PERFORMING OZONESONDE MEASUREMENTS FOR THE SOUTHERN CALIFORNIA OZONE STUDY

Final Report

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Finally, the great work of dozens students, who waited the entire summer to work crazy hours for thirteen days, made this project a success.

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ABSTRACT

Upper-air measurement of ozone (as oxidant) as part of the 1997 Southern California Ozone Study (SCOS97) was performed. Ozonesondes attached to balloons were launched at six sites in Southern California. They were launched four times a day, six hours apart, for 13 days chosen by SCOS97 management as intensive operational periods (IOPs). The ozonesondes transmitted data on ozone, temperature, relative humidity, and pressure to base stations, where the data were recorded on computer. Data were collected to an altitude of at least 10,000 feet above ground level. These data were validated, tabulated and presented to the ARB in electronic format.

An air quality monitoring station was also set up and operated at Tehachapi, CA, during the SCOS97 measurement period. Ozone, wind speed and direction, temperature, and relative humidity were recorded as one-hour averages.

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Glossary

AGL	Altitude above ground level (as opposed to altitude above mean sea level, or MSL)
ARB	California Air Resources Board
CE-CERT	College of Engineering-Center for Environmental Research and Technology at the University of California, Riverside
IOP	Intensive Operational Period
MSL	Altitude above mean sea level (as opposed to altitude above ground level, or AGL)
RH	Relative humidity
SoCAB	South Coast Air Basin
SCOS97	1997 Southern California Ozone Study

1.0 Introduction

Despite many years of reducing precursor emissions, Southern California is still classified by the U.S. Environmental Protection Agency (USEPA) as a "serious" non-attainment area for ozone. To formulate additional cost-effective emission control strategies, a better understanding of the meteorological and chemical processes contributing to high ozone concentrations is needed. While the South Coast Air Basin (SoCAB) has been the subject of several intensive studies to understand the origin and formation ozone, a new study was undertaken for several reasons. The previous studies are now dated, as the composition of gasoline and emission control technology have changed significantly since the last major study, SCAQS, in 1987. Previous studies have included little research into the effect of transfer of pollutants between air basins and generally lacked vertical measurements of ozone and ozone precursors.

The 1997 Southern California Ozone Study (SCOS97) will provide a new and expanded understanding of the distribution of ozone in Southern California and the mechanism of formation. This study emphasized the collection of data on the vertical distribution of ozone and meteorological parameters. The heart of the study was thirteen days forecasted for high ozone, during which time extensive measurements of meteorology and pollutant concentrations were made. The objective of this project was the vertical measurement of ozone concentrations.

Ozone can be measured aloft by a number of techniques. Instrumented aircraft have long been used to obtain these data, but they have many limitations. Cost has been a major limitation. The installation of monitoring instruments causes the aircraft to be placed in a "restricted category." Since the aircraft can therefore not be used for other purposes, its cost and maintenance must be paid for by sporadic specialty studies. During special studies, the crew must be maintained while waiting for acceptable study days. In addition to cost, there are several other limitations. To obtain a vertical ozone gradient, the aircraft must perform spirals over one location. It is difficult to obtain permission to do this because of the large amount of air traffic in the SoCAB. Except when taking off or landing, aircraft are limited to flying at least 1,000 feet above ground level (AGL) in populated area and 500 feet AGL in unpopulated areas. This would be a significant limitation since during the highest ozone days most of the ozone is within the first 1,000 feet AGL. Finally, there are restrictions on where the aircraft can fly because of airspace controls for the numerous airports in the SoCAB.

Ozone vertical distributions also can be measured using tethered balloons. While these balloons can be easily varied in height and do not move spatially, it is difficult in the SoCAB to get Federal Aviation Administration (FAA) permission to fly them above 200 feet, again due to potential interference with aircraft.

Vertical ozone measurements can also be made remotely by using LIDAR instruments. These are research instruments that are expensive and labor-intensive. Correction factors are often necessary, and the quality of the data is difficult to quantify.

Ozonesondes have advantages to the above-mentioned techniques. On a per-measurement basis, their cost is generally less than that of a research aircraft. There are no major limitations as to where they can be flown. The instruments are simple, direct measures of ozone (actually they may respond to other oxidants that oxidize iodide to iodine) that are easily calibrated.

The study involved measurements four times a day at six sites for a total of thirteen intensive operational days. The following report describes how the data were collected, the quality control steps taken, and how data were validated.

2.0 Approach

Our approach was to use an En-Sci model 2Z ECC ozonesonde flown on helium-filled balloons to make vertical sounding of ozone during the Intensive Operational Periods (IOPs) of the 1997 SCOS97. Ozone data from the sonde, in addition to air pressure, temperature and humidity, were collected by a Vaisala model RS80-15 Radiosonde and transmitted to a ground station. Data packets are sent every 1.2 seconds. From the receiver, the data are sent to a personal computer via a modem through an RS-232 serial port.

The En-Sci model 2Z ECC ozonesonde works on the principle of ozone reacting at constant stoichiometry with a solution of potassium iodide (KI) in a buffered solution of an electrochemical cell. Air is pumped into the measurement cell through an all-Teflon pump. As the ozone oxidizes the iodide to iodine, the iodine is electrochemically reduced back to iodide and a current is produced and measured. The concentration of ozone is therefore proportional to the current, cell temperature, and the flow rate of air sampled.

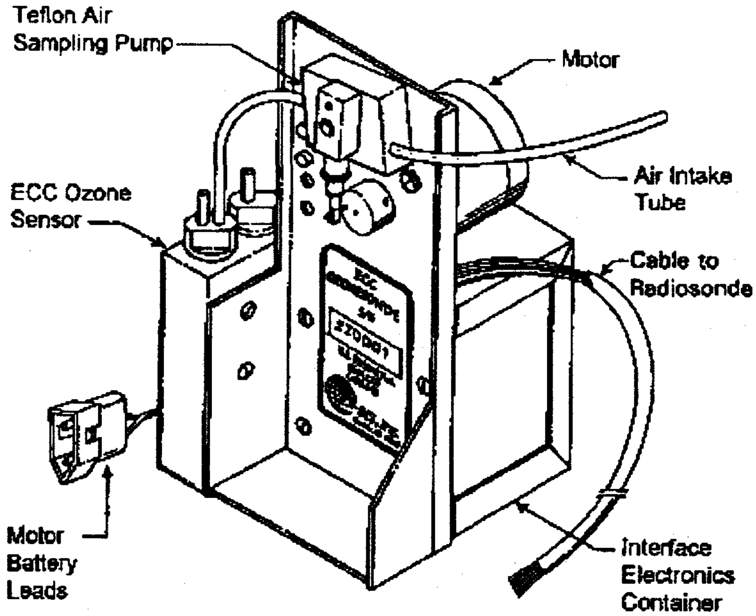
This device's response to other oxidants in the atmosphere, such as nitrogen dioxide and peroxyacetyl nitrate (PAN), which also oxidize iodide to iodine, was evaluated. These species may introduce a measurement bias in the ozonesonde output, but the response should be well correlated with the actual ozone concentration measured by specific techniques such as chemiluminescence and ultraviolet spectrometry.

2.1 Ozonesonde Description

The ozonesonde used was a model KZ-ECC manufactured by EN-SCI Corporation. Figure 2-1 is diagram of the sonde. Critical components include an air sampling pump, a thermistor for measuring pump temperature, an electrochemical cell for sensing ozone, an electronic signal conditioning module and a battery. The air sampling pump is made of Teflon and glass and powered by a small DC motor. It has a nominal flow rate of 210 ml/min. The ozone sensor consists of two bright platinum electrodes, one for the anode chamber and one for the cathode chamber. These chambers are separate and contain buffered solutions of potassium iodide at different concentrations. Air enters the cathode and ozone oxidizes iodide to iodine. The anode supplies electrons to reduce the iodine back to iodide, resulting in iodine forming in the anode chamber. This current is proportional to the partial pressure of ozone, the pump flow rate and the temperature in degrees Kelvin. The signal conditioning electronics measure the current and converts it to a voltage. The specifications from the manufacturer are ±5% for accuracy and ±4% precision for altitudes less than 10,000 feet. Although specifications were not given for higher altitudes, these sondes are normally used to determine total ozone column of the atmosphere and therefore are flown to stratospheric heights.

The ozonesonde is packaged with a Vaisala model RS80-15 meteorological radiosonde. This radiosonde transmits cell current and pump temperature data from the ozonesonde in addition to data on ambient temperature, relative humidity and pressure. Figure 2-2 shows the combined assembly as flown. The ozonesonde is encased in a polystyrene housing for temperature stability, while the radiosonde is attached to the side. Data are transmitted at a nominal 403 MHz to a receiver on the ground every 1.2 seconds. Although once locked on a signal it is unlikely to pick up the signal from another sonde, each site was assigned an integer signal between 402 and 405 MHz to which ozonesondes were tuned in order to avoid interference from other sondes launched in Southern California. The signal is then sent to a computer for processing and storage.

Figure 2-1. Sonde Diagram

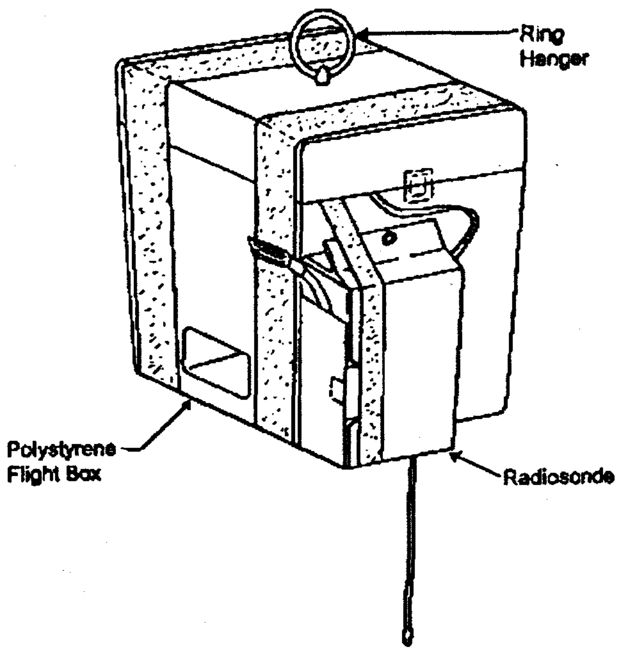


2.2 Measurement Sites

2.2.1 Ozonesonde Launching Sites

Under this contract, sondes were launched from six sites located in southern California. The general locations were specified in a memo from Bruce Jackson of the ARB. The rationale for each general location were as follows:

Figure 2-2. Ozonesonde and Radiosonde Assembly



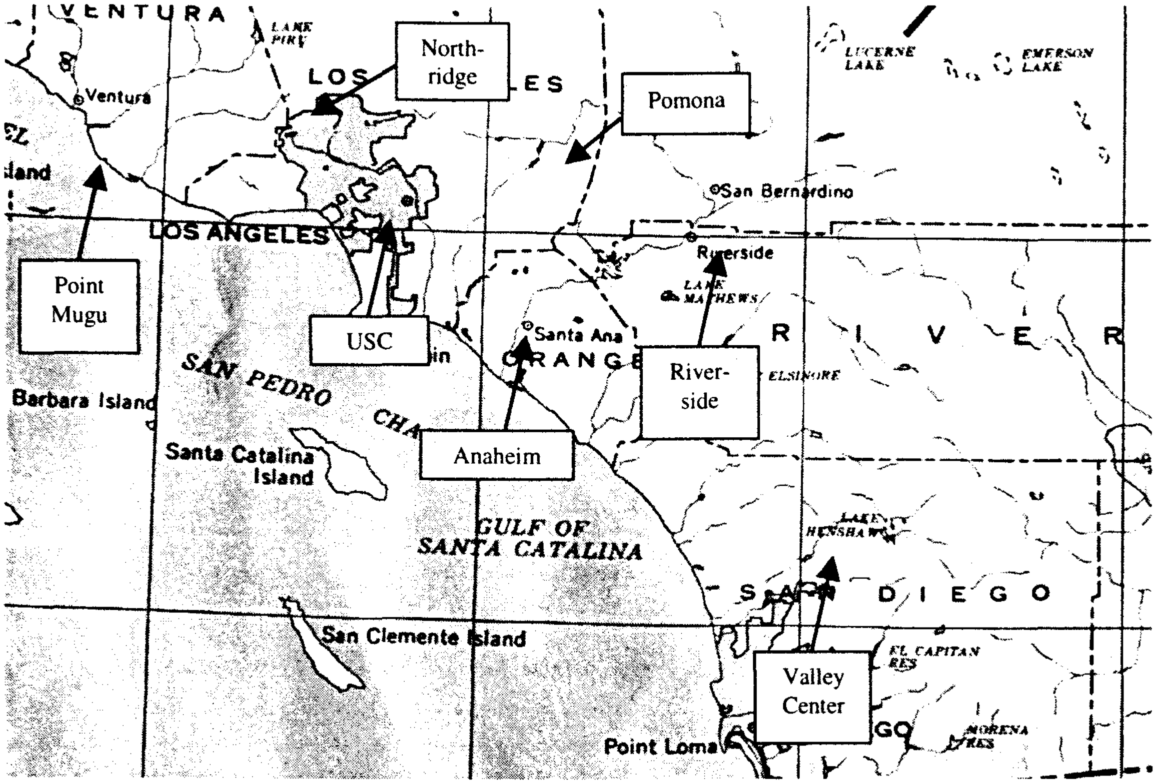
- San Fernando Valley: Monitor aloft transport through the San Fernando Valley into Ventura County.
- Central Basin: Southerly extent to which ozone is transported by recirculation from the San Gabriel Mountains.
- South Basin: Assess transport into San Diego County and measure ozone recirculated from over the Pacific Ocean.
- Northern Transport Corridor: Monitor transport and recirculation between the coastal plain and the lower Mojave Desert.
- Low Desert: Monitor transport through the Banning Pass.
- Northern San Diego County: Monitor overland transport from the SoCAB into San Diego County.

Specific sites were selected to best accommodate the following criteria:

- Availability of ground-based ozone and other pollutant analyzers.
- Nearness to radar profiler sites.
- Ease of access.
- Security.
- Suitable open space to avoid interferences with launching.
- Ability to secure permission to use the site.
- Minimum of local sources of NO which could affect ozone measurements.

Figure 2-3 is a map showing the locations of the sites chosen for ozonesonde launches. These sites are described as follows:

Figure 2-3. Ozonesonde Launch Sites



1. California State University, Northridge (34.2269 latitude; 118.5335 longitude): This site was located on the roof of the four-story Geography Building. A service bay with double doors was used as the balloon filling shelter. The ground-based ozone analyzer was set up in an air-conditioned laboratory on the second floor, with the sample line routed through a window.

2. University of Southern California (34.0193 latitude, 118.2854 longitude): The roof of the three-story Hancock Building was used. A metal shed was installed for filling balloons. The ground-based ozone analyzer was located in a third floor, un-air-conditioned, unused laboratory.

3. Anaheim South Coast Air Quality Management District Monitoring Site (33.8197 latitude, 117.9128 longitude) This monitoring station is located on a County facility at 1010 South Harbor Blvd., Anaheim. A metal shed was installed for filling balloons.

4. Pomona South Coast Air Quality Management District Monitoring Site (34.0686 latitude, 117.7503 longitude) This monitoring station is in a storefront at 924 Garey Avenue in Pomona. A metal shed was installed for filling balloons.

5. University of California Agricultural Operations site operated by the South Coast Air Quality Management District (33.9620 latitude, 117.3336 longitude) This facility is located approximately 100 meters northwest of the intersection of Canyon Crest and Pearblossom drives in Riverside.

6. Valley Center Caltrans Operational Facility (33.2366 latitude, 117.1475 longitude) This site was located at 29216 Valley Center Road at the northwest quadrant of the intersection with Cole Grade Road in Valley Center. A large garage was used for balloon filling.

A seventh ozonesonde release site was operated by the U.S. Navy at Point Mugu.

At each site except Northridge, Point Mugu, and Valley Center (where existing structures were used), steel sheds were erected to more accurately determine the free lift of the sonde before launch. This determination was critical in order to use the lowest ascent rate possible while having enough lift to avoid bouncing or being caught by nearby obstacles. The lower ascent rate allowed for better time, and hence better vertical resolution of the ozonesonde data.

2.2.2 Tehachapi Surface Monitoring Site

Surface ozone was monitored in Tehachapi, CA, to support the SCOS97 ozone measurement network. The site was located on Jameson Road just south of where the road bends from east-west to north-south. The altitude is approximately 3,700 feet. The site was located immediately north of the north road at a well operated by Calaveras Cement Company. The north-south section of Jameson Road was unpaved at the time of installation, but grading was being done for laying asphalt paving. The traffic density was approximately one car per minute during the middle of the day. The paving was completed between site visits occurring on July 31 and August 27. The area is largely open desert or agricultural with some light manufacturing. An air-conditioned trailer was used as a monitoring shelter. The station was equipped with a Dasibi model 1003AH ozone analyzer, an RM Young model AQ wind direction and velocity sensor, and a Qualimetrics temperature and RH probe mounted in a non-aspirated sun shield. A Campbell CR10 data logger was used to collect data. Shelter temperature was also recorded.

2.3 Initial Ozonesonde Evaluation

An EN-SCI model 2Z ECC ozonesonde was obtained from the manufacturer for testing to determine whether the device was suitable for obtaining the measurements desired. The sonde was tested under the conditions described in Table 2-1.

For these tests, ozone was generated using a Columbia Scientific Instruments model 1700 calibrator. A mixture of NO and NO_2 was generated using this calibrator and performing a gas phase titration of NO in N_2 followed by dilution with ultra zero air. Humidity was controlled by splitting the dilution air to the calibrator, bubbling one stream through water using a fritted disk and rejoining the dry and wet streams while controlling their flows to adjust the humidity. For the temperature study, the sonde was place in a small room with an electric space heater to control the temperature. The pressure response test was conducted by placing the sonde in a heavy plastic airtight container and using a vacuum pump to lower the pressure. Ozone was generated with a calibrator and monitored with a photometric analyzer, which was vented to the atmosphere. Ozone from the source was directed through a Teflon needle valve to the ozonesonde in the vacuum chamber. The ozonesonde was vented through a rotameter in the vacuum chamber. The needle valve was adjusted so that each analyzer had excess vent flow over the range of pressure studied. PAN was generated synthetically in an octane solution by nitrating peroxyacetic acid with nitric and sulfuric acids (Holdren and Spicer, 1984). The concentration of PAN in solution was measured with a Fourier transform infrared spectrometer and an aliquot injected into a 100l Teflon bag. The resulting PAN concentration was verified with a Teco model 42 NO-NO_x analyzer.

Table 2-1. Sonde Testing Conditions

Parameter	Condition 1	Condition 2
Ozonesonde Response Time	Temperature 20 to 25 deg. C Pressure 730 to 740 torr Sample relative humidity 0% Ozone input 0 to 100 - 100 to 0 ppb	Temperature 20 to 25 deg. C Pressure 730 to 740 torr Sample relative humidity 0% Ozone input 0 to 10 - 10 to 0 ppb
Ozonesonde Span Stability	Temperature 20 to 25 deg. C Pressure 730 to 740 torr Sample relative humidity 0% Ozone input 80 ppb	
Ozonesonde Linearity	Temperature 20 to 25 deg. C Pressure 730 to 740 torr Sample relative humidity 0% 6 points spaced between 0 and 500 ppb	
Ozonesonde Relative Humidity Response	Temperature 20 to 25 deg. C Pressure 730 to 740 torr Sample relative humidity 0% to 80% Ozone input 0 ppb	Temperature 20 to 25 deg. C Pressure 730 to 740 torr Sample relative humidity 0% to 80% Ozone input 100 ppb
Pressure Response	Temperature 20 to 25 deg. C Pressure change 740 to 580 - 580 to 740 torr Sample relative humidity 0% Ozone input 100 ppb	Temperature 20 to 25 deg. C Pressure change 740 to 580 - 580 to 740 torr Sample relative humidity 0% Ozone input 0 ppb
Interference Testing	Temperature 20 to 25 deg. C Pressure 730 to 740 torr Sample relative humidity 0% Input 100 ppb of NO_2	Temperature 20 to 25 deg. C Pressure 730 to 740 torr Sample relative humidity 0% Input 100 ppb of PAN

2.4 Quality Assurance Project Plan

Planning, management, and performance of this study was guided by a Work Plan prepared in a format following guidelines for an EPA category II Quality Assurance Project Plan (QAPP) (U.S. EPA, 1984a). It was submitted to the ARB for review prior to commencing measurement activities. The final version of the QAPP was submitted to the ARB in April, 1998. The key elements of the Work Plan are shown in Table 2-2. This project involved three fairly distinct areas of activity: preparation and training, field measurement, and data validation. The Work Plan was for the project overall and described the QA/QC activities for each of these components.

Table 2-2. Elements of the Quality Assurance Project Plan

1. Project Description
2. Project Organization and Responsibilities
3. Data Quality Indicators and Goals
4. Sampling Procedures
5. Sample Custody
6. Calibration Procedures and Frequency
7. Analytical Procedures
6. Data Reduction, Validation, and Reporting
9. Internal QC Checks
10. Internal Performance and System Audits
11. Instrument Preventative Maintenance
12. Calculation of Data Quality Indicators
13. Corrective Action
14. QA Progress Reports to Management
15. References

The data quality goals were a key part of this document. Table 2-3 presents these for the ozonesondes and Table 2-4 for the meteorological sondes. One change in the Work Plan was the substitution of John Collins for Ted Younglove as data manager. This was done because Mr. Collins, after writing the SOPs, had a much greater depth of understanding of the measurement techniques and potential problems.

The data were validated to Level Ib as defined by the SCOS97 Field Study Plan (Fujita et al., 1996). Level Ia consisted of reviewing field data sheets, insuring that QC tolerances were met, and screening to remove zero/span checks and other periods where analyzers were off-line. Level Ib screened the data for outliers, unreasonable rates of data change, and consistencies with expected altitude and diurnal profiles. Flags were applied to all data which were found to be suspect. The QC codes were as follows:

- CL: Calibration or Quality Control data
- IV: Invalid data
- SS: Suspect data
- VD: Valid data

Table 2-3. Data Quality Goals for Ozonesondes

DQI	Goal
Precision	1-sigma < larger of 5 ppb or 10%
Calibration bias	1-sigma < larger of 5ppb or 10%
Interference bias	-10 to +20 ppb
Lower quantifiable limit	< 15 ppb
Response time	> 80% of step change in 1 minute
Ascent rate	< 3.0 m/s
Response distance	> 80% in 180 meters
Time of launch	+3.0/- 0.0 hours from planned time
Location of launch	+/- 100 meters from planned location
Duration of flight	>4000 meters AGL

Table 2-4. Data Quality Goals for Meteorological Sondes

Measurement	DQI	Goal
Temperature	Precision	$\pm 1\ ^{o}C$
Temperature	calibration bias	$\pm 3\ ^{o}C$
Temperature	response time	63% of step change in < 20 sec
Pressure	precision	±2 mb
Pressure	calibration bias	±5 mb
Pressure	response time	63% of step change in < 2 sec
Relative Humidity	precision	±5% RH
Relative Humidity	calibration bias	±10% RH
Relative Humidity	response time	63% of step change in < 2 min

For ground-based analyzers, precision was determined by calculating the standard deviation of the zero-span checks performed during site visits. For the ozonesondes precision was estimated by calculating the standard deviation of the laboratory zero-span checks. The lower quantifiable limit was defined as three times the standard deviation of the field pre-flight zero checks.

2.5 Standard Operating Procedures

Standard operating procedures (SOPs) were written to cover all aspects of the sonde operation and operating ground sites. These included field management of the project, laboratory checkout and conditioning, field use of the ozonesondes, and operation of continuous ozone analyzers. Key aspects from these documents are summarized below:

- Field Management of Ozonesonde Operations for SCOS97

This document describes the logistics to conduct the program. The project organization included a PI with a coordinator, a field operations manager, a sonde checkout technician, three team leaders, and six launching teams (one for each launch site). Pagers were issued to all personnel except the launch teams. A single pager was installed at each launching site. All personnel were provided with a phone list that included work and home phones of all staff. Each launching team was divided into a day and a night team that consisted of two people each. The PI or his project coordinator checked the SCOS97 recorded message and updated the recorded message on a dedicated CE-CERT phone. All staff were required to check this message daily between 5 and 7 p.m. and to leave a message indicating that they had done so. When IOPs were called, the project coordinator checked the recording to verify that all staff had received the message and were able to perform their assigned tasks. All personnel then checked the daily message between 11:30 a.m. and 1:30 p.m. for updates on the IOP status. Any problems were referred to the team leaders to resolve. Technical problems from the launch teams were directed first to the team leader, to the field operations leader, and finally to the PI.

Upon IOP notification, 30 (one day supply + one spare per site) ozonesondes were prepared and their performance checked at zero, low, and high ozone concentrations under the direction of the field operations manager. Five sondes plus any other supplies needed for a site were set out in a marked area at the CE-CERT operations center. Between 5 and 9 p.m., one technician from each daytime launch team picked up all supplies for the following day. A nighttime team member dropped off the spare sonde, if not used, and all data and documentation.

- Laboratory Checkout and Conditioning of Ozonesondes for SCOS97

This describes how ozonesondes were prepared and their performance validated. The checkout was a two-step process. The first involved checking the pump performance and the sondes' electronic circuitry and conditioning the sampling line to high ozone concentrations. This did not require adding electrolyte and was done well in advance of the IOPs. In the second step, electrolyte was added and the response to zero and a nominal 200ppb concentration of ozone was checked by comparison with a photometric analyzer. The average response factor was applied to data obtained after launching the sondes. This step was performed the day before launch. The sondes, still filled with electrolyte, were hand-carried to the launch site.

- Field Use of Ozonesondes for SCOS97

This document describes in detail how the sondes were launched. The level of detail was such that a careful person could launch a sonde without specialized training. The document described how the ozonesonde and radiosonde are attached and prepared for launching. Once radio contact is made with the sonde using the site-specific frequency, QC checks are made and recorded. These include verifying the sampling rate with a rotameter, response to zero ozone, comparison of ambient ozone with the on-site analyzer, comparison of temperature and humidity with a sling psychrometer, and verification of pressure compared to the site standard. These QC comparisons were recorded on a data sheet, and if not within specifications, the problems were referred to the

Team Leader for resolution. The balloons were filled with helium to produce a free lift of 350 grams while in a structure that prevented wind buffeting. This provided an ascent rate of approximately 1.5 m/s. The sonde package was then launched and the data telemetered back and monitored on a computer screen until the sonde reached a pressure of 500mb or less. Data were stored on the computer's hard drive and immediately recorded on a floppy disk for transfer to the CE-CERT database.

- Calibration and Operation of Continuous Ozone analyzers for SCOS97

This document describes the operation of photometric ozone analyzers used at two of the ozonesonde launch sites (California State University Northridge) and the monitoring site in Tehachapi, CA. At installation and tear-down, multi-point calibrations were performed using a transfer standard. Site checks were performed every two to three weeks. During these site checks the instrument flow rate and sample and control frequencies were checked. A transfer standard was used for zero and span checks before and after the inlet filter was renewed. During the site check, the data logger was downloaded to a laptop PC and the data copied to a floppy disk. The data logger also recorded site temperature to determine whether analyzers were operated within the temperature range required for EPA equivalency with the reference method.

3.0 Results

3.1 Initial Evaluation

3.1.1 Response Time

Figure 3-1 shows the response of the ozonesonde to changes of 100 ppb concentration at room temperature (21°C) and a relative humidity of 47%. The lower detectable limit, 0.3 ppb, was calculated as twice the noise of the baseline before ozone was introduced. It is apparent that the instrument responds quickly to changes of concentration, with a time constant of 34 seconds to reach to within 1/e of the final response. Once the response reaches 90% of final (119 seconds), the rate of equilibration appears to slow down. If the rate were exponential, the expected response would be 98% of the final concentration. The reverse is noted when the ozone concentration is changed to zero, although the drop more closely follows exponential decay with 24 seconds required to drop to within 1/e of the final value, reaching 90% of final value in 71 seconds. It is possible that the longer time to equilibrate to upward changes may be due to the nature of the chemistry occurring within the electrochemical cell.

Figure 3-2 shows the results of repeating the experiment with a much lower concentration change that would more likely be observed in actual soundings. The lower detectable limit was 0.1 ppb this time based on twice the noise of the zero air response. The rise time was 43 seconds to reach to within 1/e of the final response and 168 seconds for 90%. This is somewhat longer than at high concentration. The fall time as in the previous high concentration test was faster, 30 seconds to reach 1/e and 82 seconds for 90%.

Figure 3-1. Response of KZ-ECC Ozonesonde after Step Changes in Ozone Concentration

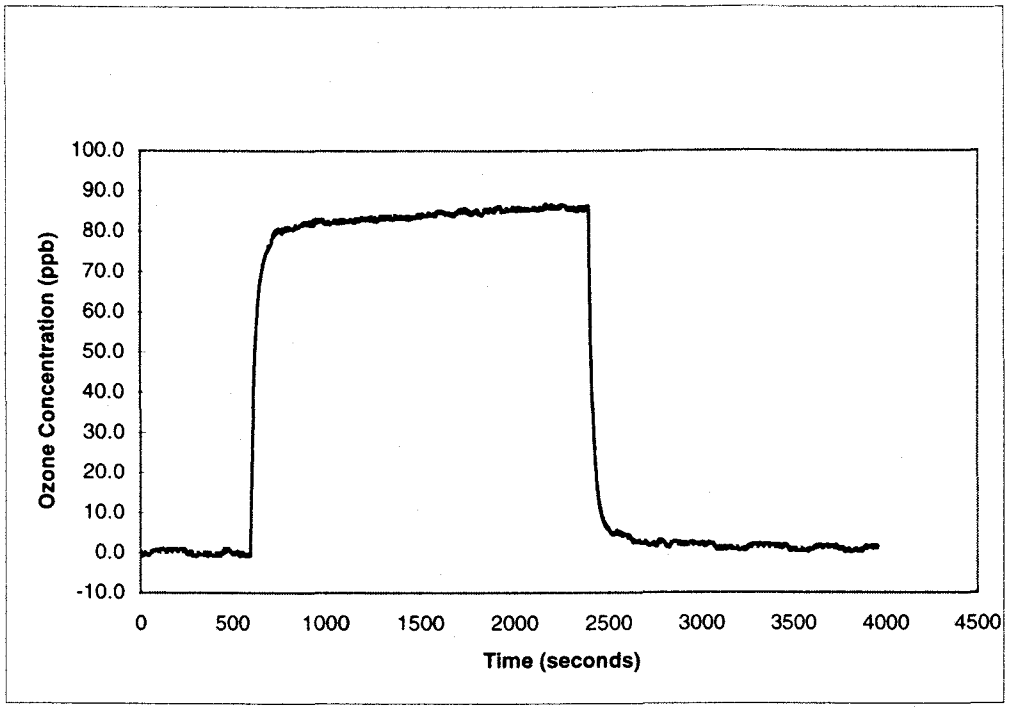
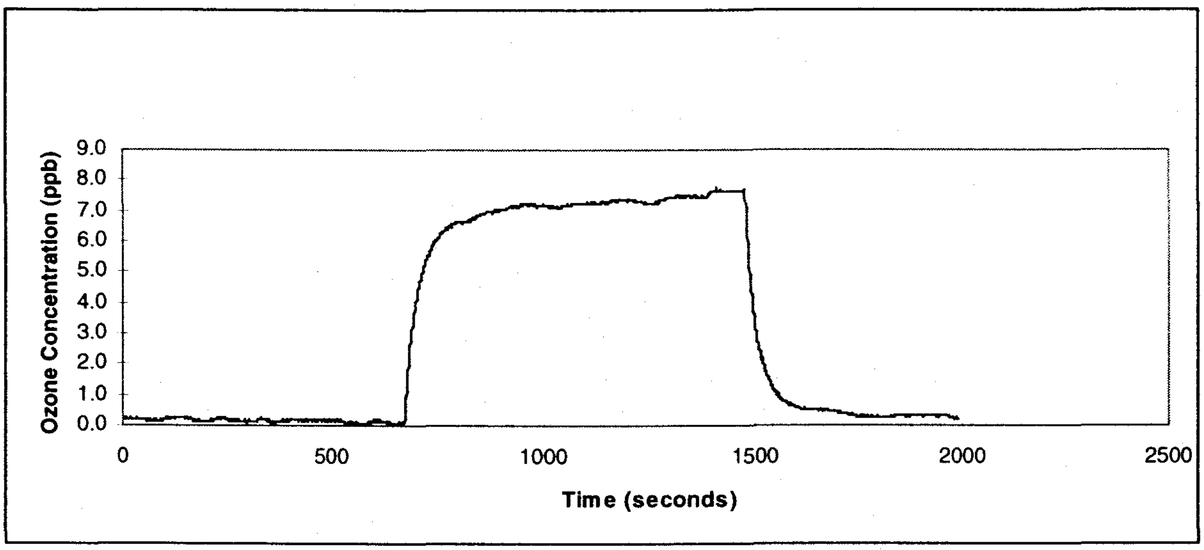
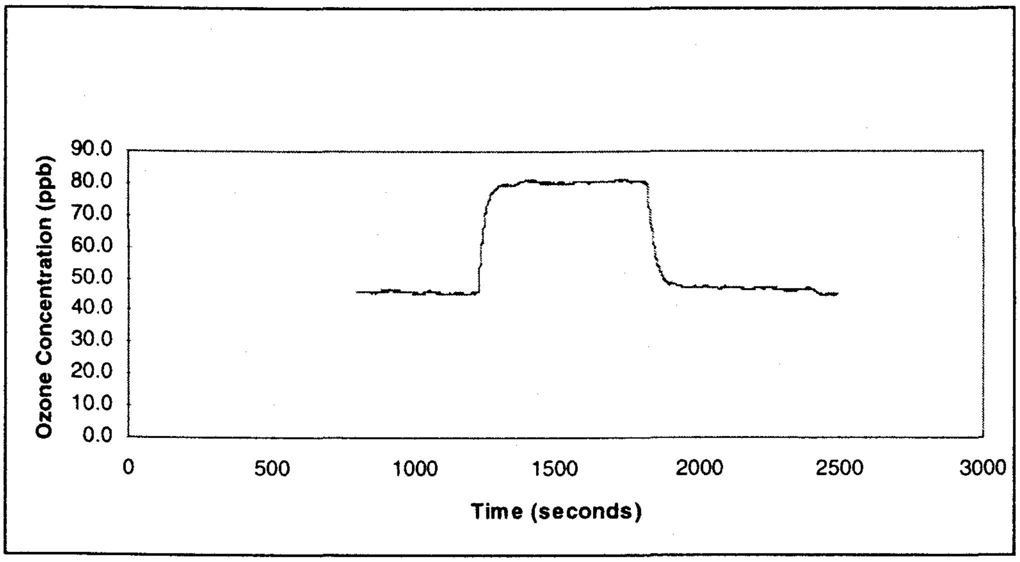


Figure 3-2. Response of KZ-ECC Ozonesonde to Concentration Step Changes Between Zero and 7 ppb ozone.



For most soundings we would not expect changes from no ozone, but rather from one concentration to another. Figure 3-3 shows 50% changes between 46 and 80 ppb. The rise time was 23 seconds to reach 1/e of the final value while the fall time required 22 seconds. The rise and fall times for reaching 90% of the final value were 55 and 52 seconds respectively. It appears that the response in changes in concentration take less time to reach the final value when step changes are not as extreme as when going to or from no ozone. Both rise and fall times were similar and showed exponential equilibration.

Figure 3-3. Response of KZ-ECC Ozonesonde after 50% Step Changes in Ozone Concentrations



3.1.2 Span Drift and Noise

The previous figures showed little change in span for several thousand seconds, or about half an hour. A typical ozonesonde flight requires 30-60 minutes of preparation once the sonde is turned on, and the flight typically lasts for an hour. These ozonesondes can operate about three hours before the electrolyte volume is reduced through evaporation to the point where it no longer functions. We therefore did a test of the sonde's stability on one fill of electrolyte while sampling dry air containing 8 ppb of ozone. Figure 3-4 shows the results. In this time-series plot ozone was added at approximately 25 minutes after filling. A plot from 30 to 180 minutes yields a slope of –0.003, indicating a decline of 0.45ppb over the period. The standard deviation of the ozone concentration during this period was 0.2 ppb, which gives a lower detectable limit of 0.4 ppb. The long-term drift at low concentration was therefore equivalent to the limit of detection, which is lower than the 1-2 ppb specifications cited by the manufacturers of UV photometric analyzers normally used at ground monitoring stations.

Figure 3-5 is a similar plot of stability, but at a nominal ozone concentration of 80 ppb. The ozone was also monitored with a Dasibi 1003AH analyzer. The standard deviation for the ozonesonde was 2.3 ppb while the Dasibi was 1.1 ppb. After approximately 1 hour the ozonesonde measurement began to drift downward, becoming 8% lower after 80 minutes. During this time the Dasibi dropped only 0.4 ppb, within the uncertainty of the instrument. It is possible that the higher concentration of ozone resulted in more oxidation products in the ozonesonde's electrochemical cell, thus leading to the reduced response. It is unlikely that an actual sounding would have an average concentration of 80 ppb, and this drift should therefore be considered an upper limit for actual uncertainty.

Figure 3-4. Ozonesonde Long-Term Stability Response to 8 ppb of Ozone

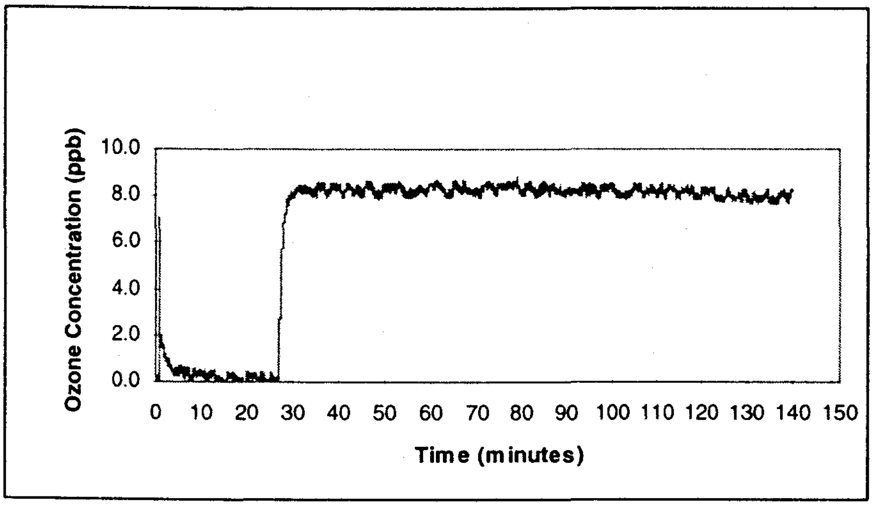
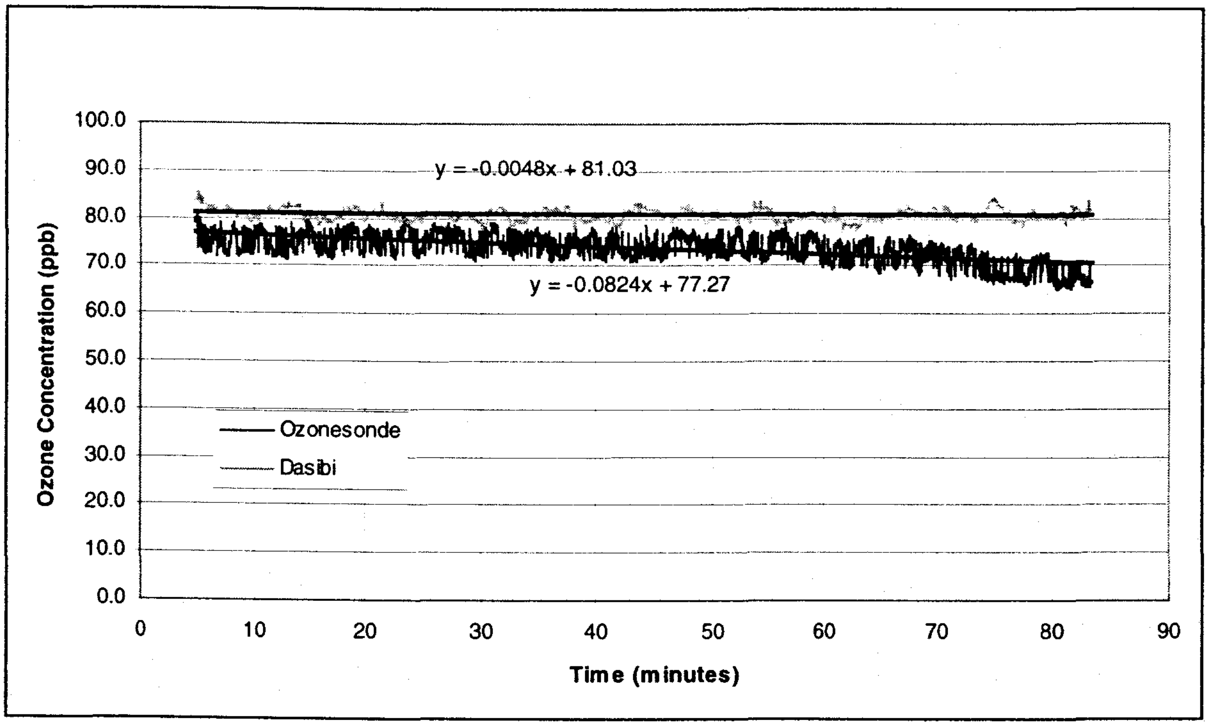


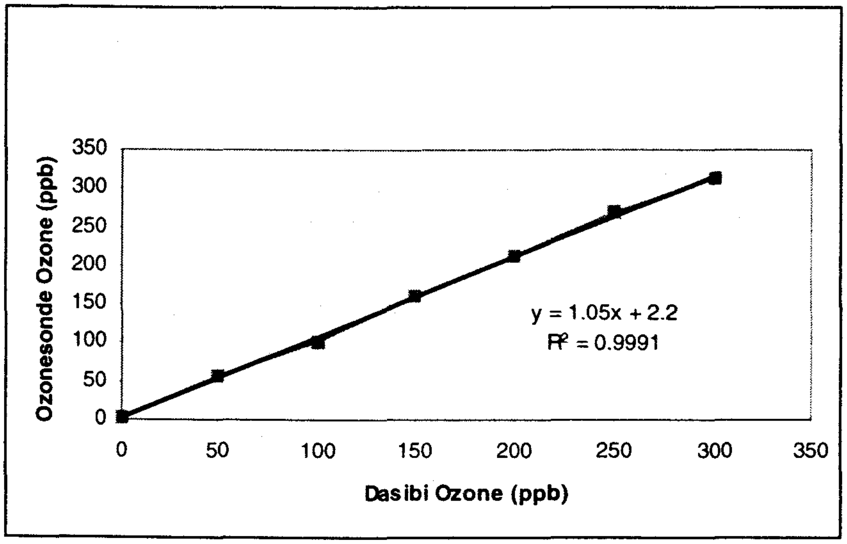
Figure 3-5. Ozonesonde Long-Term Stability Response to 80 ppb



3.1.3 Linearity

Figure 3-6 is a plot of a multi-point calibration of the ozonesonde compared with the primary standard. The R^2 is 0.9991, showing that the data are well correlated and linear. These calibrations were repeated four times and the correlation coefficient varied from 0.9972 to 0.9994. The response of the ozonesonde is therefore linear to within the instrumental error.

Figure 3-6. Comparison of KZ-ECC Ozonesonde with Dasibi 1003AH Primary Reference



3.1.4 Humidity Response

A linearity test was repeated at 80% relative humidity. The results were almost identical to those shown in Figure 3-6 for the dry system, with a slope of 1.05 and intercept of 0.2 ppb. We conclude that the ozonesondes do not have a humidity response.

3.1.5 Pressure Response

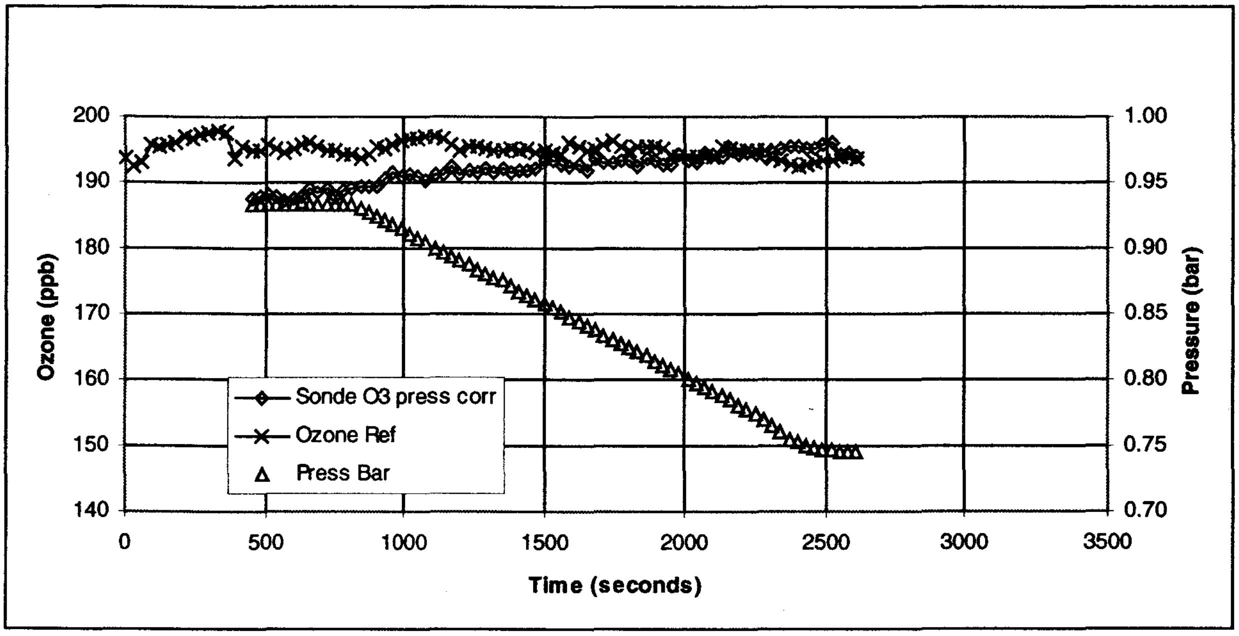
Figure 3-7 shows the ozone response results as the pressure is lowered from ambient of 0.93 bars to 0.74 bars, the limit of the vacuum chamber. The lower pressure represents an altitude between 8,000 and 9,000 feet above mean sea level (MSL). The ozonesonde output was subject to the same algorithm used during launches. This algorithm corrects for pump temperature and ambient pressure. The corrected ozonesonde output was found to rise approximately 4% during this change in pressure, which is within the manufacturer's stated specifications for accuracy and precision.

3.1.6 Interferences

• PAN Interference

A sonde was calibrated against a known ozone source, zeroed on purified air and then allowed to sample 100 ppb PAN in a 100 l Teflon bag. The ozonesonde response was somewhat slower than when subjected to ozone, requiring 47 seconds to reach 1/e of the final value. The final value was 38 ppb ozone in response to 100 ppb PAN or an interference equivalent of 0.38. The maximum PAN values in southern California are typically less than10 ppb. The ozonesonde therefore may have a positive bias of as much as a few ppb. Since ozone maxima are typically 200 ppb, this bias would be within the measurement precision of the ozonesonde.

Figure 3-7. Ozonesonde Response to Pressure Changes



• NO_2 Interference

The sonde used to measure the PAN interference was then used to sample 149 ppb of NO_2. The net response observed was 8 ppb for an interference equivalent of 3.4%. Typical ambient NO_2 maximums are about 100 ppb, and so the ozone would be biased high by a few ppb. This again is small compared to the ozone maxima of 200 ppb.

3.2 Quality Assurance/Quality Control

3.2.1 Aircraft and LIDAR Intercomparison

Two comparisons with aircraft-borne ozone analyzers and a ground-based LIDAR were performed at the El Monte Airport. These were reported by the ARB external auditor (Fujita et al., 1998).

The first intercomparison was performed on June 11 and involved the UC Davis Cessna 182 equipped with a Dasibi model 1008 ozone analyzer and the ground-based LIDAR operated by the National Oceanic and Atmospheric Administration (NOAA). The UCD aircraft started a spiral up seven minutes after the ozonesonde was launched. Figure 3-8 shows the results for the aircraft and ozonesonde measurements. The two traces generally tracked one another, although the sonde value was higher at low altitudes and somewhat lower at higher altitudes. The air parcels did not appear to be well mixed, as the UCD down spiral performed immediately before the up spiral showed much higher concentrations. Figure 3-8 also shows the temperature profiles obtained from the ozonesonde and the UCD aircraft; the two are almost indistinguishable. Figure 3-9 compares the ozone measured with the LIDAR and the ozonesonde. The ozone measured by LIDAR was significantly higher than the ozonesonde's up to an altitude of 1,500m, when the LIDAR showed a rapid drop in ozone. This drop in concentration was not observed by the UCD aircraft.

Figure 3-8. Ozone Concentrations from the Ozonesonde Compared with the UCD Aircraft

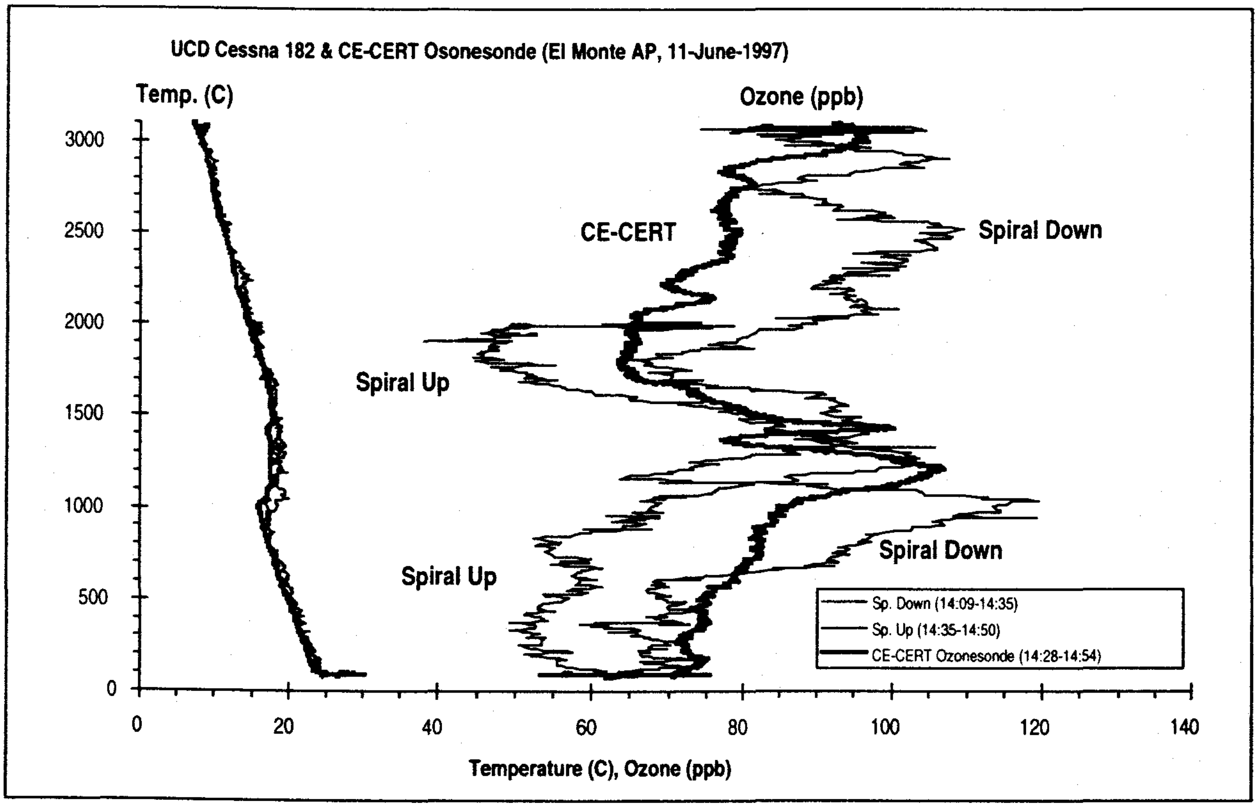
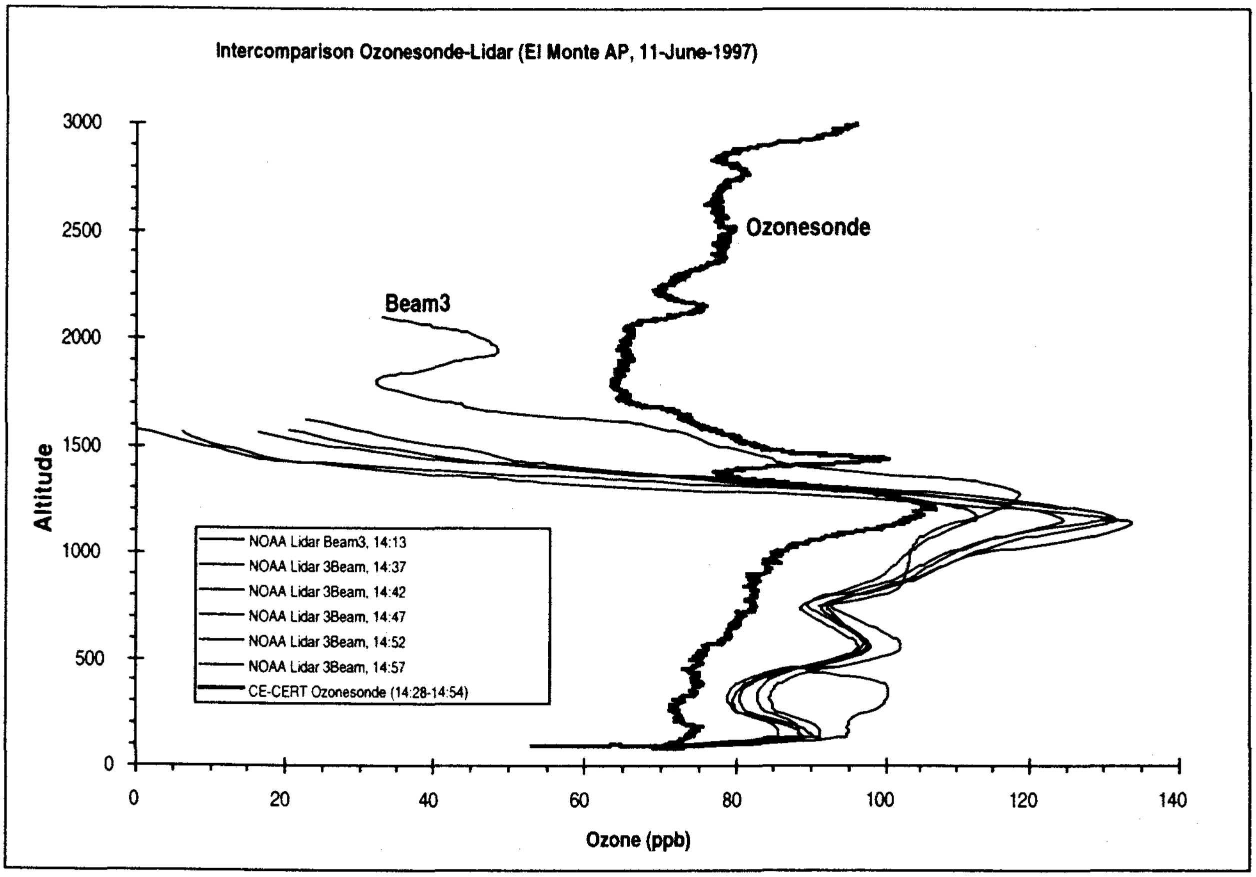


Figure 3-9. Ozone Concentrations of the Ozonesonde Compared with the LIDAR



A second comparison was made on July 8 and also included a Navajo aircraft operated by Sonoma Technology Inc. (STI). The sonde was launched as the aircraft started upward spirals and close contact was maintained. As Figure 3-10 shows, ozone concentrations from all four platforms were very similar to 500 meters MSL. All indicated an elevated maximum near 1,000 meters, although the UCD aircraft's peak was 20% lower. Above 1,500 meters the UCD aircraft and ozonesonde were in good agreement, showing a thick elevated layer with over 100 ppb ozone, the highest observed in the flight. The ozone measured by the LIDAR was nearly half as much. Figure 3-11 plots the temperature with altitude for two aircraft and the ozonesonde, and Figure 3-12 plots relative humidity. The temperatures are all within a degree at a given altitude. Although there was greater scatter for relative humidity, all three platforms showed a sharp decrease at the temperature inversion.

The results of these intercomparisons showed periods of agreement and disagreement between the methods. We conclude that the quality of the ozonesonde data is likely as good or better than the other methods.

Figure 3-10. Ozone Comparison between an Ozonesonde, the UCD and STI Aircraft, and a LIDAR

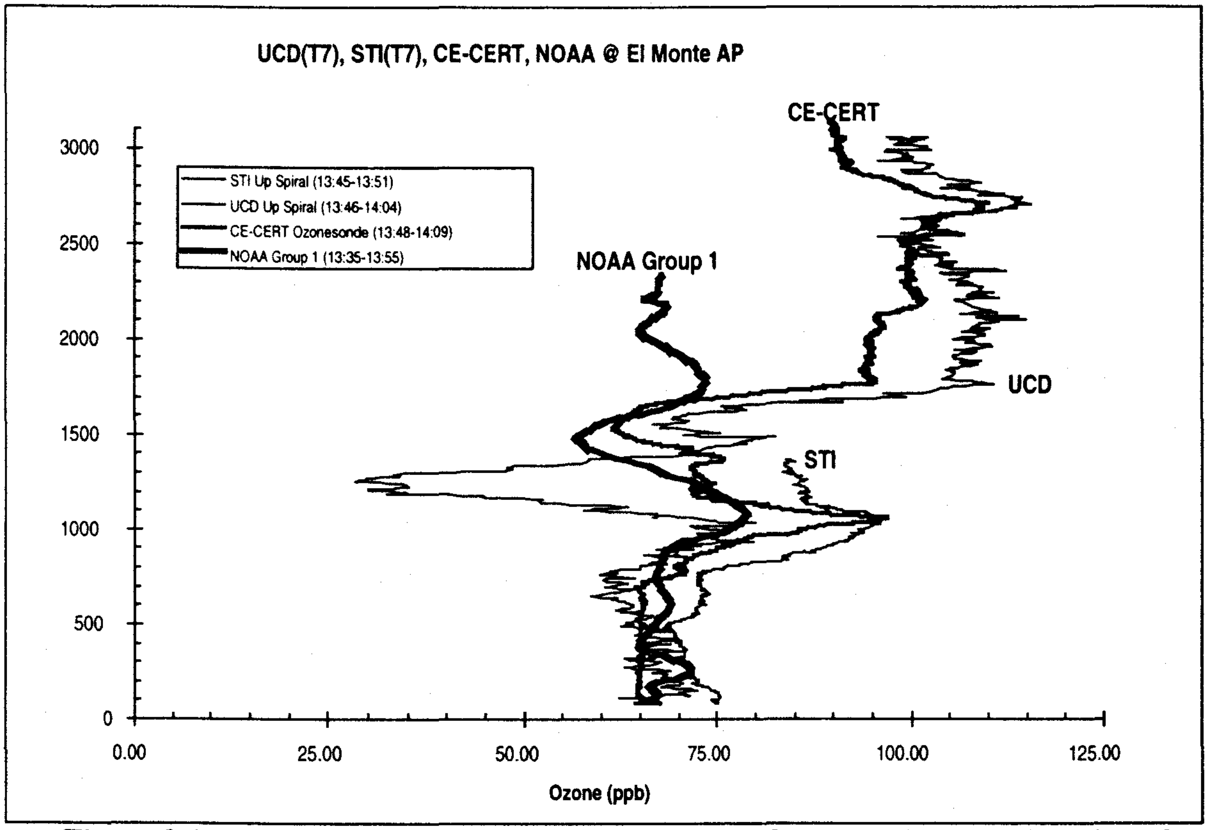


Figure 3-11. Temperature Comparison between an Ozonesonde, the UCD Aircraft, and the STI Aircraft

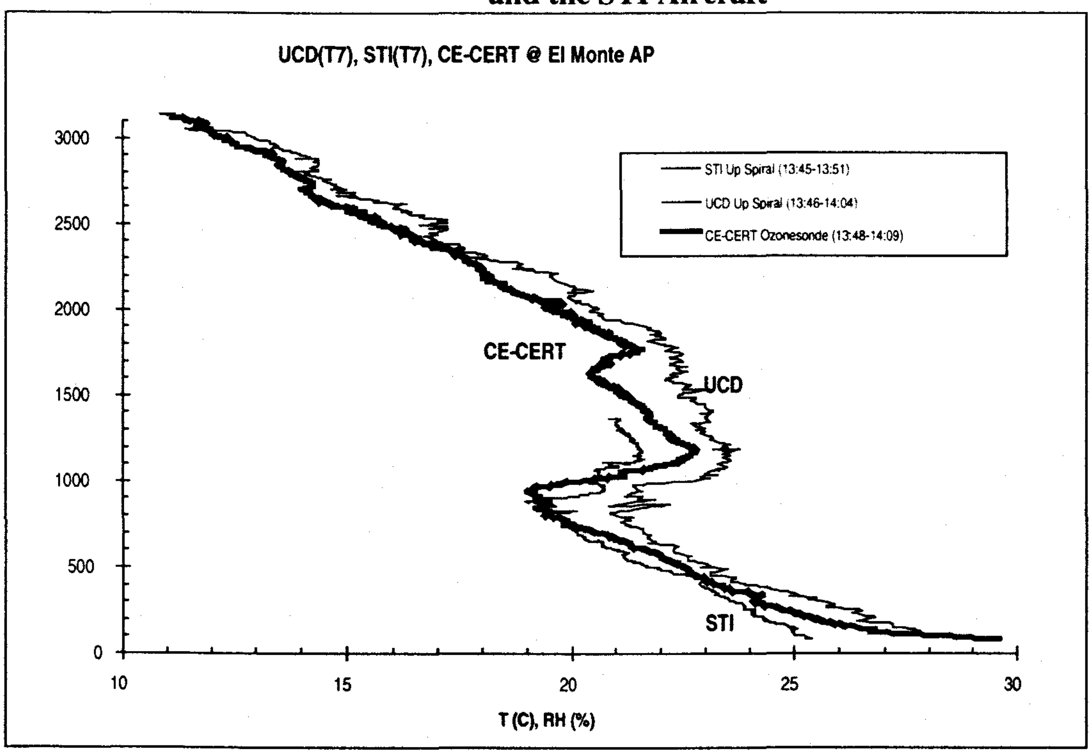
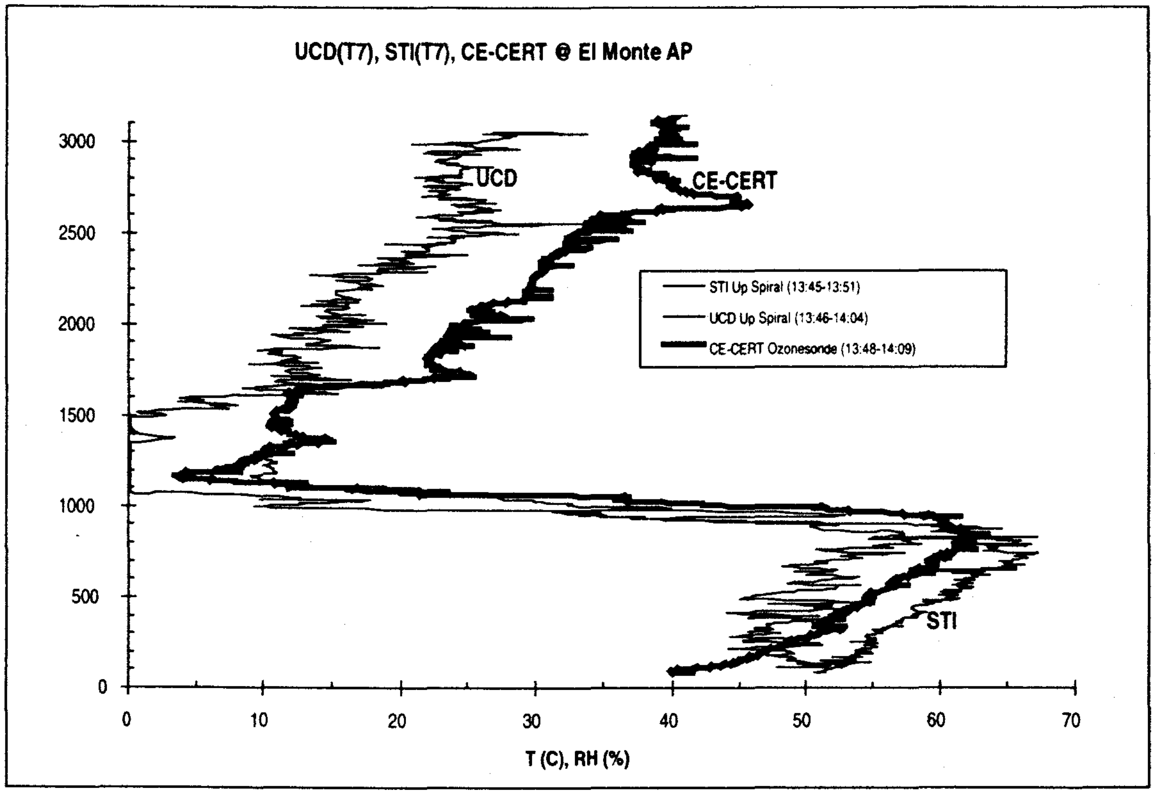


Figure 3-12. Relative Humidity Comparison between an Ozonesonde, the UCD Aircraft, and the STI Aircraft



3.2.2 Collocated Ozonesonde Fights

During the training sessions for ozonesonde launch teams, two sets of collocated launches were made. One pair of sondes was launched on 5/18/97 at 12:00, and one pair of sondes was launched on 5/18/97 at 15:00. Plots of the ozone, temperature, and relative humidity profiles from these launches are shown in Figure 3-13. The agreement between collocated sondes was excellent for both launch pairs. Temperatures agreed to with a few tenths of a degree; ozone generally agreed to within 1 or 2 ppb; RH showed differences of about 3 to 10% RH.

3.2.3 Ozonesonde Data Quality

Each ozonesonde was checked in the lab against an ozone transfer standard for zero and span before being shipped to the field. The means and standard deviations of the response to zero and to span are shown in Table 3-1. The spans are reported as percent of transfer standard ozone rather than as ppb, because the reference span value varied from day to day depending on ozone generator settings. The reference span value was approximately 100 ppb.

Figure 3-13. Collocated Ozonesonde Launch Results

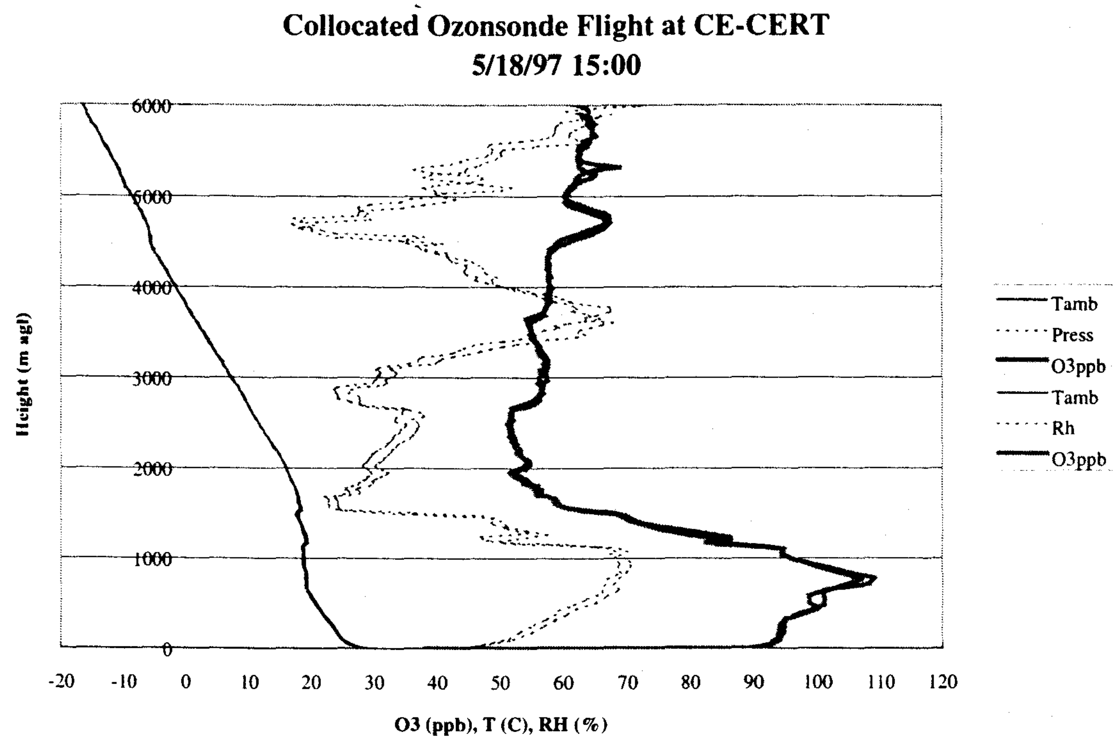


Table 3-1. Ozonesonde Accuracy and Precision

	Zero	Span
Mean	1 ppb	101 %
Standard Deviation	2 ppb	8 %

3.2.4 Ground Station Data Quality

Ground-based ozone analyzers were set up at California State University, Northridge (CSUN), and University of Southern California (USC) for use as a quality control check for ozonesondes prior to lunch. A third was established at Tehachapi Pass (TEHP) to acquire ozone data at that site. Table 3-2 shows the dates of the calibration checks for all CSUN and TEHP and summarizes the results. The calibration checks consisted of multi-point calibrations (6 points over the range 0 to 450 ppb) versus an ozone transfer standard. The ozone transfer standard was certified against CE-CERT's ozone primary standard. The slope and offsets were derived from linear regression of analyzer response versus transfer standard response. They are used as follows:

Transfer O_3 ppb = slope*(analyzer – offset)

Table 3-2. Ground Station Calibration and QC Checks

Site	Date	Slope	Offset	R^2
CSUN	8/18/97	1.377	6.9	0.9996
CSUN	9/3/97	1.317	42.8	1.0000
CSUN	9/22/97	1.471	21.3	0.9999
CSUN	10/10/97	1.359	18.0	0.9984
CSUN	Avg.	1.381	22.3	
CSUN	Std. Dev.	0.065	15.0	
TEHP	9/3/97	1.178	26.0	.9998
TEHP	9/15/97	1.180	12.3	.9997
TEHP	10/28/97	1.211	24.7	.9995
TEHP	Avg.	1.190	21.0	
TEHP	Std Dev	0.019	7.6	

Per the CE-CERT SOP, instrument gain controls were not adjusted; calibration factors were applied to the data in post processing.

No calibration checks were performed for the analyzer at USC. Therefore the absolute ozone values from this analyzer should be used with caution.

- **Tehachapi**

The first ozone calibration check visit to Tehachapi occurred on August 25, 1997. At this time, the analyzer was found to be malfunctioning. This analyzer was replaced on August 27. There are therefore no calibration checks for the first analyzer, but the audit results discussed below verify that the calibration was accurate prior to the analyzer failure. The remainder of the checks were for the second analyzer. Since the elevation-corrected responses were within 5% of the transfer standard response, the calibration checks were not used to adjust the data. A single response factor of 1.1469 was applied to all data from both analyzers. The precision was calculated as the larger of 5 ppb or 5%.

An audit was performed on August 4 by the ARB. Using an altitude correction factor 1.1469, the site ozone was 4% less than "true" ozone. At the time of the audit, there was no CE-CERT representative to give the altitude correction factor. The auditor used the instrument read-out rather than the data logger's altitude-corrected data. Since the instrument appeared to be outside the ±10% of true criterion, the site was reaudited on September 25. The analyzer had been replaced on August 27. The result of this audit, after correction for the altitude factor, was that the site analyzer was 2% higher than "true" ozone. Both analyzers therefore passed the audit criterion.

- **CSUN**

Multi-point calibration checks were performed four times on the Environics ozone analyzer at CSUN. The response slopes were consistent, and a single slope of 1.38 was applied to all data from CSUN. However, the calibration intercepts were variable. Review of time series plots and trials with the offsets from the calibrations showed that the offsets from the calibrations could not be used to correct the data. Instead, the baseline observed in the time series plots was fairly constant at about 24 ppb, with relatively brief periods of excursion. Therefore, a single baseline offset of 24 ppb was applied to these data. Precision for the data file was calculated as the larger of 10 ppb or 5%.

- **USC**

The Environics analyzer at USC performed erratically and eventually failed on August 27, 1997. Air conditioning failures at USC led to very high temperatures in the room where the analyzer was located. Based on review of time series plots, a single baseline offset of 20 ppb was applied to all of the data from the Environics analyzer. All of the Environics data is flagged as suspect. The failed analyzer was replaced with a Dasibi on September 19. By this time in the program, the weather was cooler and the air conditioning system was functioning better. This analyzer showed fairly constant baselines and reasonable diurnal patterns. Though the calibration of the Dasibi was not checked, the Dasibi instruments are inherently accurate based on first principles, and do not require a calibration except to check that they are functioning correctly. The elevation correction at USC, 1.01, is minimal and was not applied. A single offset of 12 ppb was applied to data from the Dasibi. Precision was calculated as the larger of 10 ppb or 10%.

3.3 Data Validation

3.3.1 Ozonesonde

Ozonesondes were launched at 45 time periods during the SCOS97, resulting in a potential of 270 launchings for the six sites. A total of 14 scheduled flight times produced insufficient data to be called successful. These include several flights at Pomona that did not occur due to harassment by local hoodlums or were canceled because of the threat of harassment. The overall data capture was therefore 95%.

Data validation and data processing included the following activities for each ozonesonde flight record:

1. Laboratory data sheets were reviewed to confirm that the sonde was functioning properly before being shipped to the field.
2. Field data sheets were reviewed to confirm that sonde was functioning properly immediately before being launched.
3. The text data files were reviewed to ensure that the dates and times recorded by the sonde data acquisition system matched the sonde launch date and time recorded by the field team. Discrepancies were corrected.

4. The text data files were reviewed to ensure that background (zero air) response was within tolerance and that background offset was set to zero by the field team. Discrepancies were corrected.
5. The text data files were imported into Excel.
6. The files were reviewed to check for missing data caused by ozonesonde pump temperatures above 41 degrees C. Early versions of the ozonesonde data acquisition software reported missing ozone values in the text data files when the ozonesonde pump temperatures exceeded this level. When this occurred, the raw binary data files, which did not suffer from this problem, were used to generate 1.2-sec time resolution text files. The 1.2-sec resolution files were read into Excel, and averaged into 15-sec. time resolution files, comparable with the data from normal flights.
7. The Excel data files were reviewed to ensure that ground station pressure was within tolerance for the site. Discrepancies were corrected. The discrepancies were due to misplaced flight-start markers in the text data files (i.e., the operator did not press "Flight Mode" until well after releasing the balloon). Data were fully recovered from the "Surface Mode" data acquired prior to pressing "Flight Mode."
8. Height above ground was calculated incrementally from pressure and temperature increments in Excel using the following formula:

   $\Delta H = (287.05/9.80665)*\Delta P*T_{avg}/P_{avg}$;
   where:
   ΔH = height increment (meters)
   ΔP = pressure increment (millibars)
   T_{avg} = average temperature (K)
   P_{avg} = average pressure (millibars)

9. Ozone ppb was calculated from ozone partial pressure in nanobars using the following formula:
   (O3 ppb) = (O3 nb) * 1000 / (Pressure mb)
10. Height was plotted versus ozone, temperature and RH to an altitude of 6,000 m above ground level.
11. The plots were reviewed for smooth progression of ozone and meteorological parameters with height. This insures that the data received is from the ozonesonde launched and that the ground station did not start tracking another ozonesonde. Discrepancies were corrected by deleting ozone and RH data, and using linear interpolation to fill in missing pressure and temperature values. The interpolated temperature and pressures were needed to calculate height. The plots for flights with data dropouts will therefore show a continuous record for temperature, and will show gaps for RH and O_3.
12. The data files were combined and reformatted to conform with SCOS97 database requirements. The data set was delivered in two formats: a single comma separated text file containing all data, and a set of individual Excel files with profile plots containing one flight each.

3.3.2 Ground Stations

Ground station data for ozone, temperature, RH, wind speed, and wind direction were plotted as time series and reviewed visually. Extended periods during which the analyzer response did not follow reasonable diurnal patterns were judged to be due to analyzer malfunction, and those periods were marked as invalid. Sharp spikes and short-term deviations from expected diurnal patterns were flagged as suspect.

- Tehachapi

In addition to the flagging based on review of time series plots, two other sets of flags were applied, one based on wind speed and one based on shelter temperature. Wind direction data from Tehachapi were flagged as suspect when the wind speed was below 1 meter per second. Ozone data from Tehachapi were flagged as suspect when the shelter temperature was lower than 15 or higher than 25 degrees C. The air conditioner became inoperative during periods of high ambient temperature that caused the circuit breaker to trip. This problem was resolved on August 27 by replacing the circuit breaker with one of greater amperage. Later in the study, the shelter temperature became cold at night because the shelter was not equipped with a heater.

The Dasibi ozone analyzer can operate correctly over a large temperature range, the manual specifies 0-50 °C. However it is a photometric absorption measurement based on Beer's Law, and thus has a response that is directly proportional to cell pressure and inversely proportional absolute temperature (i.e., directly proportional to air density in the cell). The instruments that we employed were not corrected for fluctuations in cell temperature and pressure. A temperature fluctuation of ±5 degrees C results in a corresponding response fluctuation of less than ±2%, which is negligible. We flagged data outside a ±5 degree range because the response shift caused by temperature starts to become large enough that it should be compensated for. We chose 20 degrees C as the center of the range because the instrument was calibrated near this temperature and because this range encompasses the large majority of the data. The data flags beyond this temperature range do not indicate analyzer malfunction, but only serve as a warning that the inverse response to temperature should be considered before using this data.

The Quality Assurance Handbook for Air Pollution Measurement Systems, Vol. II (EPA, 1994) suggests that shelter temperature be held between 20 and 30 degrees C. It also suggests that the temperature should fluctuate no more than ±2 degrees C, which therefore implies that the mean shelter temperature should be set to a value between 22 and 28 degrees C. Due to air conditioning failure and lack of a heater, we were not able to conform to these suggestions. Because this is a research program, and not compliance monitoring, failure to meet the EPA suggested conditions does not invalidate the data. We extended the temperature range from ±2 degrees °C to ±5 degrees C and used a center temperature of 20 degrees C. The effect of these modifications is to increase the uncertainty associated with temperature fluctuations from 0.7% to 1.7%.

Table 3-3 shows the data capture results at Tehachapi. The 11% of ozone data flagged as suspect is almost entirely due to shelter temperature exceeding the range 15 to 25 degrees C. The 27% of ozone data flagged as invalid consists primarily of the three-week period prior to August 27, during which the analyzer was malfunctioning. The 11% of wind direction data flagged as suspect is due to wind speeds near or below the threshold for proper operation of the wind vane. If the low wind speed periods are considered "calm," then the meteorological data capture is 100%.

Table 3-3. Data Capture at Tehachapi

Parameter	Qcflag CL	IV	SS	VD	No. of Hrs
O_3	0%	27%	11%	62%	2001
RH				100%	2001
SGT		0%		100%	2001
TMP				100%	2001
WDV		0%	11%	89%	2001
WSA		0%		100%	2001

Precision for ozone was estimated as the larger of 5 ppb or 5%. Precisions for the meteorological equipment was estimated as follows:

Relative humidity	(RH)	10%
Temperature	(TMP)	0.5 C
Wind direction, unit vector average	(WDV)	5 deg
Wind speed, scalar average	(WSA)	0.2 m/s
Sigma theta	(SGT)	-99

- California State University Northridge

Table 3-4 shows the data capture and the peak hourly ozone values on IOP days at CSUN. Table 3-2 showed the calibration and QC check data. This Environics analyzer performed reasonably well throughout the course of the study. Response to dry zero air demonstrated a large variation in zero offset during the calibration checks, but time series plots of the ambient data indicate that a single zero offset of 24 ppb is reasonable. The internal offset on this analyzer was set to 25 ppb; due to a slight offset in the A/D converter, the data logger recorded the analog offset response as 24 ppb. To calibrate this data set we used the average slope of 1.3038 from the calibrations and span checks, but we ignored the offsets from these checks and used instead the internally set value of 24 ppb. This brought most of the nighttime ozone minima to within 2 ppb of 0.0, though there is a two-week period in late July where minima reach as low as –9 ppb. Precision was estimated as the larger of 10 ppb or 5%.

Table 3-4. Data Capture and Maximum Ozone at CSUN Ground Station

	Qcflag			Max
Date	IV	VD	Total	O_3 ppb
970714		24	24	64
970804		24	24	96
970805		24	24	142
970806		24	24	121
970828		24	24	74
970829		24	24	104
970904		24	24	87
970905		24	24	65
970906		24	24	76
970928		24	24	85
970929		24	24	112
971003		24	24	99
971004	14	10	24	59
Total	14	298	312	
Percent	4%	96%	100%	

- University of Southern California.

Table 3-5 shows the data capture and the peak hourly ozone values on IOP days at USC. The Environics analyzer was located in a room in Hancock Foundation building where the air conditioning was marginal at best, and frequently failed. This analyzer performed erratically and eventually failed completely around August 27. It was replaced with a Dasibi analyzer on October 19. This analyzer performed reasonably well through the end of the study. Precision was estimated as the larger of 10 ppb or 10%.

Table 3-5. Data Capture and Maximum Ozone at USC Ground Station

	Qcflag Counts				Max
Date	IV	SS	VD	Total	O_3 ppb
970714	24			24	-99
970804		2	22	24	77
970805			24	24	97
970806			24	24	58
970822			24	24	68
970823			24	24	81
970904	24			24	-99
970905	24			24	-99
970906	24			24	-99
970928			24	24	114
970929			24	24	51
971003			24	24	55
971004			24	24	60
Total	96	2	214	312	
Percent	31%	1%	69%	100%	

3.4 Data Summary

Due to the large amount of data collected it is not feasible to present all of the data in this report, nor would it be useful for a data analyst to review it in hardcopy. All data have been transferred to the ARB-database using the specified format. In this section we will review the data and present general characteristics.

3.4.1 Ozonesonde

Nearly 300 soundings were completed, producing ozone, temperature and RH as a function of altitude. Figures 3-14 though Figure 3-17 show composited data for each site at a given launch time. One noticeable feature of all of these soundings is that the background ozone concentration above the inversion is approximately 60 ppb. Figure 3-14 shows the sounding taken at 02:00 PDT. All of the sites show depleted ozone at the surface and a mild temperature inversion between 500 and 1,000 meters AGL. Rather than enhance ozone concentrations aloft, there is an indication of depleted (with respect to the background) layers between 1,000 and 2,000 meters AGL. Figure 3-15 shows the soundings at 08:00 PDT. These are similar to those obtained at 02:00, but the ground inversion is more sharply defined. The 14:00 hour soundings presented in Figure 3-16 show some depleted ozone at the ground, but unlike the morning sounding the concentrations are well above zero. At all sites the peak ozone is above ground level, typically between 100 and 800 meters above the ground. Only small temperature inversions are observed, although this may be due to the compositing of the data. Most of the elevated ozone concentrations (with respect to the background) are found below 1000 meters above the ground. Figure 3-17 shows the composited data at 20:00 hours PDT. A distinct surface inversion has formed and the ground ozone has been depleted. The peak ozone is generally found at 1,000 meters above ground level. Table 3-6 shows the peak ozone concentration for each flight.

Figure 3-14. Composited Data for 02:00 PDT.

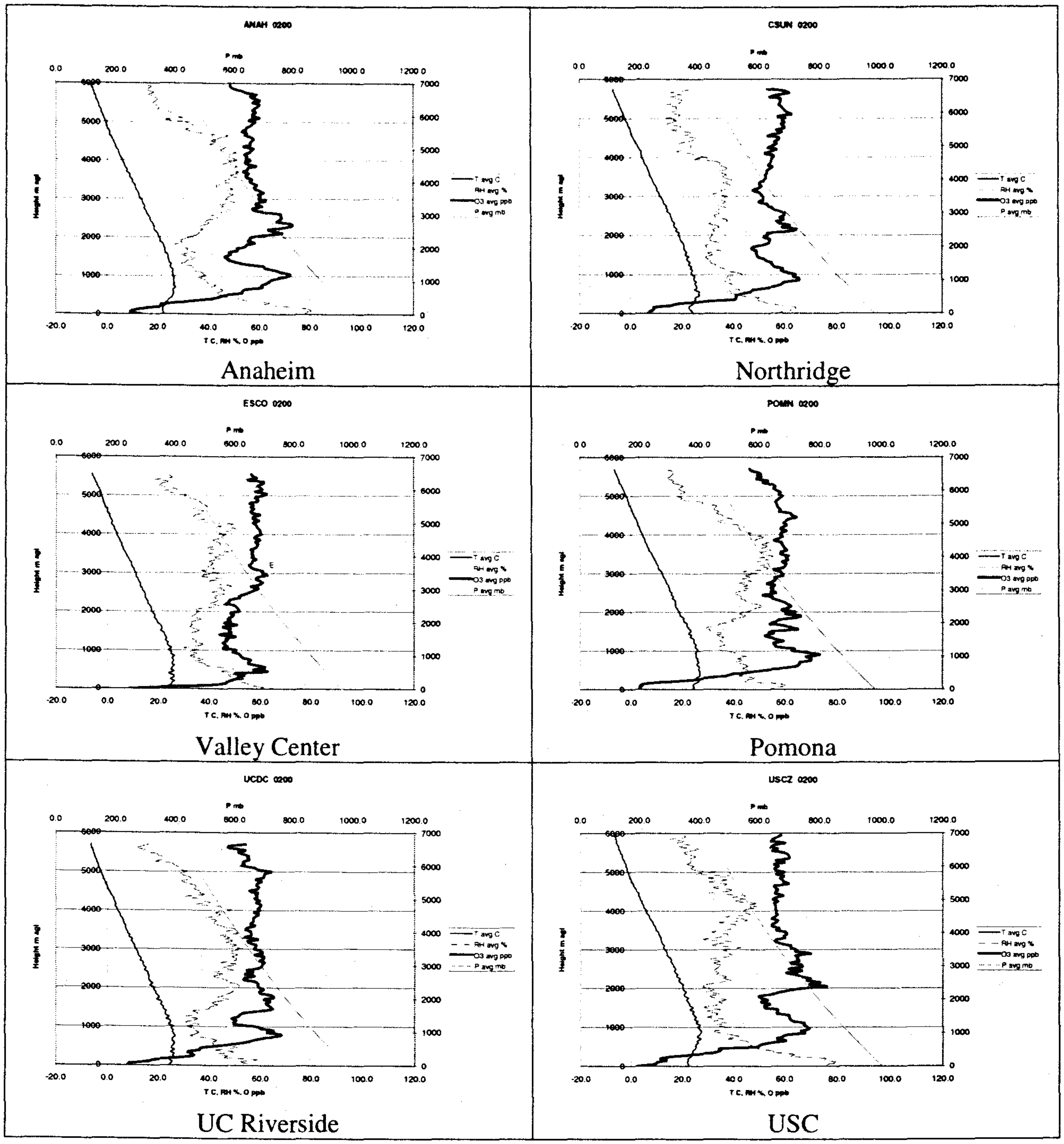


Figure 3-15. Composited Data for 08:00 PDT

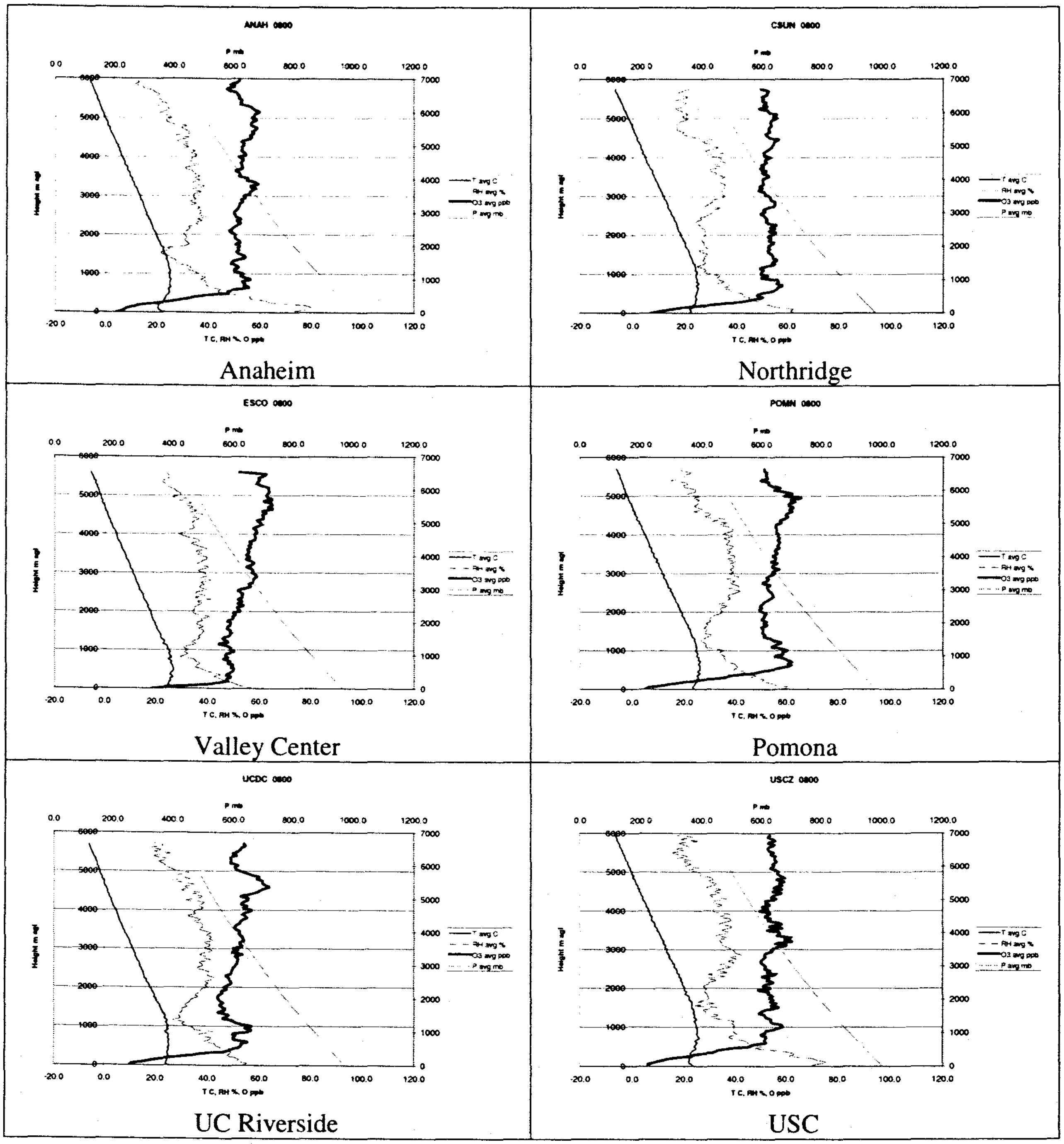


Figure 3-16. Composited Data for 14:00 PDT

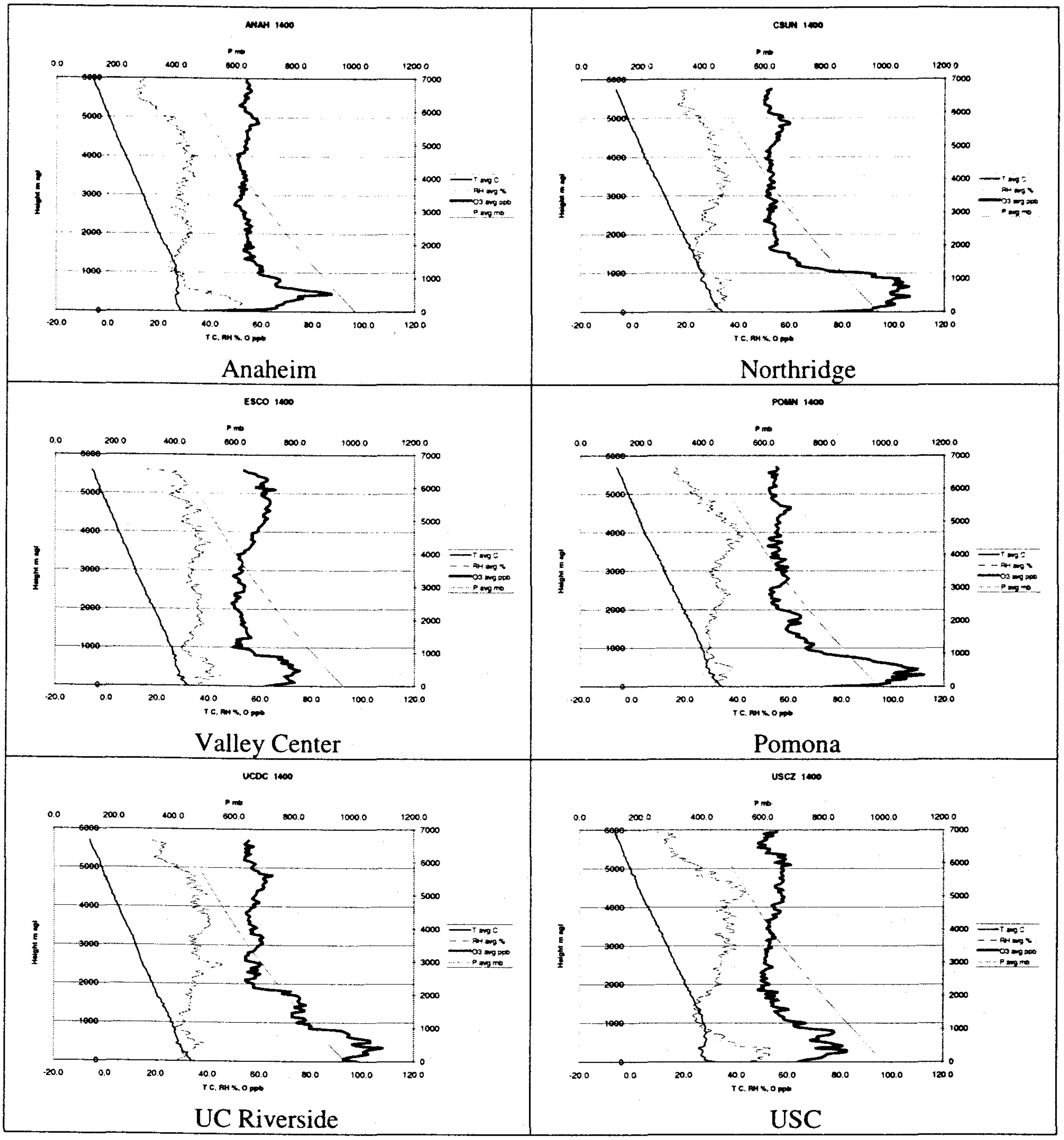


Figure 3-17. Composited Data for 20:00 PDT.

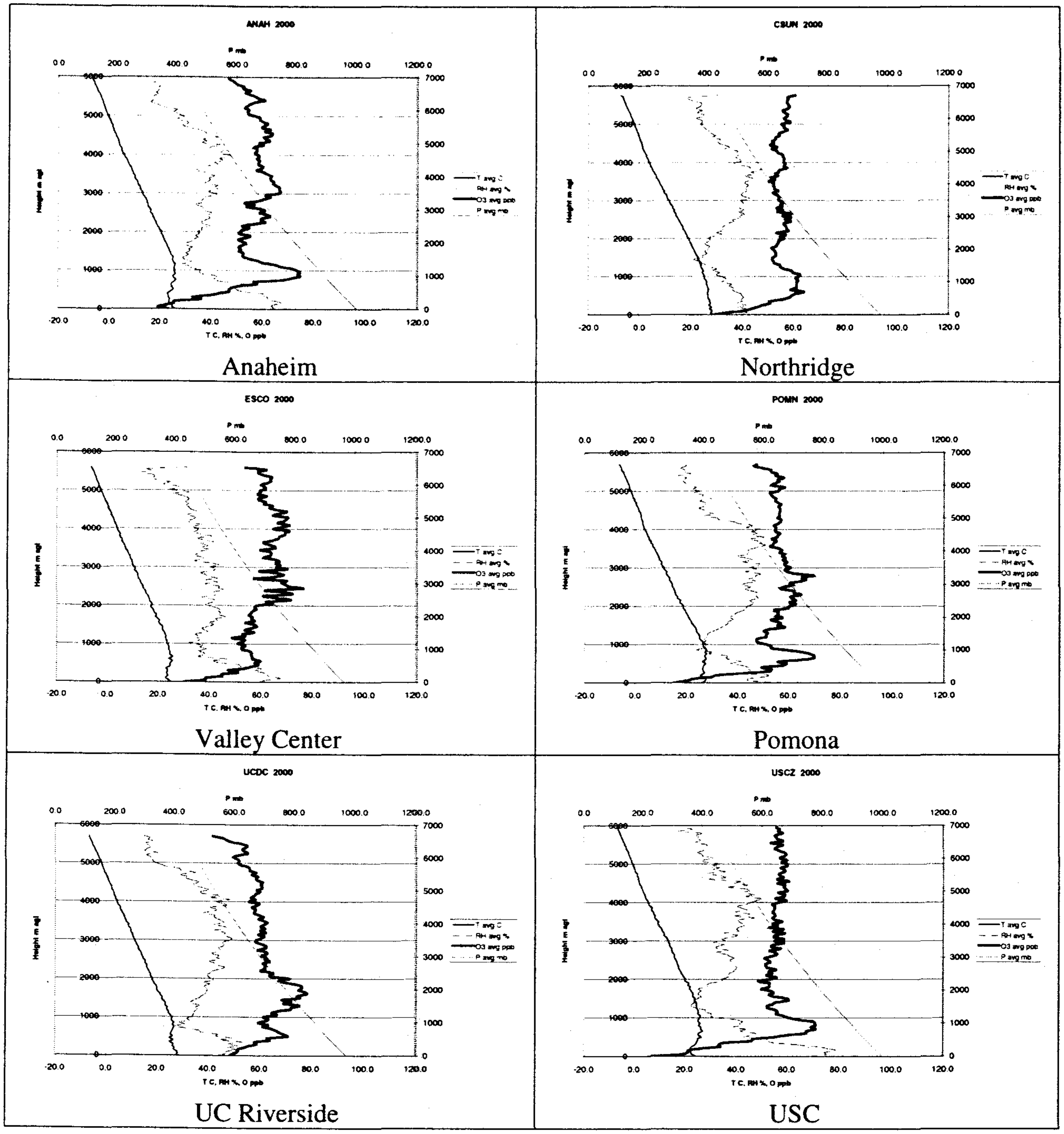


Table 3-6. Maximum Ozone Concentrations (ppb)

O_3 Max ppb		Site						
Date	Target Start	ANAH	CSUN	ESCO	POMN	UCDC	USCZ	Grand Max
970714	0800	69	68	—	73	93	72	93
	1400	80	91	86	77	102	—	102
970804	0800	80	70	82	82	67	75	82
	1400	133	118	81	127	119	103	133
	2000	101	85	86	144	133	—	144
970805	0200	140	132	73	142	111	174	174
	0800	110	97	83	92	80	112	112
	1400	147	137	89	166	—	132	166
	2000	105	89	—	112	148	102	148
970806	0200	79	60	87	79	78	74	87
	0800	76	88	88	75	64	73	88
	1400	93	125	88	131	149	99	149
	2000	101	126	96	—	118	105	126
970822	0800	54	62	67	62	51	55	67
	1400	54	135	69	67	83	89	135
	2000	—	67	75	157	132	99	157
970823	0200	93	65	71	89	92	86	93
	0800	71	81	79	88	71	74	88
	1400	78	126	74	111	147	88	147
	2000	165	81	75	117	93	90	165
970904	0800	98	76	54	97	52	91	98
	1400	116	84	80	102	102	130	130
	2000	117	84	85	74	95	79	117
970905	0200	89	91	80	90	77	87	91
	0800	85	74	87	84	63	87	87
	1400	109	59	86	105	110	74	110
	2000	67	58	94	71	66	78	94
970906	0200	78	64	90	74	84	82	90
	0800	80	75	93	84	85	73	93
	1400	86	61	93	103	96	82	103
	2000	86	61	92	88	97	51	97
970928	0800	70	51	65	78	60	—	78
	1400	107	79	110	133	64	127	133
	2000	101	101	69	124	83	—	124
970929	0200	102	100	71	—	87	102	102
	0800	81	87	72	74	74	87	87
	1400	102	137	81	85	—	81	137
	2000	120	94	103	79	102	90	120
971003	0800	98	89	90	94	94	124	124
	1400	99	85	87	86	88	85	99
	2000	91	83	218	91	88	92	218
971004	0200	82	105	95	80	81	81	105
	0800	72	67	84	71	—	71	84
	1400	85	122	78	97	124	108	124
	2000	110	—	92	—	103	105	110
Grand Maximum		165	137	218	166	149	174	218

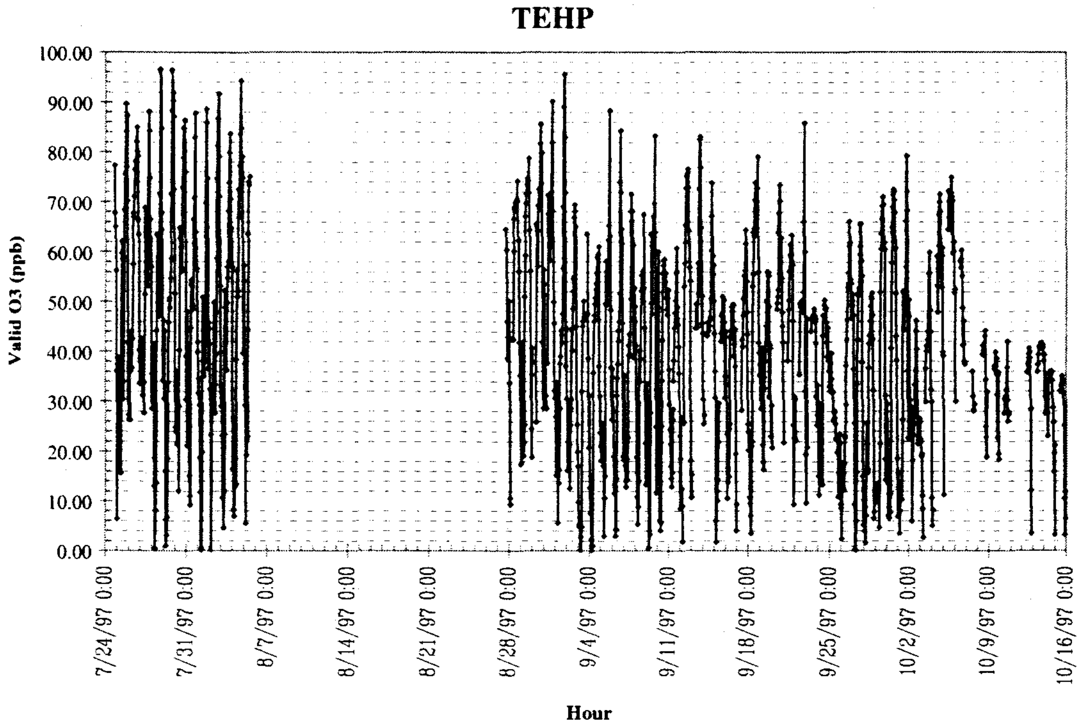
— = missing data

3.4.2 Ground Station

- Tehachapi Pass

Figure 3-18 shows the ozone concentrations from July 24, the date of installation, to October 15. Ozone concentrations follow a typical diurnal profile, peaking at 80-100 ppb during the daytime and reaching a minimum of 0-40 ppb at night. This is behavior expected from a rural location that may be subject to some scavenging from local traffic.

Figure 3-18. Tehachapi Ozone Concentrations



- California State University, Northridge

Table 3-4 shows the peak hourly average ozone concentrations on IOP days at CSUN.

- University of Southern California

Table 3-5 shows the peak hourly average ozone concentrations on IOP days at USC.

4.0 Conclusions and Recommendations

4.1 Conclusions

This project has resulted in the determination of the vertical extent of ozone for Southern California when higher-than-normal concentrations of ozone were predicted. The most notable result is that peak ozone is almost never observed at ground level and that concentration aloft may be significant higher.

4.2 Recommendations

The response time of the ozone sondes is approximately 40 seconds (for 1/e response) and data were reported as 15-second averages. At a typical ascent rate of 2 m/sec, the resolution is approximately 100 meters. This could be improved somewhat by using the 2 second data received from the sonde and applying an algorithm to interpolate concentration.

5.0 References

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