6. UPPER-AIR METEOROLOGY MEASUREMENTS

A key component of SCOS97 is the collection and validation of upper air meteorological data. The upper air data is intended to allow for the generation of gridded 3-dimensional wind and temperature fields sufficient for use to understand complex source-receptor relationships in southern California. Several sites are planned to have monitoring by more than one type of instrument (e.g., radar wind profiler and rawinsonde); this allows for daily comparisons of collocated measurements as well as help in data validation after the field study concludes.

This quality assurance plan is based principally upon guidelines from the report "Draft Guidelines for the Quality Assurance and Management of PAMS Upper-Air Meteorological Data (STI, 1995). Quality assurance for upper air monitoring has the following components: 1) siting and installation (includes testing); 2) periodic review of data (frequent inspection of collected data and evaluation of it's reasonableness); 3) system audits and performance audits; 4) a plan for quickly correcting problems; 5) data acquisition and processing; and 6) data validation and archival.

Aerovironment Environmental Services, Inc. (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). AVES will also review candidate monitoring sites and do system and performance audits of the upper-air meteorological network. AVES presented preliminary quality assurance methodologies in their proposal (AVES, 1996); these proposed methods are consistent with procedures listed in this QA plan and the PAMS upper-air guidelines. Final procedures shall be approved by the SCOS97 upper-air quality assurance manager.

NOAA's Environmental Technology Laboratory (ETL) will be the data manager for the upper-air meteorology data. ETL will be responsible for data acquisition and processing, periodic review of data, and data validation and archival. The procedures are given in the ETL proposal (NOAA/ETL, 1996).

6.1 Sampling Site Selection Criteria

The general locations of upper-air meteorological monitoring sites (Table 1-3) have been selected by the Meteorology Working Group. Detailed criteria for precisely locating sites are given in this section.

Site needs include:

- A flat location, clear of obstacles, and with good drainage
- Sufficient electrical power
- An environmentally controlled instrument shelter

- A fence around the equipment and shelter, or other sufficient security measures

- A remote communications link

Sodar and RWP/RASS sites have additional needs:

- Locate sodars and RASS away from areas that would result in annoyances due to the sound waves emitted from these instruments. Thus, before locating instruments, evaluate the expected effects (intensity, exposed population, time of day) of the instruments upon sensitive receptors.

- Avoid noise sources (roads, industrial processes, air conditioners, etc.) that may interfere with sodars and RASS. Provide sufficient acoustic shielding to minimize the effects of noise. Measure noise levels at the potential site during the expected highest noise period of the day, if possible. Noise levels should be below 60 dBA; below 50 dBA is preferable.

- Building, trees, power lines, etc. may reflect sodar and radar pulses and contaminates the data. Sites should be chosen that minimize obstructions taller than 15 degrees above the horizon. If objects extend above 15 degrees elevation, the beams should be located away from these objects.

At Rawinsonde sites:

- The vicinity of the site should be free of trees, tall buildings, power lines, and other objects that may snag the balloon or instrument package or interfere with tracking the sonde.

- If a Loran system is used, sufficient signal coverage should be established before establishing the site.

6.2 Installation

- Sodar, RWP, and radio theodolite system antennas should be aligned to true north using the solar siting technique (USEPA, 1989).

- Determine the latitude, longitude, and elevation of the site using detailed maps or a Global Positioning System (GPS) instrument.

- Site documentation: Take photographs in each of four cardinal directions, and of all shelter, instruments, and other equipment. Videotape the site, including a 360 degree view of the surrounding area. Produce a detailed site layout plan documenting location of the instruments, shelter, and other equipment. Produce a diagram that describes all objects and topographic features around the site in 30 to 45 degree increments. Include potential sources of clutter and noise sources, and distance to and elevation angle of objects.

- After installation, perform acceptance testing of the instrument following the manufacturer's procedures.

- When system becomes operational, check data for reasonableness. This is best done using collocated meteorological data from surface or upper air meteorological data. If collocated data is not available, nearby upper air data and the judgement of a person familiar with expected conditions at the site can be used.

6.3 Monitoring Site Locations

Proposed upper-air monitoring site locations were listed in Table 1-3. Locating precise locations is in process. Some modifications may be made to the site listing due to the potential inability to find suitable sites in the desired areas.

6.4 Sampling Procedures

6.4.1 Sodars

The optimum type of sodar and sampling procedure depends upon the intended use of the data. If high vertical resolution is needed over a relatively shallow layer, high frequency mini-sodars are appropriate. Mini-sodars give vertical resolution on the order of 5-20 m up to about 300 m or less AGL. If a greater depth is needed, with less resolution required, standard sodars with vertical resolution of 20-50 m and coverage typically to about 1000 m, are appropriate. For sodars collocated with radar wind profilers, a lower maximum height with greater vertical resolution may be appropriate because coverage above the sodar range is given by the RWP. For sodars located without collocated RWP, higher vertical range is usually needed. For SCOS97, the flows of interest should be sufficiently resolved by using standard sodars. For sites collocated with radar wind profilers it may be desired to operate the sodars to maximize vertical resolution.

6.4.2 Radar Wind Profilers/RASS

RWP/RASS are typically operated in the RASS mode for the first 5-10 minutes of the hour, then in the RWP mode for the remaining 50-55 minutes. At the end of each hour, hourly consensus wind and temperature profiles are computed, although they are not true hourly averages. The data can then be reviewed on a near real-time basis for forecasting purposes and quality assurance. For more reliable wind and temperature data, and a closer representation of a true hourly average, continuous, interleaved sampling of wind and RASS derived temperature may be done. In this mode, the oblique beams are sampled for 20-30 seconds, then the vertical beam with RASS is sampled for 20-30 seconds; this creates a profile for each 20-30 second sampling period. Post-processing must then be performed to obtain hourly averaged data. This post-processing has not yet been developed to routinely provide near real-time hourly averaged data, as is needed for the forecasting aspects of SCOS97. NOAA/ETL is working to make this available in time for application to SCOS97 .

The data objectives are to provide upper-level wind and temperature data meeting the data quality objectives within 3 hours of collection. Due to the higher quality and better representativeness of the continuous, interleaved data, this is the preferred method. However, if continuous, interleaved hourly averaged data cannot be provided within a few hours of collection, the standard method of 5-10 minutes RASS, followed by 50-55 minutes of wind data should be used.

6.4.3 Rawinsondes

Rawinsondes should be released at least 4 times per day (USEPA, 1995b). They should be timed to capture the early morning stable boundary layer conditions, convective boundary layer (CBL) development in mid-morning, the fully developed CBL in mid-day, and the nocturnal boundary layer (STI, 1995). For SCOS97, these times may be modified or supplemented to capture important features of local flows, such as the sea-breeze front, return flows aloft, and valley and slope flows.

6.5 Periodic Review of Data

Upper air data for SCOS97 should be evaluated daily for operational status and reasonableness. Each day (at least Monday through Friday) a meteorologist or other person knowledgeable about upper air meteorological patterns in southern California should examine the data for each site for the past 24 hours for reasonableness. Time-height cross-sections plots provide for an efficient way of inspecting data at one site. Spatial patterns at a few selected heights would also be helpful for noting suspicious data. Data from collocated and nearby sites should be compared for consistency. If data are not being received, or appear to be invalid during part or all of the 24 hour period, the organization responsible for collecting the data should be contacted immediately. The responsible organization should promptly evaluate whether a problem does exist, and remedy any problems as soon as possible. Organizations responsible for periodic review of data are specified in Section 6.10.

6.6 System Audits

System audits are used to evaluate whether a system is set-up correctly and that standard operating procedures are being followed. System audits should be conducted at all upper air monitoring sites shortly after start-up of the SCOS97 field work and again shortly before ending the field work component of the study. System audits will be performed by Aerovironment Environmental Services, Inc. The list of system audit checks for rawinsondes, sodars, and RWP/RASS from the STI (1995) draft report should be used. It appears below:

6.6.1 Remote Profiler Instrumentation (Sodar, Radar Wind Profiler/RASS)

A routine check of the monitoring station should be performed to ensure that the local technician is following all the standard operating procedures. In addition, the following items should be checked:

- The antenna and controller interface cables should be inspected for proper connection. If multi-axis antennas are used, this will include checking for the proper direction of the interface connections.

- Orientation checks should be performed on the individual antennas, or phased-array antenna. The checks should be verified using solar sitings when possible. The measured orientation of the antennas should be compared with the system software settings of the system. The antenna alignment should be maintained within ± 2° , which is consistent with wind direction vane alignment criteria specified by the USEPA (1995b).

- For multi-axis antennas, the inclination angle, or zenith angle from the vertical, should be verified against the software settings and the manufacturer's recommendations. The measured zenith angle should be within ± 0.5° of the software settings in the data system.

- For phased-array antennas, and for the vertical antenna in a multi-axis system, the level of the antenna should be within ± 0.5° of the vertical.

- For multi-axis sodar systems, a separate distinct pulse, or pulse train in the case of frequency coded pulse systems, should be heard from each of the antennas. In a frequency-coded pulse system, there may be a sound pattern that can be verified. The instrument manual should be checked to see if there is such a pattern.

- For sodar systems, general noise levels should be measured, in dBa, to assess ambient conditions and their potential influence on the altitude capabilities of the sodar. In general, levels below 50 dBA indicate a quiet site, while levels above 60 dBA are quite noisy. The altitude coverage of the sodar will be directly related to the ambient noise at the site.

- A tabular vista diagram should be prepared documenting the surroundings of the site in 30° to 45° increments. The diagram should identify any potential sources clutter and reflective and active noise sources in each of the directions, as well as the approximate distance to the objects and their elevation angle above the horizon. This information in useful in assessing the effects of the environment on the data collected. As part of this documentation, photographs in various directions may be helpful for interpreting information in the tabular diagram. If this documentation exists in the monitoring plan for the site, it should be reviewed for accuracy.

- The controller and data collection devices should be checked to ensure the instruments are operating in the proper mode and that the data being collected are those specified by the SOP's.

- Station logbooks, checklists, and calibration forms should be reviewed for completeness and content to assure the entries are commensurate with the expectations in the procedures for the site.

- The site operator should be interviewed to determine his/her knowledge of system operation, maintenance, and proficiency in the performance of QC checks.

- The antenna enclosures should be inspected for structural integrity that may cause failures as well as any sign of debris or animal or insect nests that may cause drainage problems in the event of rain or snow.

- Preventative maintenance procedures should be reviewed for adequacy and implementation.

- The time clocks on the data acquisition systems should be checked and compared to a standard of ± 2 minutes.

- The data processing procedures and the methods for processing the data from sub-hourly to hourly intervals should be reviewed for appropriateness.
- Data collected over a several-day period should be reviewed for reasonableness and consistency. The review should include vertical consistency within given profiles and temporal consistency from period to period. For radar wind profilers and sodars, special attention should be given to the possibility of ground clutter (i.e., fixed echoes) and/or active noise source contamination in the data.

6.6.2 Rawinsondes

An entire launch cycle should be observed, from the operator's arrival at the site through completion of the sounding and securing of the station, to ensure that he site technician is following the appropriate procedures. The following items should be checked:

- Ground station initialization procedures for proper setup.

- Sonde initialization procedures for proper sonde calibration.

- Balloon inflation for proper ascent rate.

- Orientation check of a radio theodolite's antenna using solar sitings when possible. Procedures for solar sitings are described in USEPA (1995b). The antenna alignment should be maintained within ± 2 , which is consistent with wind direction vane alignment criteria provided in USEPA (1995b).

- Verification that the vertical angle of a radio theodolite's antenna is within ± 0.5

- Data acquisition procedures and on-site inspection of the acquired data.

- Data archiving and backup procedures.

- Flight termination and shutdown of the system.

- Preventive maintenance procedures and implementation.

- Data processing and validation procedures to check that questionable data are appropriately flagged and that processing algorithms do not excessively smooth the data.

- Data from several representative launches should be reviewed for reasonableness and consistency.

6.7 Performance Audits

A performance audit is intended to provide a measure of the performance of a measurement system. With upper air measurements, the concept of performance audits is somewhat altered, because there is not typically a known reference value for each measurements. Sodars and radar wind profilers measure winds over varying spatial and temporal (typically 1 hour) domains. Rawinsondes measure winds that are closer to instantaneous in time and spatially averaged over a small, nearly vertical path. Thus, direct comparisons are not possible. However, comparisons among the different measurement types (RWP, sodar and rawinsonde winds; RASS and rawinsonde derived virtual temperature) can give an overall indication of instrument performance and can be useful in data validation for periods with collocated data. The SCOS97 study plan calls for collocated upper air measurements using different instrument type at several locations. These can serve as long term performance audits for the radar wind profilers. Performance audits will be conducted by Aerovironment Environmental Services, Inc.

6.7.1 Sodars

An acoustic pulse transponder (APT) shall be used in sodar performance audits to test the ability of the instrument to correctly interpret test signals representing known wind speeds. Audit results should be within ± 0.2 ms^{-1} on a component basis. Audits using an APT should be conducted over at least three averaging intervals and over a range of wind speeds corresponding to those normally observed. These audits should be conducted near the beginning of the field study at each sodar site, simultaneously with the first system audit.

6.7.2 Radar Wind Profilers

Collocated sodars and rawinsondes at several sites can be used for performance audits. If additional performance audits are needed, sodars and/or rawinsondes may be used. If rawinsondes are used, at least 3 soundings covering the diurnal cycle should be taken. If sodars are used, the sodars should be configured to match the RWP data in temporal and spatial averaging as much as possible. The sodars should be run for at least 24 hours, and data compared to the RWP data while on-site. Comparisons between sodars and rawinsondes and RWP should be done when winds are at least 2 ms^{-1}.

6.7.3 Rawinsondes

Performance audits of rawinsondes are of little value because the instruments (radiosondes) are used only once, and their general performance characteristics are well established. However, instruments that provide ground truthing prior to launch (thermometer, RH sensor, psychrometer, barometric pressure sensor) should be audited by reference instruments traceable to a known standard. Performance audits of each rawinsonde site should be performed along with the system audit at the beginning of the SCOS97 field study.

6.7.4 RASS

RASS performance audits shall be done using collocated rawinsondes to provide virtual temperature.

6.8 Corrective Actions

If problems are identified through system or performance audits, inspection of the data, or by other methods, a plan of action is needed to quickly correct such problems and avoid any further loss or corruption of data. Each contractor or agency responsible for collecting upper-air meteorological data shall submit a plan for identification and remediation of problems. Any problems noted by the audit contractor during system and performance audits shall be reported to the station operator before leaving the site. For sites without station operators on site, the contractor (principal investigator) responsible for the site will be contacted while at the site. For problems not correctly immediately, the auditor will also notify the SCOS97 Upper-air Quality Assurance Manager. If the audit results suggest that previously or currently collected data are suspect, the auditor shall notify the principal investigator and Upper-air Quality Assurance Manager and supply copies of audit reports as soon as practical.

6.9 Data Acquisition and Processing

The upper-air data acquisition and processing procedures for SCOS97 are described in the NOAA/ETL proposal (NOAA/ETL, 1996). A summary of procedures are presented here. Each contractor or agency responsible for RWP/RASS data collection shall provide for the near real-time transfer of consensus hourly-averaged data to the NOAA/ ETL (SCOS97 Upper air database manager). ETL shall coordinate data submittals from each upper-air meteorology measurement group and receive and evaluate sample data submittals before the beginning of the field study (June 15, 1997). ETL will process the data and make it available on the Internet via the World Wide Web, after performing Level-1 validation. All data used for determining vertical temperature and wind profiles shall be stored, including complete spectral moment data. All spectral moment data shall be transferred to ETL on a schedule to be determined by ETL.

6.10 Data Validation

Level-1 validation will be performed automatically by ETL shortly after the data is received using time/height consistency checks for the RWP/RASS and sodar, and height consistency checks for the rawinsondes. Graphical displays of level-1 validated upper level winds and temperatures will be inspected by ETL. Level-2 validation includes comparing collocated measurements in time and height and network-wide consistency in time, and space. Automated procedures for level-2 will be applied to the data and made available within 3 hours of receipt. After completion of the field study, all data products will be reviewed by trained personnel familiar with the study area.

On a daily basis, ETL will review data from each site to determine if any problems are likely to exist. ETL will contact the site operator who will confirm or deny suspected problems and to remedy any problems. Additional data validation will occur during data analysis activities, when data may appear inconsistent with other analysis and modeling results.

Also on a daily basis, personnel at the South Coast Air Quality Management District familiar with upper-air meteorological patterns in the study area shall review the upper-air data made available by ETL via the Internet. The data shall be visually inspected for reasonableness; any suspected problems shall be reported to the organization responsible for the measurement.

6.11 Data Archival

Upper air data archival format and location should be specified by the SCOS97 Data Manager in consultation with the Upper-Air Quality Assurance Manager. STI (1995) identified the following desired features of upper-air data:

- Ability to use the data across a range of computer systems.
- The format should be independent of the instruments used to collect the data.
- Ability to store quality control information. Data validation level should be identified and stored with the data.
- Ability to store the data in ASCII and/or binary formats.
- Ability to include self-documentation that describes the content of the data sets.
- Ability to use commercial off-the-shelf software to read, sort, and manipulate the data.