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Aircraft Measurements in Support of the 1997 Southern California Ozone Study

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

AIR RESOURCES BOARD
Research Division

AIRCRAFT MEASUREMENTS IN SUPPORT OF THE 1997 SOUTHERN CALIFORNIA OZONE STUDY

FINAL REPORT
CONTRACT NO. 95-332

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ABSTRACT

During the summer of 1997, an instrumented aircraft was deployed by the University of California at Davis (UCD) to measure meteorological and air quality variables along the foothills north and east of Central Los Angeles. This was part of a larger effort, the 1997 Southern California Ozone Study - North American Research Strategy for Tropospheric Ozone (SCOS97). Data and air samples were collected during six intensive operational periods (IOP) covering fifteen intensive operational days. Instrument calibrations showed all measuring systems operated well within design limits and generally all data are of high quality. One exception is with the oxides of nitrogen analyzer which did not correct for non-standard temperature and pressures. However, in most instances when significant levels of nitrogen oxides were measured these environmental variables were close to their standard value. The acquired data have been delivered to the California Air Resources Board (ARB) in two formats and software to facilitate viewing these data have been developed and provided as well.

EXECUTIVE SUMMARY

To further understand air pollution production and distribution in the Los Angeles Basin, the ARB, the US Environmental Protection Agency, and local air pollution control districts conducted an intensive data gathering study during the summer and early fall of 1997. Numerous data gathering methodologies were used to record air pollution concentrations and meteorological variables in and around the Los Angeles Basin. Included in these methods were several light aircraft configured to provide air pollution measurements.

UCD operated an instrumented aircraft along the northern portion of the Los Angeles Basin. Thirty six flights during six different IOPs along with intercomparison and transit flights to and from the study area were conducted. Measurements were made of NO, NOy, ozone, and particle concentrations along with meteorological variables. In general, two or three fights were made during each day of an IOP. These flights began in the early morning to capture the initial conditions for the day. Subsequent flights were made to characterize the nature of air pollution production and distribution changes throughout the day.

Vertical spirals connected by upward slanting and horizontal transects were made at six different locations on each flight in order to determine both vertical and horizontal distributions of pollutants. The initial and concluding spirals at El Monte airport provided the added function of allowing for intercomparison data between two aircraft and a ground-based lidar system operating at El Monte airport.

The six IOPs had differing mesoscale meteorological patterns, yet some air pollution distribution characteristics were similar for most IOP cases. In the early morning, a low surface layer consisting of moderate concentrations of nitrogen oxides and particles existed, while ozone concentrations were very low. The converse was generally true aloft with high ozone concentrations existing, but low amounts of NO, NOy, and particles. During the day the mixed layer would develop allowing increased concentrations of ozone near the surface while NO and NOy decreased. Generally, the highest ozone concentrations were found aloft with the highest observation of ozone (214 ppbv) occurring over El Monte near 800 m.

The operation of the UCD aircraft was highly successful with excellent deployment and data recovery rates. The six IOPs produced different distribution results which will make for a useful data set in examining and modeling various scenarios of air pollution production and distribution in the Los Angeles region.

INTRODUCTION

The ARB has determined that the Urban Air Shed model applied to southern California sometimes fails to reproduce observed concentrations of air pollutants. To better document the nature of these discrepancies and to better understand why they occur, an intensive data gathering effort was conducted during the summer and early fall of 1997. Multiple ground-based remote sensing technologies in the form of radar wind profilers (RWP), radio acoustic sounding systems (RASS), and differential absorption laser systems (DIAL) were used. These systems, especially the DIAL systems, are limited in number and their measurements were supplemented and verified by aircraft sampling flights. The air pollution research group at UCD has operated instrumented light aircraft for several years to map pollution distributions (Carroll and Baskett, 1979; Carroll and Dixon, 1990; Carroll, 1994; Carroll and Dixon, 1998) and to make comparisons with remote sensing systems (Carroll and Zhao, 1994; Carroll and Dixon, 1997). The use of the UCD aircraft in the SCOS97 study was instrumental to understanding the air pollution distribution in the northern part of the Los Angeles Basin and as a reference platform for intercomparisons of two DIAL systems and four instrumented aircraft.

The primary task of the UCD group in this study was to collect in situ meteorological and air quality data using an instrumented aircraft along the northern boundary of the central Los Angeles Basin, the area shown in Figure 1. The instrumentation used is listed in Table 1 and the variables measured are listed in Table 2. UCD also provided a similar set of instruments and data acquisition and processing software to the San Diego County Air Pollution Control District for installation in a second aircraft. In addition, the UCD aircraft served as the reference aircraft for comparison with systems in several other aircraft and for comparison with ground-based remote sensing lidar systems. Shortly before the field study, the tasks of collecting samples for laboratory analysis of reactive organic gases (ROGs) and carbonyls were added.

As our work was part of a much larger effort, several tasks that we would normally perform ourselves were delegated to other participants. The Desert Research Institute of University of Nevada, Reno (DRI) was responsible for developing quality assurance and quality control procedures for the whole program (Fujita et al., 1997). Our procedures were coordinated with them and all calibration data, intercomparison data, and audit data were transferred to DRI for evaluation and archiving. The College of Engineering-Center for Environmental Research and Technology (CE-CERT) at the University of California, Riverside was responsible for acceptance testing of several newly purchased air pollution monitors, for providing the ROG and carbonyl sampling equipment and media, and for transferring samples to the appropriate laboratories for analysis. UCD installed the sampler hardware in the aircraft and modified its design when it became clear that the initial carbonyl sampling system did not provide an adequate quantity of material for analysis.

Flights were conducted on 25 different days between June 11 and October 4, 1997 (cf. Table 3). Fifteen of these days were full intensive observation periods (IOPs). Several of these flights were intercomparison or test flights or transit flights between Davis and Los Angeles. The aircraft intercomparisons were performed with the Sonoma Technology Inc. Piper Aztec and a Piper Navajo and Cessna 182 from Gibbs Flying Service of San Diego. Lidar intercomparisons included two days with the Pennsylvania State University system located near Victorville, CA. An ozone lidar operated by the National Oceanic and Atmospheric Administration (NOAA) was located at the same airport (El Monte) from which UCD operated, making intercomparison data available at the beginning and end of each operational flight.

AIRCRAFT INSTRUMENTATION

A compact high-quality instrumentation system has been developed at UCD for installation on light aircraft. For the study, a Cessna 182 was outfitted with the instrumentation listed in Table 1. The temperature, relative humidity and airspeed sensors are mounted approximately half way up the right-hand strut of the aircraft. A 0.64 cm diameter Teflon tube enters the aircraft through the cabin ventilation system and supplies the ambient gas sample to the ozone analyzer. A 1.3 mm diameter metal tube points into the air flow from the leading edge of the right wing and feeds air directly to a particle counter. This provides isokinetic sampling at airspeeds of 50 ms^{-1}. Please note that we do not report the particle data when the airspeed varied by more than ±15% from the isokinetic sampling speed.

The intake for the NO/NOy analyzer is a short length (< 10 cm) of 1.3 cm diameter Teflon tubing protruding outward, perpendicular to the right side cabin wall, which supplies two samples to the analyzer. One is an unaltered sample (NO) plumbed directly to the analyzer. The second (NOy) enters a high temperature (> 300°C) reactor located about 15 cm from the external sampling point, with the reactor outflow then plumbed to the analyzer. The strut-mounted instruments and ozone and particle sampling tube inlets are configured in such a way as to be well outside of the propeller slipstream and aircraft exhaust. The NO/NOy inlet is within the propeller slipstream but is clear of the engine exhaust and beyond the aircraft surface boundary layer.

A pressure transducer, precision magnetic heading detector, global positioning system (GPS) components, and the data acquisition system are located within the cabin or fuselage. Data acquisition is accomplished by using a small personal computer (Pentium II, 166 MHZ) and a 16 channel analog to digital converter.

The meteorological variables are sampled at 10 Hz and averaged for the data record interval. During an IOP, data were recorded every three seconds. Due to the sampling cycle of the pollutant gas monitors, these data are essentially 10 second averages of the gaseous pollutants. The GPS position data are recorded in a separate file at 10 second intervals during an IOP. During transit flights between Davis and El Monte, the sampling was usually set at 10 seconds for the meteorological instruments and 30 seconds for the GPS data.

CALIBRATIONS AND QUALITY CONTROL

Periodic calibration of the ozone and nitrogen oxides analyzers was performed as shown in Tables 4 and 5, respectively. For ozone, the transfer standard (Dasibi 1008 PC model) was initially certified for this project on 4/25/97 by the ARB laboratory in Sacramento. For the nitrogen oxides analyzer, a calibrator which provides precise mixing of pure air with known concentration of NO was provided to us by CE-CERT. Full calibrations were performed prior to and after each IOP. Partial calibrations were performed between flights during the IOP on a daily basis. The ozone analyzer recorded ozone concentrations 9 ppbv higher than actual due to an intentional 9 ppbv offset used to observe negative values. Any negative values that occurred would not be recorded in the data acquisition system unless an offset was used (Dasibi, 1990, Section 6.6.4). This offset was removed during data processing.

Temperature and relative humidity instruments were calibrated at the beginning and end of IOPs using a transfer standard with a National Bureau of Standards traceable calibration history. The calibration data are shown in Tables 6 and 7. The maximum difference in temperature was less than 0.8 °C and generally less than 0.5 °C. The relative humidity sensor was calibrated before the project using a salt bath type calibration which had good agreement at the higher relative humidity values, but differed at the lower values. Compared with the transfer standard, the relative humidity sensor was generally within about 10% at the values normally encountered during the experiment.

Audits of the ozone and NOy instruments, conducted by the ARB on 6/10/97 and 6/13/97, showed the ozone analyzer, on average, to be within 1.3% of the true value. The NO_2 audit concluded that the nitrogen oxides analyzer was within 4.6% of the true value.

At the conclusion of the IOPs, CE-CERT did a final audit of the ozone and nitrogen oxides analyzers. The results of this audit indicated that the ozone measurements were 6 percent low and the NO/NOy measurements were approximately 5-8 percent low.

While these calibrations and audit results show that the instrumentation was well within specifications and free of major errors, there is a problem with the oxides of nitrogen data. The rate of the gas phase reaction $NO + O_3 \rightarrow NO_2 + O_2 + h\nu$ depends on the temperature and pressure in the reaction chamber. Since the concentration of NO is detected as the total number of photons emitted per unit time, the calibrations assume a standard temperature and pressure for this reaction. In addition, the internal electronics used for photon counting have a temperature dependent response as well. Therefore, if the analyzer is operated at a nonstandard pressure (i.e. altitudes greater than 50 m) or at a nonstandard temperature, the reported concentrations will be in error. The instrument design assures that following sufficient warmup, the internal temperature of the analyzer can be maintained at its "standard" value as long as the temperature of the instrument's environment does not exceed about 30 °C. The manuals provided by the manufacturer describe how to activate automatic corrections for nonstandard pressures and temperatures using internal pressure and temperature sensors. These options were selected, the output of these sensors verified and the automatic corrections were assumed to be working. Only some weeks after the end of the field program was it learned that actual implementation of these corrections required a factory installed option, that was never ordered. As a result, when the altitude reaches about 1500 m (5000 ft, all altitudes are MSL unless otherwise stated), the indicated NO and NOy concentrations are 20% too low. Similarly, if the analyzer temperature were 10 °C higher than the standard value, the indicated concentrations are likely to be 20% too low as well. While the means to calculate the chamber pressure from the known ambient pressure are available, the analyzer temperature is not easily corrected because it is not uniquely dependent on the ambient air temperature. At this writing, the NO and NOy data have not had any corrections for non-standard reaction cell temperature or pressure applied. UCD and ARB staff are attempting to develop suitable corrections. Currently, it is believed that if the altitude is less than 460 m (1500 ft) and the outside air temperature is less than 33 °C, that the temperature and pressure errors in the NO and NOy data are each less than 5%.

AIRCRAFT OPERATIONS AND DATA ACQUISITION

At the beginning of each flying day, the sampling instruments are turned on and warmed up prior to aircraft departure. The ozone instrument requires approximately fifteen minutes and the nitrogen oxides analyzer requires about 45 minutes of warm up. These instruments are powered by an external power source during the warm-up period. During this time, the aircraft is prepared for the flight. The time, date, location, and flight information are recorded on a cassette tape. The instruments are checked by running UC-TEST which displays the current values to the screen every few seconds.

During flight, power to the instruments is supplied by an inverter which is run by a 28 volt battery mounted on the aircraft instrument rack. This battery can be switched to and charged by the aircraft alternator during a flight. When the aircraft engine is off, the battery runs the instruments for 30 minutes or more without using an external power source. Therefore, just prior to engine start the power source is switched from the external to this internal source. After the flight, power is switched back to the external source for data downloading and instrument calibrations. During the time between flights of an IOP, the NO/NOy analyzer remains powered in order for it to maintain optimum performance throughout the IOP.

When the aircraft is ready for take off, the sampling instruments are again checked using UC-TEST and then the data logging program, UC-DATA, is run. To simplify this task during aircraft operation, the operator, who is also the pilot, runs A.BAT: a batch file which automatically runs UC-TEST and then UC-DATA. The operator enters the file number, sample period (default is three seconds), the navigation data sample period (default is 10 seconds), and the number of data channels to sample (default is 11).

Just prior to departure, data logging is begun and the operator records the time, file number, altitude, and the departure location on the audio tape. Periodic recording of pertinent in-flight information is also recorded on the audio tape. At the end of a flight segment, the data logging is interrupted by the operator and the time, altitude, file number, and location are again noted on the audio tape. This sequence of starting and ending data logging and audio tape notations is repeated for each flight segment as determined by the operator. During an IOP, a flight segment was typically a downward spiral followed by a climbing transition to the beginning of the next spiral. Each file can last approximately 30 minutes. Consistent with the SCOS97 protocol, all times are Pacific Standard Time (PST) unless otherwise noted. The data stream includes time, as seconds from midnight in PST, for each scan. These data files are named mm-dd-nn.DAS and mm-dd-nn.NAV where "mm" is the month, "dd" is the day and "nn" is the file number. A summary of programs used with UCD aircraft flights and corresponding data files are shown in Table 8.

FLIGHT PATTERNS

On the fifteen IOP days flown by the UCD aircraft, one to three flights per day were made generally following the pattern shown in Figure 1 and described in Table 9. An ascending spiral to 1500 m was initiated at El Monte airport (EMT) before transitioning to Burbank airport (BUR) while continuing the climb to 2000 m. After a descending spiral to 250 m and an eastbound climb to 1500 m, another descending spiral was made at Pasadena (PAS) to an altitude of 600 m. A climb to 2100 m over Azusa (AZU) was followed by a spiral to 500 m before ascending eastbound to 2100 m at Cable airport (CCB). A descent over CCB was made to 400 m prior to initiating a southwesterly climb to 1500 m over Fullerton (FUL) airport. A descending spiral at FUL was made to 50 m, and then the final transition back to EMT was flown. A concluding spiral at EMT began at 1500 m and ended at the surface (100 m).

Typical flight times for the IOP flights are shown in Table 9. For IOPs with less than three flights in one day the morning flight was flown at the normal time while the midmorning and afternoon flights were replaced with one flight starting at 1200 PST. On a couple of IOP days (July 14 and October 3), low clouds in the morning caused a delay in initiating the morning flight and kept the flight pattern to the northernmost sites only. These changes are reflected in the times and positions shown in the actual data as well as the voice logs compiled for those days. Table 3 also shows actual flight times.

Two reactive organic gas (ROG) cans and two carbonyl bag samples were taken on each flight during an IOP. During the first few IOPs the procedure for collecting these samples was progressively modified in order to provide a large enough carbonyl sample for analysis. All of the samples were taken at the same locations and at the same altitudes unless described otherwise on the individual samples. The carbonyl sampling system initially provided was designed on the assumption that ram air would be enough to fill the 30 liter bags in about two minutes, similar to the time needed to fill the ROG cans. However this was not the case. After consultation with DRI, ARB and CE-CERT colleagues, the system was changed to allow pumping of air into each carbonyl bag using one of the two pumps originally installed to fill the ROG cans. The final procedure used assured that the sample fill lines were fully purged prior to sampling. Samples were taken between 500 and 800 m altitude at both EMT and AZU.

Since it was important that the sampled layer be the same for the carbonyl and ROG samples, the ROG sample was obtained during one fairly rapid vertical traverse of the sampled layer, then the ROG sample was terminated (can pressure > 20 PSI) while the carbonyl sample continued during two more vertical traverses of the layer. The modified procedure was followed for all flights commencing on and following August 22. Notes of when the samples were taken were recorded in the voice logs as well as in the data steam by means of an event marker. After landing, the bags and cans were removed and transferred to CE-CERT personnel.

DATA REDUCTION

The audio tapes were transcribed into text files for each flight. Hard copies of these logs were printed and contain the time, altitude, and file number for each pertinent comment during a flight as well as the relevant comments. Interactive programs for data reduction are run to remove errors, convert the voltage data to scientific units, and combine decoded navigation data with the atmospheric data.

Radiated energy associated with radio transmissions from the aircraft often puts small spikes into some of the data. These erroneous readings are corrected by interpolating between the closest valid data. Any of the data-logging channels may be corrected, but primarily the errors affect channels one through five which record fast and very fast response temperatures, airspeed, relative humidity, and pressure. When one of these five channels is corrected so are the other four. A file mm-dd-nn.LOG automatically records all changes made to the original mm-dd-nn.DAS file.

Voltages recorded in the mm-dd-nn.DAS files are converted to scientific units using UC-CNVRT. Supplied with the initial altitude from the voice transcriptions, UC-CNVRT calculates altitude from the recorded pressure for the entire file. If the initial altitude for a file is unavailable, then an altitude from a corresponding pressure in a contiguous file is used. The data are converted to scientific units using the equations in Table 10. Output is to files mm-dd-nn.DAT and mm-dd-nn.NAT (cf. Table 8).

UC-CVRT2 makes the final data files, mm-dd-nn.DAC, by incorporating information from both the mm-dd-nn.DAT and mm-dd-nn.NAT files. The program applies calibration corrections, flags erroneous or missing data, and combines the navigation data with the atmospheric data. Navigation data are presented as latitude (degrees North) and longitude (degrees West). Table 2 shows the file format. UC-CVRT2 is run in batch mode, processing all pairs of mm-dd-nn.DAT and mm-dd-nn.NAT files for a given flight date unless the position information for the beginning of a file is missing. In this case, the data processing person manually inputs the initial latitude and longitude for each file. The remainder of the position information is then estimated from the heading and airspeed values. If valid GPS values occur later, those are used from that point in the record onward. Since position information is recorded every 10 seconds but the remainder of the data is sampled at 3 second intervals, in the final data set (DAC files) the position data is derived for the 3 second interval by interpolating between the actual recorded position data. The mm-dd-nn.DAC files are the primary archived data files. (For more comprehensive information on intermediary data reduction and file formats see Carroll and Dixon, 1998.)

DATA SUBMISSION

Analysis of the data collected has been limited to examining the various files for internal consistency and other quality assurance tests. The scrutinized data are contained in directories labeled by date and in files labeled by date and file number as they were originally recorded, i.e. files named mm-dd-nn.DAC. Also included with the transmission is a directory containing the installation files for a WIN-95 (and higher) application for convenient viewing of these data. This program, called

UCDACVU, allows the user to select DAC files one at a time for viewing the data in tabular form, including a summary of maximum, minimum and average of each variable in the file. In addition, time plots of the primary variables, including a position plot for the aircraft or as vertical soundings of layer averaged data (dz = 20 m or 75 feet) can be plotted and, at the user's option, saved as a bitmap file.

To further facilitate examination of these data, a second set of data files are included with a smaller number of variables than in the DAC files and organized by location rather than by file number as with the DAC files. These are named mmdd-ftp.DCC, where mm and dd are the month and date as before, "f" represents the flight number for the day, "t" represents type (S = spiral or T for transect), and "p" represents the location (1 for first El Monte spiral, 2 for Burbank, etc). There is also a set of installation files for an application called UCSCOSVU. This application is similar to UCDACVU except that it is specifically adapted to the SCOS97 observation area and to the DCC file formats.

Figure 2 shows a sample time plot from UCSCOSVU for the early morning flight of August 22 over EMT. Figure 3 shows a sample sounding plot from the same program for the same time and place as Figure 2.

RESULTS

Because the data from the audits, intercomparisons, and external calibrations have not been sent to UCD as part of the QA/QC protocol, these are not reported herein. However, the instrument calibrations indicate that, except for the temperature and pressure corrections to the oxides-of-nitrogen data and the occasional flow rate problems with the particle counter, the experiment went very well with excellent recovery rates of high quality data. Meteorological and other uncontrollable conditions during the various IOPs were quite varied and some may have compromised, to a small degree, experimental objectives. In the paragraphs below, pertinent characteristics of these intensive periods as derived from UCD aircraft observations are summarized.

A number of characteristics were common to most IOPs. Note first that the spirals at EMT, BUR, CCB, and FUL descend essentially to ground level, as these are airport locations. At PAS and AZU, minimum descents are at least 300 m above ground level, to conform with Federal Aviation Regulations regarding minimum flight altitudes over densely populated areas. Hence, low altitude, surface layer details, often seen at the airport locations, especially in the early morning hours, are absent from the PAS and AZU data. Also EMT, BUR, and FUL airports, are located close to several freeways, whereas CCB is not. Finally, the ground altitudes vary among these airports from FUL (29 m) to EMT (90 m) to BUR (236 m) to CCB (439 m), so that some low altitude features may be found at FUL and EMT which are absent from BUR or CCB. Typically, the early morning spirals at the lower altitude airports show a surface layer devoid of ozone but with moderate concentrations of nitrogen oxides and particles, and moderate to high ozone but low NO, NOy, and particle concentrations aloft. During the course of a typical day, a mixed layer develops whereby ozone increases near the surface while NO and NOy decrease. In the early morning hours, NO, NOy, and particles are inversely correlated with ozone while in the afternoon, especially east of Pasadena, NOy, ozone, and particle concentrations tend to rise and fall together near the ground. In the afternoon of most days at FUL, and occasionally at EMT, a near-surface layer (a few 100 meters deep) is seen containing low ozone and NOy concentrations and moderate particle counts. This appears to be marine air penetrating into these locations.

Additionally, there is a tendency for particle concentration data to be partially correlated with relative humidity. As the particle air sample is not preheated, the presence of hygroscopic particles, especially in the marine air, does affect these counts. However, many maxima in these counts are not associated with high humidity.

In general, the highest ozone concentrations were found well above the surface, often in layers at or above the top of the mixed layer. For example, the highest ozone concentration found among all observations (214 ppbv) was over EMT on the afternoon of August 5 in a layer between 700 and 900 m altitude. Also noted is that layers above the mixed layer showing the highest ozone concentrations in a given spiral almost always have low NO and NOy concentrations (< 10 ppbv). More than half of the time in these layers, moderate particle concentrations exist (20 to 30 $*10^6/m^3$ for $d > 0.3$ μm); whereas the remainder of the time the particle concentrations are also low (< 15 $* 10^6/m^3$ for $d > 0.3$ μm).

The July 14 IOP lasted one day as forecast conditions changed to those inconsistent with the experimental objectives. However, this first try provided an opportunity to refine operational procedures. The day had relatively low pollutant concentrations, maximum NOy ~ 90 ppbv and maximum ozone ~ 113 ppbv.

The August 4-6 IOP had the highest pollution concentrations encountered by the UCD aircraft, these being on the second and third day. August 4 began with relatively low ozone (max ~ 105 ppbv, aloft) but relatively high low altitude NOy concentrations (~100 to 140 ppbv). The early morning soundings on August 5 showed near ground layers with NOy values ~ 135 ppbv and little ozone, while aloft ozone values of 135 - 158 ppbv were found. During the course of the day, pollutant levels rose at most locations. By noon, near-ground ozone concentrations reached 140 - 150 ppbv. However by late afternoon, near ground values had decreased at most airport sites, while aloft (z ~ 700 - 900 m) concentrations of ozone reaching 180 to 214 ppbv were found. Afternoon visibility below 700 m was very poor to the southeast of Pasadena. There appeared to be a brush fire in the hills east of Fullerton that contributed to the reduced visibility. On the next day, August 6, pollutant concentrations started off at moderate values (NOy ≤ 135 ppbv near the ground and ozone ≤ 100 ppbv aloft). At midday, near-surface ozone values peaked about 125 ppbv. By late afternoon, ozone concentrations aloft (800 < z < 1000 m) reached 150 to 160 ppbv, while those near the ground were less than 60 ppbv at the low altitude sampling locations. Late afternoon visibility was very poor between Fullerton and El Monte.

The August 22-23 IOP was the first during which the carbonyl sampling was optimized. It was also a period with several complicating factors. One was a forest fire in the mountains north of Ontario which put smoke layers into our sampling areas east of Pasadena during this period. These are evident in the particle data, and often resulted in saturation of the particle counter output. A second complication was the presence of scattered rain showers over the area through the early afternoon on August 22. The day began with relatively moderate pollutant levels but with an NO/NOy rich surface layer which was deeper than on most other days studied, extending up to 500 m. By midday, ozone concentrations below 500 m reached moderate values (85 - 95 ppbv) while NOy remained moderately high as well. Perhaps the cloudy conditions curtailed the photochemical production. By late afternoon, the skies had cleared and ozone values aloft ($z \geq 500$ m) reached the highest values measured that day (130 - 154 ppbv). As with most such observations, the NO and NOy concentrations were very low (~ 0 ppbv for NO and < 15 ppbv for NOy), and particle concentrations were moderate ($\sim 30 * 10^6/m^3$ for $d > 0.3\ \mu m$) in the layers having the highest ozone concentrations. The pollutant variations on the second day were similar to the 22nd but were generally higher in total concentrations both in the mixed layer and aloft. On this day, the late afternoon ozone maxima were above 900 m ranging among sites between 145 and 172 ppbv. Ozone concentrations near the ground were generally well mixed up to 900 m with values ranging between 120 and 145 ppbv. There is some coincidence of high ozone concentrations within the layers containing the forest fire smoke.

The conditions during the September 3-6 IOP were hot and humid with relatively deep mixed layers. The early morning of the 3rd showed high NO (~50 ppbv) and NOy (157 ppbv) in the lowest few hundred meters with no ozone at EMT. From 300 to 900 m at all sites except FUL, the particle count was moderately high but concentrations of NO and NOy were small and ozone was about 40-50 ppbv. At FUL, near ground concentrations of NOy and ozone were both about 100 ppbv while NO was about 55 ppbv. Above 200 m, measurements at FUL were similar to the other locations. By midday, the mixed layer was well developed to a height of between 800 and 1200 m (increasing with surface elevation) with ozone concentrations between 75 and 112 ppbv east of PAS and lower to the west. In the same layers, NOy ranged between 30 and 80 ppbv. By late afternoon the lowest 1000 m of the atmosphere was relatively pollution free (ozone ≤ 80 ppbv, NO ~ 0, NOy ≤ 30 ppbv) while above 1100 m ozone values ranged from 120 to 194 ppbv, the latter being in a layer $1300\ m < z < 1500\ m$ over FUL.

On the 4th, the early morning spirals showed a surface layer rich in oxides of nitrogen and no ozone; a relatively unpolluted layer up to about 850 m and higher ozone concentrations (100 - 115 ppbv) above 900 m. By noon, a well mixed layer developed below about 800 m, with low concentrations of nitrogen oxides and moderate ozone (60 - 90 ppbv). Between 800 and 900 m peak ozone concentrations were found in the range 113 to 128 ppbv over EMT and BUR. A mass of low visibility air capped with small cumulus clouds was observed south of CCB and east of FUL at this time. By late afternoon, ozone levels above 1000 m were very high, 140 to 200 ppbv, all along the northern measurement locations. At FUL, an elevated ozone maximum was also seen (178 ppbv) but at a lower altitude (500 m). The elevated pollution layers also contained relatively high concentrations of particles ($40 - 50 \times 10^6\ m^{-3}$, $d > 0.3\ \mu m$) and NOy (15 - 30 ppbv).

The morning of the 5th was similar to many other mornings, with the lower few hundred meters rich in oxides of nitrogen, low in ozone and with moderate particle counts. Aloft, however ozone concentrations were moderate, with maxima ≤ 115 ppbv. Particle counts aloft were unusually high. The second, and last, flight on this day took off about two hours later than the normal second flight and the data look quite different from that obtained in the late morning flights on the previous IOP days. Specifically, a well-mixed layer up to 800 m was observed with fairly high concentrations of ozone, NOy, and particles; concentrations were low above 800 m. Since this structure was not observed near the end of the second morning flights on other days (i.e. at the same time of day as the first EMT spiral for this flight), it is believed the uniqueness of these profiles results from conditions that day and not due to differences in sampling times.

The early morning flight on September 6 followed a different route, omitting the transect to and spiral over FUL because of low clouds over the southern part of the Los Angeles Basin. Other than that the data are similar to those of the 5th for both the early morning and early afternoon flights. As on the day before, the noon time data showed a pollutant rich, well-mixed boundary layer up to about 800 m, with cleaner air aloft.

The IOP of September 27-29 begins with a noon flight on 27th. The data from this flight are similar to those earlier in the month but different from the August observations. During this period, there was a pollution rich mixed layer up to about 750 m with high NOy (45 - 50 ppbv), high particle counts (55 x 10^6 m^{-3} for smaller and 20 x 10^4 m^{-3} for the larger sizes), and ozone concentrations in the range 100 - 132 ppbv. Above 1000 m, concentrations of all decrease except ozone. One exception is at FUL where the surfaced-based mixed layer is much shallower, only 300 m deep and the peak ozone concentration seen was 163 ppbv at an altitude of 550 m.

The morning of the 28th had a deep surface-based stable layer (inversion) extending up to $z \geq 450$ m in which ozone slowly increased with height and NOy slowly decreased with height and in which a fairly high number of particles were suspended. By early afternoon, a pollutant rich surface layer extended up to 300 m, with the upper part of the boundary layer extending to $z \geq 1000$ m at all sites except FUL. In this upper layer, ozone values reached 145 ppbv and particle counts remained high, while NOy decreased to ≤ 20 ppbv. An elevated pollutant layer (~1950 m) was seen at CCB, the only site where these altitudes were sampled. At FUL, the pollutant rich mixed layer extended only to 400 m with the maximum ozone (145 ppbv) at 380 m. The early morning flight on the next day (9/29) again showed a pollutant rich surface-based stable layer but shallower, extending only up to 300 m. Above this altitude gas phase pollutants are low but particle counts are high. By early afternoon, a deep, polluted mixed layer was found at all locations, although the depths varied from 700 m at EMT, BUR and CCB, to 850 m at AZU and FUL, to 1100 m at PAS. Except at FUL, this layer had high concentrations of NOy (~ 47 ppbv) and particles and ozone between 115 and 132 ppbv. At FUL, the near ground concentration of all constituents, except particles, was low.

The last IOP occurred October 3 and 4. Presence of low clouds on the morning of the 3rd required a late start and a flight plan that limited the descent at CCB and excluded FUL. The later departure pushed the time of the flight to be later in the morning traffic peak, which is reflected in NO and NOy data, which reached 70 and 108 ppbv respectively, the highest values for NO seen during the experiment. Otherwise the data were similar to most other mornings with an ozone depleted surface layer high in NO, NOy, and particles. By early afternoon, a strong inversion was present at 950 m. Below this inversion, high particle counts and moderate NO and NOy concentrations were found, with ozone being relatively low at 60 - 75 ppbv. Above the inversion, all pollutant concentrations were small except ozone which was ≥ 75 ppbv. This inversion was still apparent during the early morning flight of the 4th, between 800 and 900 m. The lower half of this layer was rich in NO, NOy, and particles but devoid of ozone. The upper half had moderate ozone concentrations (30 - 70 ppbv) less NOy, but was depleted of NO. Above the inversion all pollutant concentrations were greatly reduced except ozone which was slightly higher (~ 75 ppbv).

On the early afternoon of October 4, the strong inversion was still present at 900 to 1000 m. Along the northern part of the sampled area, the sub-inversion layer was fairly well mixed vertically with high concentrations of NOy persisting (40 - 85 ppbv) and moderate to high ozone concentrations as well (90 - 145 ppbv). The major differences at FUL are a lower inversion height (~700 m), lower NOy, and higher particle counts. As was often the case, the higher altitude data at CCB showed an increase in pollution concentrations aloft ($z > 1800$ m) with ozone increasing to 137 ppbv at the top of the sounding accompanied by increasing particle and NOy concentrations.

SUMMARY

The overall operations were successful, with high quality data being obtained during each IOP. Instrument calibrations showed that the various sensing systems performed well during the experiment. Although some difficulties were initially experienced with the carbonyl sampling, this was rectified by the second IOP. The miscue with the ordering of the proper options for the oxides of nitrogen analyzers was unfortunate, compromising the quality of those data to some degree. Fortunately, when significant levels of NO or NOy were detected, the environmental conditions were usually sufficiently close to the assumed standard conditions that these data are useful.

The meteorological conditions during the various IOPs produced quite different patterns of pollutant distributions. On some days, the August cases, the highest ozone concentrations were found at or above the top of the mixed layer with relatively clean air near the ground in the afternoons. Conversely, the September and October conditions produced quite different vertical pollution distributions, making this data set useful for examining and modeling several important scenarios for ozone production in the region.

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TABLE 1
UCD AIRCRAFT INSTRUMENTATION SYSTEM

VARIABLE	SENSOR	MANUFACTURER & MODEL	USEFUL RANGE	ACCURACY
Pressure (Altitude)	Capacitive	Setra 270	- 30 to 3650 meters	± 0.3 mb ± 3 meters
Temperature	Platinum RTD	Omega Engineers	- 20 to 50 °C	± 0.5 °C
Relative Humidity	Capacitive	Met One 083C	0 to 100%	± 3% between 20 and 85%
Air Speed	Thermal Anemometer	T. S. I. 8460-AF-V-STD-NC	15 to 77 ms^{-1}	± 0.4 ms^{-1}
Heading	Electronic Compass	Precision Navigation TCM2	0 to 360 °	± 2 °
Position	Global Positioning System (GPS)	Garmin 10-05 Board Set	± 90 ° Latitude ± 180 ° Longitude	Position = 100 m (15 m with Selective Availability) Veloc. = 0.2 ms^{-1}
Particle Concentration	Optical counter	Climet CI-3100-0112	d > 0.3 μm d > 3.0 μm	± 2% of count
Ozone Concentration	U. V. absorption	Dasibi 1008 AH	0 to 999 ppbv	3 ppbv
Nitrogen Oxides (NO, NOy) Concentration	Gas-phase chemiluminescence	Thermo Environmental Instruments, Inc. Model 42C	0 to 200 ppbv	0.05 ppbv or 1% of reading. Linearity is ± 1% of full scale

TABLE 2

AIRCRAFT DATA FILE VARIABLE LIST FOR mm-dd-nn.DAC

HEADER VARIABLES
MONTH, DAY, YEAR, FILE NUMBER, SCAN NUMBER, SITE NUMBER, SCALE VALUE

INDEX	VARIABLE	UNITS
1	Time	Seconds[1]
2	Ave. Temperature (Ta)	°C
3	Ave. Temperature (T')	°C
4	Airspeed	ms^{-1}
5	Pressure	mb
6	Altitude	Feet MSL
7	Relative Humidity	%
8	Specific Humidity	g/Kg
9	NO	ppbv
10	NOy	ppbv
11	Ozone	ppbv
12	Heading	Degrees (magnetic)
13	Particles d > 0.3 μm	$Nx10^6/m^3$
14	Particles d > 3.0 μm	$Nx10^3/m^3$
15	rmsT (.1 sec)	°C
16	rmsV (.1 sec)	ms^{-1}
17	rmsRH (.1 sec)	%
18	rmsT (3 sec)	°C
19	rmsV (3 sec)	ms^{-1}
20	rmsRH (3 sec)	%
21	Longitude	Degrees West
22	Latitude	Degrees North
23	Event Marker	—
24	GPS Index	—

[1]Seconds past midnight (PST).

TABLE 3 SCOS97: UCD FLIGHT DAYS				
DATE	**DIRECTORY NAME**	**FLIGHT NUMBER**	**FLIGHT TIME**	**TYPE OF OPERATION**
June 11	JUN11	1	21:00 -23:25	Intercomparison (IC)
July 8	JUL8	1 2	11:00 - 11:20 12:50 -14:30	IC IC
July 14	JUL14	1 2	07:30 -09:40 13:45 - 16:00	Intensive Period (IOP) IOP
July 15	JUL15	1	11:55 - 12:19	Clean Air Bag Sample
August 3	AUG3	1	14:20 - 17:00	Transit Flight (Trans)
August 4	AUG4	1 2 3	04:45 - 07:00 10:00 - 12:10 14:45 - 17:10	IOP IOP IOP
August 5	AUG5	1 2 3	04:55 - 07:20 10:05 - 12:15 14:30 - 17:00	IOP IOP IOP
August 6	AUG6	1 2 3	04:30 - 07:10 10:05 - 12:30 14:35 - 17:15	IOP IOP IOP
August 7	AUG7	1	10:55 - 12:05	Trans
August 21	AUG21	1	13:20 - 15:05	Trans
August 22	AUG22	1 2 3	04:25 - 07:10 10:05 - 12:30 14:30 - 17:15	IOP IOP IOP
August 23	AUG23	1 2 3	04:35 - 06:55 10:00 - 12:20 14:30 - 17:00	IOP IOP IOP
August 24	AUG24	1 2 3	08:20 - 09:15 09:35 - 10:40 11:40 - 13:45	IC IC Trans
September 2	SEP2	1	13:25 - 15:55	Trans
September 3	SEP3	1 2 3	04:40 - 07:00 10:00 - 12:15 14:25 - 16:50	IOP IOP IOP
September 4	SEP4	1 2 3	04:45 - 07:10 09:50 - 12:10 14:25 - 16:45	IOP IOP IOP

TABLE 3
(Continued)
SCOS97: UCD FLIGHT DAYS

DATE	DIRECTORY NAME	FLIGHT NUMBER	FLIGHT TIME	TYPE OF OPERATION
September 5	SEP5	1 2	04:30 - 06:50 12:00 - 14:25	IOP IOP
September 6	SEP6	1 2 3	04:30 - 06:40 12:00 - 14:30 15:45 - 18:16	IOP IOP Trans
September 18	SEP18	1 2	12:55 - 16:20 19:50 - 20:35	Trans & IC (Victorville) IC (Victorville)
September 19	SEP19	1	09:05 - 12:20	IC (Victorville) &Trans
September 27	SEP27	1 2	08:20 - 09:45 12:10 - 14:30	Trans IOP
September 28	SEP28	1 2	04:30 - 06:50 11:55 - 14:20	IOP IOP
September 29	SEP29	1 2	04:30 - 06:50 11:55 - 14:25	IOP IOP
October 3	OCT3	1 2	06:55 - 08:45 12:00 - 14:25	IOP IOP
October 4	OCT4	1 2	04:30 - 06:50 11:55 - 14:25	IOP IOP

TABLE 4 OZONE CALIBRATION DATA					
PC denotes the transfer standard, **AH** the operational instrument. **Setting** is the switch selectable ozone concentration desired, **value** is the digital output appearing on the analyzer's front panel and **CPU** is the value read by the data acquisition system.					
Date	PC setting	PC value	AH value	CPU	Percent Difference[2]
05/28/97	200	200	196	202	1.0
	150	150	146	150	0.0
	100	100	96	99	-1.0
	50	50	47	49	-1.3
	0	10	7	8	-16.7
07/08/97	200	200	191	N/A	N/A
	100	99	92	N/A	N/A
	0	10	4	N/A	N/A
07/10/97	200	197	194	195	-1.4
	150	150	141	142	-5.1
	100	99	93	92	-7.4
	50	50	45	45	-9.9
	0	9	5	4	-59.3
07/14/97	200	202	200	201	-0.4
	0	9	7	7	-23.3
07/15/97	200	201	200	202	0.5
	150	150	147	148	-0.8
	100	100	102	103	3.5
	50	50	47	47	-5.4
	0	10	7	7	-32.4
08/01/97	200	200	198	N/A	N/A
	100	100	97	N/A	N/A
	50	50	50	N/A	N/A
	0	9	8	N/A	N/A

[2]Percent difference = 100 * (CPU - PC value) / PC value.

TABLE 4
(Continued)
OZONE CALIBRATIONS

Date	PC setting	PC value	AH value	CPU	Percent Difference[3]
08/05/97	200	200	199	202	1.0
	0	9	8	7	-20.7
08/06/97	200	200	197	199	-0.3
	0	9	7	9	-3.7
08/07/97	200	201	200	203	1.0
	150	151	149	151	0.0
	100	100	97	99	-0.3
	50	50	48	50	-0.7
	0	10	8	9	-3.5
08/21/97	200	198	201	204	3.0
	150	150	148	151	0.4
	100	99	98	104	4.7
	50	50	48	50	-0.7
	0	11	10	11	-2.9
08/23/97	200	195	192	195	-0.1
	0	8	8	8	0.0
08/03/97	200	204	203	206	1.0
	150	150	150	153	1.6
	100	103	102	105	2.3
	50	54	53	55	1.9
	0	9	8	11	25.9

[3]Percent difference = 100 * (CPU - PC value) / PC value.

TABLE 4
(Continued)
OZONE CALIBRATIONS

Date	PC setting	PC value	AH value	CPU	Percent Difference[4]
09/02/97	200	200	199	201	0.5
	150	150	149	151	0.2
	100	100	99	101	1.0
	50	50	49	50	0.0
	0	10	9	9	-6.9
09/04/97	200	200	201	203	1.3
	0	9	9	9	-3.6
09/05/97	200	204	204	206	1.3
	0	9	8	9	-3.7
09/06/97	200	200	210	214	7.0
	150	150	160	163	8.4
	100	102	108	111	8.9
	50	50	48	50	0.0
	0	10	8	10	0.0
09/06/97	200	200	200	202	1.2
09/29/97	200	200	200	203	1.2
	150	150	149	152	1.2
	100	101	100	103	2.1
	50	50	49	51	0.8
	0	-4	8	7	-294.2
09/29/97	200	199	201	204	2.6
	150	150	150	153	1.9
	100	99	98	101	1.2
	50	50	48	50	-0.1
	0	9	8	8	-8.1
10/03/97	200	200	201	203	1.5
	0	9	8	12	33.3

[4]Percent difference = 100 * (CPU - PC value) / PC value.

TABLE 4
(Continued)
OZONE CALIBRATIONS

Date	PC setting	PC value	AH value	CPU	Percent Difference[5]
10/04/97	200	197	198	201	1.7
	150	150	149	153	1.6
	100	100	99	102	1.9
	50	50	48	50	-0.3
	0	9	8	6	-35.0

[5]Percent difference = 100 * (CPU - PC value) / PC value.

TABLE 5 NITROGEN OXIDES ANALYZER CALIBRATION DATA					
Date	Calibration Concentration	NOy	NO	Slope[6]	Intercept[6]
7/11/97	0	Missing	Missing		
	47	39.1	34.4		
	47	39.1	34.4		
	47	39.1	34.4		
	95.8	91.8	88.2		
	95.8	92.7	90		
	95.8	94.1	91.6		
	144	145.3	141.6		
	144	146.1	142.6		
	144	145.5	142.2		
	192	195.7	190.3		
	192	195.1	191.4		
	192	194.8	190.4		
	192	193.9	[7]4.6		
	192	194.1	[7]4.3		
	192	194	[7]4.7		
	47	45.9	44.5		
	47	45.7	44.4		
	47	45.1	44.6	0.949	6.939
7/14/97	0	0	0		
	0	0.1	0		
	191.16	175	165.5		
	191.16	179.3	171.1		
	0	0.01	0		
	0	0	0	1.079	-0.016

[6]Slope and intercept values represent the daily calibration results for the NOy measurements.

[7]Low NO concentrations result from adding ozone during this part of the calibration procedure.

TABLE 5
(Continued)
NITROGEN OXIDES ANALYZER CALIBRATION DATA

Date	Calibration Concentration	NOy	NO	Slope[8]	Intercept[8]
07/15/97	0	0.2	0		
	0	0.2	0		
	0	0.2	0		
	191.16	189	181.8		
	191.16	190.7	184.1		
	191.16	191	185.5		
	143.8	142	138.7		
	143.8	141.8	138.8		
	143.8	141.4	138.6		
	95.71	92.7	91.5		
	95.71	92.6	90.6		
	95.71	92.5	90.9		
	47.37	43.8	43		
	47.37	43.9	42.8		
	47.37	43.4	42.4		
	191.4	183.1	179.4		
	191.4	180	[9]2.4	1.016	1.223
8/03/97	0	0.6	0		
	0	0.6	0.2		
	0	0.7	0.1		
	191.64	176.9	172.5		
	191.64	178.2	175.2		
	191.64	179.4	176.6		
	143.8	136	133.7		
	143.8	136.3	133.7		
	143.8	136.9	134.9		
	95.95	90.8	89.5		
	95.95	90.8	89.4		
	95.95	91.4	89.3		
	47.37	44.2	43.6		
	47.37	44.4	43.5		
	47.37	44.3	43.4		
	191.64	184.2	180.9		
	191.64	183.4	[9]6	1.062	-0.394

[8]Slope and intercept values represent the daily calibration results for the NOy measurements.

[9]Low NO concentrations result from adding ozone during this part of the calibration procedure.

TABLE 5
(Continued)
NITROGEN OXIDES ANALYZER CALIBRATION DATA

Date	Calibration Concentration	NOy	NO	Slope[10]	Intercept[10]
8/05/97	0	0.8	0.1		
	0	0.6	0.1		
	0	0.6	0.2		
	191.4	175.5	170.6		
	191.4	176.3	171.6		
	191.4	176.1	172.4		
	191.16	174.1	[11]2.8	1.094	-0.724
8/06/97	0	0.7	0		
	0	0.9	0.1		
	0	0.7	0		
	191.4	151.7	146.7		
	191.4	152.4	147.2		
	191.4	152.6	147		
	191.4	152.1	[11]1.3	1.264	-0.968
8/07/97	0	0.3	0		
	0	0.5	0		
	0	0.5	0.1		
	191.64	178.5	173.2		
	191.64	179	173.3		
	191.64	179	174.7		
	143.8	133	129.9		
	143.8	132.9	130.3		
	143.8	133	130.3		
	95.71	87.9	85.9		
	95.71	87.2	85.8		
	95.71	87.1	85.8		
	47.37	41.6	41.5		
	47.37	41.7	41		
	47.37	41.9	41		
	191.16	175	172.3		
	191.16	174.4	[11]5.6	1.076	0.967

[10]Slope and intercept values represent the daily calibration results for the NOy measurements.

[11]Low NO concentrations result from adding ozone during this part of the calibration procedure.

TABLE 5
(Continued)
NITROGEN OXIDES ANALYZER CALIBRATION DATA

Date	Calibration Concentration	NOy	NO	Slope[12]	Intercept[12]
8/21/97	2.66	0.5	0		
	2.91	0.3	0		
	2.91	0.3	0.1		
	191.64	159	148.8		
	191.64	159	148.8		
	191.64	174.2	169.2		
	143.8	130.5	126.8		
	143.8	130.5	126.7		
	143.8	130.5	127.8		
	95.95	85.7	84.5		
	95.95	87	84.5		
	95.95	87	84.7		
	47.37	42	41.1		
	47.37	41.8	40.7		
	47.37	41.8	40.7		
	191.64	178.9	175.8		
	191.64	179.6	[13]5.3	1.104	1.741
8/23/97	3.16	0.2	0		
	3.16	0.2	0		
	3.16	0.2	0		
	191.64	181.2	176.4		
	191.64	182.7	176.9		
	191.64	182.5	178.4		
	191.64	183.1	[13]7.1	1.034	2.957

[12]Slope and intercept values represent the daily calibration results for the NOy measurements.

[13]Low NO concentrations result from adding ozone during this part of the calibration procedure.

TABLE 5 (Continued) NITROGEN OXIDES ANALYZER CALIBRATION DATA					
Date	Calibration Concentration	NOy	NO	Slope[14]	Intercept[14]
8/23/97	2.91	0.2	0		
	2.91	0	0		
	2.91	0.2	0		
	191.64	172	166		
	191.64	171.3	166.1		
	191.64	171.6	167.9		
	143.8	129.1	126.9		
	143.8	129.3	127.2		
	143.8	130.3	127.2		
	95.71	86.6	85.4		
	95.71	86.8	85.4		
	95.71	86.3	86		
	47.37	42.2	41.3		
	47.37	42.5	41.3		
	47.37	42.4	41.8		
	191.64	177.5	174.3		
	191.64	179.5	[15]6	1.086	2.19
Average	All Dates			1.077	1.392

[14]Slope and intercept values represent the daily calibration results for the NOy measurements.

[15]Low NO concentrations result from adding ozone during this part of the calibration procedure.

TABLE 6 TEMPERATURE CALIBRATION DATA				
Date	Temperature (Ta) (° C)	Calibration Temperature (° C)	Temperature Difference	Percent Difference[16] (%)
08/21/97	30.8	30.4	-0.4	1.3
	30.5	30.5	0.0	0.0
	30.6	30.4	-0.2	0.7
Average	30.6	30.4	-0.2	0.7
08/23/97	29.0	29.0	0.0	0.0
	28.8	28.7	-0.1	0.3
	28.8	28.6	-0.2	0.7
	28.5	28.4	-0.1	0.4
Average	28.8	28.7	-0.1	0.3
09/02/97	33.2	32.4	0.8	2.5
	33.0	32.2	0.8	2.5
	33.0	32.2	0.8	2.5
Average	33.1	32.3	0.8	2.5
09/06/97	33.8	33.3	0.5	1.5
	33.5	33.1	0.4	1.2
	34.9	34.2	0.7	2.0
Average	34.1	33.5	0.6	1.6
09/27/97	32.3	31.7	0.6	1.9
	32.3	31.7	0.6	1.9
	32.0	31.6	0.4	1.3
Average	32.2	31.7	0.5	1.7
09/29/97	28.1	28.2	-0.1	-0.4
	28.2	28.2	0.0	0.0
	28.2	28.2	0.0	0.0
Average	28.2	28.2	0.0	-0.1

[16] Percent difference = 100 * (Ta - Calibration Temperature) / Calibration Temperature.

TABLE 7 RELATIVE HUMIDITY CALIBRATION DATA					
Date	Relative Humidity (%)	Calibration Relative Humidity (%)	Relative Humidity Difference	Percent Difference[17]	Comments
05/30/97	81.2	75.3	5.9	7.8	Salt Calibration
	81.3	75.3	6.0	8.0	
	81.4	75.3	6.1	8.1	
	81.4	75.3	6.1	8.1	
Average	81.3	75.3	6.0	8.0	
05/30/97	20.2	11.3	8.9	78.8	Salt Calibration
06/02/97	79.2	75.4	3.8	5.0	Salt Calibration
	79.3	75.3	4.0	5.3	
	79.4	75.3	4.1	5.4	
	79.4	75.3	4.1	5.4	
Average	79.3	75.3	4.0	5.3	
06/02/97	22.5	11.3	11.2	99.1	Salt Calibration
	22.3	11.3	11.0	97.3	
	22.1	11.3	10.8	95.6	
Average	22.3	11.3	11.0	97.3	
08/21/97	41.3	44.3	-3.0	-6.8	Transfer Unit
	39.9	44.0	-4.1	-9.3	
	40.5	44.5	-4.0	-9.0	
Average	40.6	44.3	-3.7	-8.4	
08/23/97	43.2	44.9	-1.7	-3.8	Transfer Unit
	43.7	45.8	-2.1	-4.6	
	45.2	46.1	-0.9	-2.0	
	44.4	46.7	-2.3	-4.9	
Average	44.1	45.9	-1.8	-3.8	
09/02/97	34.3	38.7	-4.4	-11.4	Transfer Unit
	35.5	38.7	-3.2	-8.3	
	35.4	38.8	-3.4	-8.8	
Average	35.1	38.7	-3.6	-9.5	

[17] Percent Difference = 100 * (RH - Calibration RH) / Calibration RH.

TABLE 7
(Continued)
RELATIVE HUMIDITY CALIBRATION DATA

Date	Relative Humidity (%)	Calibration Relative Humidity (%)	Relative Humidity Difference	Percent Difference[18]	Comments
09/06/97	39.3	41.5	-2.2	-5.3	Transfer Unit
	39.3	41.9	-2.6	-6.2	
	38.5	38.4	0.1	0.3	
Average	39.0	40.6	-1.6	-3.9	
09/27/97	33.7	39.8	-6.1	-15.3	Transfer Unit
	37.0	40.0	-3.0	-7.5	
	36.5	41.1	-4.6	-11.2	
Average	35.7	40.3	-4.6	-11.3	
09/29/97	56.7	53.5	3.2	6.0	Transfer Unit
	56.9	53.7	3.2	6.0	
	55.2	52.9	2.3	4.3	
Average	56.3	53.4	2.9	5.4	

[18] Percent Difference = 100 * (RH - Calibration RH) / Calibration RH.

TABLE 8
AIRCRAFT DATA PROCESSING PROGRAMS AND DATA FILES

PROGRAM	INPUT FILES	OUTPUT FILES	COMMENTS
DOS			
UC-TEST	N/A	N/A	Prints the data to the screen at approximately five second intervals to verify data logging.
UC-DATA	N/A	mm-dd-nn.DAS mm-dd-nn.NAV	Aircraft data logging program (*.DAS is the primary data. *.NAV is navigation data).
UC-CRRCT	mm-dd-nn.DAS	mm-dd-nn.DAS mm-dd-nn.LOG	Corrects radio transmission data spikes.
UC-CNVRT	mm-dd-nn.DAS mm-dd-nn.NAV	mm-dd-nn.DAT mm-dd-nn.NAT	Converts voltages to scientific units and decodes GPS nav data. Requires initial altitude of file.
UC-CVRT2	mm-dd-nn.DAT mm-dd-nn.NAT	mm-dd-nn.DAC	Makes calibration corrections, flags erroneous data and combines navigation data with other variables. *.DAC files are main working files.
UC-LOOK	mm-dd-nn.DAC	N/A	User selected screen plots and print summaries of data.
WIN-95			
UCDACVU	mm-dd-nn.DAC	Optional bitmap plots	View DAC data in tables with Max, Min, Ave summaries, time plots and sounding plots.
UCSCOSVU	mmdd-ftp.DCC	Optional bitmap plots	View DAC data in tables with Max, Min, Ave summaries, time plots and sounding plots.

Where: mm = month, dd = date, nn = file number, f = flight number, t = type (S for spiral, T for transect) and p = place or location (1 = El Monte, takeoff, 2 = Burbank, 3 = Pasadena, 4 = Azusa, 5 = Cable, 6 = Fullerton, 7= El Monte, landing)

TABLE 9
UCD FLIGHT PATTERN

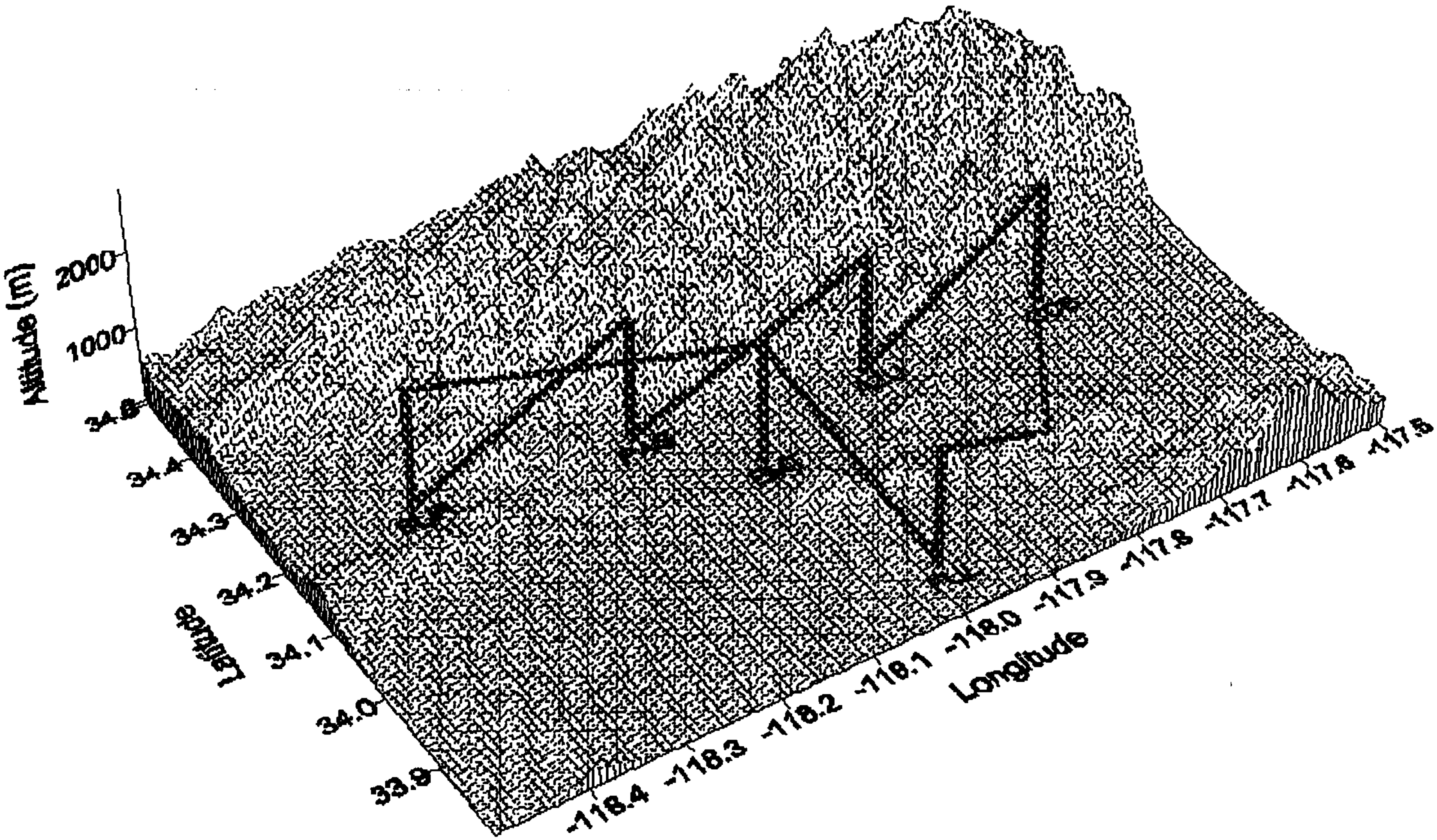
FLIGHT LEG	ALTITUDE (m MSL)	DISTANCE (nm)	COURSE (degrees magnetic)	TIME (min)	FLIGHT # 1 (PST)	FLIGHT # 2 (PST)	FLIGHT # 3 (PST)
Depart EMT	100	---	---	---	04:30	10:00	14:30
Spiral at EMT[19]	Climb to 1500	---	---	11	04:41	10:11	14:41
EMT to BUR	Climb to 2000	18	277	13	04:54	10:24	14:54
Spiral at BUR	Descend to surface	---	---	13	05:07	10:37	15:07
BUR to Pasadena	Climb to 1500	11	086	11	05:18	10:48	15:18
Spiral at Pasadena	Descend to 600	---	---	7	05:25	10:55	15:25
Pasadena to Azusa	Climb to 2100	13	083	13	05:38	11:08	15:38
Spiral at Azusa[19]	Descend to 500	---	---	11	05:49	11:19	15:49
Azusa to CCB	Climb to 2100	10	082	12	06:01	11:31	16:01
Spiral at CCB	Descend to surface	---	---	13	06:14	11:44	16:14
CCB to College	Climb to 1400	17	197	11	06:25	11:55	16:25
College to FUL	Climb 1400 to 1500	5	255	4	06:29	11:59	16:29
Spiral at FUL	Descend to surface	---	---	11	06:40	12:10	16:40
FUL to EMT	Climb to 1500	13	355	13	06:53	12:23	16:53
Spiral at EMT	Spiral to surface	---	---	11	07:04	12:34	17:04

[19] ROG can and carbonyl bag sample taken between 500 and 800 m MSL.

TABLE 10
DATA CONVERSION

VARIABLE	EQUATION	SCIENTIFIC UNITS
Pressure	P = millivolts * 0.09997 + 600	millibars
Altitude	Z = - (0.96*P + 7470)*ln(P/1013.25)/0.3048 + Zcorr Where Zcorr = Zinitial (for the first altitude)	feet
Temperature 1	Ta = millivolts * 0.172 - 18.5	°C
Temperature 2	T' = millivolts * 0.1423 - 19.15	°C
Relative Humidity	RH = millivolts / 10	%
Airspeed	V = millivolts * 0.01524 * 1013/P * (Ta + 273.15)/294.25	ms^{-1}
Heading	HDG = millivolts * 0.072	deg. magnetic
Nitric Oxide	NO = millivolts * 0.05	ppbv
Oxides of Nitrogen	NO_y = millivolts * 0.05	ppbv
Ozone	O_3 = millivolts - 9	ppbv
Particles d > 0.3 μm	PC1 = millivolts * 11307 / 1000000	# * $10^6/m^3$
Particles d > 3.0 μm	PC2 = millivolts * 113.1 / 1000	# * $10^3/m^3$

Figure 1
Relief map of Los Angeles Basin
showing UCD flight path.



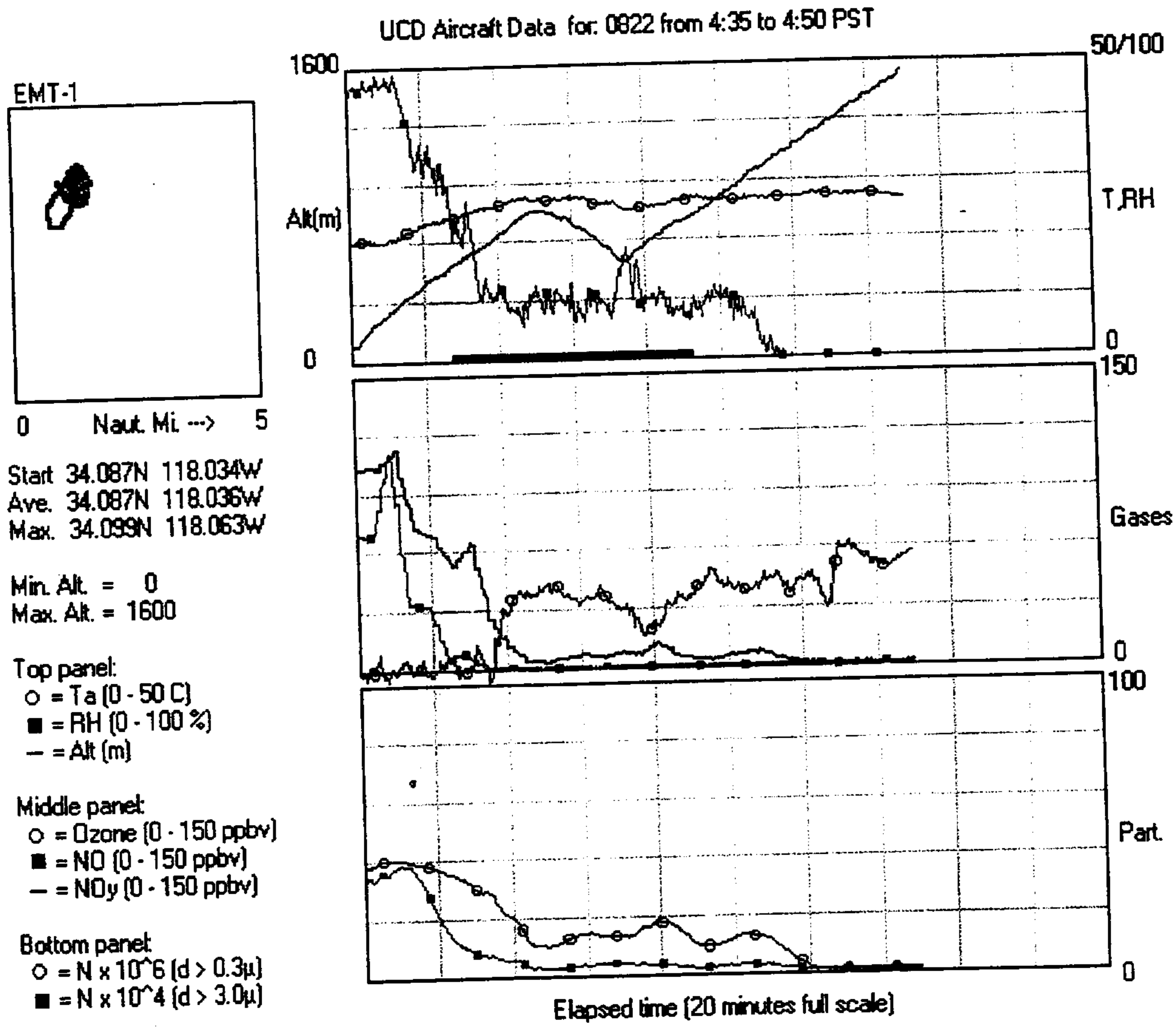


Figure 2. Sample time plot from program UCSCOSVU for the early morning flight of August 22 over El Monte. Panel at upper left shows plan view of the flight track. Top right panel shows altitude (solid line) scaled at the left side of the panel according to altitude range of the aircraft. Line with circles is temperature scaled 0 to 50°C and relative humidity (noisy line with square symbols) scaled 0 to 100% on the right side of the panel. The heavy line along the time axis is the event maker denoting the time during which the carbonyl bag was being filled. The middle panel shows concentrations of ozone (line with circles), NOy (solid line) and NO (solid line with square symbols) all scaled 0 to 150 ppbv. The bottom panel shows particle concentrations for diameters > 0.3 μm scaled 0 to 100 x 10^6 particles per m^3 and for diameters > 3.0 μm scaled 0 to 100 x 10^4 particles per m^3.

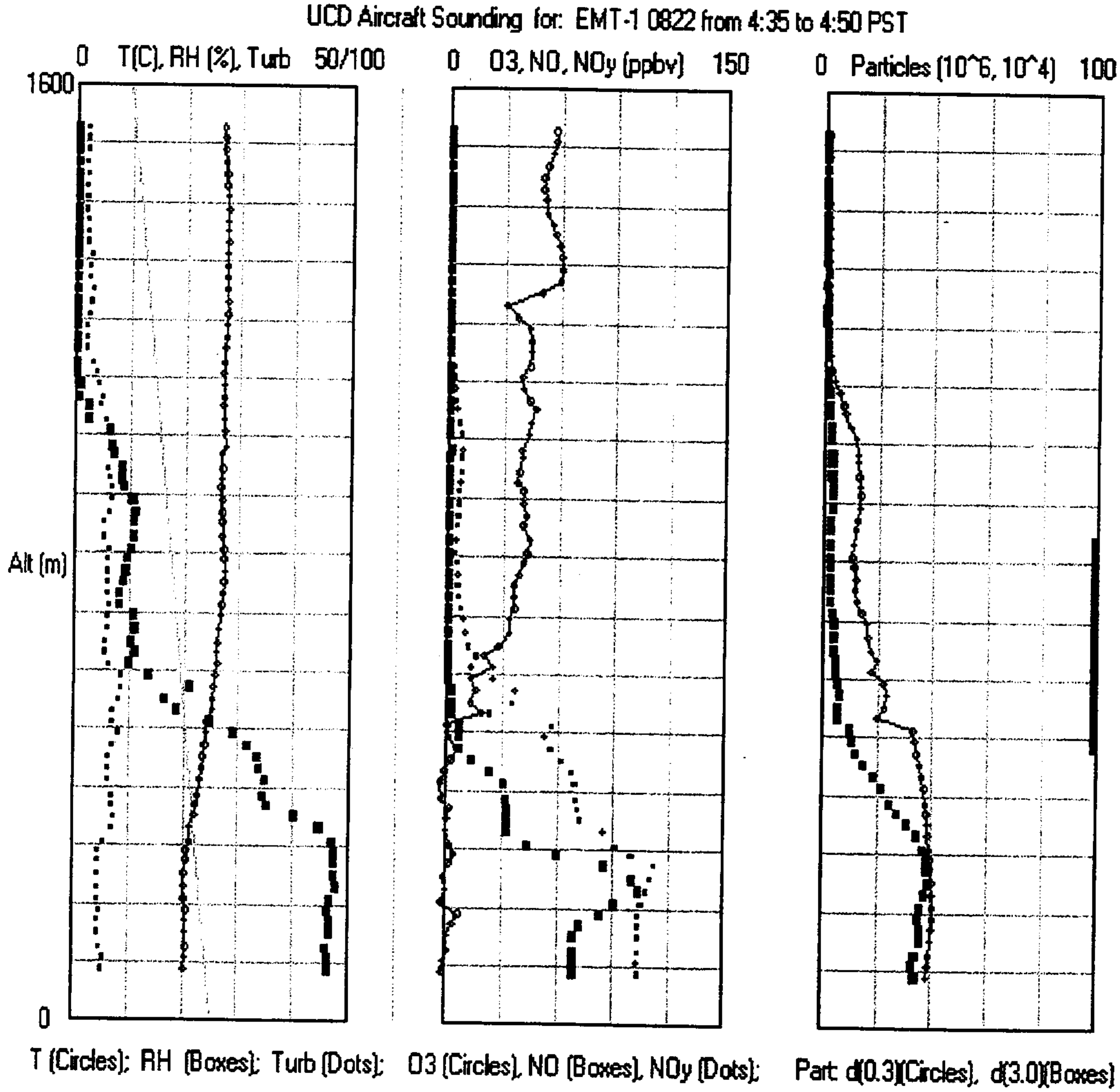


Figure 3. Sample sounding plot for the same time and place as in Figure 2. Data plotted are averages over layers 20 m thick using the same scaling and symbols as for the time plot. The heavy solid line on the right side of the right panel is the event (bag fill) marker. An additional variable is the summed rms fluctuations of airspeed, temperature and relative humidity, representing a measure of turbulence (Turb.) in the atmosphere, plotted as dots in the left hand panel. The grey sloping line across the left hand panel represents a neutral atmospheric temperature profile.