SCOS97-NARSTO
1997 SOUTHERN CALIFORNIA OZONE STUDY AND AEROSOL STUDY

VOLUME II: QUALITY ASSURANCE PLAN

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1. INTRODUCTION

The California Air Resources Board (ARB), San Diego County Air Pollution Control District (SDAPCD), South Coast Air Quality Management District (SCAQMD), Ventura County Air Pollution Control District (VCAPCD), U. S. Environmental Protection Agency (EPA) - Region IX, and the U. S. Navy are planning the 1997 Southern California Ozone Study (SCOS97) as part of the North American Research Strategy for Tropospheric Ozone (NARSTO). The goals of the study are to update and improve the existing aerometric and emission databases and model applications for representing urban-scale ozone episodes in southern California, and to quantify the contributions of ozone generated from emissions in one southern California air basin to federal and state ozone standard exceedances in neighboring air basins. The SCOS97-NARSTO Field Study Plan (Fujita et al., 1996) provides a conceptual model for the ozone episodes and transport scenarios of interest and specifies the data requirements for data analysis and modeling. It also describes the required quality assurance (QA), data validation, and data management needs. This document specifies the QA activities that will be performed during SCOS97-NARSTO.

The purpose of quality assurance is to provide a quantitative estimate of the uncertainty of the measurements through estimates of the precision, accuracy (or bias), and validity. In addition, QA ensures that the procedures and sampling methods used in the study are well documented and are capable of producing the data which meet the specifications of the study. The QA auditing program consists of two components: system audits and performance audits. System audits include review of operational and quality control procedures to assess whether they are adequate to assure valid data which meet the specified levels of accuracy and precision. After reviewing the procedures, the auditor examines all phases of the measurement or data processing activity to determine whether the procedures are being followed and the operating personnel are properly trained. Performance audits establish whether the predetermined specifications for accuracy are being achieved in practice. For measurements, the performance audit involves challenging the measurement/analysis system with a known standard sample that is traceable to a primary standard. Measurements that can be subject to sampling artifacts, such as carbonyl compounds, hydrocarbon speciation, and NOy, preclude simple performance audits. Intercomparison studies are often used in these cases to assess the representativeness, accuracy, and precision of these measurements.

Quality assurance is closely connected with data management. Before sampling starts, the QA team assists the investigators and the data management contractor to develop the format of the database; the QA team also reviews the investigators' standard operating procedures (SOPs) and makes estimates of the precision and accuracy that might be expected from the measurement systems. Prior to or during sampling the QA team carries out systems and performance audits and helps resolve any problems. Once the sampling has been completed and the investigators have provided the data management contractor with level 1A-validated (verified, screened, adjusted and flagged) data sets, the QA team helps validate the data in two stages, level 1B (univariate checks such as maxima and minima, rates of change and diurnal variations) and level 2 (multivariate consistency tests based on known physical, spatial or temporal relationships). Level 1B validation should be performed by the data manager with validation criteria determined by agreement between measurement investigators and the QA team. The QA team also makes the final estimates of the precision and accuracy of the data with the help of the investigators and the data manager.

This QA plan describes the procedures that will enable the QA Team to verify that planned quality control procedures are being followed and the measured data are meeting specified tolerances. The plan identifies the work elements to be performed, the technical approach for implementing each element, and the schedule for performing the work. It specifies the measured quantities to be challenged during the audits, criteria for evaluation of audit findings, estimated precision and accuracy of audit standards, certification of audit standards, and approaches to problem resolution and verification of corrections. Data quality objectives (see section 3) are specified prior to the study to ensure that all measured data meet the end-use requirements for air quality and meteorological model input and evaluation, data analyses, and monitoring the success of meeting data quality objectives. Precision and accuracy goals are identified for measurement variables. Many methods and procedures employed in SCOS97-NARSTO are routinely measured variables for which expected precision and accuracy are known. Other measurements are experimental and target objectives that can only be estimated.

Quality assurance will be under the overall direction of Desert Research Institute, the QA manager for SCOS97-NARSTO. DRI will coordinate a QA team consisting of staff from sponsoring agencies and other contractors that have the necessary expertise to carry out the QA activities in this plan. DRI and the QA team will review standard operating procedures, perform system and performance audits, review and validate study data processing procedures and data, and estimate the uncertainties in the data. The QA team will work closely with the data manager, the field manager, and investigators.

1.1 Goals and Technical Objectives of SCOS97-NARSTO

The goals of the SCOS97-NARSTO study are to :

1. Update and improve the existing aerometric and emission databases and model applications for representing urban-scale ozone episodes in southern California, with a primary emphasis on high ozone concentrations in the South Coast Air Basin and secondary emphasis on high ozone concentrations in the San Diego Air Basin, the South Central Coast Air Basin, and the Southeast Desert Air Basin.

2. Quantify the contributions of ozone generated from emissions in one southern California air basin to federal and state ozone standard exceedances in neighboring air basins. Evaluate the interaction of transported ozone and ozone precursors, both at the surface and aloft, with emissions in neighboring receptor areas. Apply modeling and data analysis methods to design regional ozone attainment strategies.

These goals are to be met through a process which includes analysis of existing data; execution of a large-scale field study to acquire a comprehensive database to support modeling and analysis; analysis of the data collected during the field study; and the development, evaluation, and application of an air quality simulation model for southern California.

Specific technical objectives of SCOS97-NARSTO are as follows:

1. Obtain a documented data set of specified precision, accuracy, and validity that supports modeling and data analysis efforts.

2. Document the frequency, intensity, and character of high ozone concentrations and its VOC and NO_X precursors within and between neighboring southern California air basins, and determine how these have changed over the past decade.

3. Identify and describe transport pathways between neighboring air basins, and estimate the fluxes of ozone and precursors transported at ground level and aloft under meteorological conditions associated with high ozone concentrations.

4. Quantify the uncertainty of emissions rates, chemical compositions, locations, and timing of ozone precursors that are estimated by emission models.

5. Quantify the uncertainty of meteorological models in simulating transport and mixing of precursors and end-products within and between air basins.

6. Quantify the uncertainty of air quality models in simulating atmospheric transformation and deposition.

7. Provide the meteorological and air quality measurements needed to estimate, with stated uncertainty intervals, the contributions from background, regional mixing and transport, and local emitters to ozone concentrations that exceed standards in each of the air basins.

8. Provide the meteorological and air quality measurements needed to estimate the effects of different emission reduction strategies on ozone concentrations within and beyond each air basin, and identify those that cause the greatest reduction in population exposure for the least cost.

1.2 Study Location

SCOS97 will encompass the South Coast (SoCAB), San Diego (SDAB), South Central Coast (SCCAB), and Southeast Desert (SEDAB) Air Basins extending to northern Mexico to the south and to Nevada and Arizona to the east. The northern boundary of this study will include the southern portion of the San Joaquin Valley Air Basin (SJVAB). The western boundary will be defined by the results of measurements which identify where clean air typically exists over the Pacific Ocean.

1.3 Study Area Climatology

Southern California is in the semi-permanent high pressure zone of the eastern Pacific. During summer, average temperatures are ~25 °C, with maximum daily readings often exceeding 35 °C. Precipitation events are rare. Frequent and persistent temperature inversions are caused by subsidence of descending air which warms when it is compressed over cool, moist marine air. These inversions often occur during periods of maximum solar radiation which create daytime mixed layers of ~1,000 m thickness, though the top of this layer can be lower during extreme ozone episodes (Blumenthal *et al.*, 1978). Relative humidity depends on the origin of the air mass, proximity to the coast, altitude, and the time of day, and can exceed 50 percent during daytime throughout the SoCAB with the intrusion of a deep marine layer. Relative humidity is higher near the coast than farther inland (Smith *et al.*, 1984

Smith *et al.* (1972), Keith and Selik (1977), and Hayes *et al.* (1984) describe wind flow patterns in the SoCAB. During summer, the sea-land breeze is strong during the day with a weak land-sea breeze at night. Owing to the high summer temperatures and extensive urbanization in the SoCAB, the land surface temperature does not usually fall below the water temperature at night, and nocturnal and morning winds are less vigorous than daytime winds. The land surface cools sufficiently to create surface inversions with depths as shallow as ~50 m. Surface heating usually erodes the surface and marine layers within a few hours after sunrise each day. Summertime flow patterns are from the west and south during the morning, switching to predominantly westerly winds by the afternoon. The land/sea breeze circulation moves air back and forth between the SoCAB and the Pacific Ocean, as well as along the coast to other air basins. Cass and Shair (1984) estimated that up to 50 percent of the sulfate measured at Lennox was due to emissions which had been transported to sea on the previous day. When wind speeds are low, air tends to slosh back and forth within the SoCAB.

In addition to these general features, there are many smaller features that affect the movement of pollutants within the SoCAB. Heating of the San Gabriel and San Bernardino Mountains during the daytime engenders upslope flows that can transport pollutants from the surface into the upper parts of, and sometimes above, the mixed layer. When the slopes cool after sunset, the denser air flows back into the SoCAB with pollutants entrained in it. Convergence zones occur where terrain and pressure gradients direct wind flow in opposite directions, resulting in an upwelling of air. Smith *et al.* (1984) have identified convergence zones at Elsinore (McElroy *et al.*, 1982; Smith and Edinger, 1984), the San Fernando Valley (Edinger and Helvey, 1961), El Mirage, the Coachella Valley, and Ventura. Rosenthal (1972) and Mass and Albright (1989) identified a Catalina Eddy, a counterclockwise mesoscale circulation within the Southern California Bight, as a mechanism for transporting air pollution. This eddy circulation transports pollutants from the SoCAB to Ventura, especially after the SoCAB ozone levels drop due to wind ventilation caused by an approaching low-pressure trough from the northwest. However, any southeast wind in southern California is initially capable of transporting polluted air consisting of ozone precursors and particulate matter from the SoCAB.

General meteorological conditions and trajectories during the 1987 SCAQS episodes have been examined by Douglas *et al.* (1991). Flows during the summertime were westerly, and residence times were often less than 12 hours. The backward trajectories from Claremont and Riverside on August 27 and 28, 1987 show an upper level recirculation in the middle of the SoCAB that probably led to the build-up of ozone and precursors during the episode. Trajectories during SCAQS episodes were consistent with stagnation conditions desired for selecting episodes, and they provide confidence that the SCAQS forecasting methods can be successfully adapted to SCOS97 to evaluate high ozone episodes in the SoCAB. Summer episodes showed west to east transport with potential for pollutant carryover aloft.

Green *et al.* (1992a) classified wind field patterns in the SoCAB, San Joaquin Valley, and Mojave Desert during 1984 and 1985 to evaluate visibility reduction in the desert. This analysis evaluated transport between the SoCAB and the Mojave and Arizona deserts. Winds were found to be directly related to the pressure field, which, in summer, resulted from a consistent mesoscale component added to a varying synoptic-scale component. Three main summer patterns were found, all of which had some transport into the SEDAB from the SoCAB. The first, and predominant, pattern indicated typical summer conditions with the wind field driven by the ocean/interior temperature difference and terrain features. The second pattern typically occurred in early summer (May-early June), and had stronger flow into the desert due to synoptic-scale pressure gradients (upper level low pressure over the west coast, surface low over the Intermountain region). This type was also less stable due to cold air aloft. The third pattern showed weaker flow into the desert (and flow from the SEDAB to the SoCAB for a few hours per day) due to higher pressure to the northeast.

The predominant surface wind climatologies for California have been compiled for ARB by Hayes *et al.* (1984) based on 1977-1981 wind data. Hayes *et al.* found seven types of wind flow patterns for the SoCAB and the surrounding air basins. During summer (June-August) and fall (September-November), calm, offshore, and downslope/transitional patterns dominate the early morning hours, allowing pollutants to accumulate in SoCAB industrial and business areas. Pollutants then move inland with the sea breeze in the afternoon hours. However, a period of southeast flow towards Ventura County can occur as the land breeze veers to a daytime sea breeze. While this diurnal sequence is most common during the ozone season, other combinations of wind patterns occur that drive interbasin transport. For example, off-shore surface transport from the SoCAB to San Diego may occur with the offshore winds, the downslope/transitional winds, and/or the weak Santa Ana.

1.4 Study Period and Intensive Operational Periods

The SCOS97 field measurement program will be conducted during a four-month period from June 15, 1997 to October 15, 1997. This study period corresponds to the majority of elevated ozone levels observed in southern California during previous years. Continuous surface and upper air meteorological and air quality measurements will be made hourly throughout this study period. Additional measurements will be made during intensive operational periods (IOPs) on a forecast basis for two to four consecutive days. Forecasts are prepared each day during the four-month period and IOP measurement groups are on standby. The budget for SCOS97-NARSTO allows for no more than 15 days total for the IOPs. With a minimum of two days per IOP, the maximum number of IOPs is seven. Five IOPs is more likely, with an average IOP duration of three days. The conceptual model for this study defines five categories of meteorological conditions, called scenarios, which are associated with ozone episodes and ozone transport in southern California. Intensive measurements will be made during these scenarios. The five scenarios in order of priority as specified by the SCOS97-NARSTO Technical Committee, and the periods of highest probability of their occurrence are as follows:

1. SoCAB Ozone Maximum (Type 1 IOP in late July to end of August). SoCAB pollutants remain trapped within SoCAB. There may be "local" exceedance days for other basins. This condition may be accompanied by a "coast hugger," a near-coast flow of SoCAB pollutants toward the southeast.

2. Upper- Level Transport to San Diego (Type 2 IOP in late July to end of August). Ozone in a layer 300-500 m MSL above the marine layer or above the nocturnal inversion jets southeast toward San Diego. The centerline and width of this pathway are uncertain, and may range from the Interstate 15 route (east) to an off-shore route (west).

3. Secondary SoCAB Ozone Maximum (Type 3 IOP in late July to end of August). An on-shore breeze causes inland transport, with likely transport into the Mojave Desert. This situation may also correspond to local exceedances for Ventura, Santa Barbara, and San Diego Counties.

4. Eddy Transport to Ventura after SoCAB Maximum (Type 4 IOP in june). This is an extended SoCAB episode that ends with a southeast wind offshore, over the basin, and even sometimes in the desert. It is possibly an extension of Scenario #1 or #2. The ozone peaks are often seen at Newhall or Simi Valley on these days.

5. Off-Shore Surface Transport Direct to San Diego Air Basin (Type 5 IOP in September to October). This event is characterized by a mild Santa Ana wind condition followed by the on-shore flow. It occurs with greatest frequency later in the ozone season

These five scenarios comprise the core of a "conceptual model" of the ozone episodes and transport scenarios on interest, which serves as the basis for the experimental design of SCOS97-NARSTO. In practice, there may be overlap between the scenarios. For example, also related to the Santa Ana winds discussed in Scenario #5 are subsequent periods of southeast flow which cause transport to the South Central Coast Air Basin as discussed in Scenario #4. Mild Santa Ana winds may be associated with simultaneous transport from southern portions of SoCAB to SDAB and from northern portions of the SoCAB to the SCCAB.

1.5 Forecast and Decision Protocol

The decision to declare an IOP will be based on daily meteorological and air quality forecasts provided by a forecast team consisting of meteorologist from the California Air Resources Board, local air quality districts, and U.S. Navy. These forecasts and other information on current conditions and operational status will be used by the SCOS97-NARTO Management Team to decide whether intensive sampling would be performed the next day.

Under the current budget, there are probably sufficient resources for only one IOP for each type. The abort procedure formulated by the forecast team will be implemented to terminate an IOP if meteorological conditions do not follow expectations. While it is preferable to have all measurement systems operational for each IOP, and every attempt will be made to assure their operability, the program has been designed to allow an IOP to proceed even if some equipment is inoperable. A critical level of operability needs to be defined, however, beyond which an IOP would not acquire enough data to be useful. Maintenance and re-supply between IOPs needs to be considered as well. Depending on the number of consecutive total IOP days just completed and the number of aircraft used, the aircraft equipment operators need one or two days without sampling before starting another IOP. In addition, routine maintenance, which is a function of flight hours, is required.

1.6 SCOS97-NARSTO Measurements

Continuous surface-based measurements will be made daily throughout the study period, which begins June 15, 1997 and end on October 15, 1997. The study period monitoring network consists of existing surface air quality, surface meteorology, and upper-air meteorology monitoring sites, as well as new sites added specifically for this study. The continuous data are used to:

- Characterize or describe the spatial and temporal distribution of pollutant concentrations and meteorological parameters on days leading up to and during ozone episodes and for documenting the frequency of occurrence of different measures for comparison with prior and later years.
- Document the transport of pollutants and precursors between major source regions and non-attainment receptor areas, between the major source regions, and between offshore and onshore, during both episode and non-episode conditions.
- Provide initial and boundary conditions for air quality model initialization, and input data for data assimilation by prognostic meteorological models.
- Provide data within the modeling domain to evaluate the output of the models and to diagnose deviations of model assumptions from reality.

1.6.1 Existing Surface Air Quality and Meteorological Monitoring Sites

Currently operating ozone and NO_X monitoring sites are identified with respect to location, name, and associated measurements in Appendix A. All of these sites are operated by state and local air quality districts, are subject to quality assurance programs, and report their measurements into a common database. This network is adequate to characterize O_3 and NO_X at receptor sites in the study region. Photochemical Assessment Monitoring Stations (PAMS) hydrocarbon and carbonyl compound sampling will be conducted at 13 sites from July 1, 1997 to September 30, 1997, according to the schedule shown in Table 1-1. Additionally, PAMS VOC monitoring will be needed during IOPs that occur in June and October 1997. Ozone information is also provided by the U.S. Naval Air Warfare Center which operates ozone analyzers at Point Mugu and on nearby Laguna Peak to document correlations between ozone and wind direction.

Table 1-1

VOC Measurements at Photochemical Assessment Monitoring Stations (PAMS) in Southern California

Site Location	Type of Site	Year Deployed	VOC Method	Carbonyl Method	Frequency of VOC Measurements: EPA Rule	Frequency of VOC Measurements: CA Alternative Plan	Frequency of Carbonyl Measurements: EPA Rule	Frequency of Carbonyl Measurements: CA Alternative Plan
Ventura County								
El Rio	2	1994	Canister/GC-FID	DNPH/HPLC	B	E, F	D	E
Simi Valley	3	1995	Canister/GC-FID		A or C	E, F		
Ventura - Emma Wood State Beach	1	1996	Canister/GC-FID		A or C	E, F		
South Coast Air Basin								
Pico Rivera	2	1994	Auto-GC	DNPH/HPLC	B	E, F	D	E
Upland	4	1994	Canister/GC-FID		A or C	E, F		
Azusa	3	1995	Canister/GC-FID		A or C	E, F		
Hawthorne	1	1996	Canister/GC-FID		A or C	E, F		
Burbank	2	1997?	Auto-GC?	DNPH/HPLC	B	E, F	D	E
Southeast Desert Air Basin								
Upland	1	1994	Canister/GC-FID		A or C	E, F		
Banning	2	1995	Canister/GC-FID	DNPH/HPLC	A or C	E, F	D	E
Burbank	1	1997?	Auto-GC?		A or C	E, F		
San Diego Air Basin								
El Cajon	2	1994	Canister/GC-FID	DNPH/HPLC	B	E, F	D	E
Alpine	3	1995	Canister/GC-FID		A or C	E, F		
Camp - Del Mar	1	1996	Canister/GC-FID		A or C	E, F		
San Diego - Overland	2	1994	Canister/GC-FID	DNPH/HPLC	B	E, F	D	E

Type 1 - Upwind background.
Type 2 - Maximum precursor emissions (typically located immediately downwind of the central business district).
Type 3 - Maximum ozone concentration.
Type 4 - Extreme downwind transported ozone area that may contribute to overwhelming transport in other areas.

A. Eight 3-hour samples (starting at midnight, PDT) every third day and one additional 24-hour sampler every sixth day during monitoring period (July-September).
B. Eight 3-hour samples (starting at midnight, PDT) every day during the monitoring period (July-Sept and one additional 24-hour sample every sixth day year-round.
C. Eight 3-hour samples on the 5 peak ozone days plus each previous day, eight 3-hour samples every sixth day, and one additional 24-hour sample every sixth day during monitoring period.
D. Eight 3-hour samples (starting at midnight, PDT) every day during the monitoring period (July-September).
E. Four 3-hour samples (3-6am, 6-9am, 1-4pm, 5-8pm, PDT) every third day during monitoring period (probably July-September), and four samples (6-9am, 9-noon, 1-4pm, 5- 8pm, PDT) per day on two consecutive days for five episodes during peak ozone season.
F. Continuous NMHC analyzer (e.g., Bendix 8202 or automated Preconcentration Direct injection Flame Ionization Detection gas chromatography, PDFID).

Many of the air quality monitoring sites also measure wind and temperature. In addition to those air quality sites which measure meteorology, there is an extensive network of existing surface meteorological sites spread throughout the study area, including offshore locations on islands, oil platforms and instrumented environmental buoys. These sites generally provide continuous measurement of wind speed and direction with an averaging time of one hour or less. They are operated by military and civilian airports, air quality districts, the National Weather Service, and others. Appendix B lists these surface meteorological monitoring sites. As planning progresses, it is likely that additional meteorological monitoring networks will be identified and added to this network, and Appendix B should be modified and verified accordingly. The existing network of surface measurements is adequate to determine some surface transport patterns, but it is not sufficient to determine winds aloft or some mesometeorological phenomena.

1.6.2 Supplemental Air Quality and Meteorological Measurements

The existing surface air quality and meteorological monitoring network will be supplemented by additional measurements made specifically during the SCOS97-NARSTO study period. Table 1-2 provides a summary of the supplemental surface air quality and meteorological measurements that will be made by contractors and by in-kind support from the U.S. Environmental Protection Agency. Table 1-2 also indicates planned systems and performance audits.

The majority of the supplemental surface air quality measurements are in connection with collection of volatile organic compounds (VOC) samples and continuous measurements of ozone, nitric oxide (NO), nitrogen dioxide (NO_2), oxides of nitrogen (NO_X), total oxidized nitrogen (NO_y), and peroxyacetylnitrate (PAN), especially in critical areas of the study domain (e.g., transport corridors) where these measurements are not currently being made. Accurate quantification of NO and NO_2 is important because the inter-conversion of NO and NO_2 is the photochemical mechanism for the formation and destruction of ozone in the troposphere. Organic nitrates such as PAN provide a means to transport NO_X from source regions to downwind locations. Total oxidized nitrogen (NO_y) provides an estimate of the total nitrogen budget and photochemical aging of the air mass. As described in the previous section, current PAMS networks in southern California do not measure hydrocarbons and carbonyl compounds on a daily basis, with the exception of the Pico Rivera Type 2 site in the SoCAB. Supplemental measurements are required for the SCOS97 study during multi-day intensives in order to obtain VOC measurements throughout the IOP. VCAPCD and SDAPCD will supplement their existing sampling schedules to include all SCOS97 IOP days. Because of their larger network, the SCAQMD will not be able to supplement their existing sampling schedule. The supplemental measurements for SCOS97-NARSTO include additional PAMS VOC measurements in the SoCAB. In addition, the extreme downwind PAMS site in SoCAB is scheduled for deployment in 1998, one year after the SCOS97 study. Lancaster has been tentatively selected for this site. The MDAPCD is considering VOC measurements in the Lancanster during SCOS97 to document transport of VOC through Soledad Canyon at Hesperia to document transport of VOC through Cajon Pass. The two "tracers of opportunity", perchloroethylene and methylchloroform will be measured semi-continuously near the Barstow area.

Table 1-2
SCOS97-NARSTO Supplemental Surface Air Quality Measurements

Rec. #	Institution	Investigator	Species	Units	Measurement Device	Site Location	Air Basin
1	CE-CERT	Fitz, Dennis	HNO3 & Ammonia	ppbV	Double Diffusion Denuder	Azusa	SoCAB
2	CE-CERT	Fitz, Dennis	HNO3 & Ammonia	ppbV	Double Diffusion Denuder	Riverside	SoCAB
3	CE-CERT	Fitz, Dennis	HNO3, NO2	ppbV	TDLAS	Azusa	SoCAB
4	CE-CERT	Fitz, Dennis	NOy, NO & Ozone	ppbV	TECO 42CY & Dasibi	San Nicolas Island	SoCAB
5	CE-CERT	Fitz, Dennis	NOy, NO, NO2, HNO3	ppbV	TECO 42CY & TECO 42/14	Azusa	SoCAB
6	CE-CERT	Fitz, Dennis	NOy, NO, NO2, HNO3	ppbV	TECO 42CY & TECO 42/14	Burbank	SoCAB
7	CE-CERT	Fitz, Dennis	NOy, NO, NO2, HNO3	ppbV	TECO 42CY & TECO 42	Banning	SoCAB
8	CE-CERT	Fitz, Dennis	NOy, NO, NO2, HNO3	ppbV	TECO 42CY & TECO 42	Simi Valley	SCCAB
9	CE-CERT	Fitz, Dennis	NOy, NO, NO2, HNO3	ppbV	TECO 42CY & TECO 42	Alpine	SDAB
10	CE-CERT	Fitz, Dennis	NOy, NO, NO2, HNO3	ppbV	TECO 42 + Moly Converter	Riverside	SoCAB
11	CE-CERT	Fitz, Dennis	VOCs, CH4 (CO, CO2, Carbonyls)	ppbC (ppbV)	Cans & DNPH cartridge	San Clemente	SoCAB
12	CE-CERT	Fitz, Dennis	VOCs, CH4 (CO, CO2, Carbonyls)	ppbC (ppbV)	Cans & DNPH cartridge	Azusa	SoCAB
13	CE-CERT	Fitz, Dennis	VOCs, CH4 (CO, CO2, Carbonyls)	ppbC (ppbV)	Cans & DNPH cartridge	LA North Main	SoCAB
14	CE-CERT	Fitz, Dennis	VOCs, CH4 (CO, CO2, Carbonyls)	ppbC (ppbV)	Cans & DNPH cartridge	Burbank??	SoCAB
15	DGA	Grosjean, Daniel	PAN, PPN, PERC, Meth Chlor	ppbV	Gas Chromotagraphy-ECD	Azusa	SoCAB
16	DGA	Grosjean, Daniel	PAN, PPN, PERC, Meth Chlor	ppbV	Gas Chromotagraphy-ECD	Simi Valley	SCCAB
17	DRI	Zielinska, Barbara	VOCs, CH4 (CO, CO2, Carbonyls)	ppbC (ppbV)	Cans & DNPH cartridge	Tijuana	Mexico
18	DRI	Zielinska, Barbara	VOCs, CH4 (CO, CO2, Carbonyls)	ppbC (ppbV)	Cans & DNPH cartridge	Mexicali	Mexico
19	EPA	Lewis	radiocarbon	ppbC	canisters	San Gabriel Mt Peaks	SoCAB
20	EPA	McClenny/Lewis	VOCs/radiocarbon	ppbC	Continuous GC	Azusa	SoCAB
21	PSU?	O'Brien, Bob	HO, HO2, RO2	ppbV	Laser Fluorescence	Azusa (Pico Rivera?)	SoCAB
22	UC Riverside	Arey, Janet	Isoprene, Terpenes, MVK?	ppbC (ppbV)	canisters & FID	Ojai	SCCAB
23	UC Riverside	Arey, Janet	Isoprene, Terpenes, MVK?	ppbC (ppbV)	canisters & FID	San Gabriel Mt Peaks	SoCAB
24	UC Riverside	Arey, Janet	MVK?, oxydation biogenic HC	ppbC (ppbV)	canisters & FID	El Monte	SoCAB
25	Aervironment	Pankratz, David	ozone & WS, WD, T, RH	ppbV m/s mb & C	Dasibi & Std Met	Santa Catalina-Airport	SoCAB
26	Aervironment	Pankratz, David	ozone & WS, WD, T, RH	ppbV m/s mb & C	Dasibi & Std Met	Calabasas	SoCAB
27	Aervironment	Pankratz, David	ozone & WS, WD, T, RH	ppbV m/s mb & C	Dasibi & Std Met	Palos Verdes	SoCAB
28	Aervironment	Pankratz, David	ozone NOy & WS, WD, T, RH	ppbV m/s mb & C	TECO 42 CY Dasibi & Std Met	Santa Catalina-Elevated	SoCAB
29	Aervironment	Pankratz, David	ozone NOy & WS, WD, T, RH	ppbV m/s mb & C	TECO 42 CY Dasibi & Std Met	El Cajon Pass	SoCAB
30	CE-CERT	Fitz, Dennis	ozone & met	ppbV m/s mb & C	Dasibi & Std Met	Tehachepi Pass	MDAB
31	UCD	Charles, Judy	Multifunctional Carbonyls	ppbV	PFBHA/Ion trap MS	Azusa??	SoCAB
32	UCLA	Paulson, Suzanne	Total reactive carbon	ppbC	cold trap & FID	Four sites along trajectory	SoCAB
33	UCR	Arey, Janet	PAH	ppbC	Hi-vol and PUF plugs	LA N. Main/Azusa/Riverside?	SoCAB

Table 1-2 Continued
SCOS97-NARSTO Supplemental Surface Air Quality Measurements

	Period		Averaging	Operational Checks		Calibration		Audit	
Rec. #	Starting	Ending	Time	By	Period	By	Period	Performance	System
1	IOP	IOP	Hourly	CE-CERT	Daily	CE-CERT	Daily	-	-
2	IOP	IOP	Hourly	CE-CERT	Daily	CE-CERT	Daily	-	-
3	IOP	IOP	Hourly	CE-CERT	Daily	CE-CERT	Daily	-	-
4	15-Jun-97	15-Oct-97	Hourly	CE-CERT	-	CE-CERT	Weekly	-	-
5	15-Jun-97	15-Oct-97	Hourly	SCAQMD	Daily	CE-CERT	Weekly	-	-
6	15-Jun-97	15-Oct-97	Hourly	SCAQMD	Daily	CE-CERT	Weekly	-	-
7	15-Jun-97	15-Oct-97	Hourly	SCAQMD	Daily	CE-CERT	Weekly	-	-
8	15-Jun-97	15-Oct-97	Hourly	VCAPCD	Daily	CE-CERT	Weekly	-	-
9	15-Jun-97	15-Oct-97	Hourly	SDCAPCD	Daily	CE-CERT	Weekly	-	-
10	15-Jun-97	15-Oct-97	Hourly	SCAQMD	Daily	CE-CERT	Weekly	-	-
11	IOP	IOP	8 hrs ??	CE-CERT	--	CE-CERT	IOP	DRI	DRI
12	IOP	IOP	3 hrs	CE-CERT	--	CE-CERT	IOP	DRI	DRI
13	IOP	IOP	3 hrs	CE-CERT	--	CE-CERT	IOP	DRI	DRI
14	IOP	IOP	3 hrs	CE-CERT	--	CE-CERT	IOP	DRI	DRI
15	15-Jun-97	15-Oct-97	Hourly	CE-CERT	Daily	CE-CERT	Daily	-	-
16	15-Jun-97	15-Oct-97	Hourly	DGA	Daily	DGA	Daily	-	-
17	IOP	IOP	3 hrs	Tracer ES&T	--	DRI	IOP	DRI	DRI
18	IOP	IOP	3 hrs	Tracer ES&T	--	DRI	IOP	DRI	DRI
19	1-Sep-97	1-Oct-97	hourly	EPA	Measurement	EPA	Measurement	-	-
20	1-Sep-97	1-Oct-97	hourly	EPA	Daily	EPA	Daily	DRI	DRI
21	IOP	IOP	Continuous	PSU	Daily	PSU	Daily	?	?
22	IOP	IOP	Species Dep	UCR	Measurement	UCR	Measurement	-	-
23	IOP	IOP	Species Dep	UCR	Measurement	UCR	Measurement	-	-
24	IOP	IOP	Species Dep	UCR	Measurement	UCR	Measurement	-	-
25	15-Jun-97	15-Oct-97	Hourly	CE-CERT	Daily	CE-CERT	Daily	ARB-MLD	ARB-MLD
26	15-Jun-97	15-Oct-97	Hourly	CE-CERT	Daily	CE-CERT	Daily	ARB-MLD	ARB-MLD
27	15-Jun-97	15-Oct-97	Hourly	CE-CERT	Daily	CE-CERT	Daily	ARB-MLD	ARB-MLD
28	15-Jun-97	15-Oct-97	Hourly	CE-CERT	Daily	CE-CERT	Daily	MLD (no NOy)	MLD (no NOy)
29	15-Jun-97	15-Oct-97	Hourly	CE-CERT	Daily	CE-CERT	Daily	MLD (no NOy)	MLD (no NOy)
30	15-Jun-97	15-Oct-97	Hourly	CE-CERT	Daily	CE-CERT	Daily	-	-
31	IOP	IOP	3 hrs	UCD	IOP	UCD	IOP	-	-
32	4 -1 week	1-Sep-97	hourly	UCLA	daily	UCLA	daily	-	-
33	IOP	IOP	12 hrs	UCR	IOP	UCR	IOP	-	-

The supplemental surface air quality measurements also include specialized measurements by several investigators. These measurements include radiocarbon, semi-continuous hydrocarbons, biogenic organic compounds, multifunctional carbonyl compounds, total reactive carbon and polycyclic aromatic hydrocarbons. Other than the automated gas chromagraphic hydrocarbon analysis by EPA, no system or performance audits are planned for these special measurements. In most cases, air quality data from the SCOS97 core measurements will allow for data validation checks by individual investigators.

1.6.3 Aloft Meteorological Measurements

To obtain information on temperature, relative humidity, and wind at various levels of the atmosphere above ground level, meteorological soundings will be used. Routine, twice-per-day radiosondes will provide in situ measurements of pressure, temperature, humidity, and wind speed and direction at various altitudes above ground. Two types of remote sounding, radar wind profilers and Doppler acoustic sounders, will provide continuous measurements of upper-air winds during the entire four-month SCOS97-NARSTO measurement period. Table 1-3 provides a summary of the aloft meteorological measurements that are currently being made by local agencies and that will be made by contractor. Table 1-3 also indicates planned systems and performance audits.

Radar Wind Profilers (RWP) provide sequential horizontal and vertical wind components in data assimilation and model comparison on a sub-hour time scale. RWPs generally acquire measurements within 100 to 150 m thick layers between ~0.150 and 3 km AGL with a minimum vertical resolution of 60 meters. A radio-acoustic sounding system (RASS) can be used to quantify virtual temperature to elevations of ~1 km AGL (up to 2 km AGL in ideal conditions), but this is insufficient altitude to characterize the daytime mixed layers of 2–3 km AGL often observed in much of the study area. There are currently five radar wind profilers operating in southern California, with a sixth expected near Escondido by 1997. Three of the profilers are required by the PAMS program. The Ventura County APCD operates one at Simi Valley, the South Coast Air Quality Management District operates one at Los Angeles International Airport, and the San Diego APCD operates one at Pt. Loma in San Diego. The other two are located at Ontario Airport and Vandenberg Air Force Base. The ARB has two profilers available to SCOS97 that will be sited within the SoCAB as needed, e.g., at Norton AFB and at the ARB facility in El Monte during 1996. RASS is used with each of the agency radar wind profilers to obtain a vertical profile of virtual temperature. Additional RWPs and sodars will be operated continuously during the SCOS97-NARSTO study by NOAA and Radian as shown in Table 1-3.

Acoustic Sounders (Sodars), like RWPs, also acquire continuous measurements of winds aloft. Sodars have better vertical resolution (~30 m layers from ~50 to 600 m AGL) but less vertical range (750 m AGL maximum). Sodars are most applicable in locations with lower-level structure, such as that found in marine layers, in channeling through canyons and passes, and in nighttime radiation inversions.

Radiosonde measurements provide characterization of the entire atmospheric boundary layer and portions of the upper atmosphere up to 10 mb (30 km ASL). These measurements provide information on winds, temperature, and humidity. In addition to the NWS twice-per-

Table 1-3
SCOS97-NARSTO Aloft Meteorological and Radiation Measurements

Rec. #	Institution	Investigator	Species	Units	Measurement Range	Device	Site Location	Air Basin
1	ARB	Smith, Reginald	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	El Monte Airport	SoCAB
2	ARB	Smith, Reginald	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Norton AFB	SoCAB
3	CE-CERT	Fitz, Dennis	WS, WD, RH, Pres, T	m/s mb & C	Srfc to 5 Km/100m	Rawinsonde-US Navy Base	USC-Hancock Fnd Bldg	SoCAB
4	CE-CERT	Fitz, Dennis	WS, WD, RH, Pres, T	m/s mb & C	Srfc to 5 Km/100m	Rawinsonde-US Navy Base	UCLA	SoCAB
5	CE-CERT	Fitz, Dennis	WS, WD, RH, Pres, T	m/s mb & C	Srfc to 5 Km/100m	Rawinsonde-US Navy Base	Cal State Northridge	SoCAB
6	NOAA	Neff, Bill	WS, WD	m/s	Srfc to 600m/75 m	mono Sodar	Oxnard Plain	SCCAB
7	NOAA	Neff, Bill	WS, WD	m/s	Srfc to 600m/75 m	Sodar	Santa Clarita Valley	SCCAB
8	NOAA	Neff, Bill	WS, WD	m/s	Srfc to 600m/75 m	Sodar	San Gabriel Mtn	SoCAB
9	NOAA	Neff, Bill	WS, WD	m/s	Srfc to 600m/75 m	Sodar	Banning	SoCAB
10	NOAA	Neff, Bill	WS, WD	m/s	Srfc to 600m/75 m	mono Sodar	Oceanside	SDAB
11	NOAA	Neff, Bill	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Goleta	SCCAB
12	NOAA	Neff, Bill	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Oxnard Plain	SCCAB
13	NOAA	Neff, Bill	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	USC-Hancock Fnd Bldg	SoCAB
14	NOAA	Neff, Bill	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Palmdale	SoCAB
15	NOAA	Neff, Bill	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	San Clemente Island	SoCAB
16	NOAA	Neff, Bill	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Santa Catalina	SoCAB
17	NOAA	Neff, Bill	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Cal State Northridge	SoCAB
18	NOAA	Neff, Bill	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Tustin	SoCAB
19	NOAA	Neff, Bill	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Los Alamitos	SoCAB
20	NOAA	Neff, Bill	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Alpine	SDAB
21	NOAA	Neff, Bill	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Oceanside	SDAB
22	NOAA	M.J. Post	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Brown Field	SDAB
23	NOAA	M.J. Post	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Calexico	Salton SAB
24	NWS	Helvy, Roger	WS, WD, RH, Pres, T	m/s mb & C	Srfc to 5 Km/100m	Rawinsonde	Miramar Nav Air St	SDAB
25	Radian-STI	Frederick, George	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Barstow	MDAB
26	Radian-STI	Frederick, George	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Victorville/George AFB	MDAB
27	Radian-STI	Frederick, George	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	March AFB/Riverside	SoCAB
28	Radian-STI	Frederick, George	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Thermal Airport	Salton SAB
29	Radian-STI	Frederick, George	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Temecula	SoCAB
30	SCAQMD	Durkee, Kevin	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Los Angeles Airport	SoCAB
31	SCAQMD	Durkee, Kevin	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Ontario Airport	SoCAB
32	SDCAPCD	Bigler-Engler, Virginia	WS, WD	m/s	Srfc to 600m/75 m	Sodar	Valley Center-Escondido	SDAB
33	SDCPACD	Bigler-Engler, Virginia	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Valley Center-Escondido	SDAB
34	SDCPACD	Bigler-Engler, Virginia	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Point Loma	SDAB
35	US Marines	Helgeson, Norm	WS, WD, RH, Pres, T	m/s mb & C	Srfc to 5 Km/100m	Rawinsonde	29 Palms	MDAB
36	US Navy	Helvy, Roger	WS, WD, RH, Pres, T	m/s mb & C	Srfc to 5 Km/100m	Rawinsonde	Point Mugu	SCCAB
37	US Navy	Helvy, Roger	WS, WD, RH, Pres, T	m/s mb & C	Srfc to 5 Km/100m	Rawinsonde	San Nicolas Island	SoCAB
38	US Navy	Helvy, Roger	WS, WD, RH, Pres, T	m/s mb & C	Srfc to 5 Km/100m	Rawinsonde	Tustin	SoCAB
39	US Navy	Helvy, Roger	WS, WD, RH, Pres, T	m/s mb & C	Srfc to 5 Km/100m	Rawinsonde	Naval Air St-North Island	SDAB
40	USAF	Crosiar, Chris	WS, WD, RH, Pres, T	m/s mb & C	Srfc to 5 Km/100m	Rawinsonde	Vandenberg AFB	SCCAB
41	USAF	Harvey, Phil	WS, WD, RH, Pres, T	m/s mb & C	Srfc to 5 Km/100m	Rawinsonde	Edwards AFB	MDAB
42	USAF	Crosiar, Chris	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS (915 & 449 MHz)	Vandenberg AFB	SCCAB
43	VCAPCD	Field, Kent	WS, WD, T	m/s & C	Srfc to 2 Km/100m	RWP-RASS	Simi Valley	SCCAB
44	CE-CERT	Carter, W	Broadband & UV rad data	-	-	Brewer Radiometers	Azusa	SoCAB
45	CE-CERT	Carter, W	Broadband & UV rad data	-	-	Brewer Radiometers	Riverside	SoCAB
46	CE-CERT	Carter, W	Broadband & UV rad data	-	-	Brewer Radiometers	Table Mtn/Mt. Wilson	SoCAB

Table 1-3 Continued
SCOS97-NARSTO Meteorological and Radiation Measurements

	Period		Averaging	Operational Checks		Calibration		Audit	
Rec. #	Starting	Ending	Time	By	Period	By	Period	Performance	System
1	1-Apr-97	15-Oct-97	Hourly	ARB	Daily	ARB	Daily	AV - Barnett	AV - Barnett
2	1-Apr-97	15-Oct-97	Hourly	ARB	Daily	ARB	Daily	-	-
3	IOP	IOP	seconds	CE-CERT	launch	CE-CERT	launch	RWP-RASS	-
4	IOP	IOP	seconds	CE-CERT	launch	CE-CERT	launch	-	-
5	IOP	IOP	seconds	CE-CERT	launch	CE-CERT	launch	-	-
6	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	-	-
7	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	-	-
8	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	AV - Barnett	AV - Barnett
9	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	-	-
10	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	AV - Barnett	AV - Barnett
11	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	-	-
12	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	AV - Barnett	AV - Barnett
13	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	Rawinsondes	-
14	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	-	-
15	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	-	-
16	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	-	-
17	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	-	-
18	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	-	-
19	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	Rawinsondes	-
20	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	-	-
21	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	Rawinsondes	-
22	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	-	-
23	15-Jun-97	15-Oct-97	Hourly	NOAA	Daily	NOAA	Daily	-	-
24	IOP	IOP	seconds	NWS	launch	NWS	launch	-	-
25	15-Jun-97	15-Oct-97	Hourly	Radian-STI	Daily	NOAA	Daily	-	-
26	15-Jun-97	15-Oct-97	Hourly	Radian-STI	Daily	NOAA	Daily	-	-
27	15-Jun-97	15-Oct-97	Hourly	Radian-STI	Daily	NOAA	Daily	-	-
28	15-Jun-97	15-Oct-97	Hourly	Radian-STI	Daily	NOAA	Daily	-	-
29	15-Jun-97	15-Oct-97	Hourly	Radian-STI	Daily	NOAA	Daily	-	-
30	Permanent		Hourly	SCAQMD	Daily	SCAQMD	Daily	AV - Barnett	AV - Barnett
31	Permanent		Hourly	SCAQMD	Daily	SCAQMD	Daily	AV - Barnett	AV - Barnett
32	15-Jun-97	15-Oct-97	Hourly	SDCAPCD	Daily	SDCAPCD	Daily	SDCAPCD	SDCAPCD
33	Permanent		Hourly	SDCAPCD	Daily	SDCAPCD	Daily	SDCAPCD	SDCAPCD
34	Permanent		Hourly	SDCAPCD	Daily	SDCAPCD	Daily	SDCAPCD	SDCAPCD
35	IOP	IOP	seconds	Marines	launch	Marines	launch	-	-
36	IOP	IOP	seconds	US Navy	launch	US Navy	launch	-	-
37	IOP	IOP	seconds	US Navy	launch	US Navy	launch	-	-
38	IOP	IOP	seconds	US Navy	launch	US Navy	launch	RWP-RASS	-
39	IOP	IOP	seconds	US Navy	launch	US Navy	launch	-	-
40	IOP	IOP	seconds	USAF	launch	USAF	launch	RWP-RASS	-
41	IOP	IOP	seconds	USAF	launch	USAF	launch	-	-
42	Permanent		Hourly	USAF	Daily	USAF	Daily	Rawin	-
43	Permanent		Hourly	VCAPCD	Daily	VCAPCD	Daily	AV - Barnett	AV - Barnett
44	IOP-Rad	IOP	-	CE-CERT	-	CE-CERT	-	-	-
45	IOP-Rad	IOP	-	CE-CERT	-	CE-CERT	-	-	-
46	IOP-Rad	IOP	-	CE-CERT	-	CE-CERT	-	-	-

day (0 and 12 Z) radiosonde releases at San Diego (within the modeling domain) and at Desert Rock, Nevada (on the east side of the northern border of the modeling domain), several military organizations in southern California release radiosondes, including the Naval Air Warfare Center (NAWC) which also takes regular ozonesonde data at Point Mugu (and occasionally at other selected sites in Ventura County). The frequency of radiosonde NAWC releases at San Nicolas Island and Pt. Mugu will be increased from twice-per-day to four times per day during IOPs as part of SCOS97. Radiosonde launches are also made periodically at Vandenberg AFB, Edwards AFB, Miramar NAS, and China Lake NAS, but these facilities launch on their own schedules. Also, the SCOS97 effort will provide radiosonde packages to two other military installations which can arrange to schedule twice-per-day (0 and 12 Z) radiosonde releases during IOPs in addition to their own launches. Of the four military installations, Vandenberg and Edwards AFB are the most likely candidates. Four additional radiosonde sites, with four releases per day during IOPs, will be provided as part of the SCOS97 effort.

1.6.4 Aloft Air Quality Measurements

Aloft air quality measurements will be made during IOPs using instrumented aircraft and ground-based lidar and ozonesondes. These measurements will be used to measure the three dimensional distribution of ozone, ozone precursors, and meteorological variables. The aircraft will provide information at the boundaries and will document the vertical gradients, the mixed layer depth, and nature of elevated pollutant layers. The concentrations and (in conjunction with upper air wind soundings) the transport of pollutants across selected vertical planes will be measured to document transport of pollutants and precursors between offshore and onshore and between air basins. Redundancy and operational cross-checks can be built into the aircraft measurements by including overlapping flight plans for the various types of aircraft and by doing aircraft measurements near the ground over air quality monitoring sites. Table 1-4 provides a summary of the aloft air quality measurements that will be made by contractors. Table 1-4 also indicates planned systems and performance audits.

Four aircraft are included in the core program. Two small air quality aircraft will be used to document the vertical and horizontal gradients of ozone, NO_X, ROG, temperature, and humidity in the study region. One aircraft will be used to document the horizontal and vertical gradient along the northern and eastern boundary of the study domain. A larger multi-engine aircraft will be used to document the horizontal and vertical gradients offshore and across the shoreline. The specific flight plans are being developed for these aircrafts under different meteorological scenarios by the SCOS97 Modeling Working Group.

The NOAA ground-based lidar will be used to characterize the vertical ozone structure within the SoCAB. This lidar could be located at El Monte within the San Gabriel Valley to examine the bifurcation of flow from Los Angeles to the San Fernando and San Gabriel Valleys. Ozonesondes will be released at the ground-based lidar sites for quality assurance purposes and to obtain a higher vertical range of ozone distributions. Four ozonesondes will be released at six different sites each day of an IOP. Collocation with the ozone lidars dictates that two of the six ozonesonde sites would be at El Monte and Ontario. El Monte has surface ozone but Ontario does not. However, Upland has a surface ozone monitor and is not too distant from Ontario. Four other recommended locations are at Van Nuys Airport to characterize San Fernando Valley

Table 1-4
SCOS97-NARSTO Aloft Air Quality Measurements

Rec. #	Institution	Investigator	Species	Units	Range	Device	Location	Air Basin
1	CE-CERT	Fitz, Dennis	ozone	ppbV	Srfc to 5 Km/100m	Ozonesonde - KI	Cal State Northridge	SoCAB
2	CE-CERT	Fitz, Dennis	ozone	ppbV	Srfc to 5 Km/100m	Ozonesonde - KI	USC-Hancock Fnd Bldg	SoCAB
3	CE-CERT	Fitz, Dennis	ozone	ppbV	Srfc to 5 Km/100m	Ozonesonde - KI	Anaheim	SoCAB
4	CE-CERT	Fitz, Dennis	ozone	ppbV	Srfc to 5 Km/100m	Ozonesonde - KI	North San Diego County	SDAB
5	CE-CERT	Fitz, Dennis	ozone	ppbV	Srfc to 5 Km/100m	Ozonesonde - KI	Riverside	SoCAB
6	CE-CERT	Fitz, Dennis	ozone	ppbV	Srfc to 5 Km/100m	Ozonesonde - KI	Upland	SoCAB
7	CE-CERT/STI	Fitz, Dennis	VOCs, CH4 (CO, CO2, Carbonyls)	ppbC (ppbV)	-	Cans & DNPH cartridge	Northern Boundary	Various
8	CE-CERT/UCD	Fitz, Dennis	VOCs, CH4 (CO, CO2, Carbonyls)	ppbC (ppbV)	-	Cans & DNPH cartridge	In SoCAB	SoCAB
9	NOAA	Zhao, Yan	ozone	ppbV	Srfc to 1 Km/100m	Lidar	El Monte Airport	SoCAB
10	US Navy	Helvy, Roger	ozone	ppbV	Srfc to 5 Km/100m	Ozonesonde	Point Mugu	SCCAB
11	US Navy	Helvy, Roger	ozone & met	ppbV m/s mb & C	Srfc to 1 Km/100m	Dasibi & Std Met	Point Mugu	SCCAB
12	EOPACE	Jensen, Doug	ozone, NO, NOy, met	ppbV m/s mb & C	Srfc to 1 Km/100m	Dasibi, TECO 42 CY, std Met	Montgomery Field	SDAB
13	SDCAPCD	Bigler-Engler, Virginia	ozone, NO, NO2, met	ppbV m/s mb & C	Srfc to 1 Km/100m	Dasibi, Monitor, std Met	Montgomery Field	SDAB
14	STI	Blumenthal, Don	ozone, NO, NOy, met	ppbV m/s mb & C	Srfc to 1 Km/100m	Dasibi, TECO 42 CY, std Met	Camarillo Airport	SCCAB
15	UC Davis	Carroll, John	ozone, NO, NOy, met	ppbV m/s mb & C	Srfc to 1 Km/100m	Dasibi, TECO 42 CY, std Met	El Monte Airport	SoCAB

Table 1-4 Continued
SCOS97-NARSTO Aloft Air Quality Measurements

		Period		Averaging	Operational Checks		Calibration		Audit	
Rec. #	Flight Plan	Starting	Ending	Time	By	Period	By	Period	Performance	System
1		IOP	IOP	seconds	CE-CERT	launch	CE-CERT	launch	-	-
2		IOP	IOP	seconds	CE-CERT	launch	CE-CERT	launch	-	-
3		IOP	IOP	seconds	CE-CERT	launch	CE-CERT	launch	-	-
4		IOP	IOP	seconds	CE-CERT	launch	CE-CERT	launch	-	-
5		IOP	IOP	seconds	CE-CERT	launch	CE-CERT	launch	-	-
6		IOP	IOP	seconds	CE-CERT	launch	CE-CERT	launch	-	-
7	Various	IOP	IOP	Minutes	CE-CERT	--	CE-CERT	IOP	DRI	DRI
8	Various	IOP	IOP	Minutes	CE-CERT	--	CE-CERT	IOP	DRI	DRI
9		IOP	IOP	seconds	NOAA	Daily	NOAA	Daily	Airplane-UCD	-
10		IOP	IOP	seconds	US Navy	launch	US Navy	launch	-	-
11	• 2 flights/day-north 1/2 southern boundary	15-Jun-97	15-Oct-97	Hourly	U.S. Navy	Flight	U.S. Navy	Flight	-	-
12	• 2 flights/day - saw tooth/southern boundary	IOP	IOP	seconds	EOPACE	Flight	EOPACE	Flight	Airplane-UCD	ARB-MLD
13	• transport SoCAB-SDAB-Eastern Boundary	IOP	IOP	seconds	SDCAPCD	Flight	SDCAPCD	Flight	Airplane-UCD	ARB-MLD
14	• 2 flights/day - saw tooth/northern boundary	IOP	IOP	seconds	STI	Flight	STI	Flight	Airplane-UCD	ARB-MLD
15	• 3 - 4 flights/day - 3 spirals/flight San Gabriel	IOP	IOP	seconds	UC Davis	Flight	UC Davis	Flight	MLD-Lidar	ARB-MLD

vertical ozone structure for possible transport to Ventura, Anaheim in the south basin for possible transport from the south coastal plain of the SoCAB to San Diego, and Temecula for inland transport to San Diego. Central Los Angeles is also desirable to characterize the central SoCAB, but logistics in the downtown area may be a complicating factor. Data will also be available from the existing NAWC ozonesonde release site at Pt. Mugu.

1.7 Guide to Quality Assurance Plan

This introductory section has specified the goals and technical objectives of SCOS97-NARSTO, and planned measurements. Section 2 presents a summary of quality assurance task and activities for SCOS97, and project organization and responsibilities. Section 3 specifies the data quality objectives for SCOS97 measurements. Detailed quality assurance plans for surface air quality and meteorology, upper-air air quality, upper-air meteorology, and volatile organic compound measurements are provided in Sections, 4,5,6 and 7, respectively.

2. QUALITY ASSURANCE TASKS, ORGANIZATION AND RESPONSIBILITIES

This section provides a summary of planned quality assurance tasks/activities for SCOS97-NARSTO and delineates the responsibilities of the quality assurance team. Quality assurance will be under the overall direction of Desert Research Institute, the QA manager for SCOS97-NARSTO. DRI is responsible for developing a quality assurance plan in conjunction with field managers from sponsoring agencies, measurement contractors, and quality assurance personnel from the District and the California Air Resources Board. Dr. Eric Fujita is the principal investigator for the project at DRI and will oversee QA for VOC measurements. Drs. John Bowen, Hans Moosmüller, and Mark Green will oversee QA efforts for surface air quality and meteorological, aloft air quality, and aloft meteorology, respectively. DRI will review standard operating procedures, oversee system and performance audits, and document the quality assurance findings for integration into the data archive.

QA personnel from the ARB, South Coast Air Quality Management District, San Diego Air Pollution Control District will conduct system and performance audits of surface air quality and meteorological measurements. These efforts will be directed by Ms. Alice Westerinen for the ARB, Mr. Bill Bope for the SCAQMD, and Mr. Mahmoud Hossain for the SDAPCD.

Aerovironment Environmental Services, Inc. (AVES) will review candidate upper-air meteorological monitoring sites and do system and performance audits of the network. AVES will review the measurement groups standard operating procedures, siting and set-up, quality control procedures, and procedures for communication and resolution of problems. The review will compare proposed procedures with procedures detailed in this QA plan (based on PAMS upper-air guidelines). Mr. Alex Barnett is the principal investigator for this project at AVES.

Mr. Richard Hackney of the Technical Support Division at the ARB serve as data manager for SCOS97-NARSTO. ARB will obtain project and supplemental data, integrate data into a common database, and maintain the data archive. NOAA's Environmental Technology Laboratory (ETL) will be responsible for acquisition and processing of upper-air meteorology data, periodic review of data, and data validation and archival. Dr. Bob Weber is the principal investigator for this project at NOAA.

The following is a summary of the work elements to be performed by the QA Team and the schedule for performing the work. The technical approach for implementing each element and audit procedures are described in Sections 4 through 7.

2.1 Surface Air Quality and Meteorological Measurements

The ARB, SCAQMD and SDAPCD quality assurance staff conduct regularly scheduled performance audits of all air quality monitoring stations. During the period between January and March 1997, the ARB audited 36 monitoring stations that are located in the SCOS97-NARSTO study area. During the April to June period, the ARB will audit 37 other monitoring station. In addition, twelve monitoring stations in the SoCAB will be audited based on relative importance of the monitoring data at those sites to the objectives of SCOS97. During this time, ARB will also audit the five supplemental air monitoring sites that will be operated by AeroVironment.

ARB QA staff will also audit the ozone and NOx analyzers onboard the four SCOS97 aircraft during early June.

2.2 Upper-Air Meteorological Measurement Audits

Upper-air meteorological measurement audits will be performed by Aerovironment Environmental Services, Inc. These will consist of system audits at all measurement sites and performance audits at all sodar sites and some of the radar wind profiler/RASS sites. At least one site operated by each measurement group will have performance audits. The sites, operator, instruments audited and audit method for the system audits are shown in Table 2-1. The system audits primarily evaluate whether the instrument siting and setup is proper. The performance audits evaluate the data collected by the instruments against standards or other collocateinstruments. System audits will be performed in May 1997. Performance audits will be done in early June 1997.

The radar wind profiler performance audits use sodars to check the lower gates of the RWP and rawinsondes to check the full RWP range. Sodars are performance audited by using collocated rawinsonde data and with acoustic pulse transponders (APT). The APT produces a simulated wind profile made up of sounds with known frequencies that are timed to simulate the doppler shifted echoes scattered by the atmosphere from various altitudes. The RASS performance audit will use collocated rawinsonde data to compute virtual temperature for comparison to the RASS derived virtual temperature.

Table 2-1
Sites, operators, instruments audited, and audit methods for upper-air meteorological measurement system audits

Site	Operator	Instruments Audited	Audit Method
Vandenberg[1]	USAF	RWP, RASS	Rawinsonde
Simi	VCAPCD	RWP, RASS	Mobile sodar & rawinsonde
El Monte AP	ARB	RWP, RASS	Mobile sodar & rawinsonde
Oceanside	NOAA	RWP, RASS, sodar	APT & Rawinsonde
Los Alimitos	NOAA	RWP, RASS, sodar	APT & Rawinsonde
San Gabriel Mountains	NOAA	Sodar	APT
Oxnard AP	NOAA	RWP, RASS	Mobile sodar & rawinsonde
Van Nuys AP	NOAA	RWP, RASS	Mobile sodar & rawinsonde
Temecula	Radian/STI	RWP, RASS	Mobile sodar & rawinsonde
LAX	SCAQMD	RWP, RASS	Mobile sodar & rawinsonde
Ontario	SCAQMD	RWP, RASS	Mobile sodar & rawinsonde
Point Loma	SDAPCD	RWP,RASS	Mobile sodar & rawinsonde
Escondido	SDAPCD	RWP, RASS, sodar	Mobile sodar & rawinsonde

[1] USAF will forward collocated rawinsonde and RWP/RASS data to Aerovironment Environmental Services Inc. for performance audit of RWP/RASS data.

2.3 Aloft Air Quality Measurement Audits and Comparisons

As part of SCOS97, the Air Resources Board and Desert Research Institute is organizing an aloft performance audit, prior to the main study. This performance audit will be conducted in the vicinity of El Monte Airport (EMA) with the airport serving as base. Aloft intercomparisons between the NOAA ozone lidar (located at EMA), CE-CERT ozonesondes and several instrumented aircraft (UCD, STI, Gibbs Cessna, and NAVY EOPACE) will be included in this audit. The ARB Quality Assurance staff will conduct performance audits of the onboard air ozone and NO_X analyzers. Dr. John Bowen of the conduct a system audit of onboard instrumentation and Dr. Hans Moosmüller will oversee the aloft ozone comparisons. In addition, the availability of upper air meteorological data is important to improve the comparison between different sample volumes. Data from the RWP/RASS system located at EMA will be utilized for this purpose. Arrangements will be made to have AeroVironment conduct an audit of the RWP/RASS system prior to the audit/intercomparison.

Three flight patterns for the participating aircraft will be utilized for this performance audit:

- Spiral flight patterns will be used for the intercomparison between aircraft themselves, and between aircraft, ozone lidar, and ozonesondes. This is the most generally useful flight pattern for intercomparison.

- Spiral flight patterns interspersed with orbits will be used for the intercomparison between a single aircraft and the ozone lidar. The additional orbits make it possible to distinguish between horizontal and vertical gradients encountered by an aircraft flying a spiral pattern.

- Traverses will be used for additional intercomparison between the different instrumented aircraft.

The aloft performance audit will take place prior to the main study during the week of June 9, 1997. Details of this preliminary study are described in Section 5. Conducting the audit before the main study will make it possible to identify, address, and possibly correct potential performance problems prior to commencement of the main study period.

2.4 Volatile Organic Compound Measurements

The quality assessment of SCOS97-NARSTO VOC data included system audits of the two main VOC laboratories (AtmAA for carbonyl compounds and BRC for hydrocarbons). An on-site systems audit of AtmAA was conducted in 1995 by Dr. Eric Fujita for the NARSTO-Northeast Study, and the results of this audit will be summarized in lieu of an audit for SCOS97-NARSTO. While on-site systems audit of BRC was performed twice by DRI staff within the last ten years at Dr. Rasmussen's laboratory at Oregon Graduate Institute (OGI), it has been seven years since the last audit. An on-site systems audit will be conducted at BRC by Dr. Zielinska of the DRI in May, 1997.

The hydrocarbon performance audits will consist of two ambient samples. A draft protocol is included as Appendix C. Participating laboratories include ARB, EPA, BRC, DRI, SDAPCD, SCAQMD, VCAPCD, and BAAQMD. Each participating laboratory will supply to ARB, Monitoring and Laboratory Division two cleaned, evacuated 6-liter canisters by April 25, 1997. EPA, ARB and DRI will supply two additional canisters (four in all). ARB will fill the two sets of canisters to 20-25 psi with ambient air from the Los Angeles area using a manifold sampling system supplied by the Desert Research Institute. One set of canisters will be collected in the morning (after 6:00 a.m. and before 9:00 a.m., PDT) in an area heavily influenced by mobile source emission. The other set will be collected in the afternoon (after 1:00 p.m. and before 4:00 p.m., PDT) in a downwind area with maximum ozone levels. Duplicate samples will be collected for EPA, ARB and DRI (total of eleven simultaneous canister samples at each site). ARB will send the two (or four) ambient audit samples to each participating laboratory by May 6, 1997. Each laboratory will analyze the audit samples within five working days after receiving the audit canisters. EPA, ARB and DRI will reanalyze their samples after one and two months to monitor the stability of the audit samples. Analytical results will be compiled by the California Air Resources Board, Research Division and results will be summarized by DRI.

The carbonyl performance audit will consist of sampling under field conditions with addition of a standard mixture of carbonyls from a 6-liter stainless steel canister to an ambient sample. A draft protocol is included in Appendix E. The main supply of the standard mixture will be prepared at the Desert Research Institute in a 33-liter tank. The standard mixture in a 6-liter canister and a dilution apparatus will be supplied by the Desert Research Institute, along with operating instructions. The standard audit protocol will consist of a 3-hour ambient sample using two DNPH cartridges in series (same as a breakthrough experiment) with addition of the standard mixture, with appropriate dilution, between the two cartridges. The front cartridge serves to scrub ambient carbonyl compounds and ozone. Each group will collect two samples and pass the 6-liter canister and gas dilution system on to the next group. The 6-liter canisters will hold sufficient sample for two groups. The Air Resources Board, Monitoring and Laboratory Division will analyze the contents of the canister by DNPH/HPLC prior to shipment and upon its return. The contents of the main tank will be periodically analyzed by both DNPH/HPLC and GC/FID (for higher MW carbonyls). These audits will be performed in June 1997.

The performance audit for the aircraft sampling of carbonyl compounds will be similar to surface-based measurements. The main procedural difference is that the Tedlar bag will be filled with zero-air with addition of the standard carbonyl mixture.

3. QUALITY ASSURANCE OBJECTIVES FOR MEASUREMENT DATA

Quality assurance (QA) for a program consists of two parts: one is an independent assessment of the effectiveness of the measurement program to meet its goals (often denoted as QA audits), and the other is the operational procedures or quality control (QC) necessary to evaluate ability of the measurement process to yield valid data. The Quality Assurance Project Plan defines data quality goals for the project and QC activities necessary to obtain them. These goals are stated in terms of precision, accuracy, completeness, comparability, and representativeness of the data as defined in the following:

- Accuracy is the degree of correctness with which a measurement system yields the true value or bias of an observable (Watson *et al.*, 1989). For the field project, accuracy is quantified comparing the responses of instruments to independent standards or collocated measurements.

- Precision is a measure of agreement among individual measurements of the same observable or repeatability of the measurement. For the field project, precision is quantified by periodically challenging a measurement device with known, identical input conditions.

- Completeness is the measure of the quantity of data collected by a measurement system compared to the total possible amount of data.

- Comparability is a measure of the traceability of the same type of data collected from several different organizations. Comparability can be qualitatively assessed by comparing procedures, QA/QC results, and traceability of standards.

- Representativeness is a qualitative measure of the ability of the collected data to meet the criteria necessary to model ozone formation and transport in the area of interest. Some sites may be source-oriented while others are regional in nature.

QA objectives in terms of accuracy and precision, and completeness of data collected during the field project are presented in the following tables grouped by type of measurement. This information will be updated and expanded in the course of the quality assurance program to include each of the core measurements for SCOS97-NARSTO.

Table 3-1
Data Quality Objectives - Gases - Surface Sites

Observable	Measurement Method	Precision Check	Accuracy Check	Precision Target	Accuracy Target	Completeness
Ozone	UV absorption	Weekly precision check	UV photometer	±15%	±15%	80%
NO/NO_y	Chemiluminescence with external converter	Weekly precision check	NO gas standard/ Dilution system	±15%	±15%	80%
NO/NO_x	Chemiluminescence with nylon inlet filter	Weekly precision check	NO gas standard/ Dilution system	±15%	±15%	80%

Table 3-2
Data Quality Objectives - Meteorological Data -Surface Sites

Observable	Measurement Method	Precision Check	Accuracy Check	Precision Target	Accuracy Target	Completeness
Wind Speed	Anemometer propeller or cups	None	Constant RPM motor	None	±0.25 m/s for WS<5m/s ±5% for WS>5m/s	90%
		Starting Threshold Torque wheel			< 0.3 g-cm	
Wind Direction	Vane	None	Alignment with true North	None	±5°	90%
Ambient Temperature	Thermal Resistance	None	Collocated Thermistor	None	±0.5 °C	90%
Relative Humidity	Capacitive or resistive	None	Collocated Capacitive	None	±10%	90%
Dew Point	Computed or dew cell	None	Collocated Ca Capacitive RH	None	±1.5 °C	90%
Solar Radiation	Pyranometer	None	Precision Spectral Pyranometer	None	±25 w/m^2	90%

Table 3-3
UCD Aircraft Instrumentation

Parameter Measured	Technique	Manufacturer	Time Response	Measurement Range	Accuracy
Pressure (Altitude)	Capacitive	Setra	1 s - 3 s	-30 m - 3700 m	± 0.3 mB ± 3 m
Temperature	Platinum RTD	Omega	1 s - 3 s	-20°C - 50°C	± 0.2°C
Relative Humidity	Capacitive	Qualimetrics	1 s - 3 s	10% - 98%	± 3%
Air Speed	Thermal Anemometer	T.S.I.	1 s - 3 s	15 m/s - 75 m/s	± 0.4 m/s
Heading	Electronic Compass	Precision Navigation	1 s - 3 s	0° - 359°	± 2°
Position	GPS	Garmin	10 s	Lat. - Long.	± 15 m
Particle Concentration	Optical Counter	Climet	10 s	2 channels: d > 0.3 µm & d > 3 µm	± 2%
NO, NO_2 Concentration	O_3 Titration Chemilumin.	Monitor Labs.	10 s - 15 s	0 ppmv - 20 ppmv	± 0.5 ppbv
Ozone Concentration	UV Absorption	Dasibi 1008	10 s - 15 s	0 ppbv - 999 ppbv	± 3 ppbv

Table 3-4
STI Aircraft Instrumentation

Parameter Measured	Technique	Manufacturer	Time Response	Measurement Range(s)	Accuracy[a] (Full Range)
NO/NO_y Concentration	Chemilumin.	Thermo Env. Model 42S	< 20 s	50 ppb, 100 ppb, 200 ppb	± 10%
Ozone Concentration	Chemilumin.	Monitor Labs. 8410E	12 s	200 ppb, 500 ppb	± 10%
b_{scat}	Integrating Nephelometer	MRI 1560 Series	1 s	100 Mm^{-1}, 1000 Mm^{-1}	± 10%
Dew Point	Cooled Mirror	Cambridge Systems 137-C	0.5 s/°C	-50°C - 50°C	± 10%
Altitude	Altitude Encoder	II-Morrow	1 s	0 m - 5000 m	± 10%
Altitude (backup)	Pressure Transducer	Validyne P24	< 1 s	0 m - 5000 m	± 10%
Temperature	Bead Thermistor/ Vortex Housing	YSI/MRI	5 s	-30°C - 50°C	± 10%
Temperature (backup)	Platinum Resistance	Rosemont 102 AV/AF	1 s	-50°C - 50°C	± 10%
Position	GPS	II-Morrow	< 1 s	Lat. - Long.	± 50 m
Data Logger (includes time)	Dual Floppy Acquisition	STI 486 System	1 s	± 9.99 VDC	± 10%
NO/NO_w[b]	Chemilumin.	Thermo Env. Model 42S	< 20 s	50 ppb, 100 ppb, 200 ppb	± 10%
SO_2[b]	Pulsed Fluorescence	Thermo Env. Model 43S	15 s	1 ppb, 5ppb, 50 ppb,200 ppb	± 10%
CO[b]	Gas Filter Correlation	Thermo Env. Model 48S	< 20 s	1 ppm, 2 ppm, 5 ppm, 10 ppm	± 10%

[a] For values between 10% and 90% of full scale
[b] Without modifying the aircraft for additional power, only one of these three instruments can be operated.

Table 3-5: CE-CERT Ozonesonde, Data Quality Indicators and Goals

DQI	Goal
Precision	1-sigma < larger of 5 ppb or 10%
Calibration Bias	1-sigma < larger of 5 ppb or 10%
Interference Bias	-10 to + 50 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 hours from planned time
Location of Launch	+/- 100 meters from planned location
Duration of Flight	>3000 meters AGL

Table 3-6: CE-CERT Meteorological Instruments, Data Quality Indicators and Goals

Measurement	DQI	Goal
Temperature	Precision	± 1 °C
Temperature	Calibration Bias	± 3 °C
Temperature	Response Time	> 63% response in 20 s
Pressure	Precision	± 2 mb
Pressure	Calibration Bias	± 5 mb
Pressure	Response Time	> 63% response in 2 s
Relative Humidity	Precision	± 5% RH
Relative Humidity	Calibration Bias	± 10% RH
Relative Humidity	Response Time	> 63% response in 2 min

Table 3-7

Quality Assurance Objectives for Upper-Air Meteorological Measurement Data

Measurement Method	Variables Measured	Systematic Difference (Bias)	Comparability (RMS difference)	Data Recovery % of Observations to Given Height
RASS	T_v	±1 °C	1.5 °C	50%, 1000 m
RWP	WS, WD	WS: ±1 m s^{-1} WD: ±10°	WS: 2 m s^{-1} WD: 20°	50%, 3000 m
Sodar	WS, WD	WS: ±1 m s^{-1} WD: ±10°	WS: 2 m s^{-1} WD: 20°	50%, 500 m
Rawinsonde	WS, WD, T, T_d, RH, p	WS: ±1 m s^{-1} WD: ±10° T: ±1 °C Td: ±2 °C RH: ±0% P: ±1 mb	WS: 2 m s^{-1} WD: 20° T: 1.5 °C Td: 3 °C RH: 10% P: 2 mb	90%, 5000 m

Table 3-8
Data Quality Objectives for VOC and Related Measurements

Observable	Measurement Method	Number of Species	Detection Limit	Precision Target	Accuracy Target	Completeness
C2-C11 hydrocarbons	Canister GC-FID	57 to 150	0.1 ppbC	± 5%	± 15%	90%
Methane	Canister GC-FID		20 ppbv	± 5%	± 15%	90%
CO	Canister GC-FID after conversion to methane		20 ppbv	± 5%	± 15%	90%
CO2	Canister GC-FID after conversion to methane		3 ppmv	± 5%	± 15%	90%
MTBE	Canister GC-FID		0.1 ppbv	± 5%	± 15%	90%
Carbonyl Compounds	DNPH - HPLC/UV	3 to 14	1 ppbv	± 10%	± 20%	90%
Halogenated Compunds	GC-ECD	Perc and CH_3Cl_3	0.01 ppbv	± 5%	± 15%	90%

4. SURFACE AIR QUALITY ANALYZERS AND METEOROLOGICAL MEASUREMENTS

Field monitoring includes continuous measurements over several months and intensive studies that are performed on a forecast basis during selected periods when episodes are most likely to occur. The continuous measurements are made in order to assess the representativeness of the intensive study days, to provide information on the meteorology and air quality conditions on days leading up to the episodes, and to assess the meteorological regimes and transport patterns which lead to ozone episodes. The intensive study components are designed to provide a detailed aerometric database which, along with the emission estimates and continuous monitoring data, can be used to improve our understanding of the causes of pollutant episodes in the study region and to provide data for input to the models and for model evaluation. This section describes the existing routine air quality and meteorological monitoring network in southern California, and the options for continuous and intensive air quality and meteorological measurements (surface and aloft) to be made during SCOS97.

In the SCOS97 study region, the Ventura County Air Pollution Control District (VCAPCD), South Coast Air Quality Management District (SCAQMD), Mohave Desert Air Quality Management District (MDAQMD), and San Diego Air Pollution Control District (SDAPCD) are charged with the responsibility for determining compliance with state and federal air quality standards, proposing plans to attain those standards when they are exceeded, and for implementing those plans. Several agencies at the periphery of the study area (Santa Barbara Air Pollution Control District (SBAPCD), Imperial County Air Pollution Control District (ICAPCD), and the ARB) have similar responsibilities. To these ends, these agencies operate a network of sampling sites which measure ambient pollutant levels. Three types of surface air quality monitoring stations are operated by the air pollution control districts. The National Air Monitoring Stations (NAMS) were established to ensure a long term national network for urban area-oriented ambient monitoring and to provide a systematic, consistent database for air quality comparisons and trend analysis. The State and Local Air Monitoring Stations (SLAMS) allow state and local governments to develop networks tailored to their immediate monitoring needs. Special purpose monitors (SPM) fulfill very specific or short-term monitoring goals. SPMs are typically used as source-oriented monitors rather than monitors which reflect the overall urban air quality. Data from all three types are submitted by state and local agencies to EPA's Aerometric Information Retrieval System (AIRS), which serves as the national repository for air quality, meteorological and emissions data.

Under Title I, Section 182, of the 1990 Amendments to the Federal Clean Air Act, the EPA proposed a rule to revise the current ambient air quality surveillance regulations. The rule requires implementing a national network of enhanced ambient air monitoring stations (Federal Register, 1993). States with areas classified as serious, severe, or extreme for ozone nonattainment are required to establish photochemical assessment monitoring stations (PAMS) as part of their State Implementation Plan (SIP). In California, PAMS are required in Ventura County, and the South Coast, Southeast Desert and San Diego air basins. Each station measures speciated hydrocarbons and carbonyl compounds, ozone, oxides of nitrogen, and surface meteorological data. Additionally, each area must monitor upper air meteorology at one representative site. The VOC monitoring requirements under the PAMS program are described in Section 7. The program is being phased in over a five-year schedule, beginning in 1994, at a rate of at least one station per area per year. Intended applications for the PAMS database include ozone and precursor trends, emission inventory reconciliation and verification, population exposure analyses, photochemical modeling support, and control strategy evaluation.

The operators of these routine measurement networks have in place or are developing quality assurance plans specific to their network or are using the operating procedures developed by the ARB. In all cases, the operating plans are reviewed and approved by the ARB. The ARB also provides regularly scheduled air quality audits of field sites and equipment.

The need for additional measurements at several locations has been identified for the SCOS97 field study. The installation and operation of these sites will be independent of the routine monitoring network.

4.1 Sampling Site Selection Criteria

There are 100 active monitoring stations in southern California. These sites have been installed at their locations to meet the needs of the local agencies. The criteria for site selection will not be discussed here.

The general locations for the supplemental monitoring sites have been chosen because they are in key locations for assessing ozone and ozone precursor transport from the Southern California Air Basin (SoCAB). Measurements at the sites will include concentrations of ozone and NO/NO_X and meteorological observations.

AeroVironment Environmental Services, Inc., (AVES) has been selected to install and operate the supplemental sites. AVES will use the following site selection criteria for the sites:

- Exposure to regional air transport
- Absence of local sources or sinks of measured species
- Adequacy to meet EPA-PSD siting criteria for air pollutant and meteorological measurements
- Availability of power and telephone
- Cost for site preparation
- Ease of access
- Security

4.2 Installation

At the supplemental sites, equipment will be installed in either available buildings at the site or in temporary shelters installed specifically for the purpose. In any event, the air quality instruments will be placed inside temperature-controlled environments with sample inlet systems and manifolds, air conditioning, instrument racks, and power distribution. Meteorological equipment will be installed on 10 meter towers at all sites. Telephone lines will be connected to the sites for regular data access and instrument checks.

4.3 Monitoring Site Locations

Table 4-1 lists the monitoring sites of the air pollution control districts and the air quality parameters measured at these sites. Of the active sites, 96 measure ozone and 81 measure NO_X. Carbon monoxide and total hydrocarbons are measured at 46 and 42 sites, respectively.

The supplemental surface air quality sites and equipment will be installed at the approximate locations given in Table 4-2.

4.4 Sampling Procedures

Sampling methods are summarized in this section. Actual operational procedures are contained in Standard Operating Procedures (SOP) of the various agencies and in the instrument manufacturers' manuals.

All the Air Pollution Control Districts measure ozone and NO/NO_X with continuous analyzers. At present, most of the NO/NO_X analyzers are operated with an inline filter made of Teflon to remove particulate matter from the ambient air before the measurement is made. For the SCOS97 study, the Teflon filters will be replaced by nylon filters (Membrana-Ghia Nylasorb) that will remove particles and nitrogen species such as nitric acid so that only NO_X is measured.

AVES will deploy continuous analyzers for the measurement of ozone and NO/NO_X concentrations at 5 supplemental sites. AVES will develop a quality assurance project plan specific to measurements at these sites that include standard operating procedures (SOPs) to describe the quality assurance/quality control plans for the project. Nylon filters (Membrana-Ghia Nylasorb) will be installed on the NO/NO_X analyzers. Teflon filters (Millipore LS 5.0 μm) will be installed on the Ozone analyzers to remove particles. Filters will be replaced once a week.

The equipment associated with the continuous air quality analyzers at the supplemental sites is summarized in Table 4-3.

Surface meteorological sensors are operated at the many of the Agency sites and will be installed at the supplemental sites. Wind speed, wind direction, temperature, and relative humidity or dew point temperature are measured at most of all sites. Solar radiation is measured at some sites. The measurements at the supplemental sites are summarized in Table 4-4.

Table 4-1
Air Quality Monitoring Sites in Southern California

Site ID	Air Basin	County	Data Source	Site Name	Variables Measured						
					O3	NO	NOx	CO	THC	CH4	NMHC
ARVN	SJVAB	Kern	CARB	ARVIN-20401 BEAR MTN BLVD	x	x	x				
BKGS	SJVAB	Kern	SJVUCD	BAKERSFIELD-1138 GOLDEN STATE	x	x	x	x	x	x	x
BLFC	SJVAB	Kern	CARB	BAKERSFIELD-5558 CALIFORNIA ST	x	x	x	x	x	x	x
EDSN	SJVAB	Kern	CARB	EDISON-JOHNSON FARM	x	x	x				x
OLDL	SJVAB	Kern	CARB	OILDALE-3311 MANOR ST	x	x	x		x	x	x
ARGR	SCCAB	San Luis Obispo	XONTEC	ARROYO GRANDE-RALCOA WAY					x	x	x
ATAS	SCCAB	San Luis Obispo	SLOCO	ATASCADERO-6005 LEWIS AVE	x	x	x				
GCTY	SCCAB	San Luis Obispo	SLOCO	GROVER CITY-9 LE SAGE DR	x	x	x				
MOBY	SCCAB	San Luis Obispo	SLOCO	MORRO BAY-MORRO BAY BL & KERN	x						
NIPO	SCCAB	San Luis Obispo	UNOCAL	NIPOMO-1300 GUADALUPE RD	x						
NPSW	SCCAB	San Luis Obispo	SLOCO	NIPOMO-148 S WILSON ST	x	x	x				
PSRB	SCCAB	San Luis Obispo	CARB	PASO ROBLES-235 SANTA FE AVE	x						
SLPL	SCCAB	San Luis Obispo	EMC	SAN LUIS OBISOP-7020 LEWIS		x	x		x		
SLOM	SCCAB	San Luis Obispo	CARB	SAN LUIS OBISPO-1160 MARSH ST	x	x	x	x	x		
CPGB	SCCAB	Santa Barbara	CHVRON	CARPINTERIA-GOBERNADOR RD	x	x	x				
ECSP	SCCAB	Santa Barbara	SBAPCD	EL CAPITAN STATE PARK	x	x	x		x		
GAVE	SCCAB	Santa Barbara	CHVRON	GAVIOTA EAST-N OF CHEVRON PLAN	x	x	x		x		
GAVW	SCCAB	Santa Barbara	CHVRON	GAVIOTA WEST-NW OF CHEVRON PLA	x	x	x		x		
GTCA	SCCAB	Santa Barbara	TEXACO	GAVIOTA-GTC A .5 MI SW OF PLT	x	x	x				
GTCC	SCCAB	Santa Barbara	TEXACO	GAVIOTA-GTC C 1 MI E OF PLANT	x	x	x		x		
GLWF	SCCAB	Santa Barbara	SBAPCD	GOLETA-380 W FAIRVIEW AVE	x	x	x	x			
LPSH	SCCAB	Santa Barbara	SBAPCD	LOMPOC-128 S 'H' ST	x	x	x	x			
LPHS	SCCAB	Santa Barbara	UNOCAL	LOMPOC-HS&P FACILITY 500 M SW	x	x	x		x		
LOSP	SCCAB	Santa Barbara	UNOCAL	LOS PADRES NF-PARADISE RD	x	x	x				
GTCB	SCCAB	Santa Barbara	TEXACO	NOJOQUI PASS-GTC B HWY 101	x	x	x				
PTAR	SCCAB	Santa Barbara	UNOCAL	POINT ARGUELLO-NE OF SLC	x	x	x		x		
PTCL	SCCAB	Santa Barbara	CHVRON	POINT CONCEPTION LIGHTHOUSE	x	x	x				
SBWC	SCCAB	Santa Barbara	CARB	SANTA BARBARA-3 W. CARRILLO ST	x	x	x	x			
SMSB	SCCAB	Santa Barbara	CARB	SANTA MARIA-500 S BROADWAY	x	x	x				
SMBB	SCCAB	Santa Barbara	UNOCAL	SANTA MARIA-BATTLES BETTERAVIA	x.	x	x		x		
SYAP	SCCAB	Santa Barbara	SBAPCD	SANTA YNEZ-AIRPORT RD	x						
UCSB	SCCAB	Santa Barbara	EXXON	UCSB WEST CAMPUS-ARCO TANK, IS	x	x	x		x		
VBPP	SCCAB	Santa Barbara	VBGAFB	VANDENBERG AFB-STS POWER PLANT	x	x	x	x	x		
ELRO	SCCAB	Ventura	VCAPCD	EL RIO-RIO MESA SCHOOL	x	x	x	x	x	x	x
EMMA	SCCAB	Ventura	VCAPCD	EMMA WOOD STATE BEACH	x	x	x				
THOS	SCCAB	Ventura	CARB	OAK VIEW-5500 CASITAS PASS RD	x	x	x		x		
	SCCAB	Ventura	VCAPCD	OJAI - OJAI AVENUE	x	x	x				
OJAI	SCCAB	Ventura	VCAPCD	OJAI-1768 MARICOPA HIWY	x	x	x				
PRTG	SCCAB	Ventura	VCAPCD	PIRU-2SW, 2815 TELEGRAPH RD	x						
SVAL	SCCAB	Ventura	VCAPCD	SIMI VALLEY-5400 COCHRAN ST	x	x	x	x	x	x	x
TOMP	SCCAB	Ventura	VCAPCD	THOUSAND OAKS-9 2323 MOORPARK	x	x	x				
AZSA	SoCAB	Los Angeles	SCAQMD	AZUSA-803 N LOREN AVE	x	x	x	x	x	x	x
BRBK	SoCAB	Los Angeles	SCAQMD	BURBANK-228 W PALM AVE	x	x	x	x	x		x
GLDR	SoCAB	Los Angeles	SCAQMD	GLENDORA-840 LAUREL	x	x	x				
HAWH	SoCAB	Los Angeles	SCAQMD	HAWTHORNE-5234 W. 120TH ST	x	x	x	x			
NLGB	SoCAB	Los Angeles	SCAQMD	LONG BEACH-3648 N LONG BEACH	x	x	x	x	x	x	x
LANM	SoCAB	Los Angeles	SCAQMD	LOS ANGELES-1630 N MAIN ST	x	x	x	x	x	x	x
LYNW	SoCAB	Los Angeles	SCAQMD	LYNWOOD-11220 LONG BEACH BLVD	x	x	x	x	x	x	
PDSW	SoCAB	Los Angeles	SCAQMD	PASADENA-752 S. WILSON AVE	x	x	x	x			

Table 4-1 Continued
Air Quality Monitoring Sites in Southern California

Site ID	Air Basin	County	Data Source	Site Name	Variables Measured						
					O3	NO	NOx	CO	THC	CH4	NMHC
PICO	SoCAB	Los Angeles	SCAQMD	PICO RIVERA-3713 SAN GABRIEL	x	x	x	x	x		x
POMA	SoCAB	Los Angeles	SCAQMD	POMONA-924 N. GAREY AVE	x	x	x	x	x		x
RSDA	SoCAB	Los Angeles	SCAQMD	RESEDA-18330 GAULT ST	x	x	x	x	x		
	SoCAB	Los Angeles	SCAQMD	SAN DIMAS-GLADSTONE (open by 1/96)	x	x	x				
CLAR	SoCAB	Los Angeles	SCAQMD	SANTA CLARITA-SAN FERNANDO RD	x	x	x	x			
VALA	SoCAB	Los Angeles	SCAQMD	W LOS ANGELES-VA HOSPITAL	x	x	x	x	x	x	
ANAH	SoCAB	Orange	SCAQMD	ANAHIEM-1610 S HARBOR BLVD	x	x	x	x	x		
CMMV	SoCAB	Orange	SCAQMD	COSTA MESA-2850 MESA VERDE DR	x	x	x	x			
ELTR	SoCAB	Orange	SCAQMD	EL TORO-23022 EL TORO RD	x	x	x	x	x		
LHAB	SoCAB	Orange	SCAQMD	LA HABRA-621 W. LAMBERT	x	x	x	x	x		
HEMT	SoCAB	Riverside	SCAQMD	HEMET-880 STATE ST	x						
LELS	SoCAB	Riverside	SCAQMD	LAKE ELSINORE-506 W FLINT ST	x	x	x				
	SoCAB	Riverside	SCAQMD	MIRA LOMA-BELLEGRAVE AVE (by 1/9	x						
PERR	SoCAB	Riverside	SCAQMD	PERRIS-237 .5 N "D" ST	x						
RIVM	SoCAB	Riverside	SCAQMD	RIVERSIDE-7002 MAGNOLIA AVE		x	x	x	x		
RUBI	SoCAB	Riverside	SCAQMD	RUBIDOUX-5888 MISSION BLVD	x	x	x	x	x	x	
TCCC	SoCAB	Riverside	SCAQMD	TEMECULA-COUNTY CENTER	x	x	x	x			
UCDC	SoCAB	Riverside	RIVER	UC RIVERSIDE-4919 CANYON CREST	x						
LGRE	SoCAB	San Bernardino	SCAQMD	CRESTLINE-LAKE GREGORY-LAKE DR	x						
FONT	SoCAB	San Bernardino	SCAQMD	FONTANA-14360 ARROW BLVD	x	x	x				
	SoCAB	San Bernardino	SCAQMD	LAKE ARROWHEAD (Open by 1/96)	x	x	x				
RDLD	SoCAB	San Bernardino	SCAQMD	REDLANDS-DEARBORN	x						
SANB	SoCAB	San Bernardino	SCAQMD	SAN BERNARDINO-24302 4TH ST	x	x	x	x			
UL	SoCAB	San Bernardino	SCAQMD	UPLAND	x	x	x				
CLXC	SEDAB	Imperial	ICAPCD	CALEXICO-900 GRANT ST	x	x	x				
CALE	SEDAB	Imperial	CARB	CALEXICO-CALEXICO HS ETHEL ST	x	x	x	x			x
EC9S	SEDAB	Imperial	ICAPCD	EL CENTRO-150 9TH ST	x						
WEST	SEDAB	Imperial	ICAPCD	WESTMORLAND-202 W FIRST ST	x						
MOJP	SEDAB	Kern	CARB	MOJAVE-923 POOLE ST	x	x	x				
LANC	SEDAB	Los Angeles	SCAQMD	LANCASTER-315 W. PONDERA ST	x	x	x	x			x
BANN	SEDAB	Riverside	SCAQMD	BANNING-135 N ALLESANDRO	x				x		x
INDO	SEDAB	Riverside	SCAQMD	INDIO-46-990 JACKSON ST	x						
PALM	SEDAB	Riverside	SCAQMD	PALM SPRINGS-FS 590 RACQUET CL	x	x	x	x	x		x
BARS	SEDAB	San Bernardino	MDAQMD	BARSTOW-401 MOUNTAIN VIEW	x	x	x	x			
HESP	SEDAB	San Bernardino	MDAQMD	HESPERIA-17288 OLIVE ST	x	x	x	x			
JOSH	SEDAB	San Bernardino	NPS	JOSHUA TREE NATIONAL MONUMENT	x						
PHEL	SEDAB	San Bernardino	MDAQMD	PHELAN-BEEKLEY & PHELAN RDS	x	x	x	x			
TRNA	SEDAB	San Bernardino	MDAQMD	TRONA-83732 TRONA ROAD	x	x	x				
29PM	SEDAB	San Bernardino	MDAQMD	TWENTYNINE PALMS-6136 ADOBE DR	x	x	x	x			
VICT	SEDAB	San Bernardino	MDAQMD	VICTORVILLE-14029 AMARGOSA RD	x	x	x	x			
ALPN	SDAB	San Diego	SDAQMD	ALPINE-2300 VICTORIA DR	x	x	x		x	x	
CHVT	SDAB	San Diego	SDAQMD	CHULA VISTA-80 E "J" ST	x	x	x	x	x		x
DMMC	SDAB	San Diego	SDAQMD	DEL MAR-MIRACOSTA COLLEGE	x						
ECAJ	SDAB	San Diego	SDAQMD	EL CAJON-1155 REDWOOD AVE	x	x	x	x	x	x	x
ESCO	SDAB	San Diego	SDAQMD	ESCONDIDO-600 E. VALLEY PKWY	x	x	x	x	x		x
OCEA	SDAB	San Diego	SDAQMD	OCEANSIDE-1701 MISSION AVE	x	x	x	x	x		
OTAY	SDAB	San Diego	SDAQMD	OTAY-1100 PASEO INTERNATIONAL	x	x	x	x			
SDUN	SDAB	San Diego	SDAQMD	SAN DIEGO-1133 UNION ST				x			
SD12	SDAB	San Diego	SDAQMD	SAN DIEGO-330A 12TH AVE	x	x	x	x	x	x	x
SDOV	SDAB	San Diego	SDAQMD	SAN DIEGO-5555 OVERLAND AVE	x	x	x	x	x	x	x

Table 4-2
Locations for Supplemental Surface Air Quality Sites

Location	Measurement Purpose	Approximate Latitude	Approximate Longitude	Approximate Elevation (m)
Santa Catalina Island, Airport	Transport from SoCAB aloft	33°25' N	118°25' W	480
Santa Catalina Island, Avalon	Transport from SoCAB near surface	33°20' N	118°20' W	5
Palos Verdes	Transport from coast out to sea	33°35' N	118°25' W	10
Calabasas	Transport to northeast end of SoCAB	34°10' N	118°40' W	300
Cajon Pass	Transport to Lucerne Valley and Mojave Desert	34°20' N	117°30' W	1200

Table 4-3
Air Quality Equipment at Supplemental Surface Sites

Equipment	Measurement Method	Instrumentation	Operating Range
Ozone	UV Photometry	Dasibi Model 1003AH	0 to 500 ppb
$NO/NO_2/NO_X$	Chemiluminescent	TEI Model 42	0 to 500 ppb
Calibration System	Mass flow meter dilution with ozone/NO GPT	Dasibi 5008 CSI 1700	Full range of instruments
	Ozone transfer standard	Dasibi 1003RS	
	In station systems: Metering valve dilution	ML8500	
Data Logger	Digital data acquisition system	Campbell CR10 Campbell 21X	Full range of instruments
Station	Catalina, Airport: To be determine Catalina, Avalon: To be determine Palos Verdes: To be determine Calabasas: To be determine Cajon Pass: To be determine		

Table 4-4
Meteorological Equipment at Supplemental Sites

Equipment	Measurement Method	Instrumentation	Operating Range
Wind Speed as Scalar Wind Speed	Propeller	RM Young Wind Monitor-AQ and -RE	0 to 50 m/s
Wind Direction as Unit Vector Wind Direction	Attached Vane	RM Young Wind Monitor-AQ and -RE	0 to 360°
Sigma Theta	Yamartino method	Campbell DAS	0 to 100°
Temperature	Thermistor	Vaisala HMP35C	-40 to 50 °C
	Thermistor	Fenwal UUT51J1	
Relative Humidity	Capacitive device	Vaisala HMP35C	0 to 100%
	Resistive device	Phys-Chem PCRC11	
Solar Radiation	Pyranometer	LiCor LI-200SZ	0-1500 w/m^2
Data Logger	Digital data acquisition system	Campbell CR10 Campbell 21X	Full range of instruments

4.4.1 Ozone

The Air Pollution Control Districts measure ambient ozone concentrations with instruments made by several different manufacturers. All analyzers employ the UV photometric technique to determine ozone concentration. All analyzers have been designated as EPA Equivalent Methods. The following analyzers are deployed in the networks:

Thermo Environmental Inc., model 49
Dasibi Environmental, model 1003
Advanced Pollution Instrumentation, Inc., model 400

At the supplemental sites, Dasibi model 1003AH ozone analyzers will be used.

The general methods for measurement for the different analyzers are similar. The analyzers consist of a sample chamber illuminated with a continuous ultraviolet (UV) lamp with frequency at 394 nm. The air sample is first introduced to the chamber after passing through a molybdenum oxide scrubber to catalytically convert ozone to oxygen. A sensing system measures the amount of radiation that passes through the chamber without ozone in it. Then the sample is introduced to the chamber with ambient ozone in it. The difference between the UV light passing through the chamber without ozone and with ozone is proportional to the amount of ambient ozone. Some analyzers also contain sensors to measure temperature and pressure in the sample chamber so that ozone readings can be referenced to ambient conditions. Other analyzers require the measurements to be referenced to fixed conditions as determined by the average absolute pressure and temperature in the analyzer sample chamber so that ozone concentrations are given at approximately ambient conditions.

4.4.2 Oxides of Nitrogen

The Air Pollution Control Districts measure ambient NO/NO_X concentrations with instruments made by several different manufacturers. These analyzers measure the concentration of nitric oxide (NO) and total oxides of nitrogen (NO_X) by a chemiluminescence method and nitrogen dioxide (NO_2) by difference between NO_X and NO. Each analyzer has been designated as an EPA Reference Method. The following analyzers are deployed in the networks:

Thermo Environmental Inc., model 14B/D
Thermo Environmental Inc., model 42
Advanced Pollution Instrumentation, Inc., model 200A

At the supplemental sites, TEI Model 42 NO/NO_X analyzers will be used.

When NO and ozone are mixed, a gas-phase reaction occurs that produces a characteristic luminescence with an intensity that is linearly proportional to the concentration of NO. A photomultiplier tube senses the luminescence generated by the reaction. Other oxides of nitrogen can also be measured by first reducing them to NO with a molybdenum converter heated to 325 °C and then measuring the result by chemiluminescence as NO_X. The analyzer switches between measuring NO and NO_X and electronically computes difference between NO_X and NO. The difference can in some cases be attributed to NO_2 as the other major constituent of NO_X. The instruments converter can also convert other nitrogenous species, such as nitric acid and PAN, to NO. Nitric acid and nitrate particles can be removed from the sample by installing a nylon filter on the sample inlet.

4.4.3 Wind Speed Sensor

Wind speed is measured by cup or propeller anemometers of several manufacturers and models. As the cup or propeller turns a pulse is generated by a magnetic or optical switch or a direct voltage is generated by a small electrical generator. The frequency of the pulses or the generated voltage is proportional to the wind speed. The manufacturers supply relations between wind speed and rotation rate for their sensors. The sensors using a propeller are generally combined with a moveable vane to align with the wind. The cups rotate about a vertical shaft have an omnidirectional response to the wind. The following sensors are found in the study area:

Met One, model 010 and 014
Climatronics, model F460
R.M. Young, model Wind Monitor-AQ, Wind Monitor-RE
Bendix Aerovane

The supplemental sites will use R.M. Young, model Wind Monitor-AQ and Wind Monitor-RE sensors.

4.4.4 Wind Direction Sensors

Wind direction is measured with a vane to that aligns itself along the direction of the wind. The orientation of the vane relative to a fixed direction, generally true north, is measured by the voltage across a potentiometer and is proportional to the angle of the vane. The following sensors are found in the study area:

Met One, model 020 and 024
Climatronics, model F460
R.M. Young, model Wind Monitor-AQ, Wind Monitor-RE
Bendix Aerovane

The supplemental sites will use R.M. Young, model Wind Monitor-AQ and Wind Monitor-RE sensors.

4.4.5 Temperature Sensor

Temperature at the sampling sites is measured with a thermistor, a platinum resistance thermometer, or a thermocouple. The thermistor and RTD are both resistance devices that respond proportionally to temperature with a voltage output that is proportional to temperature. The thermocouple develops a voltage proportional to temperature because of the proximity of dissimilar metals. A data acquisition system linearizes the voltage output for these sensor. The sensors are installed in radiation shields to reduce the effect of direct solar radiation. The shields are either mechanically aspirated with a small blower or naturally aspirated by air movement around the sensor.

The supplemental sites will use Vaisala model HMP35C temperature/relative humidity sensors. The temperature sensor is a thermister.

4.4.6 Relative Humidity/Dew Point Sensor

The relative humidity or dew point is measured at some sites. Relative humidity is measured with capacitance or resistive devices having thin polymer films that change characteristics as water is absorbed. Dew point is measured with a chilled mirror sensor or LiCl dew cell with a heated wire-wound bobbin that absorbs water vapor and releases water vapor in proportion to the dew point.

The supplemental sites will use Vaisala model HMP35C temperature/relative humidity sensors. The relative humidity sensor is a capacitive device.

4.4.7 Solar Radiation Sensor

Solar radiation at most sampling sites is measured with LiCor model LI-200SZ pyranometers. This sensor consists of a silicon photodiode that responds to light over the range that includes visible spectrum. When calibrated and orientated properly, the sensor has an output that is proportional to the incoming solar radiation, both direct and diffuse. Some sites use Epply thermopile sensors that generate a voltage by differential heating of white and black materials.

4.5 Calibration Procedures and Frequency

Calibration procedures are described in the following section. Specific instructions are contained in available QA Plans in the form of standard operating procedures and in the manufacturers' manuals.

The Air Pollution Control Districts have routine calibration procedures that include multipoint calibrations of the ozone and NO/NO_X analyzers when instruments are installed or repaired.

At the supplemental sites, multipoint calibrations of the continuous air quality analyzers for ozone and NO/NO_X will be performed at the start and end of the study, following a zero and/or span adjustment necessitated by out-of-tolerance zero/span checks, and after instrument repair.

In addition to calibrations, routine site visits are made to each site by field technicians on a regular schedule at least once a week but usually daily. The technicians have been trained to follow procedures setup by the APCD or by AVES. Automated zero/span checks are performed every night at most sites. Manual precision checks are made once a week at many sites.

Site visits are used to ensure that all equipment are operating properly, to identify instrument problems and to give warning of developing problems.

Station checks are performed each site visit following the steps prescribed on station check forms.

Each site visit, the site technician visually inspects the meteorological sensors, the ambient air sampling probe and inlet system, and the air sampling systems.

All visits are documented. Copies of recorded data and documentation are returned at specified intervals, generally once a month, to the agency office for processing.

Quality control checks consist of periodic zero/span checks and precision checks. In both cases, test atmospheres are introduced to the analyzer operating in its normal sampling mode through a solenoid valve controlled by the site DAS. Test gases pass through all filters, scrubbers, conditioners, and other components used during normal sampling.

At many sites, each air quality analyzer is subjected to an automated zero/span check once a night. Test gases at zero and one span concentration are introduced to each analyzer. The span gas concentration is about 80% of the analyzer's nominal operating range. Zero/span data are used to determine if an analyzer needs adjustment and to evaluate validity of data. Zero/span data are accessed by telephone along with the ambient data and are reviewed daily. The following criteria are used in evaluating the data:

- Zero checks: Daily check should be within ±2% of full scale from the zero value established during calibration. If two consecutive zeros exceed ±2%, the instrument is removed from service, the problem corrected, and the instrument recalibrated and returned to operation. If the check exceeds ±3%, the instrument is immediately taken off line, given a "before" calibration, fixed, and given an "after" calibration. If the check exceeds ±5%, the instrument has serious problems and data is invalidated. The same action as the 3% criteria is done.

- Span checks: Daily check (about 80% of full scale) should be within ±10% of span value established during calibration. If two consecutive spans exceed ±10%, the instrument is removed from service, the problem corrected, and the instrument recalibrated and returned to operation. If the check exceeds ±15%, the instrument is immediately taken off line, given a "before" calibration, fixed, and given an "after" calibration. If the check exceeds ±25%, the instrument has serious problems and data is invalidated. The same action as the 15% criteria is done.

At some sites, the technician performs a manual precision check once a week. For this, gas with concentration between 80 and 100 ppb is introduced to the analyzer. The response of the analyzer is entered on the log sheet. Precision checks are made before any instrument adjustments or recalibrations are done. Procedures for calibration, zero/span, and precision checks are summarized in the following sections.

4.5.1 Ozone

The ozone transfer standard and clean air system are taken to the monitoring site. Ozone-free air is generated by passing ambient air through a desiccant and activated charcoal and a desiccant. The ozone transfer standard has an internal ozone generator that supplies ozone to the instrument to be calibrated and its own measurement chamber.

First, ozone-free air from the dilution system is introduced to the instrument to obtain the zero level. Then, up to five concentrations of ozone are supplied to the analyzer ranging from 10% to 90% of the analyzer range with one near the span point of 450 ppb and one near the precision point of 100 ppb. The test gases are delivered to the analyzer's sample inlet via a Teflon tube to reduce losses of ozone. This tube contains a Teflon vent to allow excess flow escape and maintain the inlet at atmospheric pressure. Test gas passes through as much sample tubing as possible including any filter normally associated with the sampling process.

Readings from the calibrator display and primary site DAS are recorded on a calibration form and a least-squares linear regression between DAS and calibrator readings is computed. The regression for a valid calibration has a slope of 1.000±0.01, an intercept of 0.0±0.01, a regression coefficient of at least 0.999. Instruments exceeding these tolerances require further checking and possibly repair or replacement.

The ozone transfer standards are calibrated approximately once a quarter with a laboratory transfer standard. The laboratory standard verified annually with the long-path UV Photometer at the California Air Resources Board in Sacramento, CA.

4.5.2 Oxides of Nitrogen

The calibration standards consists of a dilution flow metering system, NO/NO_X-free dilution air (zero air) system, and a cylinder of compressed gas containing a known amount of NO. The manually operated dilution system contains one flow controller (mass or volumetric) to meter accurate amounts span gas, a second flow controller (mass or volumetric) to meter accurate amounts of dilution air, and a Teflon-lined or glass mixing chamber. The dilution air is generated by forcing ambient air through desiccant, Purafil, and activated charcoal. Purafil (potassium permanganate) oxidizes NO to NO_2 which is then removed by the charcoal. A cylinder of compressed gas provides a source of approximately 50 ppm NO in a balance of nitrogen. The dilution system also has a section that produces a known concentration of NO_2 by performing a gas phase titration (GPT) in which O_3 is mixed with NO to generate NO_2.

Zero and up to five upscale concentrations of NO are introduced to the instrument. The concentrations of NO range from 10% to 90% of the analyzer range with one near the span point of 450 ppb and one near the precision point of 100 ppb. Delivery to the analyzer is through as much sample line as possible including the switching solenoid valve and any inline filters.

Readings from the analyzer display and primary DAS for NO and NO_X are recorded and linear regressions of sampler versus calibrator NO and NO_X are computed. For linear operation of the analyzer, the computed regression coefficient should be at least 0.999.

The NO_2 channel response and the efficiency of the NO_X to NO converter are tested with NO_2 generated in the GPT section of the dilution system. These tests are done at 3 different NO_2 and NO_X concentrations while the NO concentration remains between 80 to 100 ppb. NO gas with concentrations for the three points are near 450, 300, and 150 ppb. The responses of the NO and NO_X channels to this NO are recorded and adjusted by the linear regression equations relating instrument response to calibration concentration. Ozone is mixed with the NO to generate NO_2 concentrations near 350, 200, and 50 ppb which are introduced to the instrument. The responses of NO and NO_X are recorded and corrected for the calibration results.

For each test, the response of the NO_2 channel is compared to the NO_2 concentration generated by the GPT as determined from

$$GPT\ NO_2 = Orig\ NO - Rem\ NO$$

where: Orig NO is adjusted response of NO channel before O_3 is mixed and
Rem NO is adjusted response of NO channel after O_3 is mixed.

The converter efficiency, Conv Eff, is determined in the following steps:

$$\_NO_X = Orig\ NO_X - Rem\ NO_X$$

$$Conv\ NO_2 = GPT\ NO_2 - \_NO_X$$

$$Conv\ Eff = 100 \times (conv\ NO_2)/(GPT\ NO_2)$$

where: Orig NO_X is adjusted response of NO_X channel before ozone is mixed and
Rem NO_X is adjusted response of NO_X channel after ozone is mixed.

An overall converter efficiency is calculated by averaging the efficiencies at the three levels. A converter efficiency less than 96% indicates that the converter material should be replaced.

4.5.3 Wind Speed

The wind speed sensors are calibrated one to two times a year when routine maintenance is done on the sensors, such as replacement of bearing. Known rotation rates are applied to the sensors while monitoring the DAS reading. Variable or fixed rate motors are attached to the anemometer in place of propeller or cups and the sensor shaft is turned at known angular speeds. DAS wind speeds are compared to the values supplied by the manufacturer of the sensor for known rotation rates.

Bearings are checked before calibration to determine if they affected the wind speed data before replacement. Rotation of shaft is checked for smoothness of operation and starting torque is measured with a torque wheel. For the RM Young Wind Monitors, bearings are replaced if a sensor fails to respond to a 0.3 g-cm torque.

4.5.4 Wind Direction

The wind direction sensors are calibrated one to two times a year using an angle calibrator. With the sensor in place on the calibrator and connected to the DAS, the vane is moved around the

360° circle in 10° increments. The DAS readings are compared to the calibrator angles. Sensors that have readings within ±2° of calibrator are used without correction. Sensors outside that limit are inspected for problems or used with an correction developed from the calibration.

4.5.5 Temperature

Temperature sensors that can be immersed in water are calibrated one to two times a year using water baths over the range of the sensor. Low temperature is obtained with an ice bath. Higher temperatures are reached by heating the bath with an immersion heater. A calibration thermometer with NIST-traceability should be used to measure the bath temperature. The error associated with this method is less than ±0.5 °C.

For temperature sensor than cannot be immersed in water, the calibration can be checked by placing an aspirated, NIST-traceable thermometer near the sensor and comparing the site sensor reading to the calibration thermometer. The side-by-side calibration check can have an error of about ±1 °C when done outdoors because of the effect of solar radiation.

4.5.6 Relative Humidity/Dew Point

The calibration of the relative humidity/dew point sensor is checked by placing the sensor in chambers containing different saturated salt solutions. These solutions give relative humidities that depend on the salt and the temperature. The range of relative humidity for typical salts is about 12% for LiCl to 97% for K_2SO_4. This calibration is best done in controlled environment and not outdoors.

The calibration can be checked in the field by placing a separate relative humidity sensor or an aspirated, psychrometer with NIST-traceable thermometers near the sensor. As with the temperature check, the psychrometer should be shaded from direct solar radiation while being exposed to the free-air. Simultaneous readings from the sensor and the wet- and dry-bulb thermometers of the psychrometer are recorded. The relative humidity is determined from psychrometric tables or a psychrometric slide rule.

4.5.7 Solar Radiation

The calibration of the solar radiation sensors is best done by returning the sensor to the manufacturer on an routine schedule. A secondary check of the sensor can be made with a side-by-side comparison between the site pyranometer and a similar pyranometer that is only used for comparison. This comparison sensor is placed as near to and with similar exposure as the site pyranometer for a several hour period. A comparison of the readings of the two pyranometers gives an indication of the operating characteristics of the site sensor.

4.6 Systems Audits

Formal, in-depth systems audits will not be conducted for the air quality and meteorological sites. Personnel from Quality Assurance Section (QAS) of the ARB will complete Comprehensive Site Surveys during site visits. The Site Survey is a qualitative evaluation of the sampling site and its operation.

Each Site Survey will be conducted by completing a standard form specific, which will consist of the following tasks:

- Document site location, measurements at site including instrument type, sampling purpose, and applicable measurement scale.
- Describe vicinity of site within 100 m radius including heights of sensors, length of probes, and towers.
- Describe obstacles near site including direction, distance, height, distance to tree dripline, distance to walls, and arc for free air flow.
- Describe nearby sources including distance and direction for flues, non-vehicular local sources, and traffic. Give dominant influence category.
- Describe the ambient air delivery system to analyzers including inlet probe, sample manifold, and tubing to instruments. Include conposition, inside diameters, lengths, and flow rates. Determine probe and total residence times.
- Determine if approved QA Plan is used, schedule for cleaning, auto-calibration type and schedule, use of inline filter, control and recording of station temperature.

4.7 Performance Audits

Performance audits will be conducted by personnel from Quality Assurance Section (QAS) of the ARB. Each measurement method will be audited on the project.

Performance audits are quantitative assessments of instrument operation that are accomplished by challenging site instruments with known audit standards. This section provides an overview of the key procedures that will be used. All audit procedures are described in detail in several appendices of ARB's "Audit Procedures Manual" (ARB, 1990, 1993a, 1993b, 1994a, 1994b, 1995a, 1995b, 1995c, 1995d, 1996a, 1996b). The procedures are also consistent with EPA guidelines for audits of gaseous and particulate samplers (40 CFR 58, App A, B, and E; EPA, 1984; EPA, 1986; EPA, 1987) and for meteorological instruments (EPA, 1989).

All audit results will be entered on QA Audit Station Data Worksheet forms and into an audit computer. Calculations are done by the computer and by hand for verification. Preliminary results will be summarized in reports for each measurement issued to the site operator at the conclusion of the audit. For gas analyzers, the reports will present the audit concentrations, the instrument responses, and the percent differences. Instrument performance will be assessed by comparing the percent differences to EPA criteria as shown in Table 4-5. For meteorological equipment, the reports will present the expected instrument responses, the actual instrument responses, and their differences. Instrument performance will be assessed by comparing the differences to the EPA criteria as shown in Table 4-5. For those instruments that exceed the criteria, the auditor will issue an Air Quality Data Action (AQDA). The site operator will be required to respond to the AQDA by detailing the actions done to correct instrumental problems found during the audit.

Table 4-5a
Audit Criteria - Continuous Gas Analyzers

Quantity	Measure	Excellent	Satisfactory	Unsatisfactory
Difference	Percent	0 - ±5	±(5 - 15)	<-15, >15

Table 4-5b
Audit Criteria - Meteorological Sensors

Sensor	Satisfactory Limits
Wind Speed	±0.25 m/s for WS ≤ 5.00 m/s ±5% value for WS > 5.00 m/s not to exceed 2.5 m/s
Wind Speed (starting threshold)	< 0.5 m/s
Wind Direction	±5 degrees relative to True North
Wind Direction (starting threshold)	< 0.5 m/s
Temperature	±0.5 °C
Dew Point	±1.5 °C
Dew Point (in fog)	±0.5 °C
Solar Radiation	greater of ±5% or ±25 w/m^2
Pressure	±10 mb (±7.5 mmHg)

4.7.1 Ozone

Performance audits of ozone analyzers will be conducted with one of two methods depending on the accessibility of the analyzers. In the first method, a Dasibi 1009 CP gas calibrator will be used as an ozone source and transfer standard. This instrument is contained in QAS's audit van. The Dasibi 1009 CP will generate known concentrations of ozone that will be supplied to the site analyzer through a 150 foot gas presentation line connected to the site inlet probe. The generated ozone will be measured by the Dasibi 1009 CP itself or by a separate API 400 Ozone analyzer. In the second method, a Dasibi 1008 PC portable ozone transfer standard will be transported to air monitoring site. The Dasibi 1008 PC will generate and measure concentrations of ozone to be introduced at the rear of the site analyzer.

The Dasibi 1009 CP and Dasibi 1008 PC instruments will generate ozone with an adjustable UV lamp. The concentration of the generated ozone will be measured with a UV photometer, either within the instrument or contained in a separate analyzer. For the van system, ozone-free air will be produced by an Aadco 737R pure air system in the audit van and a compressor capable of producing a constant 20 lpm supply of air at the end of the gas presentation tube. For the portable ozone standard, ozone-free air will be produced by passing ambient air through a cartridge of activated charcoal connected zero-air inlet of the instrument. Ozone concentrations measured by the transfer standards will be corrected to account for calibration factors for the standards, for the altitude correction factor if standard does have temperature/pressure correction, and for line loss in the gas presentation line.

Before starting the audit, the standard will be warmed up for at least one hour. It will be verified that all connections are made according to standard procedures. Instrument checks will be made and recorded.

The first audit point will be the response to ozone-free air. Three upscale ozone concentrations will be generated and delivered to the site analyzer and audit standard. The ranges of the concentrations will be 0.35 to 0.45 ppm, 0.15 to 0.20 ppm, and 0.03 to 0.08 ppm. A final response to zero air will be done after the 3 upscale points. For each concentration, the instruments will equilibrate for 30 minutes. Then ten consecutive readings of the ozone transfer standard will be recorded followed by ten consecutive readings from the data collection device site for the site analyzer. The average responses, differences, and percent differences will be calculated will be calculated for each audit point. The overall percent difference will be calculated for comparison to the audit criteria.

The ozone transfer standards are submitted to ARB's Standards Laboratory on a quarterly basis for recertification against the EPA-verified Primary Ozone Photometer. For a valid certification, it is required that the standard differ by less than ±1.5% from past certification values and the slope and intercept fall within one standard deviation of the last six certification equations.

4.7.2 Oxides of Nitrogen

Performance audits of NO/NO_X analyzers will be conducted using the Thru-the-Probe method as generated by instrumentation contained in QAS's audit van. Known quantities of National Institute of Standards and Technology (NIST) traceable gases will be diluted with 20 lpm of pure air will be introduced to the site analyzer through a 150 foot gas presentation line connected to the site inlet probe. NO will be supplied from a cylinder of compressed air. NO_2 will be generated by the gas phase titration (GPT) of NO with ozone.

The audit standard will consist of a Dasibi 1009 CP dilution flow metering system, an Aadco 737R pure air system to generate NO-free dilution air (zero air) and compressor capable of supplying 20 lpm system, a superblend cylinder of compressed gas containing a mixture of NO and CO (along with other gases) in NIST-traceable concentrations, a Thermoenvironmental (TEI) Carbon Monoxide analyzer, model 48, two cylinders of compressed gas with known amounts of CO, and one cylinder of compressed ultrapure air.

The Dasibi 1009 CP system also contains an ozone generator and second mixing chamber for the generation of NO_2. When ozone is mixed with NO, a GPT results which oxidizes some NO to NO_2. The generated NO_2 is calculated from the change in NO. The analyzer NO_2 readings and the converter efficiency are determined from the GPT.

Before starting the audit, the TEI 48 and dilution system will be warmed up for at least one hour. The CO analyzer will first be calibrated using the zero air cylinder and two CO cylinders. The CO concentration of the gas mixture generated by the Dasibi 1009 CP using the Aadco pure air and gas from the mixed gas cylinder will then be measured with the TEI 48. The dilution ratio of the generated audit sample will be calculated. The generated NO concentration will be calculated using the dilution ratio and the cylinder concentration.

The first audit point will introduce zero air to the site analyzer. The next steps will consist of introducing NO to the analyzer for the response of the NO and NO_X channels followed by the generation of NO_2 by GPT. A total of three NO_2 concentrations will be generated. A final low NO concentration will be generated. The ranges of concentration for NO, NO_2, and NO_X delivered to the site analyzer will be 0.35 to 0.45 ppm, 0.15 to 0.20 ppm, and 0.03 to 0.08 ppm. A final response to zero air will be done at the end of the audit.

Readings will be recorded from the primary data acquisition system. Sufficient time is allowed for the response to stabilize before recording any information. The measured values from the display, analog output, and data logger are compared to the audit concentration.

The dilution ratio will be calculated according to the equation:

$$\text{DILUTION RATIO} = \frac{\text{True CO Response (ppm)}}{\text{Superblend Cylinder CO Concentration (ppm)}}$$

The true concentration in ppm will be calculated from

TRUE CONCENTRATION = Superblend Concentration × Dilution Ratio

The NO_2 channel response and the efficiency of the NO_X to NO converter will be tested with NO_2 generated in the GPT section of the dilution system. These tests are done at 3 different NO_2 and NO_X concentrations while the NO concentration remains between 80 to 100 ppb. NO gas with concentrations for the three points are near 450, 300, and 150 ppb. The responses of the NO and NO_X channels to this NO are recorded and adjusted by the linear regression equations relating instrument response to calibration concentration. Ozone is mixed with the NO to generate NO_2 concentrations near 350, 200, and 50 ppb which are introduced to the instrument. The responses of NO and NO_X are recorded and corrected for the calibration results.

The converter efficiency, Conv Eff, will be determined in the following steps:

$$\text{Conv Eff} = 100 \left(\frac{\Delta\ NO - \Delta\ NO_X}{\Delta\ NO} \right)$$

$$\Delta\ NO = (\text{Orig NO} - \text{Rem NO}) \ / \ \text{Slope NO}$$

$$\Delta\ NO_X = (\text{Orig } NO_X - \text{Rem } NO_X) \ / \ \text{Slope } NO_X$$

where: Orig NO is adjusted response of NO channel before ozone is mixed,
Rem NO is adjusted response of NO channel after ozone is mixed,
Orig NO_X is adjusted response of NO_X channel before ozone is mixed and
Rem NO_X is adjusted response of NO_X channel after ozone is mixed.

An overall converter efficiency will be calculated by averaging the efficiencies at the three levels. A converter efficiency less than 96% will require an AQDA.

4.7.3 Wind Speed

Wind speed sensor audit will consist of an evaluation of the starting threshold of each sensor and a comparison of sensor response to fixed inputs with a variable speed motor at several constant rotation rates (EPA, 1989d). If possible, sensors will be audited in place with tower standing or tilted down but with cups or propellers removed. The auditor will not climb the tower. The site operator will handle the sensor. The only sensors that have been calibrated recently will be audited. There will be some limitations on the audits because sensor accessibility and sensor type.

The condition of bearings and any dirt/materials in the anemometer shaft affects the starting threshold. The auditor will qualitatively evaluate these by rotating the sensor shaft by hand and feeling for drag and grinding. The starting threshold will be measured with a torque watch or torque disk to determine if the starting threshold is 0.5 mps or less.

Accuracy of the wind speed output of the system will be determined by replacing the anemometer or propeller a variable speed anemometer drive (R.M. Young) to turn the shaft at rotation rates of 0, 60, 300, 600, and 1800 RPM. Instrument responses as registered by the DAS are compared to the manufacturer's speeds for these rotation rates. Differences between site and audit wind speeds is computed and compared to audit criteria.

4.7.4 Wind Direction

Wind direction sensor audits will consist of an evaluation of the threshold, orientation of cross arm, and instrument responses to known positions. If possible, the sensor will be audited in place on the tower. The auditor will not climb the tower. The site operator will handle the sensor. The only sensors that have been calibrated recently will be audited. There will be some limitations on the audits because sensor accessibility and sensor type.

The auditor will check the starting threshold qualitatively in the same manner as for the wind speed sensor by feeling for drag and grinding. A quantitative measurement of starting threshold with a torque gauge can only be done under conditions of no air motion. With the sensor in a sheltered location, a gram gauge will be used to measure the starting threshold which should be less than 0.5 mps at a deflection of 10°.

Sensor orientation can be determined in several ways depending on the accessibility and type of sensor. In general, the audit will consist of holding the vane at several known positions covering the 360° circle and comparing the sensor reading to the position relative to true north. Angular bearings will be measured with measured with a Brunton Pocket Transit on a tripod or Site Path Transit. Magnetic bearings from these transits will be converted to bearings relative to true North using current magnetic declination for the location obtained from the USGS GEOMAP program. The crossarm or sensor orientation will be measured. The vane orientation will be compared to known landmarks, the crossarm, or a degree orientation fixture such as the R.M. Young model 18212 or Met One models 040/044. The vane will be held in at least 4 different directions that are separated by approximately 90°. The output of the DAS for the 4 directions will be compared to the angle computed from bearing relative to true North. Differences between site and audit wind directions will be computed and compared to audit criteria.

4.7.5 Temperature

The accuracy of the temperature sensor will be evaluated one of two methods. If the sensor can be immersed in water, it will be removed from its shield and placed in water baths of three temperatures. The bath temperature will be measured with a calibrated audit thermocouple. The audit sensor will be a Digi-Sense J,K,T Thermocouple thermometer with a T-type thermocouple. Different bath temperatures will be obtained with ice, an immersion heater, and near ambient water. The audit comparison will consist of the difference between readings of the audit thermometer and the site sensor.

If the site sensor cannot be immersed in water, a side-by-side comparison will be made between the sensor and the audit thermocouple for a total of three readings. The sensors will be shaded to minimize the effect of solar radiation.

The audit thermometer and thermocouple are certified annually by a certification laboratory.

4.7.6 Relative Humidity/Dew Point

Accuracy of relative humidity/dew point sensor will be determined by placing the audit relative humidity sensor near the site sensor and obtaining 3 readings. The primary relative humidity probe will be a Rotronic Hygroskop GT-L relative humidity/temperature probe. This sensor will measure relative humidity directly. A secondary audit instrument will be an Environmental Tectonics Psychro-Dyne dry bulb/wet bulb psychrometer. The psychrometer measures wet- and dry-bulb temperature from which relative humidity and dew point can be calculated.

Since EPA's acceptance criteria for relative humidity is in terms of dew point temperature. The audit and site relative humidity will be converted to dew point using an expression for vapor pressure versus temperature for the Rotronic instrument or the psychrometric tables and/or psychrometric equation for the psychrometer. The difference between site and audit dew point will be computed and compared to the audit criteria.

The Rotronic probe is calibrated quarterly using salt solutions in a calibration device. Readings at 35, 50 and 80% relative humidity are obtained. The probe is returned to the manufacturer annually recertification of the temperature sensor and a 35 and 80% relative humidity comparison.

4.7.7 Solar Radiation

Accuracy of solar radiation sensor will be determined by installing an audit pyranometer near the site sensor and obtaining several readings. The audit probe will be an Eppley model PSP precision spectral pyranometer with a LI-1000 data logger. The data logger will collect a series of 10-minute readings or readings integrated over a longer time period. The audit sensor will be placed as near the site sensor with the same exposure as possible. The difference between site and audit solar radiation will be computed and compared to audit criteria. The solar radiation audit will not be done if it is raining. The audit should be done near noontime if possible.

The audit pyranometer is returned annually to Eppley for recalibration against the companies standards.

4.8 Corrective Action

Corrective action will be initiated when a problem is identified. Problems may be identified during operations and/or during performance audits. The goal of corrective action is to remedy any problem before the affected quantity drops below the desired accuracy, precision, or completeness.

Problems found during the audits will be documented with the Air Quality Data Action (AQDA) mechanism. The site operator will be notified of problems during the audit. A response to the AQDA that covers the resolution of the problem will be required. The audits will be somewhat limited in determining operational problems since they will occur only once during the study.

During routine operations of the air quality and meteorological sites, data from the field sites will be reviewed on a daily schedule. This daily review will provide the primary initiation for corrective action when problems with the data are identified. The site operators will be secondary in identifying most problems except those by visual inspection.

Once a problem has been identified, it will be evaluated for most efficient way to fix that may involve the combined efforts of the data analyst, an instrument technician, and the site operator. The local supervisors, the study QA officer, and the study project manager will be informed of the problem, and later its resolution, through verbal and written notification. This will documents the problem, its resolution, and the effect on the particular quantity and the project in general.

4.9 Data Acquisition and Processing

The individual agencies and other participants in the field project are responsible for acquiring and processing data from their networks. In general, all procedures meet the requirements and guidelines of EPA (40 CFR 58, Appendices A and B; Quality Assurance Handbook for Air Pollution Measurement Systems, Volume I, II, and IV). The objective of the data reduction and validation effort is a quality assured data base monitoring data in a consistent format.

Continuous data are collected by data acquisition systems (DAS) in the field at the agency sites and at the supplemental sites. The DAS samples the outputs from the instruments serially at fixed intervals and converts analog voltage signals to digital numbers for processing. Each hour, it computes hourly averaged data as scalar averages. Day and time of sample are collected also. Meteorological data may also include hourly and 15-minute averages are computed with temperature and relative humidity as scalar averages and winds as average scalar wind speed and unit vector wind direction. The standard deviation of the wind direction may be computed using the Yamartino method over 15-minute segments with an hourly averaged sigma theta computed as the root-mean-square value of the four 15-minute averages. Each record stored by the DAS is identified with a date and time. The time collected by most data loggers is time at the end of the sample period. The time associated with specific data records, beginning or ending, needs to be specified in the final data product.

At many sites, the DAS commands the site calibration system to perform daily automated zero/span checks of the instruments.

At many sites, averaged air quality and meteorological data and automated calibration data are retrieved automatically from the field each night by telephone and modem. At some agencies and for supplemental sites, these data are automatically screened for anomalies that are flagged for further investigation. The screening routines check for outliers, instrument problems, and data system problems. They can test for data that exceed set minima, maxima, and rate-of-change values. For the supplemental sites, reports from the screening programs will be available for review the next day. Data are entered into a raw data base as they are received. This data base is saved in its original form and noted as such to assure that it could be obtained again if necessary. Subsequent data bases are updated as processing proceeds.

All site documentation are sent from the field to the operations office at least once a month. This includes site logs, checklist logs, zero/span checks, and multipoint calibration results. The ancillary site data are logged in and made available for use during data processing and validation.

4.10 Data Validation

All data are reviewed before use, starting with observations and reports from the site operators and continuing with the review of logs, checklists, and data. All flagged or anomalous data are investigated. All data are retained unless substantial evidence is available for their deletion.

For air quality data, zero and span check data are reviewed as an integral part of the process. Data for which the span response deviates by more than 25% or the zero by more than 25 ppb from expected values are invalidated. Data for which the span response deviates by 15 to 25% are adjusted using correction factors obtained for zero/span and calibration data.

All changes resulting from reviewing documentation are made directly on the raw data report and comments added as required. Raw data reports are reviewed to see that outliers have been corrected, replaced by missing data code if deleted, or checked as valid. When raw data are completely checked, corrected, and approved, changes are made to the data base and any necessary correction factors applied.

For supplemental sites, a data report will be generated that describes the data collected including units and lists missing data.

4.11 Data Archival

Data from the Air Pollution Control Districts are archived in AIRS format and are submitted to ARB and EPA. Data from the supplemental sites will also be archived in AIRS format and submitted to ARB.

5. UPPER-AIR AIR QUALITY MEASUREMENTS

Aloft air quality measurements during SCOS97-NARSTO IOPs include ground-based lidar, instrumented aircraft and ozonesondes.

5.1 Ground Based Ozone Lidar

Differential Absorption Lidar (DIAL) has previously been used in a number of regional air quality studies to measure both spatial and temporal distribution of atmospheric pollutants. The pollutant of interest in most studies was ozone (O_3). Recent studies in the United States which have utilized DIAL ozone measurements include the 1991 Lake Michigan Ozone Study (LMOS) (Uthe et al., 1992), the 1993 Coastal Oxidant Assessment for Southeast Texas (COAST) study (Moosmüller, 1994; Moosmüller et al., 1994), the 1993 Los Angeles Atmospheric Free Radical Study (Zhao et al., 1994) and the 1995 Southern Oxidant Study (SOS) (Alvarez II et al., 1997). Generally, DIAL systems have been operated in these studies on an exploratory basis without formal quality assurance procedures. However, to fully utilize DIAL capabilities for the respective study purposes, well established quality assurance procedures are necessary to provide quantitative estimates of precision, accuracy, and validity of the measurements and to optimize measurement and data analysis procedures. Therefore, every effort should be made to establish an effective DIAL quality assurance program for SCOS97. It is important that the QA team does not treat the DIAL system as a "black box" for measuring ozone concentrations, but has an in-depth understanding of the measurement and data analysis process, the DIAL hardware, and the potential problems involved. The specialized nature of ozone DIAL measurements precludes simple performance audits for these measurements. Intercomparison studies are typically used to assess the accuracy and precision of DIAL measurements.

In addition to the measurement of ozone concentration profiles ozone lidars can utilize their "off channel" to monitor aerosol backscatter structures. The resulting aerosol data are extremely valuable for the visualization of atmospheric layers, but are only semi-quantitative in nature due to limitations in lidar inversion techniques.

The Atmospheric Lidar Division of NOAA's Environmental Technology Laboratory in Boulder has developed a transportable ozone and aerosol lidar specifically for the measurement of ozone in the boundary layer and the lower free troposphere. This lidar has been employed in several field experiments:

- July 1993, Intercomparison Experiment in Davis, CA, sponsored by ARB (Zhao *et al.,* 1994)
- September 1993, LAFRS Experiment in Claremont, CA, sponsored by ARB (Zhao *et al.,* 1994)
- August, 1995, Ozone Transport Experiment in Victorville, CA, sponsored by ARB
- October–November 1995, Table Mountain Vertical Ozone Transport and Intercomparison Experiment in Boulder, CO, sponsored by NOAA.

This system is based on a solid state laser, the Nd:YAG laser with a fundamental wavelength of 1064 nm and a pulse repetition rate of up to 10 Hz. The third harmonic of this wavelength (i.e., 355 nm) with an operating pulse energy of 7–10 mJ is used for aerosol profiling with a range of about 9 km. The fourth harmonic of the fundamental (i.e., 266 nm) with an operating pulse energy of 20–30 mJ is used as "on-line" for the ozone measurement. The "off-line" for the ozone measurement is generated by Raman shifting the second harmonic (i.e., 532 nm) by the vibrational frequency of the deuterium molecule (i.e., 2987 cm-1) to 632.5 nm, and subsequent sum-frequency mixing of 532 nm and 632.5 nm, yielding an "off-line" at 289 nm. The Raman shifting takes place in a specially designed Raman cell, yielding a pulse energy of 1-2 mJ at 289 nm. This process utilizes the laser energy better than the more direct Raman shifting of the fourth harmonics (Ancellet et al., 1989; Zhao et al., 1994), while yielding the same wavelength.

The receiver section utilizes an 8"-diameter telescope to collect the backscattered light. Dichroic beamsplitters separate the light from the different laser lines for the detection by photomultiplier tubes. The signals are digitized by 12 bit A/D converters for the subsequent analysis. The aerosol channel formerly had an 8 bit A/D converter which is being replaced by a 12 bit A/D converter.

Ozone measurements can be obtained for a range of up to 3 km under moderate to high surface ozone concentrations (< 150 ppb) while, for extremely high concentrations, a range of 2 km can still be achieved. The lower range limit is very good (≈ 50 m) due to the use of an innovative technique for the compression of the lidar dynamic range (Zhao et al., 1992). The measurement direction of the lidar system can be scanned in one dimension from 30° to 150° yielding a two dimensional ozone measurement.

The data quality objectives for ozone measurements with the NOAA ozone lidar are ±5 ppb for ranges up to 1.5 km and ±10 ppb for ranges up to 3 km for moderate to high surface ozone concentration (< 150 ppb) under the assumption of 1 min temporal and 50 m spatial averaging. The lidar observation in a 2-dimensional vertical plane will take 11 min for a scan from 30° to 150° in 10° steps, firing 100 laser shots at each angle with a pulse repetition rate of 2 Hz. If higher temporal resolution is desired the system can be operated with a pulse repetition rate of 10 Hz. Preliminary ozone data for visualization and for intercomparison with in situ sensors will be available in near real time. This ability will greatly facilitate an ozone lidar performance audit.

Successful use (i.e., meeting the quality objectives) of the NOAA ozone lidar in 2-dimensional scanning mode is contingent on improvements of the scanning system. Previous use of the system in scanning mode has yielded relatively poor quality data due to problems with thermal expansion of a scanning mirror and subsequent optical distortions. NOAA expects to have eliminated these problems and to have conducted system and performance tests prior to the system's deployment in SCOS97.

The NOAA ozone lidar will be transported to California in June 1997 and set up at the El Monte site. During SCOS97, the lidar will gather 350 hours of data, split up into seven intensive measurement periods to capture various types of ozone episodes. When an ozone episode of interest is expected to develop, NOAA staff will fly within 24 hours to the lidar site and begin to collect data.

5.2 Instrumented Aircraft

Instrumented aircraft will be used to measure the three-dimensional distribution of ozone, ozone precursors and meteorological variables. The aircraft will provide information at the boundaries of the modeling domain and will document the vertical gradients, the mixed layer depth, and nature of the polluted layers aloft. Four aircraft are included in the core program and additional aircraft may be available for short periods. The University of California, Davis Cessna 182 will be used to characterize processes resulting in ozone layer aloft in the SoCAB and ozone fluxes into the San Fernando Valley. It will also provide data to validate the ground-based lidar measurements by NOAA at the El Monte Airport. The Sonoma Technology Piper Aztec will provide boundary and initial conditions in the northern portion of the study domain and serve as back-up to the western boundary aircraft. It will also provide data to characterize ozone and NO_Y fluxes through Tehachapi and Cajon Passes and profiles in the eastern portion of the SoCAB. The Gibbs Flying Service Cessna 182 will provide initial condition in the southern portion of the modeling domain and provide data to determine the presence of pollutant transport between the SoCAB and the San Diego Air Basin. The EOPACE aircraft will provide boundary and initial conditions in the western (over-water) region of the modeling domain and provide data on any offshore movement of pollutants from the SoCAB.

5.2.1 UCD Airborne Instrumentation (UCD Cessna 182, Gibbs Cessna 206)

Air quality instrumentation provided by Dr. John J. Carroll of the University of California at Davis (UCD) will be utilized in two aircraft, UCD Cessna 182 and Gibbs Flying Service Cessna 206. The instrumentation has been used in the UCD C-182 for several years. It is being duplicated and installed onboard the Gibbs Flying Service Cessna 206. The air quality instrumentation onboard this aircraft will be maintained and calibrated by the San Diego Air Pollution Control District (SDAPCD). An overview of the UCD instrumentation complete with data quality objectives, i.e., accuracy is given in Table 5-1.

The UCD aircraft will be used to investigate up to seven ozone episodes. During each episode of interest the aircraft will be based at the El Monte Airport (close vicinity to NOAA lidar) and will operate for three days. Each day, three flights consisting of up to four vertical spirals (460 to 3,050 m MSL) will be conducted. On selected days, a fourth flight consisting of two spirals will be made. The Gibbs Cessna will be based at Montgomery Field in San Diego. It will make two flight on IOP days consisting of up to five spirals.

System performance checks will be done daily and calibrations will be performed before and after each operational period. Each day's data will be screened as it is collected to check the performance of each component.

Table 5-1
UCD Instrumentation

Parameter Measured	Technique	Manufacturer	Time Response	Measurement Range	Accuracy
Pressure (Altitude)	Capacitive	Setra	1 s - 3 s	-30 m - 3700 m	± 0.3 mB ± 3 m
Temperature	Platinum RTD	Omega	1 s - 3 s	-20°C - 50°C	± 0.2°C
Relative Humidity	Capacitive	Qualimetrics	1 s - 3 s	10% - 98%	± 3%
Air Speed	Thermal Anemometer	T.S.I.	1 s - 3 s	15 m/s - 75 m/s	± 0.4 m/s
Heading	Electronic Compass	Precision Navigation	1 s - 3 s	0° - 359°	± 2°
Position	GPS	Garmin	10 s	Lat. - Long.	± 15 m
Particle Concentration	Optical Counter	Climet	10 s	2 channels: d > 0.3 µm & d > 3 µm	± 2%
NO, NO_2 Concentration	O_3 Titration Chemilumin.	Monitor Labs.	10 s - 15 s	0 ppmv - 20 ppmv	± 0.5 ppbv
Ozone Concentration	UV Absorption	Dasibi 1008	10 s - 15 s	0 ppbv - 999 ppbv	± 3 ppbv

5.2.2 STI Airborne Instrumentation (STI Piper Aztec)

Sonoma Technology, Inc. (STI) will use its instrumented twin-engine Piper Aztec aircraft for this study. The onboard instrumentation can measure continuously ozone, NO, NO_y, b_{scat}, position, temperature, dew point, turbulence, and one of SO_2, CO, or NO_y minus nitric acid and aerosol nitrate (NO_w). The NO/NO_y, NO_w, SO_2, and CO instruments are high-sensitivity instruments, capable of measuring background concentrations likely to be observed in the study area. An overview of the STI instrumentation complete with data quality objectives, i.e., accuracy is given in Table 5-2.

The STI aircraft will be based at Camarillo and about 38 flights (150 flight hours) will be conducted over 15 to 20 days during the study period. The aircraft will be available for two flights a day for up to four days in a row. On a few selected days three flights per day can be conducted.

Instrument calibrations will be performed before and after each flight day. This makes it possible to immediately identify and correct problems and to know which data are affected.

Some potential instrument problems are not identified by calibration. Therefore flight data will be reviewed in the field on a daily basis.

Table 5-2
STI Instrumentation

Parameter Measured	Technique	Manufacturer	Time Response	Measurement Range(s)	Accuracy[a] (Full Range)
NO/NO_y Concentration	Chemilumin.	Thermo Env. Model 42S	< 20 s	50 ppb, 100 ppb, 200 ppb	± 10%
Ozone Concentration	Chemilumin.	Monitor Labs. 8410E	12 s	200 ppb, 500 ppb	± 10%
b_{scat}	Integrating Nephelometer	MRI 1560 Series	1 s	100 Mm^{-1}, 1000 Mm^{-1}	± 10%
Dew Point	Cooled Mirror	Cambridge Systems 137-C	0.5 s/°C	-50°C - 50°C	± 10%
Altitude	Altitude Encoder	II-Morrow	1 s	0 m - 5000 m	± 10%
Altitude (backup)	Pressure Transducer	Validyne P24	< 1 s	0 m - 5000 m	± 10%
Temperature	Bead Thermistor/ Vortex Housing	YSI/MRI	5 s	-30°C - 50°C	± 10%
Temperature (backup)	Platinum Resistance	Rosemont 102 AV/AF	1 s	-50°C - 50°C	± 10%
Position	GPS	II-Morrow	< 1 s	Lat. - Long.	± 50 m
Data Logger (includes time)	Dual Floppy Acquisition	STI 486 System	1 s	± 9.99 VDC	± 10%
NO/NO_w[b]	Chemilumin.	Thermo Env. Model 42S	< 20 s	50 ppb, 100 ppb, 200 ppb	± 10%
SO_2[b]	Pulsed Fluorescence	Thermo Env. Model 43S	15 s	1 ppb, 5ppb, 50 ppb,200 ppb	± 10%
CO[b]	Gas Filter Correlation	Thermo Env. Model 48S	< 20 s	1 ppm, 2 ppm, 5 ppm, 10 ppm	± 10%

a For values between 10% and 90% of full scale

b Without modifying the aircraft for additional power, only one of these three instruments can be operated.

5.2.3 Navy EOPACE Airborne Instrumentation (Gibbs Piper Navajo)

The Navy EOPACE aircraft will be instumented with an UV absorption instrument (Dasibi) for the measurement of ozone concentrations, four canisters for hydrocarbon sampling, three tedlar bags for carbonyl sampling and ancillary instrumentation for the measurement of temperature, relative humidity, and position. Position will be determined with a GPS instrument and a pressure (altitude) monitor. Further details and data quality objectives are currently not available.

5.2.4 Ancillary Instrumentation

Ancillary airborne instrumentation includes navigational instruments measuring quantities such as position, altitude, heading, and time, and instruments which determine additional atmospheric properties such as temperature, humidity, and aerosol characteristics. Some of the instruments used to measure these quantities on SCOS97 air quality aircraft are briefly described in the following.

5.2.5 Navigational Instruments

Position of the airborne platform in space and time is extremely important for the use and intercomparison of all other measured quantities. The Global Positioning System (GPS), a satellite system operated by the U.S. Department of Defense (DOD) provides radio signals from which GPS receivers can calculate 3-dimensional position and time at several different accuracy levels.

Civilian users worldwide use the Standard Positioning System (SPS) without charge or restrictions. Most receivers are capable of receiving and using the SPS signal. The SPS accuracy is intentionally degraded by the DOD by the use of Selective Availability (SA). The SPS predictable accuracies are: 100 m horizontal accuracy, 156 m vertical accuracy, and 340 ns time accuracy. These GPS accuracy figures are from the 1994 Federal Radionavigation Plan. The figures are 95% accuracies, and express the value of two standard deviations of radial error from the actual antenna position to an ensemble of position estimates made under specified satellite elevation angle (five degrees) and Position Dilution of Precision PDOP (less than six) conditions. For horizontal accuracy figures 95% is the equivalent of 2drms (two-distance root-mean-squared), or twice the radial error standard deviation. For vertical and time errors 95% is the value of two-standard deviations of vertical error or time error. Receiver manufacturers may use other accuracy measures. Root-mean-square (RMS) error is the value of one standard deviation (68%) of the error in one, two or three dimensions. Circular Error Probable (CEP) is the value of the radius of a circle, centered at the actual position that contains 50% of the position estimates. Spherical Error Probable (SEP) is the spherical equivalent of CEP, that is the radius of a sphere, centered at the actual position, that contains 50% of the three dimension position estimates. As opposed to 2drms, drms, or RMS figures, CEP and SEP are not affected by large blunder errors making them an overly optimistic accuracy measure. Some receiver specification sheets list horizontal accuracy in RMS or CEP and without Selective Availability, making those receivers appear more accurate than those specified by more responsible vendors using more conservative error measures.

Authorized users with cryptographic equipment and keys and specially equipped receivers use the Precise Positioning System (PPS). U.S. and Allied military, certain U.S. Government agencies, and selected civilian users specifically approved by the U. S. Government, can use the PPS. The PPS predictable accuracies are: 22 m horizontal accuracy, 27.7 m vertical accuracy, and 100 ns time accuracy.

Differential GPS (DGPS) techniques improve the accuracy of GPS by correcting bias errors at one location with measured bias errors at a known position. A reference receiver, or base station, computes corrections for each satellite signal. Because individual pseudo-ranges must be corrected prior to the formation of a navigation solution, DGPS implementations require software in the reference receiver that can track all satellites in view and form individual pseudo-range corrections for each satellite. These corrections are passed to the remote, or rover receiver which must be capable of applying these individual pseudo-range corrections to each satellite used in the navigation solution. Applying a simple position correction from the reference receiver to the remote receiver has limited effect at useful ranges because both receivers would have to be using the same set of satellites in their navigation solutions and have identical Geometric Dilution of Precision (GDOP) terms (not possible at different locations) to be identically affected by bias errors. Differential corrections may be used in real-time or later, with post-processing techniques. Real-time corrections can be transmitted by radio link. The U. S. Coast Guard maintains a network of differential monitors and transmits DGPS corrections over radio beacons covering much of the U. S. coastline. DGPS corrections are often transmitted in a standard format specified by the Radio Technical Commission Marine (RTCM). Corrections can be recorded for post processing. Many public and private agencies record DGPS corrections for distribution by electronic means. Private DGPS services use leased FM sub-carrier broadcasts, satellite links, or private radio-beacons for real-time applications. To remove Selective Availability (and other bias errors), differential corrections should be computed at the reference station and applied at the remote receiver at an update rate that is less than the correlation time of SA. Suggested DGPS update rates are usually less than twenty seconds. DGPS removes common-mode errors, those errors common to both the reference and remote receivers (not multipath or receiver noise). Errors are more often common-mode when receivers are close together (less than 100 km). Differential position accuracies of 1-10 meters are possible with DGPS.

An extensive overview of the GPS system and further references have been given by Dr. Peter H. Dana of the University of Texas at Austin and can be found on his web site at *http://www.utexas.edu/depts/grg/gcraft/notes/gps/gps.html*.

The vertical accuracy of standard GPS (156 m for SPS) is marginal for lower tropospheric studies. Therefore, vertical position, i.e., altitude is often derived from pressure measurements. If the pressure-derived altitude measurement is corrected for atmospheric pressure changes before take-off and/or after landing an accuracy of ± 3 m can be obtained.

5.2.6 Temperature Measurement

Temperature can be measured via a diverse array of sensors. All of them infer temperature by sensing some change in a physical characteristic. Resistive temperature devices (RTDs and thermistors) are commonly used to measure air temperature in conjunction with a data acquisition system.

Resistive temperature devices capitalize on the fact that the electrical resistance of a material changes as its temperature changes. Two key types are the metallic devices (commonly referred to as RTDs), and thermistors. As their name indicates, RTDs rely on resistance change in a metal, with the resistance rising more or less linearly with temperature. Thermistors are based on resistance change in a ceramic semiconductor; the resistance drops nonlinearly with temperature rise.

A typical RTD consists of a fine platinum wire wrapped around a mandrel and covered with a protective coating. Usually, the mandrel and coating are glass or ceramic. The mean slope of the resistance versus temperature plot for the RTD is often referred to as the alpha value, alpha standing for the temperature coefficient. The slope of the curve for a given sensor depends somewhat on purity of the platinum in it. The most commonly used standard slope, pertaining to platinum of a particular purity and composition, has a value of 0.00385 (assuming that the resistance is measured in ohms and the temperature in degrees Celsius). A resistance versus temperature curve drawn with this slope is a so-called European curve, because RTDs of this composition were first used extensively on that continent. Complicating the picture, there is also another standard slope, pertaining to a slightly different platinum composition. Having a slightly higher alpha value of 0.00392, it follows what is known as the American curve. If the alpha value for a given RTD is not specified, it is usually 0.00385. However, it is prudent to make sure of this, especially if the temperatures to be measured are high.

The resistance-temperature relationship of a thermistor is negative and highly nonlinear. This poses a serious problem for engineers who must design their own circuitry. However, the difficulty can be eased by using thermistors in matched pairs, in such a way that the nonlinearities offset each other. Furthermore, vendors offer panel meters and controllers that compensate internally for thermistors' lack of linearity. Thermistors are usually designated in accordance with their resistance at 25°C. The most common of these ratings is 2252 Ω; among the others are 5,000 Ω and 10,000 Ω. If not specified to the contrary, most instruments will accept the 2252 Ω type of thermistor.

5.2.7 Humidity Measurement

The humidity of air can be expressed as absolute humidity (either dew point or water concentration) or relative humidity. These quantities can easily be converted from one to the other if the atmospheric temperature is known. Two common methods of measuring atmospheric humidity are described in the following.

The <u>dewpoint monitor</u> determines absolute humidity from a fundamental measurement and therefore does not depend on empirical calibration factors. This instrument cools a small mirror to the point at which moisture condenses on the mirror surface and optically detects the first sign of condensation. The mirror temperature is measured accurately, often with an RTD resulting in a measurement of the dewpoint which is directly related to the absolute humidity.

The capacitive humidity sensor measures relative humidity via the change in capacity of a thin film polymer capacitor. The thin polymer film either absorbs or exudes water vapor as the relative humidity of the ambient air rises or drops. The dielectric properties of the polymer film depend on the amount of water contained in it: as the relative humidity changes, the dielectric properties of the film change and so the capacitance of the sensor changes. The electronics of the instrument measure the capacitance of the sensor and converts it into a humidity reading.

5.3 Ozonesondes

The objective of the ozonesonde program is to collect, validate and report vertical profiles of oxidant concentration, temperature, and humidity four times per day at each of six monitoring locations on 15 intensive operating period days, and to characterize these data with respect to precision and accuracy. The primary data quality objective for this project is 100% valid data capture for the resulting 360 oxidant profiles. To be considered valid, the profiles must meet specified tolerances for place and time of collection, for vertical extent and resolution, and for precision and accuracy.

The general locations of ozonesonde launch sites and the rationale for their location are as follows:

- Van Nuys Airport: monitor ozone aloft in the San Fernando Valley that may contribute to transport through Thousand Oaks, Simi Valley, or Newhall.

- Downtown Los Angeles: monitor southern extent of recirculation from the San Gabriel Mountains or recirculation from the ocean.

- Anaheim: monitor transport into San Diego County, and monitor recirculation from the ocean.

- Upland/Ontario: monitor transport and recirculation between the coastal plain and the low desert.

- Riverside: monitor ozone aloft in the low desert that may contribute to transport through the Banning Pass.

- North County/Escondido: monitor overland transport from SoCAB into San Diego County.

CE-CERT has established tentative data quality indicators (DQI) and goals for the ozonesonde instrumentation. Data quality indicators and goals for ozonesondes and the associated meteorological instruments are summarized in Tables 5-3 and 5-4, respectively.

The accuracy of the ozonesondes is mainly limited by the large interference bias of -10 ppb to +50 ppb. If the concentration range of interferents can be estimated it may be possible to reduce the interference bias.

Table 5-3: CE-CERT Ozonesonde, Data Quality Indicators and Goals

DQI	Goal
Precision	1-sigma < larger of 5 ppb or 10%
Calibration Bias	1-sigma < larger of 5 ppb or 10%
Interference Bias	-10 to + 50 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 hours from planned time
Location of Launch	+/- 100 meters from planned location
Duration of Flight	>3000 meters AGL

Table 5-4: CE-CERT Meteorological Instruments, Data Quality Indicators and Goals

Measurement	DQI	Goal
Temperature	Precision	± 1 °C
Temperature	Calibration Bias	± 3 °C
Temperature	Response Time	> 63% response in 20 s
Pressure	Precision	± 2 mb
Pressure	Calibration Bias	± 5 mb
Pressure	Response Time	> 63% response in 2 s
Relative Humidity	Precision	± 5% RH
Relative Humidity	Calibration Bias	± 10% RH
Relative Humidity	Response Time	> 63% response in 2 min

5.4 System Audits

5.4.1 Some Aspects of Ozone Lidar System Audits

Both accuracy and precision of ozone DIAL measurements are multi-dimensional functions of the specific DIAL system used, the measurement distance, spatial and temporal resolution of the ozone measurement, and of atmospheric conditions such as ozone and aerosol concentration, properties, and distribution. It is the task of the DIAL contractor to determine a useful approximation to this function. This information can then be used, prior to field operations, to decide on some of the standard operating and data analysis procedures. As these procedures are dependent on the desired accuracy, precision, and spatial and temporal resolution, they should not be determined by the DIAL contractor alone. Instead they ought to be the result of discussions between data users, DIAL contractor, and QA team.

The accuracy of ozone DIAL measurements is limited by both statistical and systematic errors. Statistical errors can be reduced by averaging, thereby improving precision and potentially also accuracy. However, as standard samples cannot be used, it is not trivial to distinguish between statistical errors and atmospheric fluctuations. Systematic errors are due to both the system itself and due to atmospheric conditions. Both types of error sources are discussed in the following sections.

The consideration of all error sources together with the accuracy, precision, spatial and temporal resolution goals for SCOS97 should result in standard operating procedures for the operation of the DIAL system during SCOS97 and for the subsequent data analysis. While the main data analysis will undoubtedly take place after the end of the SCOS97 measurement program, it is important that some data analysis takes place either in real time or at least on a daily basis. This will allow some direct intercomparison and performance testing to uncover possible DIAL system malfunction.

Systematic Errors due to DIAL Hardware

The lidar return signal, as described by the lidar equation, drops off dramatically with increasing range r. This drop off is due to three factors:

1. The $1/r^2$ drop off is due to the decreasing solid angle of the telescope aperture as seen from the backscattering location r, i.e., the fraction of the backscattered light collected by the telescope decreases as $1/r^2$.

2. The exponential signal drop off as a function of r is due to atmospheric extinction, i.e., both scattering and absorption. This drop off is especially serious for high aerosol loading and, below a wavelength of 300 nm, for high ozone concentrations.

3. For an upward pointing lidar system the backscatter coefficient $\beta(r)$ generally decreases with altitude due to both smaller aerosol and air density.

The rapid signal drop off with range results in a large dynamic range of the measured lidar signals, especially if measurements close to the system are of importance. This is usually the case for air pollution studies such as SCOS97. The large dynamic signal range can result in a number of hardware related systematic errors such as

- Quantization errors result from the limited range of Analog-to-Digital (A/D) Converters used to digitize the signal from the light detector (photomultiplier). State of the art A/D converters which are fast enough to yield a spatial resolution on the order of 10 m (i.e. 67 ns) commonly have a resolution of 12 bit, they are able to cover a dynamic range of $2^{12} = 4096$. To fully exploit this dynamic range, the photomultiplier high voltage and the analog system gain have to be set appropriately to ensure that the maximum signal closely corresponds to the maximum input of the A/D converter. In addition, A/D converter nonlinearities may also be present (Langford, 1995).

- Photomultiplier tube (PMT) linearity should be comparable to, or preferable less than the quantization error of the A/D converter. For a 12 bit system, variations in both signal gain and signal linearity should be better than about 0.1%, a non trivial objective (Lee et al., 1990; Bristow et al., 1995).

- In the ultraviolet spectral region fluorescence from optical components can also cause errors near the far end of the DIAL range (Kempfer et al., 1994).

To reduce the dynamic range of the DIAL signals a number of methods have been tried. Examples are multibeam transmitters (Zhao et al., 1992), multiple telescopes and PMTs (e.g., Kempfer et al., 1994), PMT gain switching (Kempfer et al., 1994), PMT r^2-gain modulation (Bundy, 1992), logarithmic amplifiers (e.g., Optech Systems Corporation), etc. Of cause the linearity of these dynamic range reduction techniques also has to be high enough, which is not always the case.

Other potential error sources include the suppression or subtraction of background light in the near UV, optical crosstalk between different receiver channels, and electronic interference by the laser itself. These error sources are some of the more common problems. Each potential error source has to be eliminated or carefully characterized in its influence on the final measurement accuracy and precision under a range of operating conditions.

<u>Systematic Errors due to Aerosol Extinction and Backscattering</u>

In the planetary boundary layer, aerosol scattering can not be neglected and strong aerosol gradients occur frequently. Therefore both the extinction and backscattering corrections in the DIAL equation have to be evaluated for aerosol. It has been shown (Browell et al., 1985) that the extinction correction is on the order of only a few ppb. In regions of spatially inhomogeneous aerosol, the main correction term comes from the backscattering correction. This term can be calculated by retrieving the aerosol distribution from the off-line lidar signal and assuming an Ångström coefficient (Ångström, 1929; Völger et al., 1996) to describe the wavelength dependence of the aerosol backscatter coefficient. It should be noted that the retrieval of the aerosol distribution depends on assumptions of a boundary value at some calibration height towards the far range of the system and of the scattering phase function. The calculation of both extinction and backscattering corrections has been described in detail in a number of publications (e.g., Pelon and Mégie, 1982; Browell et al., 1985; Milton, 1987;

Papayannis et al., 1990; Kovalev and McElroy, 1994; Völger et al., 1996). In conclusion, the calculation of the aerosol corrections in the DIAL equation has potential for sizable errors. The output of the DIAL data processing should therefore include both uncorrected and corrected ozone concentration profiles and in addition the retrieved aerosol profile.

Systematic Errors due to DIAL Algorithms and Software

While the DIAL equation itself is an unequivocal mathematical expression, it describes the measured quantities as continuos functions. In reality however, only a limited number of data points are available. To device DIAL algorithms from the DIAL equation it has to be decided how to process (i.e., average, take derivatives, etc.) these discrete data points. For example the seemingly trivial issue of averaging data from multiple laser pulses is in reality quite complex (Milton and Woods, 1987). These difficulties have been expressed previously (Kempfer et al., 1994): "Perhaps the most difficult task of the lidar (referring to ozone DIAL) development has been to prepare the computer program for the data evaluation." The resulting software tends to be complex and it is advisable to subject it to separate performance testing. This can be done by writing a program which calculates DIAL signals for a variety of model atmospheres. These "fake" signals can then be used as test input to the data analysis program.

The complete, well documented data analysis software and some results of its performance testing should become a part of the system documentation. Version upgrades should implement and document software changes and any processed data must include the version number of the processing software.

Statistical Errors

Statistical errors result from random fluctuations in the measurement both due hardware induced noise such as electronic noise and quantization noise, and the more basic shot noise resulting from quantum statistics of detected photons and of photoelectrons emitted by the photocathode in the PMT. These errors can be reduced by both spatial (in beam direction) and temporal (over many laser pulses) averaging resulting in increased measurement precision at a given distance and in increased useful measurement range at a given precision. However, averaging also suppresses potentially interesting fine structure of the atmospheric ozone concentration, both in space and time. These trade-offs should be evaluated in conjunction with the desired data accuracy and desired spatial and temporal resolution as a function of measurement distance (e.g., height above ground) and atmospheric conditions. If the DIAL system is not pointed in a fixed direction, but operated in scanning mode, the scanning pattern becomes an additional variable. It is important that this part of the standard operating and analysis procedures is determined in discussion between DIAL contractor and DIAL data users, prior to field operations. In the past, these decisions have frequently been left to the DIAL contractor. Therefore, the resulting DIAL ozone data have not been optimized for their intended use.

5.4.2 Ozone Lidar System Audits

A first system audit should take place well before the start of the SCOS97 field measurement program to leave sufficient time to correct possible deficiencies of the system and its operational and quality control procedures. This audit should include a review of system design, operation, data analysis procedures including quality control procedures, and if possible, results of a previous performance audit. If major problems are discovered, a second audit should confirm the correction of these problems before measurements commence. A final system audit should be planned during a DIAL data acquisition period in SCOS97 to ensure the proper operation according to the standard operating procedures. At this point the QA team should already be intimately familiar with the DIAL system, its operation, and its data analysis procedures.

In reality, ozone lidar systems are prototypes, generally operated by the scientists which designed and built the system. Standard operating procedures often do not exist and may be less important as the operators are intimately familiar with their system. Effective ozone lidar system audits, as discussed above, are quite involved requiring extensive lidar expertise and time commitment. At this point (March 1997) it seems rather unlikely that an ozone lidar system audit will take place for SCOS97.

5.4.3 Aircraft Based *in Situ* Instrumentation

The systems audit of the aircraft will be done at the level of the Comprehensive Site Survey as described in Section 4.6 by personnel from the Quality Assurance (QAS) of ARB at the time the performance audits are done. The sampling procedures will be reviewed including operating procedures, calibration equipment and standards, and instrumentation. An additional review of the sampling and measurement systems will be made during the period of the aircraft intercomparisons to ensure that ambient air samples are collected and measured without bias.

5.4.4 Ozonesondes

The systems audit of the CE-CERT ozonesonde will review available test reports and standard operating procedures (SOP). This will include documentation on the ozone transfer standard used to calibrate and test the sondes and its traceability, the testing procedures, and the routine operating procedures. The release site locations will be confirmed. At least two sites will be visited and the operations observed to see if standard procedures are being followed.

5.5 Performance Audits

5.5.1 Ground Based Performance Audits

Performance audits of instruments installed on the aircraft will be conducted by personnel from Quality Assurance (QAS) of the ARB. Each measurement method will be audited on the project. The CE-CERT ozonesonde will also be audited.

As with the surface monitoring stations, performance audits are quantitative assessments of instrument operation that are accomplished by challenging site instruments with known audit standards. The procedures described in Section 4.7 for instruments at the surface sites will be followed for the aircraft equipment in as far as they are applicable. Some modifications may have to be made. The delivery of the audit gases may have to be changed to match the instrument sample inlets. The higher ranges of audit concentrations likely exceed the operating range of the aircraft instruments. At the low concentration end, the lowest audit concentrations should be as low as possible.

Ozone concentrations will be introduced to representative number of the ozonesondes. At least 3 sondes should be used. The procedures for introducing gas to the surface analyzers will be followed although the range of points may differ some. The audit concentrations will be compared to the telemetered data.

Meteorological instrumentation on the aircraft will also be audited. The audit criteria will have to be relaxed for those instruments that require air flow past them at speeds attained by the aircraft. The measurements of temperature and relative humidity are particularly affected by the moving and static air streams. For instruments that depend on orientation during flight, such as a solar radiation sensor, the audit sensor will have to positioned in approximately the same orientation as the aircraft sensor which may not be horizontal when the aircraft is on the ground.

All audit results will be entered on QA Audit Station Data Worksheet forms and into an audit computer. Calculations are done by the computer and by hand for verification. Preliminary results will be summarized in reports for each measurement issued to the site operator at the conclusion of the audit. For gas analyzers, the reports will present the audit concentrations, the instrument responses, and the percent differences. Instrument performance will be assessed by comparing the percent differences to EPA criteria as shown in Table 4-5. For meteorological equipment, the reports will present the expected instrument responses, the actual instrument responses, and their differences. Instrument performance will be assessed by comparing the differences to the EPA criteria as shown in Table 4-5, although possible modified as indicated above. For those instruments that exceed the criteria, the auditor will issue an Air Quality Data Action (AQDA). The site operator will be required to respond to the AQDA by detailing the actions done to correct instrumental problems found during the audit.

5.5.2 Ozone Lidar Performance Audits

A minimum of two performance audits should take place, one well before the start of the SCOS97 field measurement program. For established ozone DIAL systems like the ground based NOAA system it is likely that a previous performance audit can be used for this purpose. The second performance audit should take place during or just before the SCOS97 field program when additional intercomparison measurements are available. In addition, this audit will be more realistic taking place under atmospheric conditions comparable to those during the intensive operating periods. The actual performance audit will take the form of an intercomparison study as discussed in the following.

It is virtually impossible to test an ozone DIAL system with a standard sample under realistic, atmospheric conditions. While samples contained in a chamber have been used to calibrate some DIAL systems (e.g., Grant et al., 1974), aerosol concentrations, gradients, and size distributions, which have an important influence on ozone DIAL measurements, are much harder to control on the needed scale. Therefore, the best solution is an intercomparison study, which characterizes the DIAL measurement volume with a NIST traceable, in *situ* instrument under a variety of realistic atmospheric conditions. Previous intercomparison studies between tropospheric, ground based ozone DIALs and *in situ* instruments include

- Ground based testing of the U.S. EPA (now NOAA ETL) airborne ozone DIAL including near horizontal pointing intercomparison with surface measurements by an ultraviolet analyzer (Moosmüller et al., 1992).

- A joint experiment (TROLIX '91), where four ozone DIAL systems from RIVM Bilthoven, MPI Hamburg, SA/CNRS Paris, and LTH Lund were compared against each other, and to ECC-sondes and ultraviolet analyzer carried by a helicopter. In addition, horizontally pointing intercomparisons were performed for two of the lidars, surface measurement by ultraviolet analyzers, and a dual-path DOAS system (Bösenberg et al., 1993).

- An intercomparison experiment between the NOAA ETL ground based ozone DIAL and an airplane based ultraviolet analyzer (Zhao et al., 1994).

- Two dedicated intercomparison campaigns between lidar, electrochemical sondes, and airborne ultraviolet analyzer in the upper troposphere and stratosphere (Beekmann et al., 1994).

- Intercomparisons between the Fraunhofer Institute ozone DIAL and nearby mountain stations, ECC-sondes, and instrumented aircraft (Kempfer et al., 1994).

- An intercomparison experiment between the MPI Hamburg ozone DIAL and ECC-sondes attached to both tethered and free flying balloons (Grabbe et al., 1996).

- The Table Mountain vertical ozone transport and intercomparison experiment. An intercomparison between NOAA ETL ground based and airborne (in ground based operation) ozone lidars. Additional intercomparison with an ground based ultraviolet analyzer for near horizontal paths (Alvarez II, 1996).

It should be kept in mind that the value of horizontal intercomparisons is limited, because aerosol interference is generally negligible for horizontal lidar measurements. For intercomparisons with vertical, or near vertical pointing ozone DIALs in the boundary layer, the natural variability of the ozone concentration in space and time is generally the limiting factor for the assessment of accuracy. This is due to the difficulty in probing the DIAL measurement volume with similar sampling properties in both space and time. In particular, DIAL systems integrate their measurements over an approximately cylindrical sample volume, while *in situ* instruments sample only at one inlet location. In addition, it is difficult to position *in situ* instruments in or near the DIAL measurement volume. Previous intercomparison studies have used free flying and tethered balloons, helicopters, airplanes, and adjacent mountain stations for this purpose. One intercomparison strategy puts special emphasis on the intercomparison of time averages and variances at one or several fixed altitudes (Grabbe et al., 1996). Due to the influence of wind, not only temporal but also spatial averaging is achieved. This strategy is limited to the use of constant altitude platforms for the *in situ* instrument, such as tethered balloons, helicopters, towers, or airplanes. Restricting intercomparisons to relatively homogeneous atmospheric conditions can result in artificially good results as some systematic errors for both DIAL and *in situ* measurements occur only in the presence of strong atmospheric gradients.

A very simple, but practical piece of advice is to compare ozone concentrations in the dimension of number or mass densities. This corresponds to units of m^{-3} or $\mu g/m^3$. For all instruments these are the quantities which are directly measured. At a later point, ozone concentrations may be converted to the more commonly used mixing ratios (i.e., ppb). This conversion involves the additional knowledge of atmospheric density or of temperature and pressure at the measurement location. While trivial, this conversion introduces additional errors from pressure and temperature measurements (or models) which, in practice, can be sizable (e.g., Hilsenrath et al., 1986).

5.5.3 Aloft Performance Audits

Aloft performance audits for aircraft and balloon based instrumentation complement ground based performance audits. They take place in the same setting as the actual measurements and are able to identify some problems which are not noticed in ground based audits, such as problems related to air speed, altitude, and vibrations. For ozone lidar systems, aloft performance audits constitute the only meaningful kind of performance audit, making them a necessity.

The aloft performance audits for SCOS97 are not true performance audits as no primary standard is being used but take the form of intercomparison studies. The ideal lidar location for such a study is adjacent to an air quality monitoring station for ground based intercomparison, close to an ozonesonde launch site, and close to an airport, so that airborne *in situ* ozone measurements can be extended to ground level.

As part of SCOS97, the Desert Research Institute (DRI) is organizing an aloft performance audit, prior to the main study. This performance audit will be conducted in the vicinity of El Monte Airport (EMA) with the airport serving as base. Aloft intercomparisons between the NOAA ozone lidar (located at EMA), CE-CERT ozonesondes and several instrumented aircraft (UCD, STI, Gibbs Cessna, and NAVY EOPACE) will be included in this audit. In addition, the availability of upper air meteorological data is important to improve the comparison between different sample volumes. Data from the RWP/RASS system located at EMA will be utilized for this purpose.

Three flight patterns for the participating aircraft will be utilized for this performance audit:

- Spiral flight patterns (Figure 5-1) will be used for the intercomparison between aircraft themselves, and between aircraft, ozone lidar, and ozonesondes. This is the most generally useful flight pattern for intercomparison.
- Spiral flight patterns interspersed with orbits (Figure 5-2) will be used for the intercomparison between a single aircraft and the ozone lidar. The additional orbits make it possible to distinguish between horizontal and vertical gradients encountered by an aircraft flying a spiral pattern.
- Traverses will be used for additional intercomparison between the different instrumented aircraft.

The aloft performance audit will take place prior to the main study during the week of June 9, 1997. Conducting the audit before the main study will make it possible to identify, address, and possibly correct potential performance problems prior to commencement of the main study period.

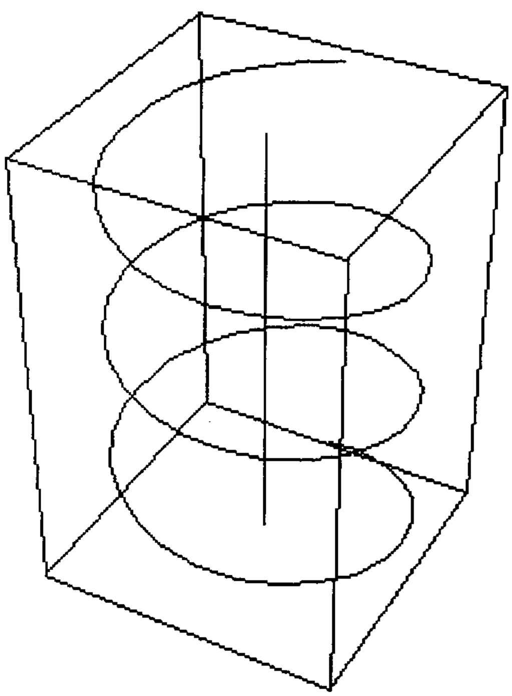

Figure 5-1: Spiral flight pattern, centered on laser beam

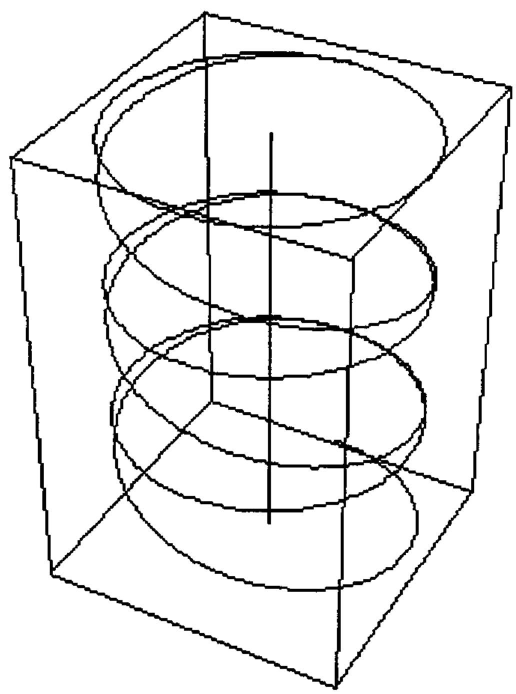

Figure 5-2: Spiral flight pattern interspersed with constant altitude orbits

The NOAA lidar is scheduled to be on-line by June 9, 1997 and it is planned to have all participating aircraft stationed at EMA during this week. The actual intercomparison day will be selected according to recommendations from the forecast team, which will be asked to begin forecasts at least a week before commencement of the main study period. If possible, a high pollution day will be chosen for the intercomparisons. Atmospheric conditions on high pollution days are more likely to resemble those during intensive study periods, making the intercomparison more relevant to the measurements during the main study. This is especially significant for ozone lidar and ozonesondes, which can suffer from aerosol and oxidant interferences, respectively.

Spatial and Temporal Resolutions

The aircraft used for upper-air air quality measurements travel with a horizontal speed of about 50 m/s and make ascents or descents with a vertical speed of about 150 m/min. Gas analyzers used aboard of these aircraft have a time resolution of about 15 s. This corresponds to a horizontal resolution of about 750 m and a vertical resolution of about 40 m. Spirals and orbits will be near circular projected on a horizontal plane and have a diameter of about 2 km. This corresponds to a circumference of about 6 km, which takes about 2 min per revolution.

The NOAA ozone lidar operates with a range resolution of about 50 m. This corresponds to a vertical resolution of about 50 m $\times$ cos θ, where θ is the angle between the vertical and the pointing direction of the lidar system. Therefore the vertical resolution for zenith looking operation is about 50 m.

The ozone analyzer aboard the CE-CERT ozonesondes has a time resolution of about 1 min. Combined with a typical ascent rate of 180 m/min this results in a vertical resolution of about 180 m, less than either lidar or aircraft profiles. The ozonesonde ascent rate is nearly identical to aircraft ascent rates.

Spiral Flight Patterns for Intercomparison between Aircraft, Ozone Lidar, and Ozonesondes

Spiral flight patterns will be used for the intercomparison between aircraft themselves, and between aircraft, ozone lidar, and ozonesondes. This is the most generally useful flight pattern for intercomparison. An idealized example is shown in Fig. 5-1. Here the airplane spirals around the zenith pointing laser beam of the ground based ozone lidar system. Airplane flight patterns are designed taking the temporal resolution of the *in situ* instruments as well as the temporal and spatial resolution of the DIAL system into account.

Specifically, circular spirals with 2 km diameter, centered on the ozone lidar location will be flown. Most spirals will extend from ground level (takeoff or landing) to about 3000 m AGL. At an ascent/descent rate of 150 m/min flying one spiral will take about 20 min. Individual aircraft will be spaced 2 min in time, corresponding to 300 m in altitude. This spacing takes the need for both flight safety and near simultaneous measurements into account.

Spiral flight patterns will be flown with the ozone lidar zenith pointing and with the ozone lidar scanning in a one-dimensional plane. The scanning data will verify lidar performance in this mode of operation and yield data about horizontal atmospheric gradients.

Two ozonesonde releases will be conducted during the spiral intercomparison with the ozone lidar in zenith pointing mode for one release and in scanning mode for the other. Ideally, the ozone lidar would be scanning in a plane parallel to the wind direction. This plane would include the ascent path of the ozonesonde for comparison with the ozonesonde data. In practice, the lidar scanning plane cannot be change readily and such an agreement would be coincidental. However, the high temporal resolution of the lidar in connection with wind profiler data could possibly be used to estimate lidar measured ozone concentrations in the ascent path of the ozonesonde.

To transform the *in situ* airplane data into a vertical profile, one assumes horizontal homogeneity over the spiral area. This assumption is frequently not justified, for example inhomogeneous conditions were observed for some spirals during the COAST study (Moosmüller, 1994). An example of the difficulties in comparing *in situ* spiral data with DIAL data has been discussed for the Davis, CA intercomparison experiment in 1993 (Zhao et al., 1994). To evaluate and eliminate these potential problems spiral flight patterns interspersed with orbits have been added to the performance audit and are discussed in the following section.

<u>Spiral Flight Patterns Interspersed with Orbits for Intercomparison between Aircraft and Ozone Lidar</u>

A modified spiral pattern is shown in Fig. 5-2. Here the airplane flies a spiral around the laser beam, interspersed with orbits at multiple altitudes. These orbits give a check on the assumption of horizontal homogeneity over the spiral area. Each orbit will be flown over a duration longer than the time resolution of the ozone DIAL system. In this fashion horizontal inhomogeneities can be averaged out. Circles flown over substantial longer times allow not only comparisons of time averaged data, but also comparison of time evolution and variances. This type of flight pattern allows not only for better quality assurance of the *in situ* vertical profiles but also for extended comparison at several altitudes. Details of the actual flight take into account DIAL and *in situ* spatial and temporal resolutions, airplane capabilities, and of course FAA regulation.

Specifically, the following orbits will be integrated into a spiral: three orbits at 300 m AGL, three orbits at 600 m AGL, three orbits at 1200 m AGL, and three orbits at 2400 m AGL. Each of these spiral-orbit ascents or descents will take about 45 min; 20 min for ascend or descend over 3000 m and 24 min for a total of twelve orbits at 2 min each. The maximum height AGL agrees with the approximate maximum range of the ozone lidar.

Some spiral-orbit flight patterns will be flown with the ozone lidar zenith pointing and some with the ozone lidar scanning in a one-dimensional plane. The scanning data will verify lidar performance in this mode of operation and yield additional data about horizontal atmospheric gradients.

<u>Traverse Flight Patterns for Intercomparison between Aircraft</u>

Traverses will provide additional intercomparison between the different instrumented aircraft. Traverses will include constant altitude sections, ascents, and descents. Traverses will be flown in the lidar scanning plane with the individual aircraft flying side-by-side at safe distances from each other.

Strawman Measurement Program for Aloft Intercomparison

This measurement schedule consists of one flight for aloft intercomparison between all four aircraft, ozonesondes (two releases) and the NOAA ozone lidar in both zenith pointing and scanning operation. This flight will take place in the morning hours when it is likely that stronger gradients in pollutant concentration and other atmospheric parameters exist and the wind speed is expected to be lower. Strong atmospheric gradients yield a more meaningful intercomparison incorporating a variety of conditions. Low wind speeds result in a more vertical ascent path for the ozonesondes, resulting in better spatial overlap with lidar and aircraft measurements. The flight plan consists of two spirals (one up and one down, between ground level and 3000 m AGL), one ascending traverse (from 500 m AGL to 3000 m AGL), one descending traverse (from 3000 m AGL to 500 m AGL) and two level traverses (at 500 m AGL and at 3000 m AGL). Ozonesondes will be released during both the ascending and the descending spiral. The ozone lidar will be operated in zenith pointing mode during the ascending spiral and in scanning mode thereafter. A sketch of the flight plan is shown in Figure 5-3 and an idealized schedule is given in the following. All altitudes refer to AGL at El Monte Airport.

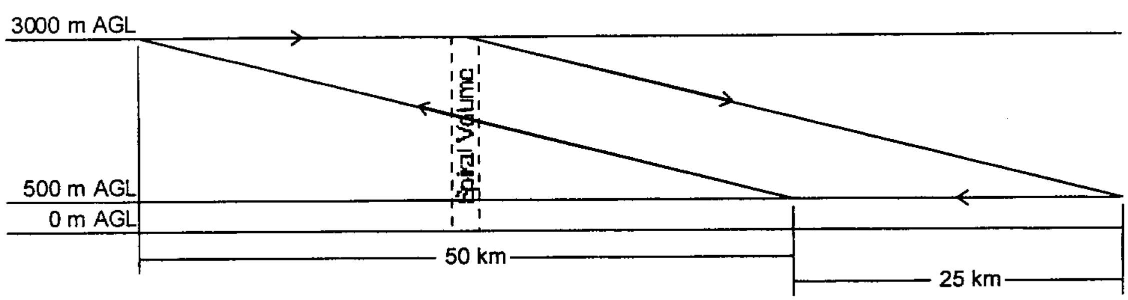

Figure 5-3. Flight plan for airplane intercomparison.

Intercomparison schedule for four aircraft, two ozonesondes, and the NOAA ozone lidar

06:30 PDT	Ozone lidar starts operating in zenith pointing mode
07:00 PDT	First airplane takes off and starts spiral
07:02 PDT	Second airplane takes off and starts spiral
07:04 PDT	Third airplane takes off and starts spiral
07:04 PDT	Ozonesonde release at El Monte
07:06 PDT	Fourth airplane takes off and starts spiral
07:20 PDT	First airplane arrives at 3000 m AGL at top of spiral
07:22 PDT	Second airplane arrives at 3000 m AGL at top of spiral
07:24 PDT	Third airplane arrives at 3000 m AGL at top of spiral
07:26 PDT	Fourth airplane arrives at 3000 m AGL at top of spiral

07:27 PDT	All airplanes start descending traverse to 500 m AGL
07:44 PDT	At 500 m AGL all airplanes start level traverse
07:45 PDT	Ozone lidar switches to scanning mode
07:52 PDT	All airplanes start ascending traverse from 500 m AGL to 3000 m AGL
08:09 PDT	At 3000 m AGL above El Monte, first airplane starts descending spiral
08:11 PDT	At 3000 m AGL above El Monte, second airplane starts descending spiral
08:13 PDT	At 3000 m AGL above El Monte, third airplane starts descending spiral
08:15 PDT	At 3000 m AGL above El Monte, fourth airplane starts descending spiral
08:23 PDT	Ozonesonde release at El Monte
08:29 PDT	First airplane lands
08:31 PDT	Second airplane lands
08:33 PDT	Third airplane lands
08:35 PDT	Fourth airplane lands
09:05 PDT	Ozone lidar stops operating

The next two flights on the same day will intercompare the measurements from one instumented aircraft (UCD Cessna 182) with those from the NOAA ozone lidar. Each flight will incorporate two spirals and two spiral-orbits taking a total of 2 hours and 10 minutes. During one flight the lidar will be operated in scanning mode, during the other in zenith pointing mode. Idealized schedules are given in the following.

Intercomparison schedule for UCD aircraft and the NOAA ozone lidar in scanning mode

10:05 PDT	Ozone lidar starts operating in scanning mode
10:35 PDT	UCD airplane takes off and starts spiral
10:55 PDT	UCD airplane arrives at 3000 m AGL at top of spiral
10:55 PDT	UCD airplane starts descending spiral-orbit with three orbits each at 2400 m, 1200 m, 600 m and 300 m
11:40 PDT	UCD airplane arrives at or near ground level
11:40 PDT	UCD airplane starts ascending spiral-orbit with three orbits each at 300 m, 600 m, 1200 m and 2400 m
12:25 PDT	UCD airplane arrives at 3000 m AGL at top of spiral-orbit
12:25 PDT	UCD airplane starts descending spiral
12:45 PDT	UCD airplane lands

13:15 PDT Ozone lidar stops operating

Intercomparison schedule for UCD aircraft and the NOAA ozone lidar in zenith pointing mode

14:15 PDT	Ozone lidar starts operating in zenith pointing mode
14:45 PDT	UCD airplane takes off and starts spiral
15:05 PDT	UCD airplane arrives at 3000 m AGL at top of spiral
15:05 PDT	UCD airplane starts descending spiral-orbit with three orbits each at 2400 m, 1200 m, 600 m and 300 m
15:50 PDT	UCD airplane arrives at or near ground level
15:50 PDT	UCD airplane starts ascending spiral-orbit with three orbits each at 300 m, 600 m, 1200 m and 2400 m
16:35 PDT	UCD airplane arrives at 3000 m AGL at top of spiral-orbit
16:35 PDT	UCD airplane starts descending spiral
16:55 PDT	UCD airplane lands
17:25 PDT	Ozone lidar stops operating