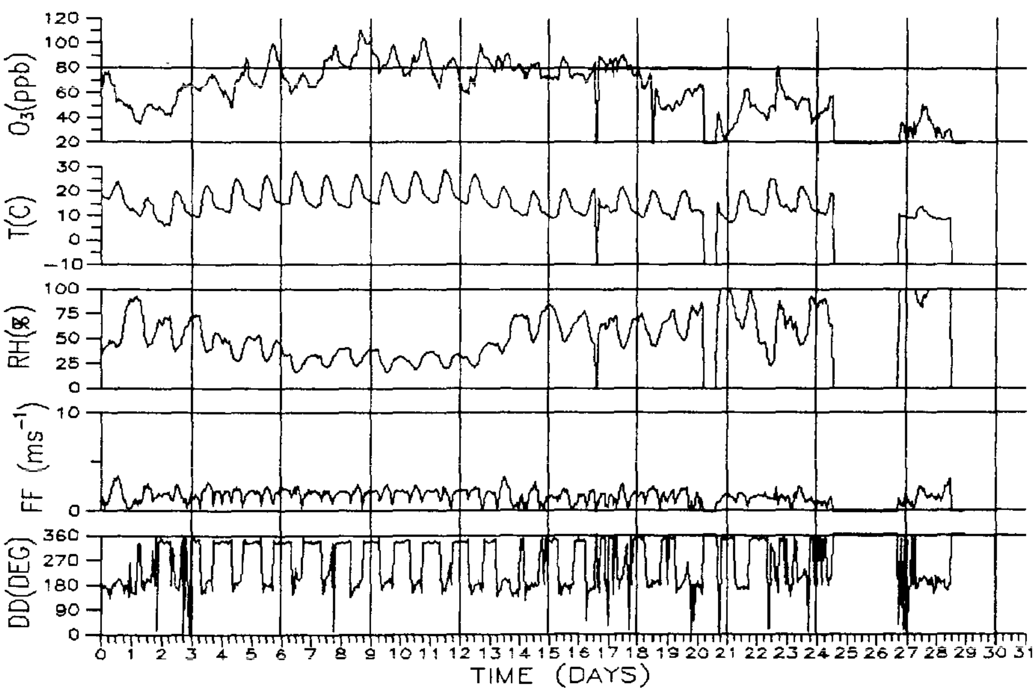

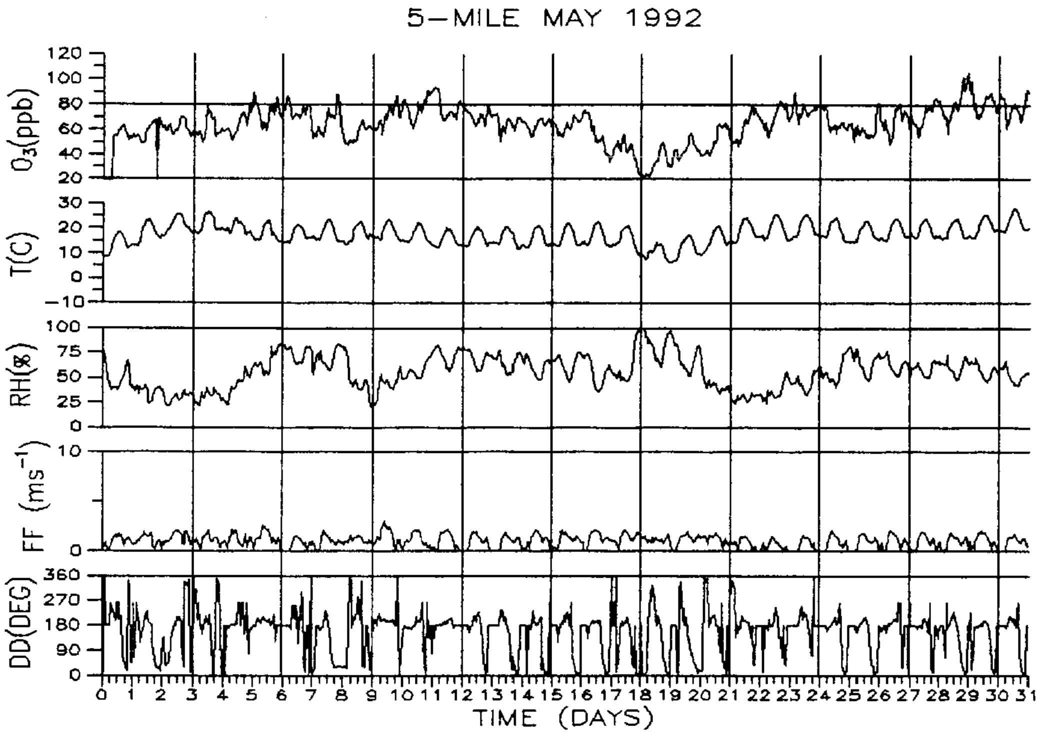
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T(C)
RH(%)
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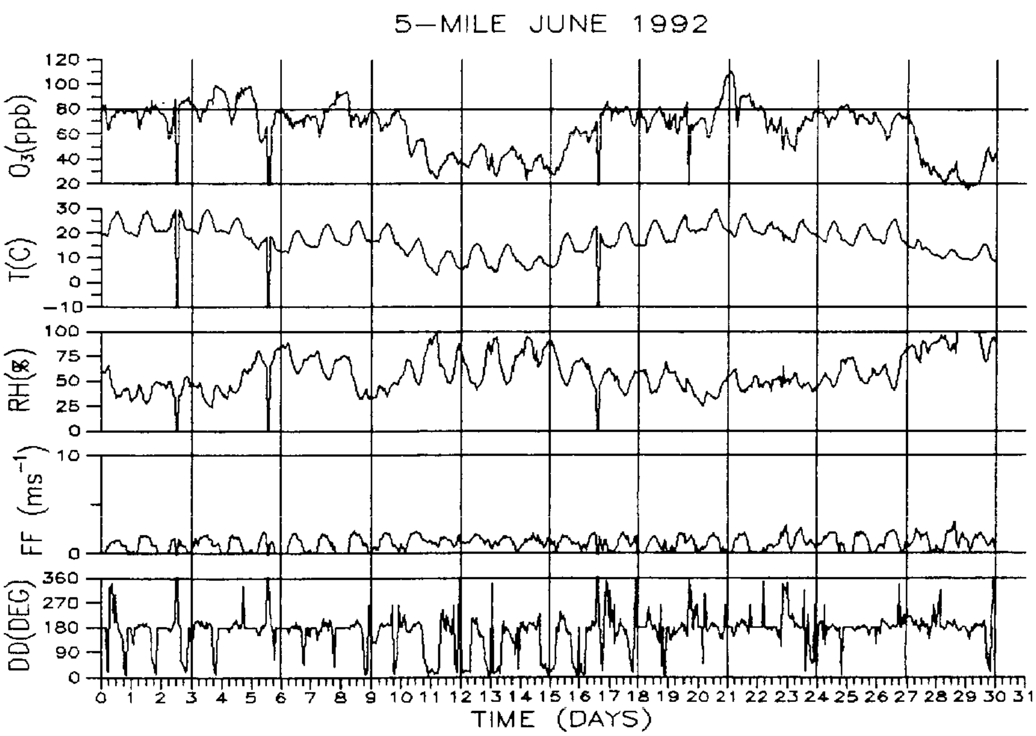
DD(DEG)
TIME (DAYS)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RH(%)
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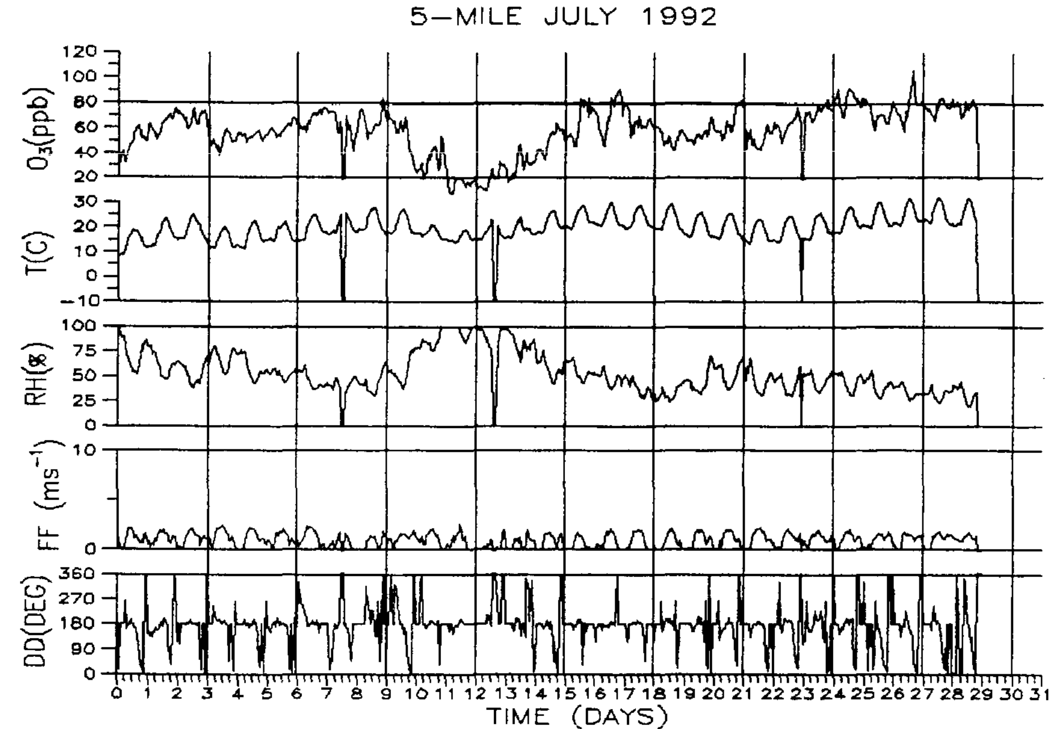
DD(DEG)
TIME (DAYS)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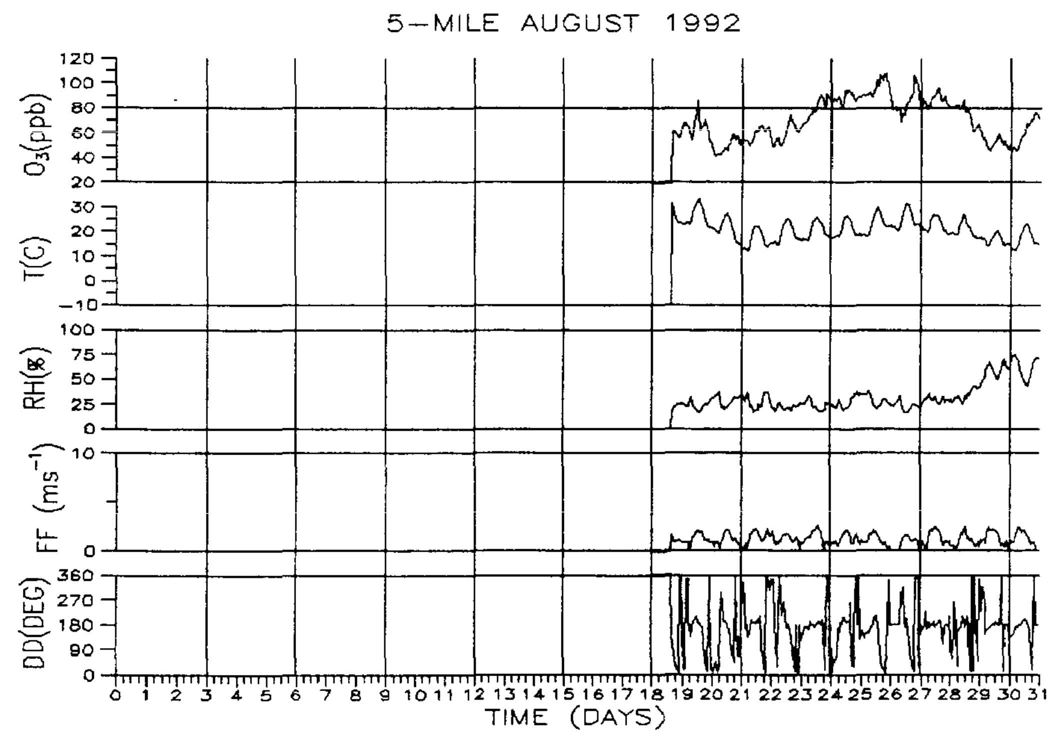
DD(DEG)
TIME (DAYS)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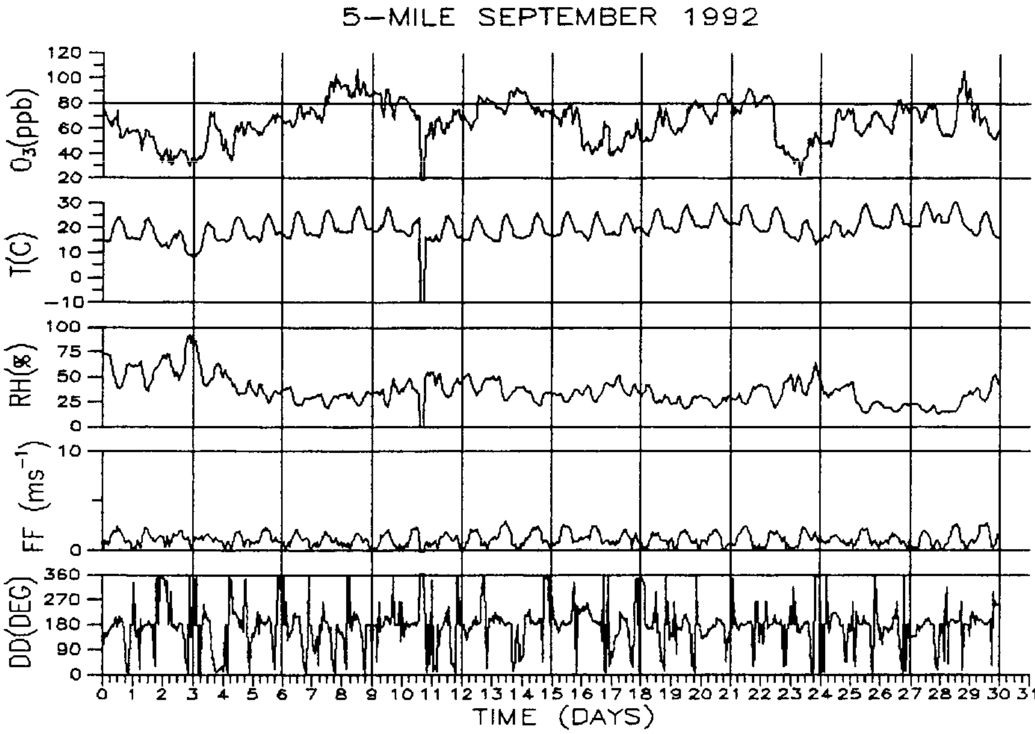
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)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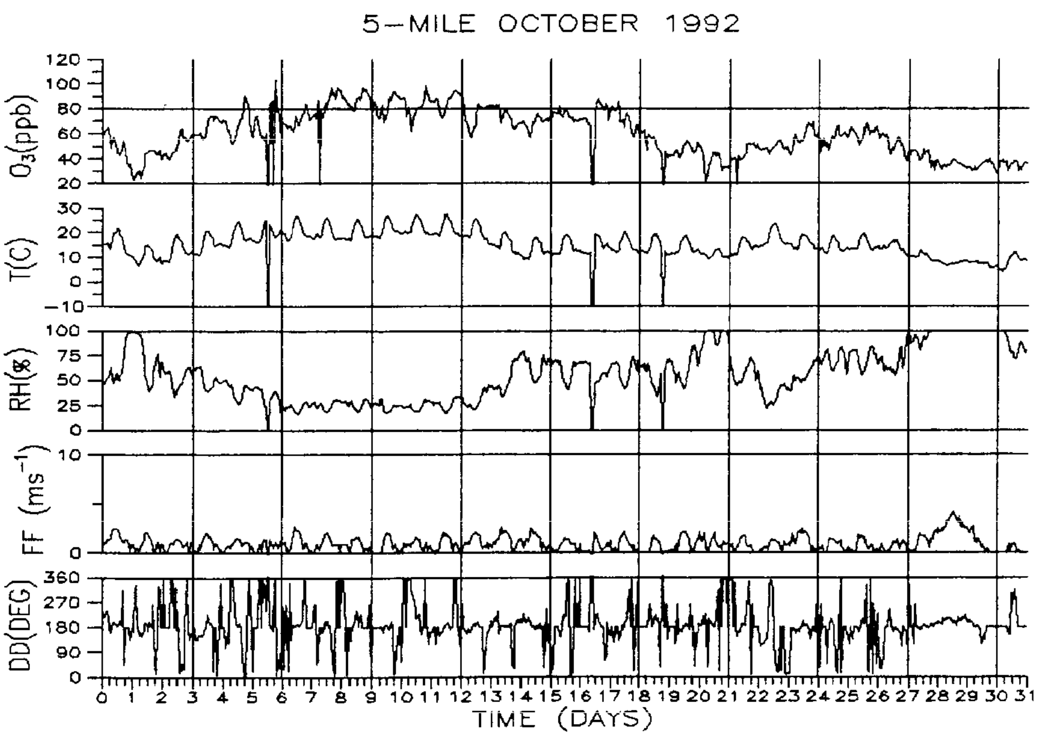
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)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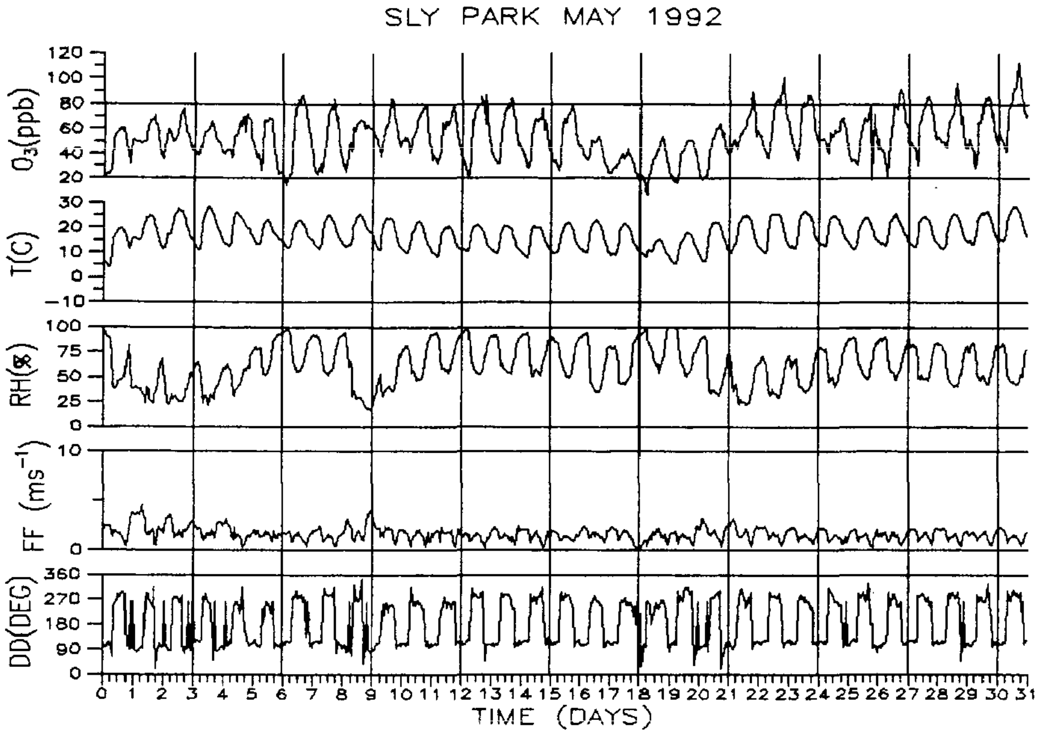
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)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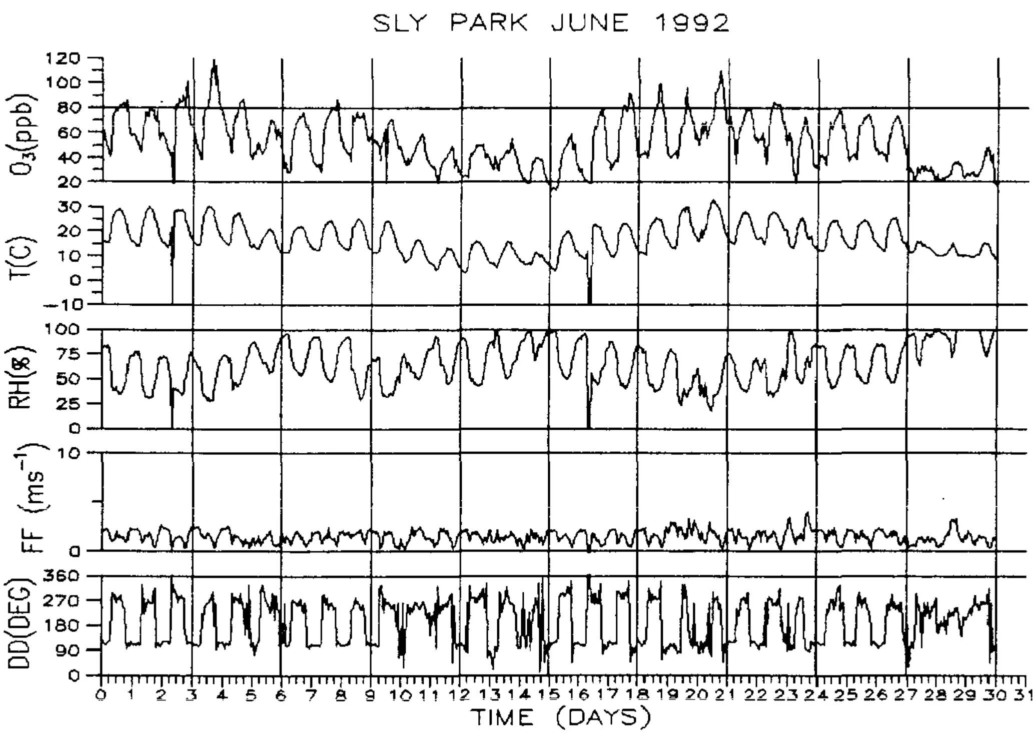
T(C)
RH(%)
FF (ms^{-1})
DD(DEG)
TIME (DAYS)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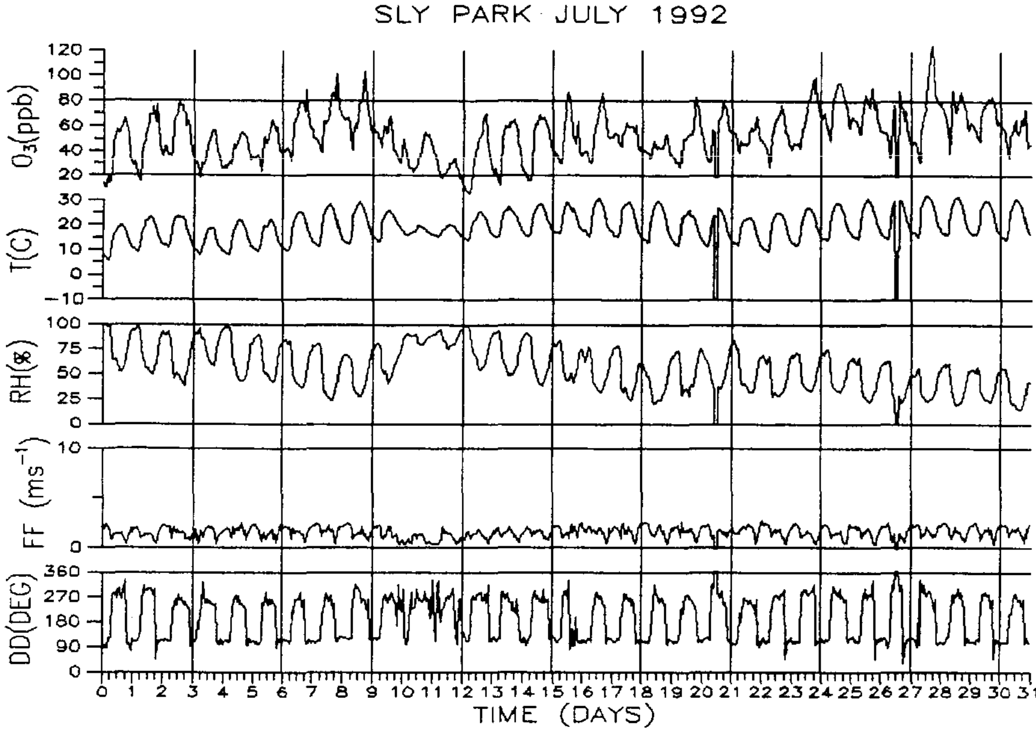
O_3(ppb)
T(C)
RH(%)
FF (ms^{-1})
DD(DEG)
TIME (DAYS)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T(C)
RH(%)
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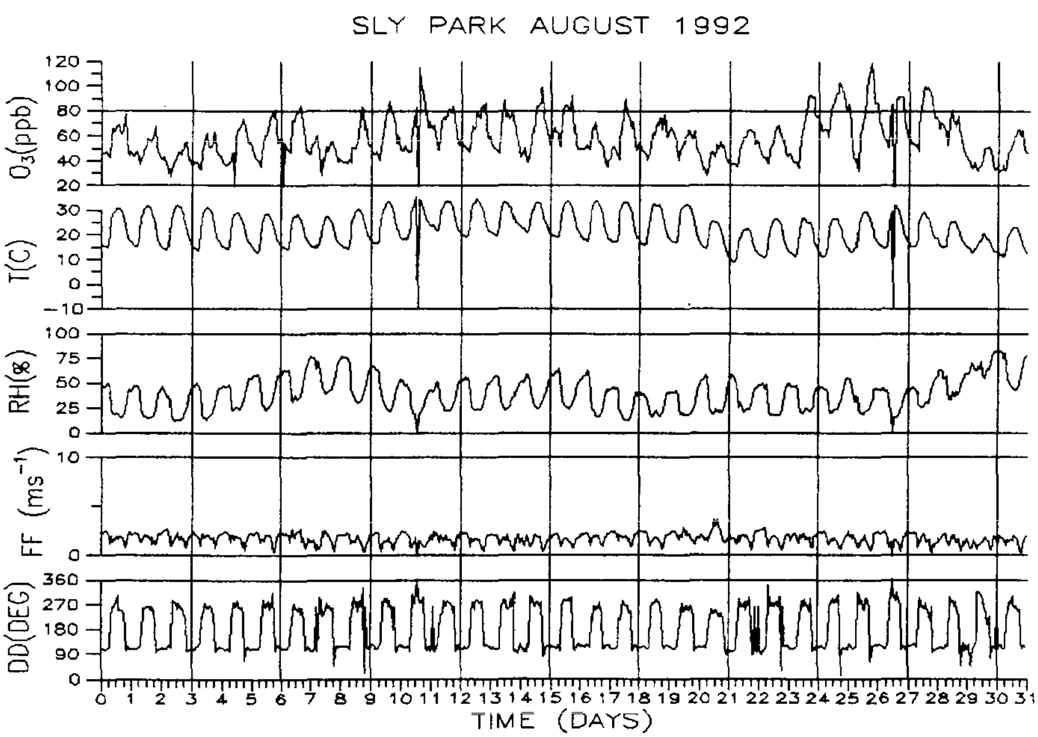
DD(DEG)
TIME (DAYS)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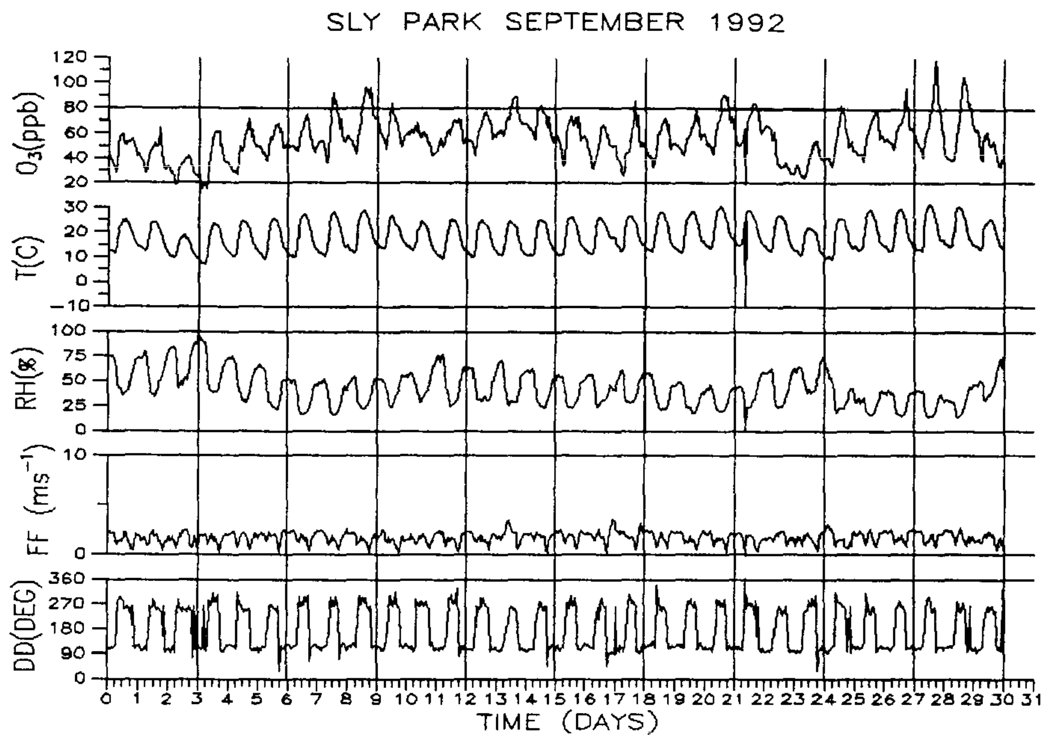
DD(DEG)
TIME (DAYS)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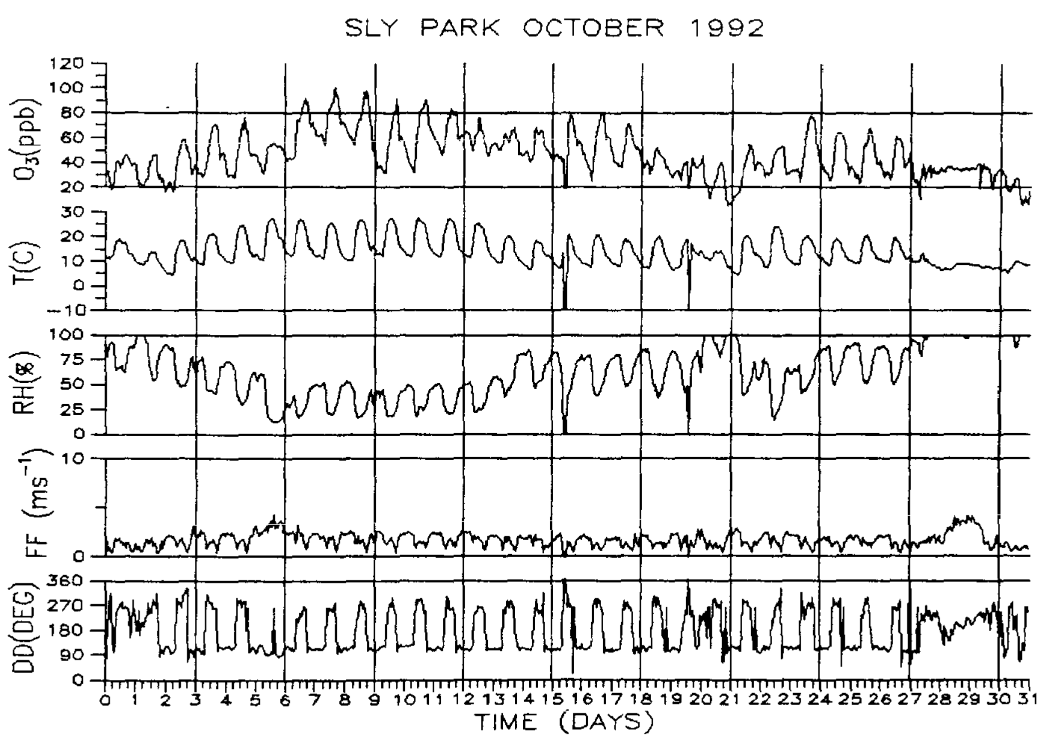
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)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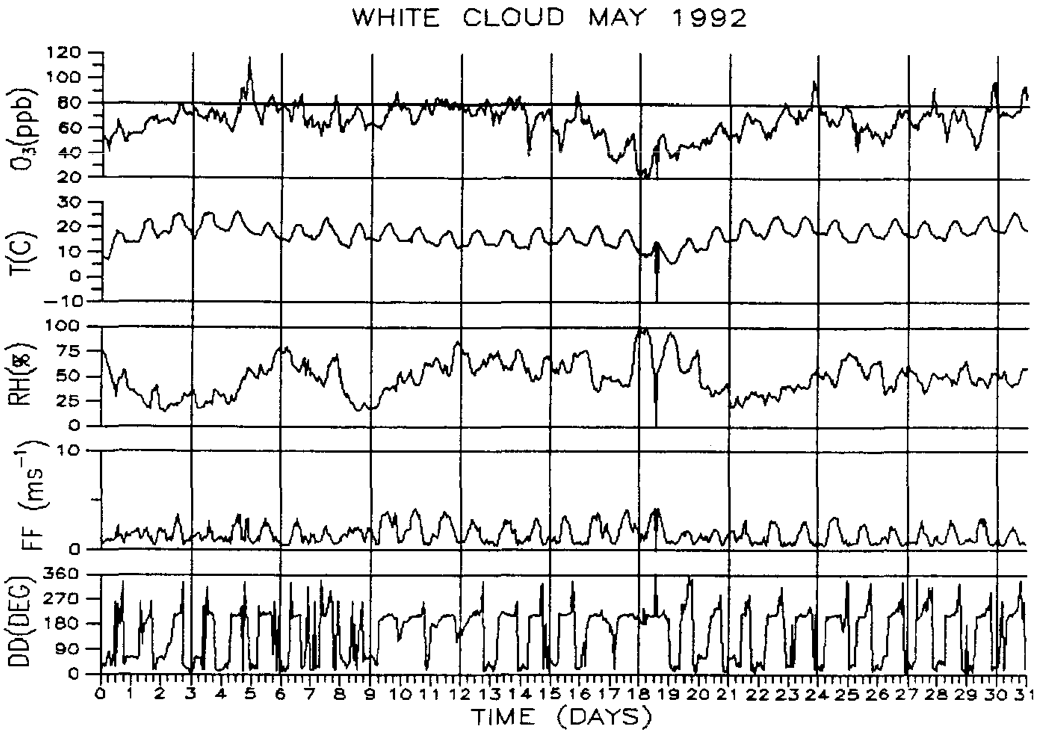
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)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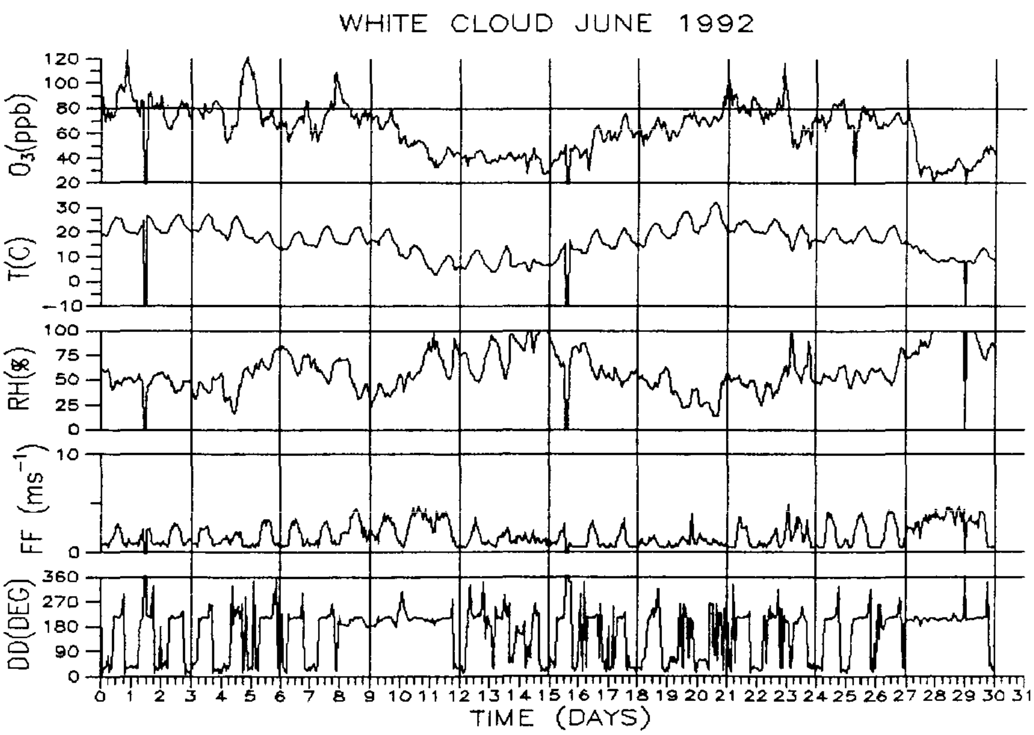
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)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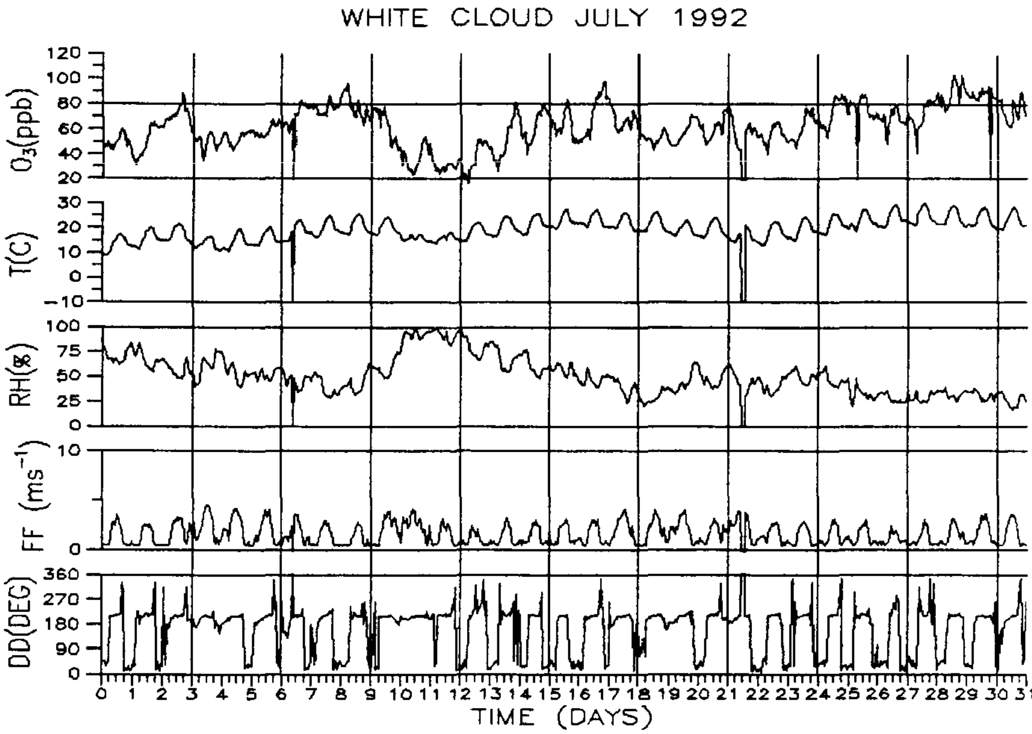
O3(ppb)
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)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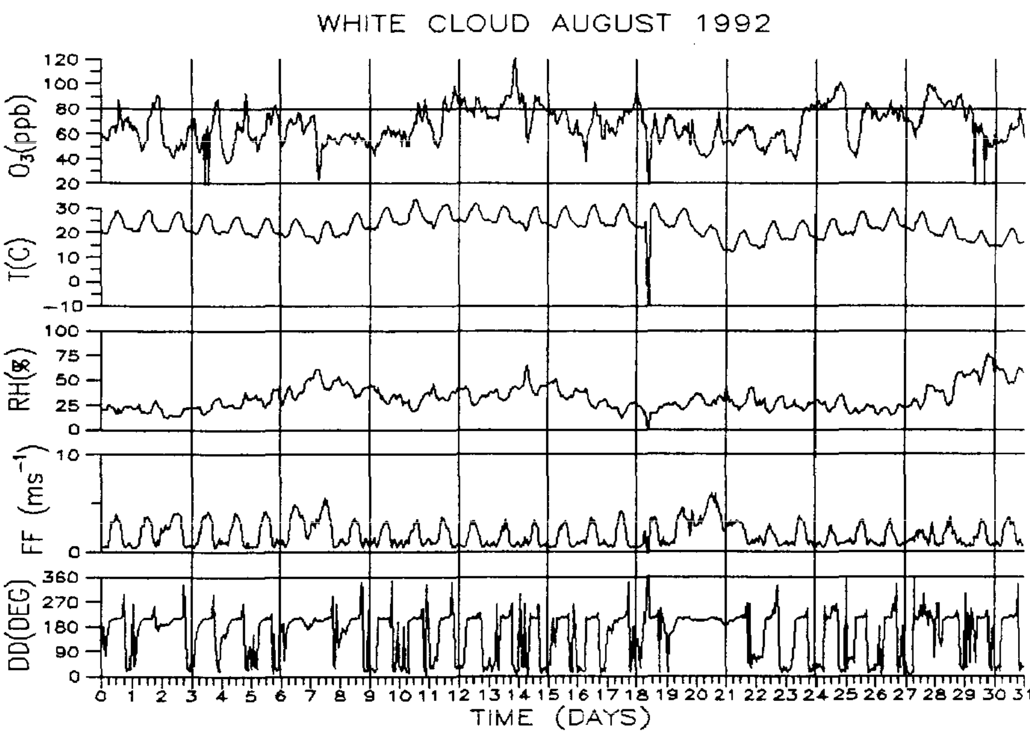
O3(ppb)
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)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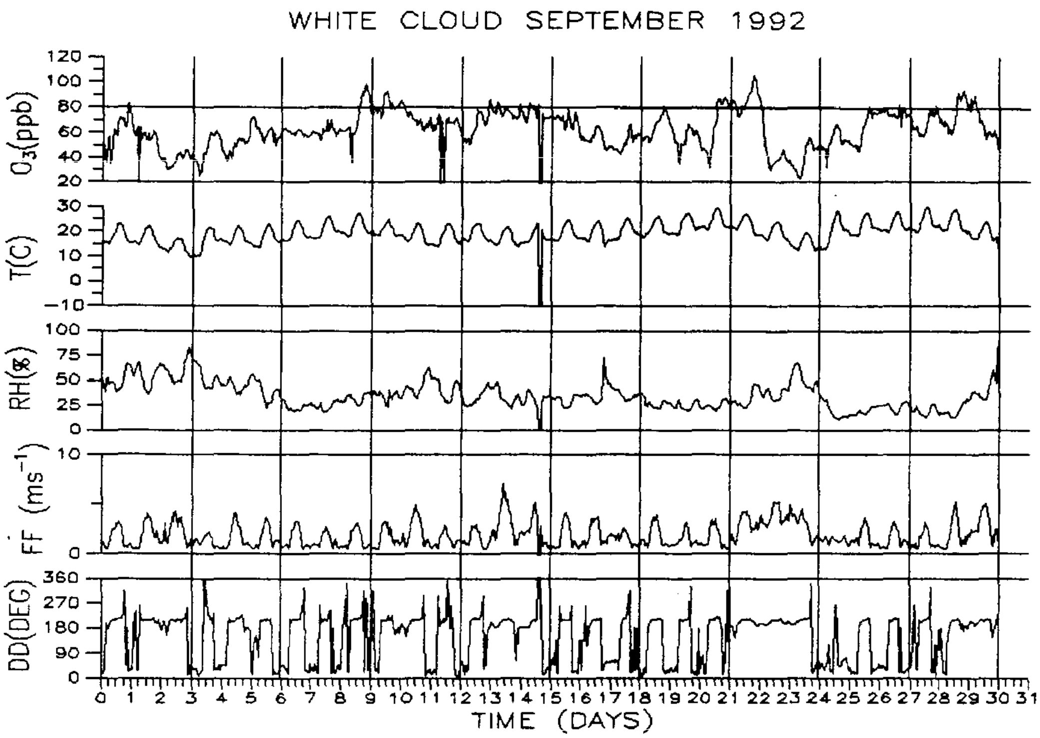
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)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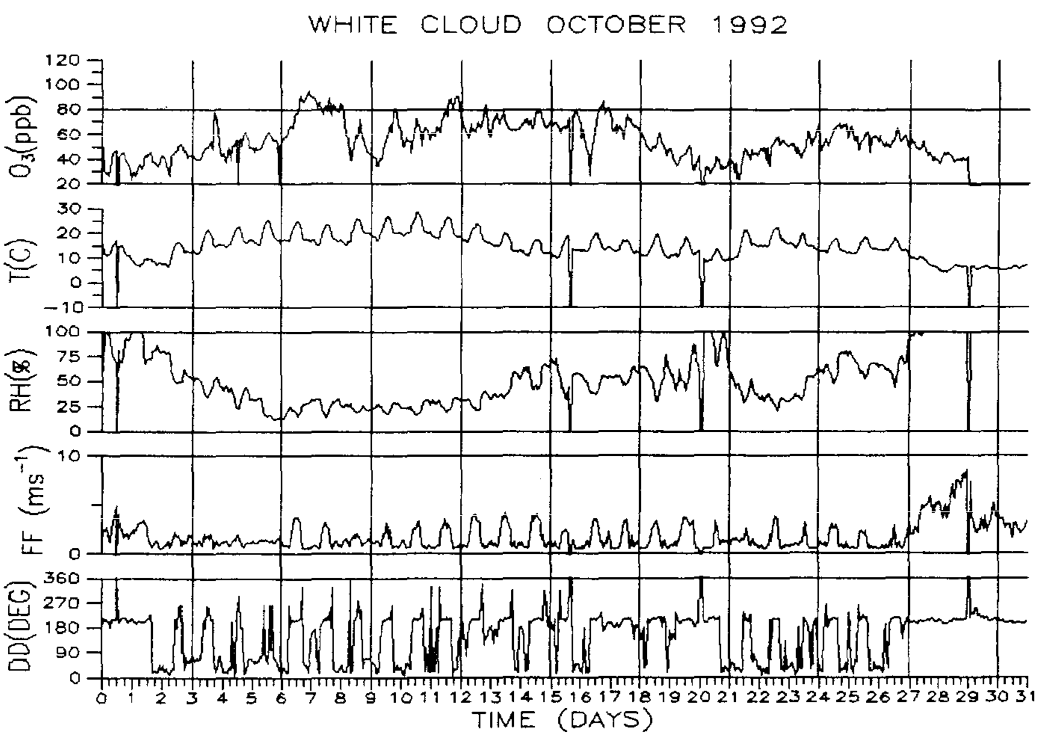
O3(ppb)
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)


WHITE CLOUD OCTOBER 1992
O3(ppb)
T(C)
RH(%)
FF (ms-1)
DD(DEG)
TIME (DAYS)

APPENDIX B:

FIELD QUALITY ASSURANCE AUDITS

AND

DATA BASE DEVELOPMENT

FOR

THE SIERRA COOPERATIVE OZONE IMPACT ASSESSMENT STUDY

FINAL REPORT, 1992/93

SUBMITTED TO

DEPARTMENT OF LAND, AIR AND WATER RESOURCES

UNIVERSITY OF CALIFORNIA, DAVIS

BY

KENNETH P. MacKAY

DEPARTMENT OF METEOROLOGY

SAN JOSE' STATE UNIVERSITY

SAN JOSE', CA 95192

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10 OCTOBER 1993

ACKNOWLEDGEMENTS: Matt Jackson and Robert Bryan completed the field audits in 1992, and Dennis Dismachek, Sheng-Jun Wang and Chi-Jan Meng in 1993. Robert Bryan prepared the case study. Dennis Dismachek did much of the organization of the project. My thanks to all of them for their assistance.

1. INTRODUCTION

The University of California, Davis, Department of Land, Air and Water Resources (UCD) installed a network of six stations to measure meteorological parameters and ozone along the western slopes of the Sierra Nevada. The San Jose' State University, Department of Meteorology (SJSU) has contracted with UCD to (1) conduct a field quality assurance audit of network instrumentation to help insure the reliability of the data gathered, (2) develop the software for a user-friendly data base of the measurements collected by this network, and (3) identify a suitable case study and conduct a meteorological analysis of the case. This report will summarize the progress made on completing the proposed tasks.

2. AIR QUALITY ASSURANCE AUDITS

Two field quality assurance audits were performed for SCOIAS in 1992 and one in 1993. The audits were completed on 26 June and 18 October 1992 and 15 July 1993. The audits are timed to be completed early in the measurement season and just prior to instrument removal in the fall. Three reports detailing the audit results have been submitted to UCD (MacKay and Jackson, 1992; MacKay and Bryan, 1992; Dismachek and MacKay, 1993).

2.1 Audit One, June 1992

This audit was performed over two separate time periods: June 16-19 and June 26. This schedule resulted from a site computer keyboard malfunction at the Jerseydale station during the first audit expedition. Ozone values recorded by the data logger when challenged by input concentrations greater than 50 ppbv differed from the transfer standard by less than +/- 7.0 percent except for one deviation of -11.9 percent at Shaver Lake. At input concentrations of zero or 50 ppbv, the data logger recorded values within +/- 8 ppbv, with errors in the range of +/- 15 percent. Wind instruments showed no apparent calibration problems. Temperature recordings ranged from 0.6F to 2.0F below the transfer standard reading. Relative humidity readings differed from the transfer standard by less than ten percent at all stations, except Sly Park where the difference was 10.6 percent.

2.2 Audit Two, October 1992

This audit was performed during 16-18 October 1992. Data loggers generally recorded within +/- 9.0 percent of the transfer standard ozone concentrations at input concentrations above 50 ppbv. Exceptions were a single value of -11.5% at Sly Park and a single value of +17.8% at Five-Mile when the back of the transfer standard was exposed to direct sunlight. Wind instruments again showed readings within acceptable deviations from the appropriate transfer standard. Temperatures recorded by the data logger were within 2F of the transfer standard except for Jerseydale and Mountain Home which recorded errors of -6.2F and -6.6F, respectively. Relative humidity errors were less than 4 percent except at Mountain Home where it was 6.2 percent.

2.3 Audit Three, June and July 1993

This audit was completed in two steps: 14-18 June for all variables except wind direction and 13-15 July 1993 for the wind direction. The second trip was caused by an incorrect setting on the voltage supplied to the wind vane calibration during the first attempt. Temperature and relative humidity instruments were challenged again on this trip. Wind instruments showed no calibration or friction problems. Data loggers recorded within +9.0 percent of the transfer standard ozone concentrations at input concentrations of 50 ppbv and above. Temperatures recorded by the data logger were within 2F of the transfer standard at all stations except Five-Mile where the error was -3.1F. The range of relative humidity readings in the data logger over a one minute period included the value of the transfer standard at all stations except Sly Park where the logger recorded 1.6% to 9.2% higher than the standard.

3. DATA PROCESSING

A data base program, titled REPORT, was completed and submitted to UCD last year. REPORT reads original data from floppy disks and produces summaries of the data. During this contract year, REPORT was modified to accept solar radiation data. This turned out to be a major modification which took longer and cost more than expected, entailing a major rewrite of a large part of the program. All modifications have been completed and reliability checks have been completed on the resulting program. Data for part of 1991 and for the 1992 ozone season have been processed and floppy disks and a hard copy of the results will be forwarded to UCD by 15 November 1993.

4. EPISODE ANALYSIS

The previous Annual Report noted that two episodes were identified during the 1991 ozone season, viz. 10-11 July and 21-30 July 1991. The first period coincided with a quality assurance audit during which a number of stations experienced ozone monitor malfunctions. Therefore little attention was paid to this episode.

The 21-30 July period was chosen for analysis. Table 1 shows the highest hourly ozone concentration measured during the period at the SCOIAS stations, and those of local Air Quality Management District and ARB stations. MacKay (1992) listed the inventory of data available for analysis. Table 2 lists a more complete data inventory.

Robert Bryan analyzed much of the available data and is in the process of writing up the results. The most notable pattern in the diurnal variation of ozone at the SCOIAS stations is a dramatic shift in wind direction at about the time of the ozone maximum. Figures 1 and 2 show typical examples of the diurnal ozone and wind direction patterns at Mountain Home (24-25 July) and White Cloud (26-27 July).

At Mountain Home winds are westerly at about 1 to 2 m/s from noon to 5:00 p.m. LST, while hourly average ozone concentrations simultaneously increase from about 100 ppbv to near 120 ppbv. At 6:00 p.m. LST, winds shift to the easterly and the hourly ozone concentrations decrease to 90 ppbv at 7:00 p.m. and continue to decrease to near 60 ppbv at 5:00 a.m. on 25 July.

Winds at White Cloud are southeasterly from noon to 5:00 p.m. LST on 26 July with speeds decreasing from 3 m/s at noon to 1 m/s at 5:00 p.m.. Ozone concentrations increase from 70 ppbv to 110 ppbv during this time. At 6:00 p.m., the wind direction veers to northeasterly and the speed decreases to below 0.5 m/s. Between 7:00 p.m. (26 July) and 1:00 a.m. (27 July) winds are northerly or northeasterly with hourly average speeds between 0.5 m/s and 1 m/s. Hourly ozone concentrations peak at 115 ppbv at 7:00 p.m. and decrease to about 75 ppbv at

1:00 a.m. (27 July). (The peak five-minute concentration is 125 ppbv at 7:55 p.m.). There is a repeat of the pattern of southwesterly winds and increasing ozone followed by decreasing ozone concentration with northeasterly winds during the early morning hours of 27 July.

It appears that local ozone concentrations increase due to upslope transport and/or local photochemical production until sunset. Decreases in ozone concentration coincide with a marked wind shift. This seems to indicate that ozone poor air is subsiding to the monitoring site accompanied by the nocturnal downslope winds. A complete report of this case study is due from Robert Bryan by the end of December.

5. SUMMARY

Three field audits of the SCOIAS network of meteorological and ozone monitoring stations were accomplished during July and October, 1992, and July, 1993. Reports summarizing the results of the instrument challenges were submitted to UCD shortly after the audits were completed. A program called REPORT was written in 1992, which produces data summaries and printouts. The modification of REPORT to include solar radiation data required a major effort. Data summaries from 1992 have been processed, but are not yet printed. Robert Bryan analyzed the ozone episode of 21-30 July 1991. The most striking feature is the coincidence of peak ozone concentrations in the afternoon and the near 180 degree shift in wind direction. This pattern indicates that the decrease in ozone concentrations in the late afternoon coincides with the advent of downslope winds.

Table 1: July 1991 High Hour Ozone Concentrations (ppbv)

Station Date	19	20	21	22	23	24	25	26	27	28	29	30	31
Bay Area — Elev. in meters: Sea Level - 150 m													
Livermore	40	50	70	60	40	30	50	80	70	70	100	70	30
Los Gatos	20	40	70	60	30	30	60	80	60	70	90	70	60
Fremont-Chplvy.	30	40	50	*40	30	30	50	50	60	50	60	50	30
Between the Bay Area and the Central Valley — Elev. Sea Level - 150 m													
Bethel Is. Rd.	30	40	50	50	40	40	60	60	50	50	80	70	40
Concord	30	40	60	50	30	20	30	70	50	50	70	50	30
Pittsburg	30	30	40	50	40	30	50	50	50	50	60	50	40
Sacramento Valley — Elev. Sea Level - 150 m													
Davis	40	40	*60	*20	---	*50	70	80	60	60	90	*100	*30
Sac.-Del Paso	40	60	80	90	80	60	*110	90	80	80	*150	*180	40
Rocklin	50	60	90	100	80	80	*100	*110	*110	90	*130	*100	50
San Joaquin Valley — Elev. Sea Level - 150 m													
Bakersfield	60	70	80	90	90	70	70	90	*100	*100	*110	*130	90
Fresno-1st St.	80	80	90	130	100	*80	---	*100	*110	*100	90	*140	*110
Maricopa	70	70	70	90	90	70	70	80	*100	*100	*100	*100	*100
Sierra Mountain COUNTIES — Elev. 150 - 760 m													
Mariposa	70	70	80	80	80	80	80	100	100	100	90	90	100
Nevada	70	70	70	80	100	80	80	110	90	80	90	100	*80
SCOIAS Network — Elev. 1140 - 1890 m													
White Cloud	74	68	71	82	100	98	86	117	93	104	94	108	95
Sly Park	66	63	68	88	83	76	79	80	92	80	71	116	80
Five-Mile	79	76	75	89	88	80	83	96	105	101	92	90	89
JerseyDale	74	70	73	78	80	68	71	96	91	90	83	88	94
Shaver Lake	---	---	---	---	---	*77	92	113	130	118	136	142	117
Mountain Home	93	93	104	101	123	112	*83	---	---	---	---	---	---

* --> insufficient number of valid data points were collected to meet criteria for representativeness.
DATA SOURCE FOR ELEVATIONS < 760 m: California Air Resources Board (CARB)

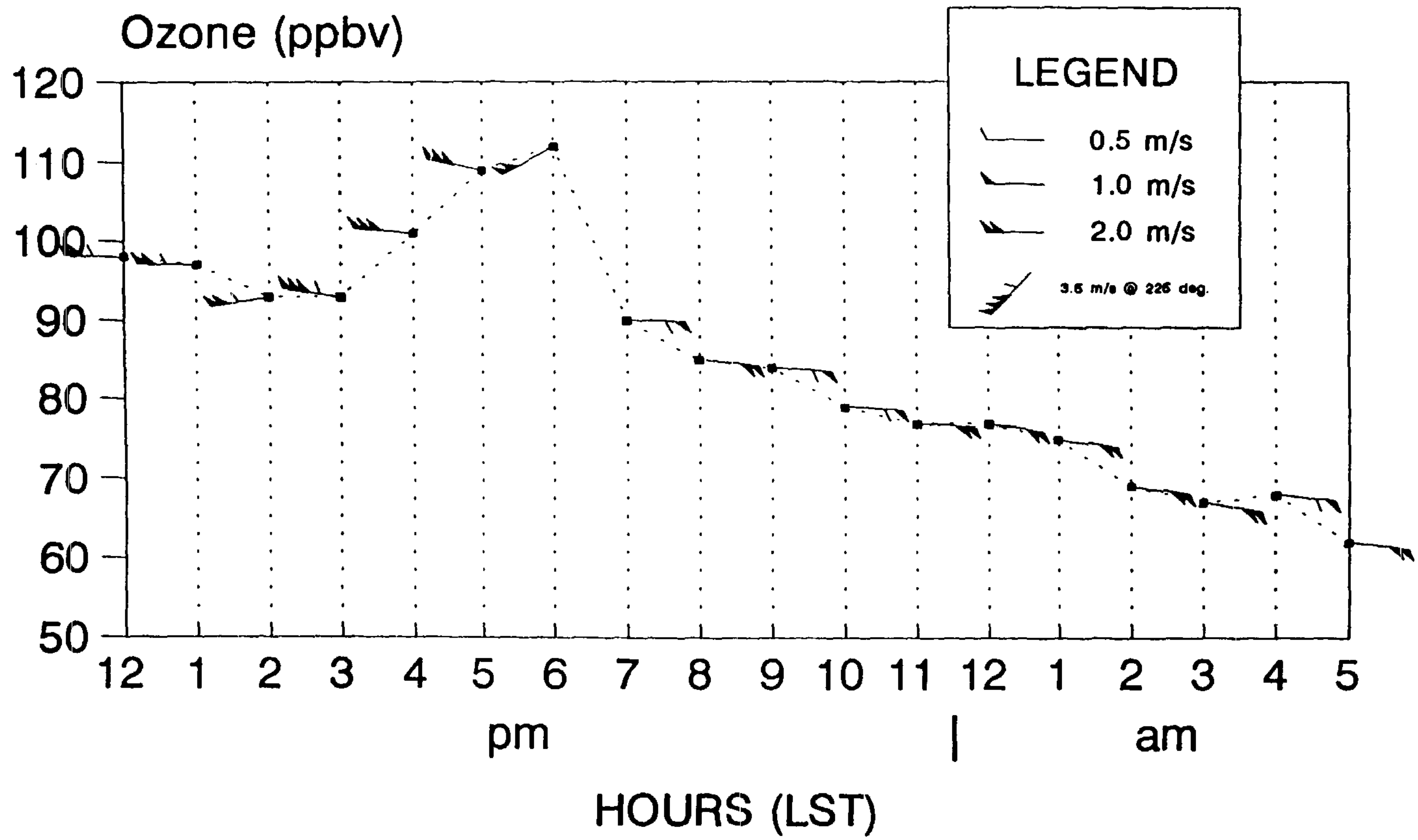
Table 2: **Available Episode Data**

CATEGORY / LOCATION/TYPE	FORMAT: TIME SCALE	FORMAT: DURATION
SURFACE OZONE CONCENTRATION		
Statewide/CARB	hrly max.	
SCOIAS Network	hrly avg.	April-Oct.
MESOSCALE ANALYSIS		
CARB Air Flow Charts	8h	07/19-08/01
SURFACE OBSERVATIONS		
Bakersfield/SA's	1h	07/17-07/31
Fresno/ SA's	1h	" "
Sacramento/ SA's	1h	" "
SCOIAS Network	hrly avg.	April-Oct.
Stockton/ SA's	1h	07/17-07/31
Visalia/ SA's	1h	" "
SYNOPTIC ANALYSIS		
Northern hem./sfc maps	12h	07/20-07/31
North Am./500 mb heights.	12h	July
UPPER AIR SOUNDINGS		
Oakland/radiosonde	12h	July
Columbia/aircraft sounding	24h	07/19-08/01
Sacramento/ " "	24h	07/27-08/01
Salinas/ " "	24h	07/24-07/26

Ozone Concentration (ppbv) and Winds

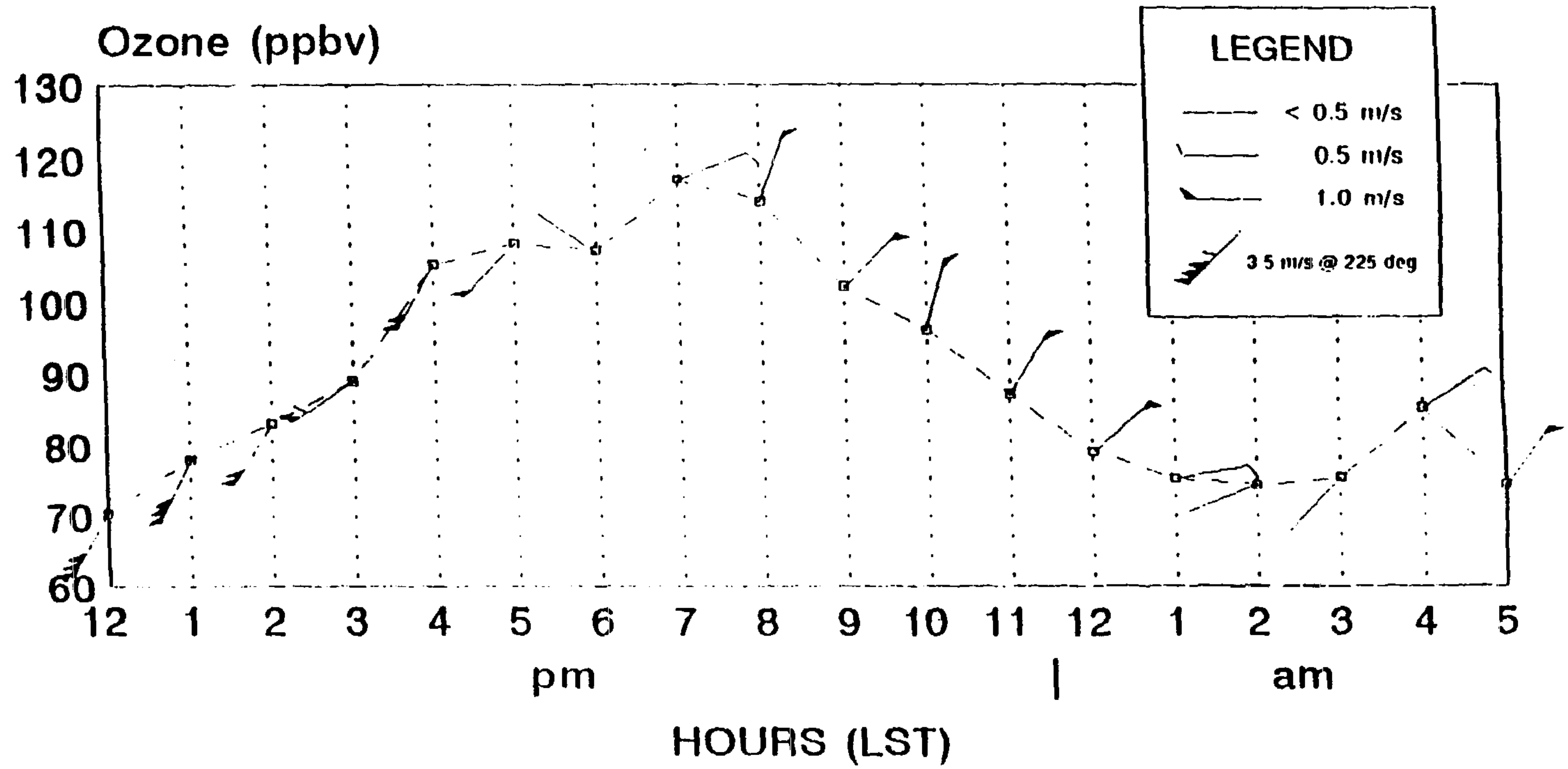
24- 25 July 1991

LOCATION: Mountain Home, California; ELEVATION: 1900m



PEAK: 120 at 6:05 pm (LST)

26 - 27 July 1991
White Cloud, California



PEAK: 125 at 7:55 pm (LST)

Fig. 2: Ozone and wind patterns
White Cloud, CA 26-27 July 1991

6. REFERENCES

Dismachek, D.C., and MacKay, K.P., 1992. Field Quality Assurance Audit for the Sierra Cooperative Ozone Impact Assessment Study: 14-18 June 1993 and 13-15 July 1993. Report submitted to U.C. Davis, Department of Land, Air and Water Resources. Dept. of Meteor. San Jose State University, 4 August 1993.

MacKay, K.P. 1992. Field Quality Assurance Audits and Data Base Development for the Sierra Ozone Impact Assessment Study. Submitted to U.C.Davis Department of Land Air and Water Resources. Dept. of Meteor. San Jose State University, 10 October 1992.

MacKay, K.P., and M.P. Jackson, 1992. Field Quality Assurance Audit for the Sierra Cooperative Ozone Impact Assessment Study: 16-19 and 26 June 1992. Submitted to U.C. Davis, Department of Land, Air and Water Resources. Dept. of Meteor. San Jose State University, 14 July 1992.

MacKay, K.P., and R.L. Bryan, 1992. Field Quality Assurance Audit for the Sierra Cooperative Ozone Impact Assessment Study: 16-18 October 1992. Report submitted to U.C. Davis, Department of Land, Air and Water Resources. Dept. of Meteor. San Jose State University, 29 October 1992.