4.0 CCOS FIELD MEASUREMENT PROGRAM

This section summarizes the major components of the field measurement program with consideration of alternatives, options, and tradeoffs. Cost estimates are itemized in Section 5. Measurement methods are described in Appendix A and requirements for quality assurance and data management are specified in Appendices B and C, respectively.

4.1 Study Design Principles

The proposed measurement program is designed to meet the goals and technical objectives specified in Section 1 and incorporates the following design guidelines that combine technical, logistical and cost considerations, and lessons learned from similar studies.

1. CCOS is designed to provide the aerometric and emission databases needed to apply and evaluate atmospheric and air quality simulation models, and to quantify the contributions of upwind and downwind air basins to exceedances of the federal 8-hour and state 1-hour ozone standards in northern and central California. While urban-scale and regional model applications are emphasized in this study, the CCOS database is also designed to support the data requirements of both modelers and data analysts. Air quality models require initial and boundary measurements for chemical concentrations. Meteorological models require sufficient three-dimensional wind, temperature, and relative humidity measurements for data assimilation. Data analysts require sufficient three-dimensional air quality and meteorological data within the study region to resolve the main features of the flows and the spatial and temporal pollutant distributions. The data acquired for analyses are used for diagnostic purposes to help identify problems with and to improve models.

2. Since episodes are caused by changes in meteorology, it is useful to document both the meteorology and air quality on non-episode days. For this reason, surface and upper air meteorological data as well as surface air quality data for NOx and ozone will be continuously collected during the entire summer of 2000. The database will be adequate for modeling and a network of radar profilers will allow increased confidence in assigning qualitative transport characterization (i.e., overwhelming, significant, or inconsequential) throughout the study period.

3. Many of the transport phenomena and important reservoirs of ozone and ozone precursors are found aloft. CCOS is designed to include extensive three-dimensional measurements and simulations because the terrain in the study area is complex and because the flow field is likely to be strongly influenced by land-ocean interactions. Several upper air meteorological measurements are proposed at strategic locations to elucidate this flow field.

4. Although specific advances have been made in characterizing emissions from major sources of precursor emissions, the accuracy of emission estimates for mobile, biogenic and other area sources at any given place and time remains poorly quantified. Ambient and source measurements, with sufficient temporal and chemical resolution, are required to identify and evaluate potential biases in emission inventory estimates.

5. Past studies document that the differences in temporal and spatial distributions of precursor emissions on weekdays and weekends alter the magnitude and distribution of peak ozone levels. Measurements are needed to evaluate model performance during periods that include weekends.

6. Boundary conditions, particularly for formaldehyde, significantly affected model outputs in the SARMAP modeling resulting in over-prediction of ozone levels in the Bay Area. Measurements of documented quality and adequate sensitivity are needed along the western boundary of the modeling domain to adequately characterize the temporal and spatial distributions of ambient background levels of ozone precursors.

7. The measurements should be designed such that no single measurement system or individual measurement is critical to the success of the program. The measurement network should be dense enough that the loss of any one instrument or sampler will not substantially change analysis or modeling results. The study should be designed such that a greater number of intensive days than minimally necessary for modeling are included. This helps minimize the influence of atypical weather during the field program and decreases the probability of equipment being broken or unavailable on a day selected for modeling. Most measurements should be consistent in location and time for all intensive study days and during the entire study period (i.e., no movement of measurements). In this way, one day can be compared to another. Continuous measurements should be designed to make use of the existing monitoring networks to the extent possible.

4.2 Study Domain

The study domain includes most of northern California and all of central California. The northern boundary extends through Redding and provides representation of the entire Central Valley of California. The western boundary extends approximately 200 km west of San Francisco and allows the meteorological model to use mid-oceanic values for boundary conditions. The southern boundary extends below Santa Barbara and into the South Coast Air Basin. The eastern boundary extends past Barstow and includes a large part of the Mojave Desert and all of the southern Sierra Nevada.

4.3 Study Period

The CCOS field measurement program will be conducted during a three-month period from 6/15/00 to 9/15/00 (***study period***). This period corresponds to the majority of elevated ozone levels observed in northern and central California during previous years. Continuous surface and upper-air meteorological measurements and surface air quality measurements of O_3 NO, NOx or NOy will be made hourly throughout the study period in order to provide sufficient input data to model any day during the study period. These measurements are made in order to assess the representativeness of the episode 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.

Additional continuous surface air quality measurements will be made at several sites during a shorter two-month study period from 7/6/00 to 9/2/00 (***primary study period)***. These measurements include nitrogen dioxide (NO_2), peroxyacetylnitrate (PAN) and other peroxyacylnitrates (PAcN), particulate nitrate (NO_3^-), formaldehyde (HCHO), and speciated volatile organic compounds. These measurements allow detailed examination of the diurnal, day-to-day, and day-of-the-week variations in carbon and nitrogen chemistry at transport corridors and at locations downwind of the San Francisco Bay Area, Sacramento, Fresno, and Bakersfield where ozone formation may be either VOC- or NOx-limited depending upon time of day and pattern of pollutant transport. These data support operational and diagnostic model evaluations, evaluations of emission inventories, and corroborative observation-based data analyses.

Additional data will be collected during ozone episodes (***intensive operational periods***, ***IOP***) to better understand the dynamics and chemistry of the formation of high ozone concentrations. The budget for CCOS allows for up to 15 days total for episodic measurements. With an average episode of three to four days, four to five episodes are likely. These measurements include instrumented aircraft, speciated VOC, and radiosonde measurements, which are labor intensive and require costly expendables or laboratory analyses. IOPs will be forecasted during periods that correspond to categories of meteorological conditions called scenarios, which are associated with ozone episodes and ozone transport in northern and central California. These intensive measurements will be made on days leading up to and during ozone episodes and during specific ozone transport scenarios. The additional measurements are needed for operational and diagnostic model evaluation, to improve our conceptual understanding of the causes of ozone episodes in the study region and the contribution of transport to exceedances of federal and state ozone standards in downwind areas.

4.4 Surface 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. This section describes the existing routine air quality and meteorological monitoring network in northern and central California, and the options for continuous and intensive air quality and meteorological measurements (surface and aloft) to be made during CCOS.

The existing meteorological network in central California is extensive, but uncoordinated among the different agencies. Figure 4.4-1 shows the locations of surface meteorological monitoring sites operated by the Air Resources Board (ARB), the Bay Area Air Quality Management District (BAAQMD), the National Oceanic and Atmospheric Administration (NOAA), the California Irrigation Management Information Service (CIMIS), Interagency Monitoring of PROtected Visual Environments (IMPROVE), the National Weather Service (NWS), Pacific Gas and Electric Company (PG&E), the U.S. Coast Guard, Remote Automated Weather Stations (RAWS) for fire fighting, and a few miscellaneous monitors. Wind speed and direction, temperature, and relative humidity are the most common measurements. The network of surface pressure and solar radiation measurements is also extensive. Three sites measure ultraviolet radiation in the Sacramento Valley, in the San Joaquin Valley, and along the south coast in Santa Barbara County.

Figure 4.4-2 shows the surface meteorological observables measured at each monitoring location, regardless of the network from which they are derived. Wind speed and direction, temperature, and relative humidity are the most common measurements. The network or surface pressure and solar radiation measurements is also extensive. Three sites measure ultraviolet radiation in the Sacramento Valley, in the San Joaquin Valley, and along the south coast in Santa Barbara County. The specific measurements at each site and the networks they belong to are documented in Appendix C of Watson et al., (1998).

Thuillier et al. (1994) document the methods used to acquire and report data in most of these networks with their similarities and differences. Wind speed measurements are taken at heights ranging from 2 m to 10 m agl at most sites and temperatures are measured by aspirated and unaspirated thermometers. The major limitations of existing network instrumentation are: 1) wind thresholds of ~1 m/s for most instruments, which is adequate for non-winter periods, but not for low winds in the surface layer during winter; 2) relative humidity sensors that are inaccurate at high (<90%) humidities; and 3) insufficient temporal resolution (i.e. on the order of minutes) to detect wind gusts that might suspend dust.

The existing meteorological network will be augmented with the CCOS supplemental sites described below. Ten meter meteorological towers at each of these sites will be equipped with low threshold (~0.3 m/s) wind sensors and high sensitivity relative humidity sensors. Section 10 describes the monitors available for these measurements. Five-minute average measurements will be acquired so that the data can be interpreted with respect to wind gusts that might raise dust, short-term shifts and wind direction that might correspond to pulses measured by continuous particle monitors, and short duration clouds and fogs that cause rapid changes in the 90% to 100% RH interval. With these supplemental measurements and surface measurements at the upper air sites, the existing surface monitoring network provides adequate coverage for the northern and central California study domain.

4.5 Surface Air Quality Measurements

The California Air Resources Board and local air pollution control districts currently operate 185 air quality monitoring stations throughout northern and central California. Of the active sites, 130 measure ozone and 76 measure NOx. Carbon monoxide and hydrocarbons are measured at 57 and 11 sites, respectively. Data from these sites are routinely acquired and archived by the ARB and Districts. This extensive surface air quality monitoring network provides a substantial database for setting initial condition for the model, and for operational evaluation of model outputs. ARB, in collaboration with the California air quality management districts, is establishing the $PM_{2.5}$ monitoring sites. The PM_{10} acquires filter samples every sixth day. Several of the PM_{10} sites have continuous monitors that measure hourly PM_{10} everyday. Watson et al. (1998) describes the PM measurement network.

Supplemental air quality measurement are required at several existing monitoring sites to increase the extent of chemical speciation and in key areas of the modeling domain where routine monitoring stations do not currently exist. Measurements of documented quality and adequate sensitivity are needed along the western boundary of the modeling domain to adequately characterize the temporal and spatial distributions of ambient background levels of ozone precursors because boundary conditions can significantly affected model outputs.

Background sites intend to measure concentrations that are not influenced by northern and central California emissions. Interbasin transport sites are intended to evaluate concentrations along established or potential transport pathways between basins, including the Bay Area, the North Central Coast, the Sacramento Valley, the San Joaquin Valley, Mountain counties, the South Central Coast Air Basin, and the Mojave desert. Intrabasin gradient sites are located in non-urban areas between routine network sites. They are intended to evaluate the extent to which one urban area affects ozone concentrations in another urban area, as well as the extent to which urban contributions arrive at suburban and rural locations.

The CCOS field measurement program consists of four categories of supplemental measurement sites with increasing levels of chemical speciation and time resolution – Type 0, 1, and 2 “supplemental” (S) sites and “research” (R) sites. The instruments to be used in the supplemental network are listed in Table 4.5-1. Appendix A describes the various types of instruments and measurements methods. Table 4.5-2 shows the instrument configuration at each of the CCOS supplemental air quality monitoring sites, using the letter designations introduced in Table 4.5-1. Figure 4.5-1 shows the locations of the existing monitoring stations measuring ozone and NOx. Figure 4.5-2 shows the locations of existing monitoring stations measuring carbon monoxide and speciated hydrocarbons and carbonyl compounds in relation to proposed CCOS supplemental monitoring sites.

4.5.1 CCOS Type 0 Supplemental Monitoring Sites (S0)

S0 sites are intended to fill in key areas of the modeling domain where ozone, nitrogen oxides, and surface meteorology are not currently measured. Proposed sites include McKittrick and Kettleman City (both along the western side of the San Joaquin Valley), Shasta (downwind of Redding), and Carizo Plain (along transport route between San Luis Obispo and the southern San Joaquin Valley). In addition NO/NOy analyzers will be added at several existing monitoring sites that currently measure only ozone. Three of these sites are located along pollutant transport routes (Vacaville, San Martin, and Walnut Grove Tower at two elevations). Yosemite (Turtleback Dome) is proposed in order to monitor NO/NOy at one site where formation of ozone is expected to be always NOx limited.

4.5.2 CCOS Type 1 Supplemental Monitoring Sites (S1)

S1 sites are intended to establish boundary and initial conditions for input into air quality models. These sites are needed at the upwind boundaries of the modeling domain, in the urban center and at downwind locations. The following aerometric parameters are measured at S1 supplemental monitoring sites.

1. Continuous surface wind speed and direction and temperature during study period.

2. Continuous ozone during study period.

3. Continuous NO and NOy during study period by high sensitivity chemiluminescence analyzer (e.g., TEI42S or equivalent) with the converter near the sample inlet.

4. Four 3-hour canister samples for up to 15 IOP days (with option for 2 additional days) for analysis of CO, CO_2, methane by gas chromatography, reduction of CO and CO_2 to CH_4,

and analysis by flame ionization detection; and C_2-C_{12} hydrocarbons and MTBE by gas chromatography with flame ionization detection.

5. Four 3-hour DNPH cartridge samples for up to 15 IOP days (with option for 2 additional days) for C_1-C_7 carbonyl compounds by HPLC with UV detection.

With the exception of NOy measurements, S1 sites are equivalent to Photochemical Assessment Monitoring Stations (PAMS) sites. Measurements of speciated volatile organic compounds (VOC) made under CCOS (four 3-hour samples on 15 IOP days) supplement the 11 existing PAMS sites in the study area (four in Sacramento, four in Fresno, and three in Bakersfield. The ozone episodic samples that will be collected under PAMS will coincide with the CCOS IOP days. S1 sites are proposed for Bodega Head and along the south central coast north of Morro Bay at or near Piedras Blancas Point to obtain background data near the western boundary of the CCOS modeling domain. Sutter Buttes and Turlock provide characterization of ambient air transported into the upper Sacramento Valley and into the northern San Joaquin Valley, respectively, as a function of the nature of the flow bifurcation downwind of the San Francisco Bay Area. Measurements at Anderson (located south of Redding) are designed to determine whether ozone precursors immediately upwind of Redding are largely transported or are attributable to local sources. Similar transport issues are address by measurements in the foothill communities near Grass Valley and San Andreas. Type S1 measurements are also proposed for the CRPAQS Anchor site at Angiola. The Bay Area AQMD will operate the existing San Jose and San Leandro monitoring sites as S1 sites during CCOS.

4.5.3 CCOS Type 2 Supplemental Monitoring Sites (S2)

S2 sites are located at the interbasin transport and intrabasin gradient sites, and near the downwind edge of the urban center where ozone formation may either be VOC or NOx limited depending upon time of day and pattern of pollutant transport. S2 sites also provide data for initial conditions and operation evaluations and some diagnostic evaluation of model outputs. The following aerometric parameters are measured at Type 2 supplemental monitoring sites.

1. Continuous surface wind speed and direction and temperature during study period.

2. Continuous O_3 during study period.

3. Continuous NO and NOy during study period by a high sensitivity chemiluminescence analyzer (e.g., TEI 42S) for new sites or NOy and NOy* (NOy minus HNO_3) with TEI42CY for existing monitoring sites with a NO/NOx analyzer. Nitric acid can be estimated by difference between the signals with and without a NaCl impregnated fiber denuder.

4. Continuous NO_2 and peroxyacylnitrate (PAcN) during primary study period by gas chromatography with Luminol detector. A second estimate of HNO_3 is obtained by the difference between NOy and the sum of NO, NO_2, and PAcN. This second estimate is an upper-limit because NOy also includes other organic nitrates and particulate ammonium nitrate.

5. Continuous formaldehyde (HCHO) during primary study period by an instrument that continuously measures the fluorescent, dihydrolutidine derivative formed by the reaction of formaldehyde with 1,3-cyclohexanedione and ammonium ion (Dong and Dasgupta, 1994; Fan and Dasgupta, 1994).

6. Four 3-hour canister samples for up to 15 IOP days (with option for 2 additional days) for analysis of CO, CO_2, methane by gas chromatography, reduction of CO and CO_2 to CH_4, and analysis by flame ionization detection; and C_2-C_{12} hydrocarbons and MTBE by gas chromatography with flame ionization detection.

7. Four 3-hour DNPH cartridge samples for up to 15 IOP days (with option for 2 additional days) for C_1-C_7 carbonyl compounds by HPLC with UV detection.

Measurements at S2 sites include those at S1 sites plus continuous NOy*, nitrogen dioxide (NO_2), peroxyacetylnitrate (PAN) and formaldehyde (HCHO). The measurements allow more detailed assessments of VOC- and NOx-limitation by observation-driven methods during the entire two-month primary study period. S2 sites are proposed along the three main passes connecting the Bay Area and the Central Valley (Bethel Island, Altamont Pass, and Pacheco Pass. S2 measurements are also proposed downwind of Fresno at the Mouth of the Kings River and downwind of Bakersfield at Edison. One additional S2 site is proposed at a location northeast of Sacramento.

4.5.4 CCOS Research Sites

Research sites have the same site requirements as S2 sites. The sites are intended to measure a representative urban mix of pollutants, and must be carefully selected to minimize the potential influence of local emission sources. As with S2 sites, research sites are located where ozone formation may either be VOC or NOx limited depending upon time of day and pattern of pollutant transport. Research site are intended to provide the maximum extent of high-quality, time-resolved chemical and other aerometric data for rigorous diagnostic evaluation of air quality model simulations and emission inventory estimates. The following aerometric parameters are measured at Research monitoring sites.

1. Continuous surface wind speed and direction and temperature during study period;

2. Continuous ozone during study period;

3. Continuous NO/NOx analyzer during study period.

4. Continuous NOy and NOy* during study period with TEI42CY. Nitric acid estimated by difference between the signals with and without a NaCl impregnated fiber denuder.

5. Continuous NO_2 and PAcN during primary study period by gas chromatography with Luminol detector. A second estimate of HNO_3 is obtained by the difference between NOy and the sum of NO, NO_2, and PAcN. This second estimate is an upper-limit because NOy also includes organic nitrates and particulate ammonium nitrate.

6. Continuous formaldehyde during primary study period by an instrument that continuously measures the fluorescent, dihydrolutidine derivative formed by the reaction of formaldehyde with 1,3-cyclohexanedione and ammonium ion (Dong and Dasgupta, 1994; Fan and Dasgupta, 1994).

7. Semi-continuous hourly organic compound speciation data during primary study period by gas chromatography with mass spectrometry. VOC speciation includes C_2 and higher volatile hydrocarbons, carbonyl and halogenated compounds. Collect up to 10 sets of canister and DNPH samples for measurement comparisons with GC/MS and continuous HCHO analyzer.

8. Continuous CO by TEI 48C or equivalent and continuos CO_2 by TEI 41C or equivalent during study period.

9. Continuous NO_2 and O_3 photolysis rates during study period by filter radiometer.

10. Semi-continuous particulate nitrate during primary study period by Aerosol Dynamics Inc. (ADI) automated particle nitrate monitor. The monitor uses an integrated collection and vaporization cell whereby particles are collected by a humidified impaction process, and analyzed in place by flash vaporization with quantitation of the evolved gases by chemiluminescent analyzer. A commercial unit is anticipated by next summer.

11. Continuos total light absorption by aethalometer and total light scattering by ambient integrating nephelometer during primary study period.

12. Continuous NO_2, HNO_3, HCHO and H_2O_2 on twenty IOP days by dual tunable diode laser absorption spectrometers at the Fresno research site.

13. Semi-continuous measurements of multi-functional carbonyl compounds on 15 IOP days by derivatization and analysis by GC/MS at the Sacramento research site.

14. Continuous HONO by Differential Optical Absorption Spectroscopy on 15 IOP days at one research site. (Contingent upon available funding).

15. Four 3-hour Tenax cartridge samples for up to 15 IOP days (with option for 2 additional days) for analysis C_8-C_{20} hydrocarbons.

Research sites are proposed downwind of Sacramento and Fresno, and near Dublin between Oakland and Livermore.

4.6 Upper Air Meteorological Network

Figure 4.6-1 and 4.6-2 show the locations of types of upper air meteorological monitors to be deployed for the summer 2000 field study. Table 4.5-1 describes the upper air sites, their measurements and operators. Radar profilers, doppler sodars, and RASS are used at most sites because they acquire hourly average wind speed, wind direction, and temperature by remote sensing without constant operator intervention. Sodars are collocated with profilers at several locations because they provide greater vertical resolution in the first 100 m agl. This is especially important near terrain features and during winter.

Several radar profilers are being installed to acquire a multi-year database, and one of the important functions of the CCOS/CRPAQS supplements to this network is to relate these relatively sparse measurements to the detailed meteorological patterns determined during CCOS. The ARB operates two profilers (with RASS) in the San Joaquin Valley, and the San Joaquin Unified APCD and Sacramento Metropolitan AQMD operate one profiler/RASS each as part of their PAMS monitoring program. Military facilities with operational profilers include Travis AFB, Vandenberg AFB, and the Naval Post Graduate School in Monterey. Because these profilers are operated by different entities, equivalent methods of data evaluation and reporting need to be established among these entities prior to CCOS field study. Six profiles/RASS will be installed and operational during summer 2000 as part of the CRPAQS. In addition, nine profilers/RASS and 5 sodars will be installed for the CCOS summer 2000 field study.

Radiosondes are needed to determine changes in relative humidity and to quantify conditions at elevations above ~2000 m agl. They are also the only practical means of acquiring upper air measurements in cities where the noise and siting requirements of remote sensing devices make them difficult to operate. Radiosondes are routinely launched through the year at 0400 and 1600 PST from Oakland, with additional launches at Vandenberg, Edwards, and Pt. Mugu according to military mission requirements. None of these locations are within the Central Valley, so these will be supplemented by launches at Sacramento and in the southern San Joaquin Valley on 20 episodic days during summer with six radiosondes (with ozonesonde) releases per day. The 490 MHz RWP will be place in the Fresno area to provide higher vertical sounding in the southern portion of the Central Valley.

In addition to ozonesondes mentioned in the previous section, aloft air quality measurements are available from fixed platforms that are part of the routine monitoring network (e.g., Walnut Grove radio tower and Sutter Buttes). CCOS will add NOy measurements at Walnut Grove and Sutter Buttes to provide additional information on oxidants available as carry-over to mix-down on the following day.

4.7 In-Situ Aircraft Measurements

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 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. Three aircraft are included in the program and one additional aircraft is equipped with an ozone lidar.

Instrumented aircraft will be used to measure the three dimensional distribution of ozone, ozone precursors, and meteorological variables. The aircraft will provide information about boundary concentrations, vertical concentration gradients, the mixed layer depth, and the spatial extent of some 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. Four aircraft are included in the base program.

Three small air quality aircraft are needed to document the vertical and horizontal gradients of ozone, NOx, ROG, temperature, and humidity in the study region. One aircraft is needed for the Bay Area and the northern San Joaquin Valley, a second aircraft for the Sacramento Valley and northern Sierra Nevada, and a third aircraft the San Joaquin Valley and southern Sierra Nevada. Onboard air quality instruments should have high sensitivity and fast response (e.g., modified TEI 42S for NO and NOy). The small aircraft will make one flight in the early morning (0500 to 0900 PDT) to document the morning precursors and the carryover from the day before and a second flight in mid-afternoon (1300 to 1700 PDT) to document the resulting ozone distribution. An occasional third flight might be considered during the night to characterize the nocturnal transport regime and pollutant layers. Flights last between three to four hours and may consist of a series of spirals (over fixed points on the ground) and traverses (at constant altitude from one point to another) throughout the mixed layer. One of these aircraft will also participate in characterizing flux-planes. This aircraft should have the capability to measure wind direction and speed.

VOC samples are collected in the morning during downward spirals between 200 and 600 m AGL in order to characterize carryover of VOC from the previous day. VOC samples in the afternoon are collected in the mixed layer in the bottom 350 m of the downward spiral. Sample durations in these layers are approximately two minutes. Hydrocarbon samples are collected in stainless steel canisters and carbonyl samples are collected in Tedlar bags and transferred to dinitrophenyl hydrazine impregnated C_{18} cartridges on the ground at the conclusion of the flight. Hydrocarbon samples are subsequently analyzed in the laboratory by gas chromatography with flame ionization detection per EPA Method TO-14 and carbonyl samples are analyzed in the laboratory by HPLC with UV detection per Method TO-11. The budget allows for collection and analysis of three sets of hydrocarbon and carbonyl samples per flight. Analytical laboratories must demonstrate the capability to achieve detection limits that are anticipated for these samples .

A larger multi-engine aircraft is needed to document the horizontal and vertical gradients along the offshore boundaries of the modeling domain. This plane carries the same instrumentation as the smaller planes with the capability to measure wind direction and speed. This long-range aircraft will make two flights per day, one in the early morning and one in mid-afternoon. The flights will take about four hours and will likely consist of a series of dolphin patterns (slow climbs and descents along the flight path) and traverses. During one leg of the morning flight of the first day of an IOP, this aircraft will measure the concentrations at the western, overwater boundary of the study area. On the return leg, the aircraft will document the concentrations and fluxes across the shoreline. VOC samples are collected during constant-altitude traverses for the overwater boundary and during several spirals for the shoreline legs. Boundary measurements will be made during both non-episode and episode days. This plane will also participate in flux plane measurements.

This long-range aircraft will make two flights per day, one in the early morning and one in mid-afternoon. The flights will take about four hours and will consist of a series of dolphin patterns (slow climbs and descents along the flight path) and traverses. During one leg of the morning flight of the first day of an IOP, this aircraft will measure the concentrations at the overwater (western) boundary of the study area. On the return leg, the aircraft will document the concentrations and fluxes across the shoreline. VOC samples are collected during constant-altitude traverses for the overwater boundary and channel legs and during several spirals for the shoreline legs. The specific flight plans will need to be developed over the next year for this aircraft under different meteorological scenarios.

The specific flight plans will be developed over the next several months for the four aircraft under different meteorological scenarios. The above general description of flight patterns and objectives of each flight will be specified in the operational program plan. Aircraft that are available during the summer 2000 field study include two single-engine Cessna from UCD, twin-engine Aztec and up to two additional single engine aircraft by STI. The capabilities of these aircraft and associated personnel vary with each group.

4.8 Consideration of Alternative Vertical Ozone Measurements

In addition to the instrumented aircraft described in Section 4.7, both airborne and ground-based lidars, and ozonesondes have been used in previous studies to obtain vertical ozone measurements. The CCOS Technical Committee discussed the merits of these alternative approaches and reached the consensus that a small fleet of instrumented aircraft would provide the most cost-effective approach given the tradeoffs between temporal and spatial information and requirements for pollutant flux and plume measurements. The following summary provides the rationale for the Committee's recommendation.

The Atmospheric Lidar Division of NOAA's Environmental Technology Laboratory in Boulder operates an airborne, downlooking UV-DIAL, which was originally developed by EPA's Environmental Monitoring Systems Laboratory – Las Vegas. This system is capable of measuring range resolved ozone concentrations and aerosol, nadir looking from its airborne platform to near the ground level. The current measurement range for ozone is from about 0.8 km to 2.5–3 km, with the lower limit corresponding to the complete overlap of laser beams with the field of view of the telescope. The lower limit might be reduced somewhat in the future by applying the overlap correction in the data analysis and/or different alignment of the hardware. Generally, the DIAL data are analyzed for ozone concentrations down to about 90–150 m above ground. Accuracy of the DIAL data is 4 ppbv from comparisons with in situ instruments. Precision is 3 ppbv at 1.5 km range from the lidar to 11 ppbv at 2.5 km range with 500 m horizontal resolution (8 seconds at 65 m/s flight speed) and 90 m vertical resolution (Alvarez, 1999).

Cost estimate for NOAA's airborne ozone lidar including preliminary on-site data processing is $300,000 for 1 month deployment and 80 flight hours and $70,000 for one additional week deployment with additional 20 flight hours. Including $150,000 for data processing, the total cost is $520,000 for 100 flight hours. The airborne system is currently scheduled to participate in the Texas 2000 experiment from 8/15/00 through 9/15/00, and will be available only during the first five weeks of the CCOS primary study period.

An airborne lidar system provides the advantage of spatial coverage, but the disadvantage of limited temporal information. These attributes are reversed for a ground-based lidar system. 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. 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. Aerosol profiles for a maximum range of about 10 km can be obtained with a range resolution of 15 m. 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). Using the 266/289 nm wavelengths pair, averaging 600-1200 pulses (5-10 min at 2 Hz or 1-2 min at 10 Hz), the retrieval of ozone concentrations has a range resolution from a few tens of meters in the lower boundary layer to 150-200 m at about 3 km. Range resolution decreases with height because the signal-to-noise ratio decreases with distance.

The NOAA ground-based lidar has the necessary range to make useful measurements further inland where the boundary layer height is larger. The measurement direction of the lidar system can be scanned in one dimension from 30^o to 150^o yielding a two dimensional ozone measurement. The vertical scanning capability provides a valuable internal system check, frequent calibration, and was desired for both monitoring and modeling studies. This system is being modified to add a new wavelength at 299 nm, to provide a longer maximum range of ozone measurements in a thick boundary layer. Cost estimate for NOAA's ground based ozone lidar (OPAL) is $230,000 for one month deployment with 150 hours of operation.

The ground-based lidar could be located at up to two sites (with one move during the field study). The ground-base lidar could serve as an anchor site within a network of ozonesonde launch locations arrayed along the following transport routes: 1) west-east transport path between the Bay Area, Sacramento, and the Sierra Nevada foothills; and 2) north-south transport up the San Joaquin Valley. Ozonesondes have the disadvantages of being labor intensive and expensive. In addition, ozonesonde data is difficult to interpret in region where ozone is not spatially uniform.

4.9 Measurements for Special Studies

In addition to the measurement described above, data are also needed to develop day-specific emissions data and to evaluate the validity of emission estimates as described under CCOS technical objectives B-2 and D-4, respectively. The following experiments are also required to address specific technical issues that cannot be fully address by the proposed CCOS monitoring program.

Contribution of Transported Pollutants to Ozone Violations in Downwind Areas

In principle, well-performing grid models have the ability to quantify transport contributions. However, many of the interbasin transport problems involve complex flow patterns with strong terrain influences that are difficult and expensive to model. Upper-air meteorological and air quality data in critical transport locations is generally required in order to properly evaluate and use grid models for quantifying transport contributions. In combination with modeling, data analyses can improve the evaluation of modeling results and provide additional quantification of transport contributions.

In order to quantify pollutant transport and to provide data for modeling and data analyses, surface and aloft measurements are needed at locations where transport can occur and at the times when transport is occurring. These monitoring locations include in and near mountain passes, along coastlines, offshore, and at various locations in the downwind air basin. Aloft measurements made by instrumented aircraft are used to calculate transport across flux planes. Vertical planes, intersecting the profiler sites downwind of and perpendicular to the transport path, can be defined and provide estimates of transport through these passes using surface and aircraft measurements of pollutant concentrations and surface and wind profiler data for volume flux estimations.

Contributions of Elevated NOx Sources to Downwind Ozone

Power plants and other sources with tall stacks are significant sources of NOx, which in the presence of NMHC can lead to catalytic formation of ozone downwind of the source. However, close to the stack there is a temporary decrease in ozone levels due to "titration" by high levels of NO in the near field of the plume. Further downstream, ozone levels above the local background indicate net ozone production due to the reaction of plume NOx with NMHC that are entrained into the plume in the dilution process. However, question remain as to how much ozone is actually produced in the plume, how the ozone production efficiency depends on the chemical composition of the plume, and what the relative contributions of power plants are to high ozone episodes ozone in downwind areas.

It is not clear that the treatment of plumes by state-of-the-art models is adequate. Vertical transport (e.g., plume rise and fall the plume during downwind transport) may not be adequately described. Recent power plant plumes studies (Senff et al., 1998) utilized airborne ozone and aerosol lidar in conjunction with other instrumented aircraft. Because of its ability to characterize the two dimensional structure of ozone and aerosols below the aircraft, the airborne lidar is well suited to document the evolution of the size and shape of the power plant plume as well as its impact on ozone concentration levels as the plume is advected downwind. This aircraft was considered as a study option, but budget constraints will prevent its use during CCOS. However, aircraft measurements of NOx, ozone and VOC concentrations made in plumes are required to test the validity of the treatment of plume dispersion and chemistry and the procedures for terminating the plume into the regular model grid by plume-in-grid parameterizations.

Helicopter based measurements of power plant plume will be used to evaluate the plume-in-grid (PiG) parameterizations used in air quality models. With PiG parameterizations plume emissions are simulated in a Lagrangian reference frame superimposed on the Eulerian reference frame of the host grid model. Ozone formation rates in the plume of an elevated point source will be different from the ambient air because of their very different VOC/NOx ratios. CCOS measurements of ozone, VOC and nitrogenous compounds in plumes and in the surrounding air will be compared with the simulations of models using the PiG approach. The plume study is described in Addendix D.

Deposition Studies

During the California Ozone Deposition Experiment (CODE) in 1991, aircraft and tower-based flux measurements were taken over different types of San Joaquin Valley crops, irrigated and non-irrigated fields, and over dry grass. Estimates of ozone deposition velocities are 0.7-1.0 cm/s (Pederson et al. 1995). Order of magnitude calculations by Pun et al. show that dry deposition can be a few percent (~3-5%) of the total ozone budget in the San Joaquin Valley. However, modeling studies (Glen Cass, personal communication) have shown that dry deposition can play a more significant role in the budget of an important ozone precursor, NO_2. Three alternative deposition studies are described in this conceptual plan. Two are tower-based and could take advantage of the 100-m tower at Angiola planned for CRPAQS. The third is an aircraft flux measurement and could be used for a variety of different terrain types.

As part of CRPAQS, a 100 m, walk-up, scaffold tower will be constructed and maintained at the Angiola site to support year-long micrometeorological measurements as well as other vertical experiments. For the long-term measurements, the tower will be instrumented at five elevations with high precision anemometers, relative humidity, and temperature measurements and will record five minute averages of wind speed, wind direction, temperature, and relative humidity as well as average cross-products in the vertical and horizontal directions. These micrometeorological measurements will be used to create a diurnal and seasonal climatology for surface layer evolution, describe turbulent mixing and dispersion at the sub-grid scale level, and to determine micrometeorological conditions near the surface that affect suspension and deposition of dust, gases, and fine particles.

A tower-based experiment using a DOAS lidar at three to five different heights could be employed to measure vertical O_3, NO_2, HONO, NO_3, and HCHO concentration gradients. Optical fibers would distribute the laser pulse to each height, and a multi-pass cells could be used to increase the path length and thereby the accuracy. The O_3 and NO_2 measurement has an estimated accuracy on the order of 1.5 ppb for a five-minute averaging period over a 100-m pathlength (5 m folded 20 times). (Accuracy for any other species measured may be part of the investigation.) To get fluxes from the lidar gradient measurement, either an assumed form of eddy diffusivity would be required, or a modified Bowen ratio approach could be employed. The modified Bowen ratio and a direct eddy correlation measurement both require fast-response sonic anemometry (on the order of 10 Hz) to measure turbulent perturbations in the vertical velocity. With direct eddy correlation techniques, the species of interest must also be measured at the same rate to find the covariance with the vertical turbulent perturbations. This is the approach used in aircraft flux measurements. With the modified Bowen ratio technique, fast response measurements of a surrogate species (typically CO_2 or H_2O) are made and are then related to the species of interest via the ratio of vertical concentrations. Since fast response instruments are available for ozone (chemi-fluorescence) and for NOx (chemi-luminescence), the two techniques could be directly compared, giving greater confidence in the HONO, NO_3, and HCHO flux estimates.

Instrumented aircraft can also be a part of a wider study to investigate more divers land types. For example, the NOAA Long-EZ operated by the NOAA Air Resources Lab is already instrumented with fast response O_3 and NOx analyzers and has a wind probe providing 2 cm/s accuracy in turbulent perturbations. As was done in CODE, the aircraft could be periodically flown near the tower for crosscheck and QA purposes.

The consensus view of the CCOS Technical Committee was that a proper study of atmospheric deposition would require far more funds than available within CCOS. Rather than dilute the CCOS effort, the Committee recommended that separate funding be sought for a comprehensive deposition study in the year 2001.

Table 4.5-1
CCOS Supplemental Surface Measurements

Observable and Method	Code	Period	Avg Time	Type of Sites
Meteorology and Radiation				
Meteorology (WS,WD, T and RH) at 10 m	A	6/15/00 to 9/15/00	5-minute	S0, S1, S2 and R
Radiation (J_{NO2} and J_{O1D})	T	6/15/00 to 9/15/00	5-minute	R
Oxidants				
Ozone (ultraviolet absorption monitor)	B	6/15/00 to 9/15/00	5-minute	S0, S1, S2 and R
H_2O_2 (TDLAS)	Q	15 IOP days	10-minute	R (1)
Nitrogen Species				
NO, NOx (chemiluminescent monitor)	C	6/15/00 to 9/15/00	5-minute	S2, R
NO, NOy (high sensitivity chemiluminescent monitor with external converter)	D	6/15/00 to 9/15/00	5-minute	S0, S1
NOy, NOy-HNO_3 (high sensitivity chemiluminescent monitor with dual converters w/ & w/o NaCl impregnated fiber denuder)	E	6/15/00 to 9/15/00	10-minute	S2, R
NO_2, PAcNs (GC - Luminol)	F	7/2/00 to 9/2/00	30-minute	S2, R
NO^- (flash vaporization)	G	7/2/00 to 9/2/00	10-minute	R
NO_2, HNO_3 (TDLAS)	P	15 IOP days	10-minute	R (1)
Carbon Species				
CO, CO2, CH4, C_2-C_{12} hydrocarbons (canister/GC-FID)	J	15 IOP days	4 x 3-hr	S1, S2, R
C_1-C_7 carbonyls(DNPH-HPLC/UV)	N	15 IOP days	4 x 3-hr	S1, S2, R
HCHO (dihydrolutinine derivative/fluorescent detection)	M	7/2/00 to 9/2/00	10-minute	S2, R
C_8-C_{20} hydrocarbons (Tenax GC-FID, MSD)	K	15 IOP days	4 x 3-hr	R
VOC (Automated-GC/ion trap mass spectrometer)	L	7/2/00 to 9/2/00	hourly	R
HCHO (TDLAS)	Q	15 IOP days	10-minute	R (1)
Hydroxy carbonyls	O	15 IOP days	hourly,	R(2)
CO (nondispersive infrared)	H	6/15/00 to 9/15/00	5-minute	R
CO_2 (nondispersive infrared)	I	6/15/00 to 9/15/00	5-minute	R
PM/Visibility				
PM2.5 light absorption (aethalometer)	R	6/15/00 to 9/15/00	5-minute	R
PM2.5 light scattering (portable nephelometer)	S	6/15/00 to 9/15/00	5-minute	R

(1) At the Fresno research site only.
(2) At the Sacramento research site only.

Table 4.5-2
Supplemental Surface Air Quality and Meteorological Measurements

Site	County	Type	Site Acquisition	Operation	Measurements: Existing	Measurements: CRPAQS	Measurements: CCOS
Walnut Grove Tower	Sacramento	NOy	SMAQMD	CCOS	AB	S	2-D
Vacaville - El Mira Rd	Solano	NOy	Yolo-Solano	Yolo-Solano	AB	--	D
San Martin	Santa Clara	NOy	BAAQMD	BAAQMD	AB	--	D
Yosemite - Turtleback	Mariposa	NOy	NPS, CRPAQS	CCOS	AB	SJ (1)	D
Shasta	Shasta	S0	New - CCOS	CCOS	--	--	ABD
Kettleman City	Kings	S0	CRPAQS	SJVUAPCD	--	S	ABD
McKittrick	Kern	S0	New - CCOS	SJVUAPCD	--	--	ABD
Carizo Plain (California	San Luis Obispo	S0	CRPAQS	SLOAPCD	--	S	ABD
Anderson	Shasta	S1	Shasta Co.	CCOS	AB	--	DJN
Sutter Buttes	Sutter	S1	ARB	ARB	AB	--	DJN
White Cloud	Nevada	S1	ARB	CCOS	AB	--	DJN
Bodega Bay	Sonoma	S1	CRPAQS	CCOS	--	RSJ(1)	ABDJN
San Leandro	Alameda	S1	BAAQMD	BAAQMD	ABCJ(2)N(2)	--	--
San Jose 4th Street	Santa Clara	S1	BAAQMD	BAAQMD	ABCHJ(2)N(2)	S	--
San Andreas	Calaveras	S1	ARB	CCOS	ABH	--	DJN
Turlock	Stanislaus	S1	SJVUAPCD	CCOS	ABCH	--	EJN
South Central Coast	San Luis Obispo	S1	New - CCOS	CCOS	--	--	ABDJN
Angiola	Tulare	S1+	CRPAQS	CCOS	--	ABDJ(1)SRUVW	FJMN
Bethel Island	Contra Costa	S2	BAAQMD, CRPAQS	CCOS	ABCH	S	JMN
Altamont	Alameda	S2	CRPAQS	CCOS	--	ASU	BCEFJMN
Pacheco Pass	Merced	S2	CRPAQS	CCOS	--	AS	BCEFJMN
Northeast Sacramento	Sacramento	S2	SMAQMD	CCOS	ABC		EFJMN
Trimmer (Forest Service)	Fresno	S2	CRPAQS	CCOS	--	A(3)S	BDFJMN
Edison	Kern	S2	ARB	ARB/CCOS	ABC	--	EFJMN
Dublin (Nextel)	Alameda	R	CRPAQS	CCOS	--	S	ABCEFGHI JKLMNRST
Sloughhouse	Sacramento	R	SMAQMD	CCOS	ABC	--	EFGHI JKLMNORST
Downwind of Fresno	Fresno	R	New - CCOS	CCOS	--	--	ABCEFGHI JKLMNPQRST

(1) CRPAQS Annual Site, 24-hour canister sample every 6th day.
(2) Bay Area component of CCOS, samples collected and analyzed by BAAQMD.
(3) 10-m meteorological tower located nearby.

Table 4.6-1
Upper Air Meteorological Measurements for CCOS

Site ID	Name	Purpose	Justification	Operator[a]	Contractor	Radar[b]	RASS[b]	Sodar[b,c]	Sonde[b,d]	Nexrad
ABK	Arbuckle	Intrabasin transport	Location provides coverage of predominant summer flow through Sacramento Valley.	CCOS	NOAA-ETL	SC	SC			
ABU	N. of Auburn, S. of Grass Valley	Upslope/downslope flow, downwind of major area source	Site to monitor possible summer eddy flow, vertical temperature structure evolution, model input and evaluation data. Downwind of Sacramento area source.	CCOS	NOAA-ETL	SC	SC			
ACP	Angel's Camp	Upslope/downslope flow, complex terrain for challenging model evaluation	Served as site to capture eddy flow, mixing, vertical temperature structure, model input and evaluation data during SJVAQS/AUSPEX	CCOS	NOAA-ETL			SC		
ANGI	Angiola	Intrabasin transport, vertical mixing, micrometeorology	Positioned to monitor transport up the valley, low level nocturnal jet flow, and Fresno eddy flow patterns. Collocated with tall tower.	CRPAQS-rwp, CCOS-sodar	NOAA-ETL	AC	AC	SC		
BBX	Beale AFB-Oro Dam Blvd West	Northern boundary transport, synoptic conditions	Fulfill needs of National Weather Service and Beale AFB flight operations; existing long-term site.	BAFB						AC
BHX	Humboldt County	Onshore/offshore transport	Fulfill needs of National Weather Service; existing long-term site	NWS						AC
CAR	Carizo Plain	Interbasin tranport.	Monitor tranport between San Joaquin Valley and South Central Coast Air Basins.	CCOS	NOAA-ARL	SC	SC	SC		
CRG	Corning	Nothern Valley barrier, characterize Northern SV convergence zone.	To observe southerly barrier winds along the Sierra Nevada which may be a transport mechanism. May characterize extent of northerly flow into SV for some scenarios.	CCOS	NOAA-ETL	SC	SC			
DAX	Sacramento	Intrabasin transport	Fulfill needs of National Weather Service; existing long-term site	NWS						AC
EDI	Edison	Interbasin transport through Tehachapi Pass. Downwind of major source.	Site to observe possible divergence flow at southern end of the valley, low level jet flow, and eddy flows. Data from SJVAQS/AUSPEX taken at Oildale supports these observations. Downwind of Bakersfield area source.	ARB		AC	AC			
EDW	Edwards AFB	Intrabasin transport	Existing long term site. Transport through Tehachapi Pass, desert mixed layer, synoptic conditions.	EAFB					AS SE	

Table 4.6-1 (continued)
Upper Air Meteorological Measurements for CCOS

Site ID	Name	Purpose	Justification	Operator[a]	Contractor	Radar[b]	RASS[b]	Sodar[b,c]	Sonde[b,d]	Nexrad
EYX	Edwards AFB	Intrabasin transport	Fulfill needs of National Weather Service and Edwards AFB flight operations; existing long-term site.	EAFB						AC
FAT	Fresno Air Terminal	Intrabasin transport	Capture the Fresno eddy, characterize urban mixing heights, transport from major Fresno area source.	CCOS	NOAA_ETL	SC-449	SC	SC		
FSF	Fresno-First Street	Urban Heat Island, Intrabasin Transport, Synoptic Conditons. Characterize	Site to monitor possible summer eddy flow, vertical temperature structure evolution, model input and evaluation data. Flow out of Fresno.	CCOS	T&B				SE	
HNX	Hanford-edge of town between fairgrounds and municipal	Intrabasin Transport	Fulfill needs of National Weather Service; existing long-term site.	NWS						AC
HUR	Huron	Intrabasin transport	This is to monitor daily transport from north to south with average surface winds during afternoons and early evening and the low level nocturnal jet on the western side of the SJV; models should do well with topographic	CRPAQS or ARB	NOAA-ETL or ARB	AC	AC			
LGR	Lagrange	Upslope/downslope flow	This site represents valley/Sierra interactiion in northern SJV. Monitor possible upslope flow transport of pollutants during day and possible recirculation via Mariposa River Valley exit jet by night. Also completes the west to east transect across SJV from SNA to LIV sites.	CCOS	NOAA_ETL	SC	SC			
LHL	Lost Hills	Intra&interbasin transport across Carizo Plain	Situated east of the coastal range and represents uniform flow aloft at 1000m as opposed to a site on the Tremblor Range. Good position to detect the direction of flow between the Carrizo Plain and the SJV	ARB or NOAA		AC	AC			
LIV	Livingston	Intrabasin transport	Representative of mid SJV flow since variation in flow is small along the valley's central axis.	CRPAQS-rwp, CCOS-	NOAA_ETL	AC	AC	SC		
LVR	Livermore	Intrabasin transport	Monitor flow through Castro Valley between San Leandro/Oakland and Livermore.	CCOS	STI	SC	SC			

**Table 4.6-1 (continued)
Upper Air Meteorological Measurements for CCOS**

Site ID	Name	Purpose	Justification	Operator[a]	Contractor	Radar[b]	RASS[b]	Sodar[b,c]	Sonde[b,d]	Nexrad
MJD	Mojave Desert	Interbasin transport	Chosen to monitor interbasin flow out of the San Joaquin Valley to the desert via Tehachapi Pass. Previous monitoring studies have shown a clear exit jet out of the SJV in this region. The exact site is to be determined.	CRPAQS	NOAA_ETL	AC	AC			
MKR	Mouth Kings River	Upslope/downslope flow	The current suspicion is that the mountain exit jets flow along the axis of the valley over Trimmer. A site between Academy and Humphrey's Station is more likely to observe the flow than a site at Piedra.	CRPAQS	NOAA_ETL	AC	AC			
MON	Monterey	Onshore/offshore transport	Existing long term site. Transport through Tehachapi Pass, desert mixed layer, synoptic conditions.	USNPGS		AC	AC			
MUX	Santa Clara	Interbasin transport	Fulfill needs of National Weather Service; existing long-term site.	NWS						AC
NTD	Point Mugu USN	Onshore/offshore transport, synoptic conditions.	Existing long term site	USN					AS SE	
OAK	Oakland airport	Onshore/offshore transport, synoptic conditions.	Fulfill needs of National Weather Service; existing long-term site.	NWS					AS SE	
PLE	Plesant Grove	Intra- and interbasin tranport.	Monitor transport between Sacramento and Upper Sacramento Valley and North Mountain	CCOS	NOAA-ETL	SC	SC			
POR	Pt. Reyes	On-shore flow, along coast flow	Coastal meteorology impacts air quality not only in coastal regions but by modulating the strength, and intrusion extent of the sea breeze.	CCOS	STI	SC	SC			
REV	Reno National Weather Service Office	Northern boundary transport, synoptic conditions	Fulfill needs of National Weather Service; existing long-term site.	NWS					AS	
RGX	Washoe County-Virginia Peak	Northern boundary transport, synoptic conditions	Fulfill needs of National Weather Service; existing long-term site	NWS						AC
RIC	Richmond	Onshore/offshore transport.	Monitor possible deeper mixed layer.	CCOS-p, CCOS-sodar	NOAA-ETL	SC	SC	AC		

Table 4.6-1 (continued)
Upper Air Meteorological Measurements for CCOS

Site ID	Name	Purpose	Justification	Operator[a]	Contractor	Radar[b]	RASS[b]	Sodar[b,c]	Sonde[b,d]	Nexrad
SAC	Sacramento	Intra and interbasin transport	Monitor N-S flow within Sacramento Valley, afternoon sea breeze intrusion, and flow from San Francisco Bay Area; help resolve northern boundary of SV/SJV divergence zone.	SMUAPCD/ARB		AC	AC		SE	
SHA	Shasta	Intrabasin transport	Monitor flow at the northern end of the Sacramento Valley. Eddy flows.	CCOS	NOAA-ETL	SC	SC			
SNA	Santa Nella, E of I-5 toward Los Banos	Interbasin transport from Pacheco Pass, model QA.	May represents flow through Pacheco pass during some coastal valley intrusions; represents along-valley flow on western side at other times. Models should handle channeled, along-valley flow well at this point.	CRPAQS or ARB	NOAA-ETL or ARB	AC	AC			
SNM	San Martin	Intra- and interbasin transport, flow through Santa	Monitor transport from SFBA to NCC via Santa Clara Valley south of San Jose.	CCOS	STI	SC	SC			
SOX	Orange County	Onshore/offshore transport.	Fulfill needs of National Weather Service; existing long-term site	NWS						AC
TRA	Travis AFB	Interbasin transport between San Joaquin Valley and Bay	Existing long term site	TAFB		AC		WC		
TRC	Tracy, W of Tracy, S of I-205, W of I-580	Interbasin transport through Altamont Pass.	Monitor flow through Altamont Pass for San Francisco Bay Area to SJV transport in p.m.; also help monitor less frequent off-shore flow.	CCOS	STI	SC	SC			
VBG	Vandenberg AFB	Onshore/offshore transport, synoptic conditions.	Existing long term site	VAFB		AC			AS SE	
VBX	Orcutt Oil field-Vandenberg	Onshore/offshore transport.	Fulfill needs of National Weather Service and Vandenberg operations; existing long-term site.	VAFB						AC
VIS	Visalia	Intrabasin transport.	Existing long term site	SJVUAPCD		AC	AC			
VTX	Ventura County	Intrabasin transport-onshore/offshore transport.	Fulfill needs of National Weather Service; existing long-term site.	NWS						AC
	Pittsburg	Plume Study		PG&E	PG&E	SC	SC			
	Moss Landing	Plume Study		PG&E	PG&E	SC	SC			

Table 4.6-1 (continued)
Upper Air Meteorological Measurements for CCOS

Totals by Operator:

Operator[a]	Contractor	Radar[b]	RASS[b]	Sodar[b,c]	Sonde[b,d]	Nexrad
CCOS		13	13	5	2	
CRPAQS		6	6			
ARB/Districts		4	4	1		
Military/U.S.		3	1		4	10
TOTALS		26	24	6	6	10

Footnotes

[a]CCOS=Central California Ozone Study (this study)' ARB=Air Resoures Board, BAAQMD=Bay Area Air Quality Management District; USNPGS=U.S. Navy Post Graduate School; SJVUAPCD=SJV Unified Air Pollution Control District, NWS=National Weather Service; SMAQMD=Sacramento Metropolitan Air Quality Management District, CRPAQS=California Regional PM10/PM2.5 Air Quality Study; VAF=Vandenberg Air Force Base, TAF=Travis Air Force Base, EAF=Edwards Air Force Base, USN=U.S. Navy.

[b]AC=Annual continuous measurements; AS=Annual sporadic measurements, SC=Summer continuous, 6/1/2000-9/30/2000; SE=Summer episodic measurements on forecasted days.

[c]Summer campaign sodars added at some sites as part of CRPAQS/CCOS except at RIC.

[d]Balloon launch on episode days. Frequency should be 4-8 times per day but include 0700 and 1900 PST.

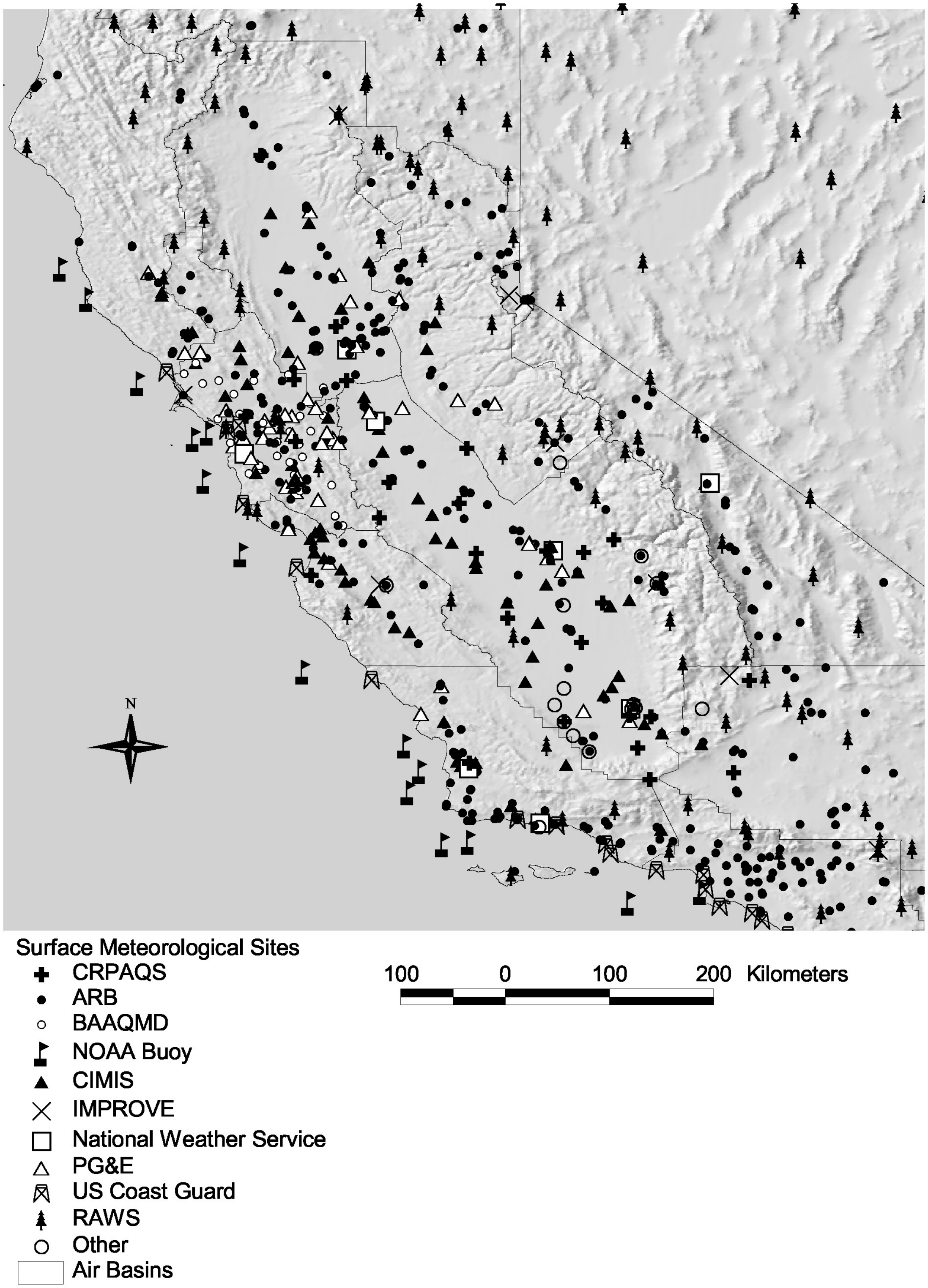

Figure 4.4-1. Central California surface meteorological networks and measurement locations.

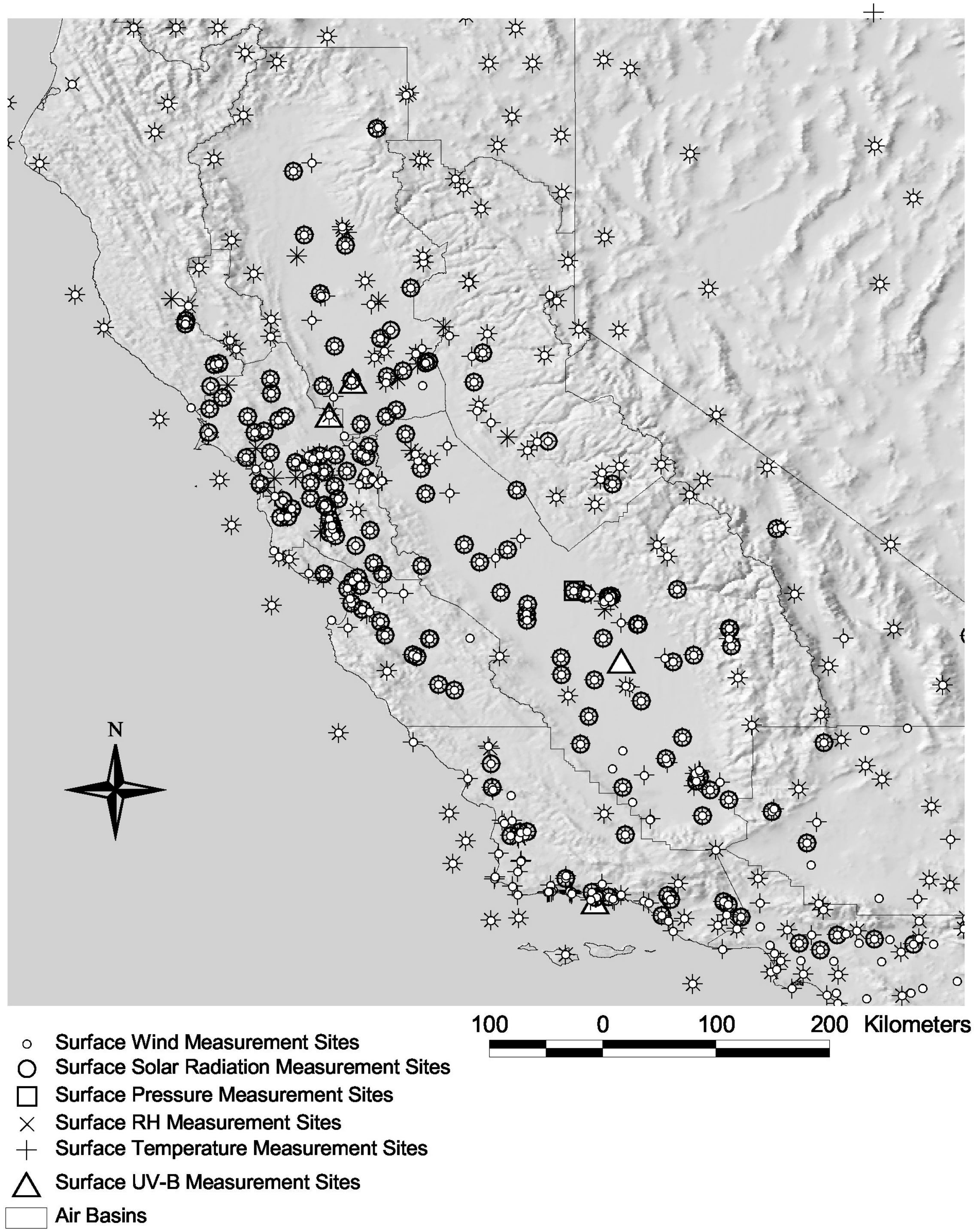

Figure 4.4-2. Surface meteorological observables measured in the combined central California meteorological network.

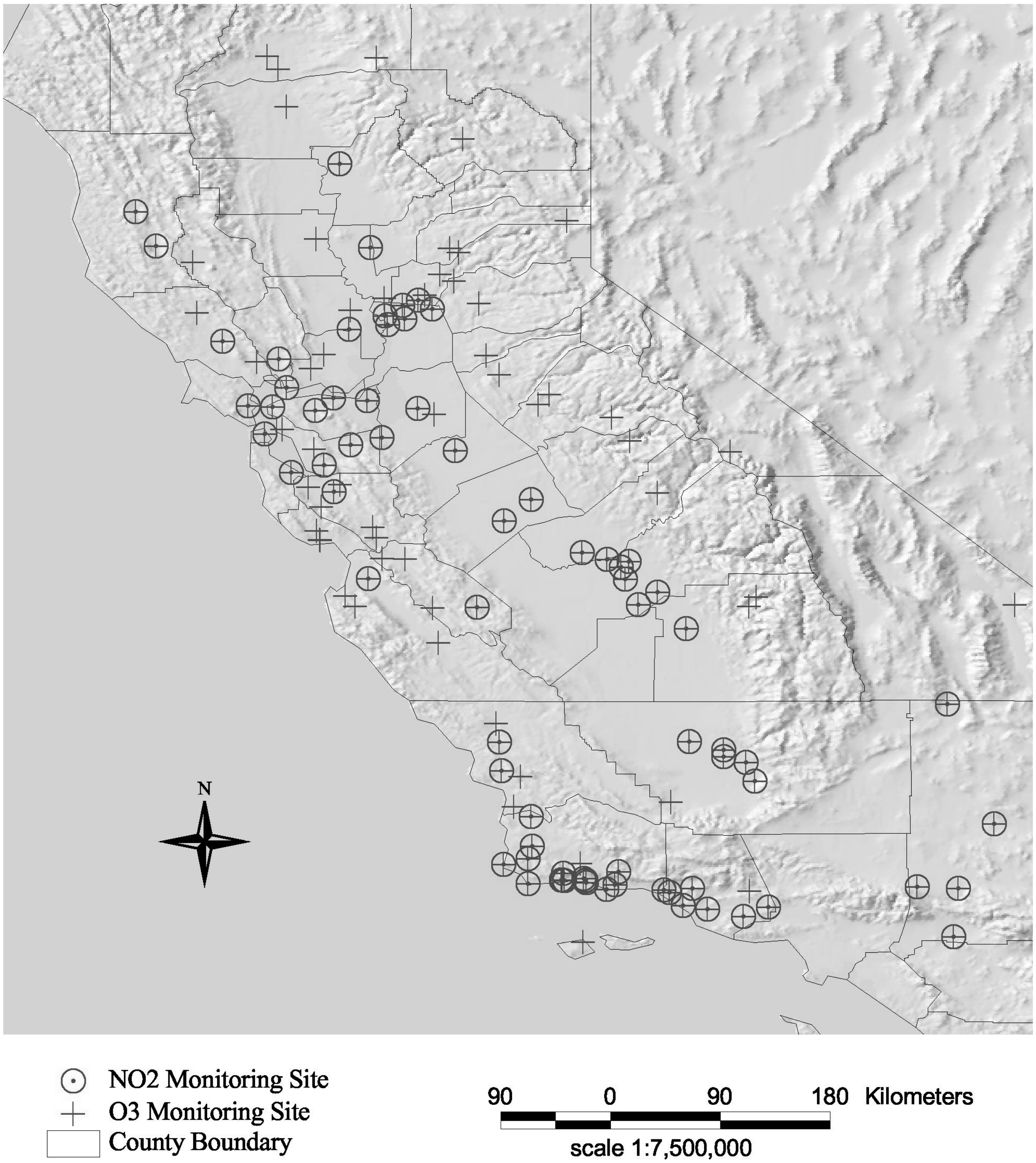

Figure 4.5-1. Existing routine O_3 and NOx monitoring sites

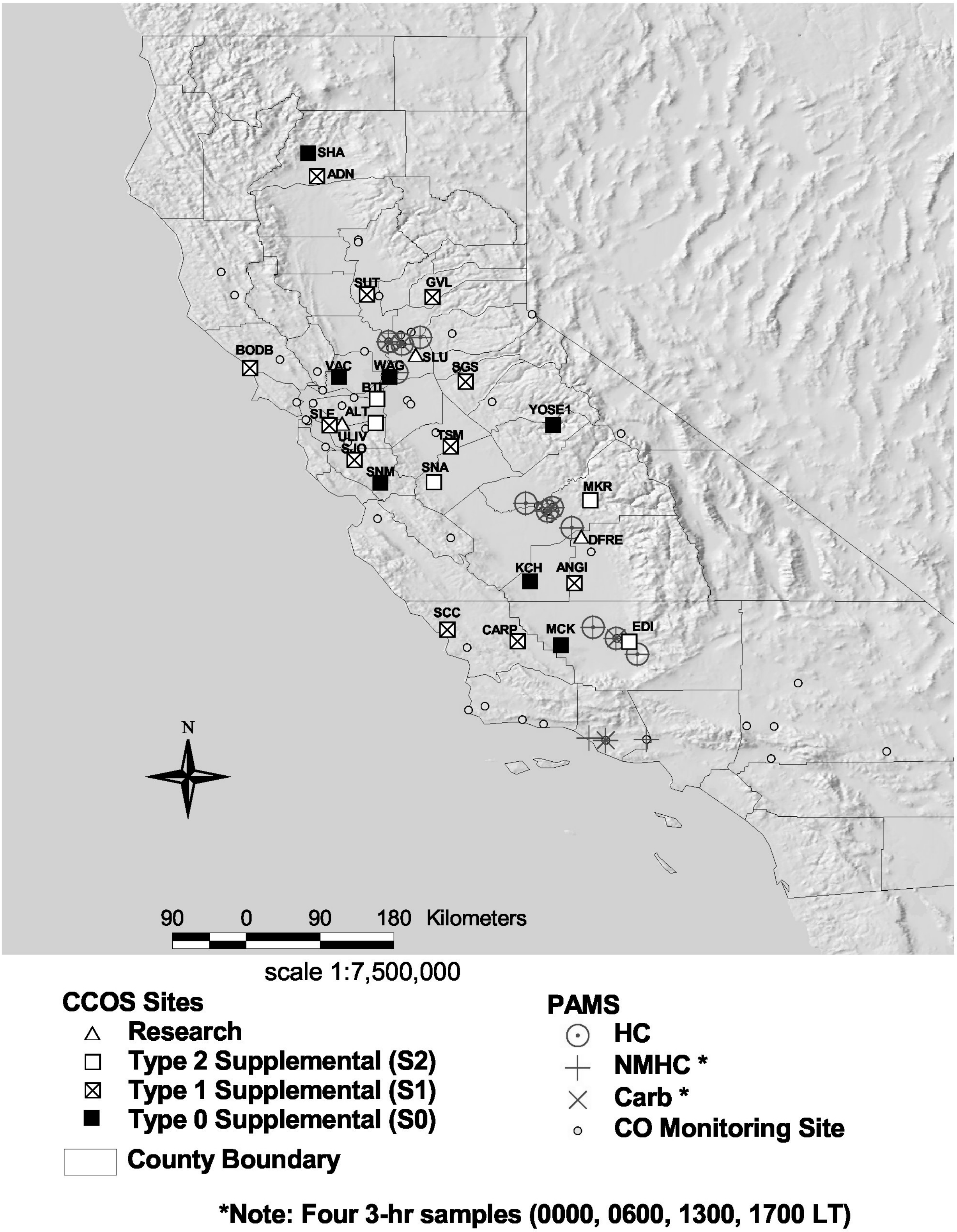

Figure 4.5-2. CCOS supplemental air quality and meteorological monitoring sites and Photochemical Assessment Monitoring Stations

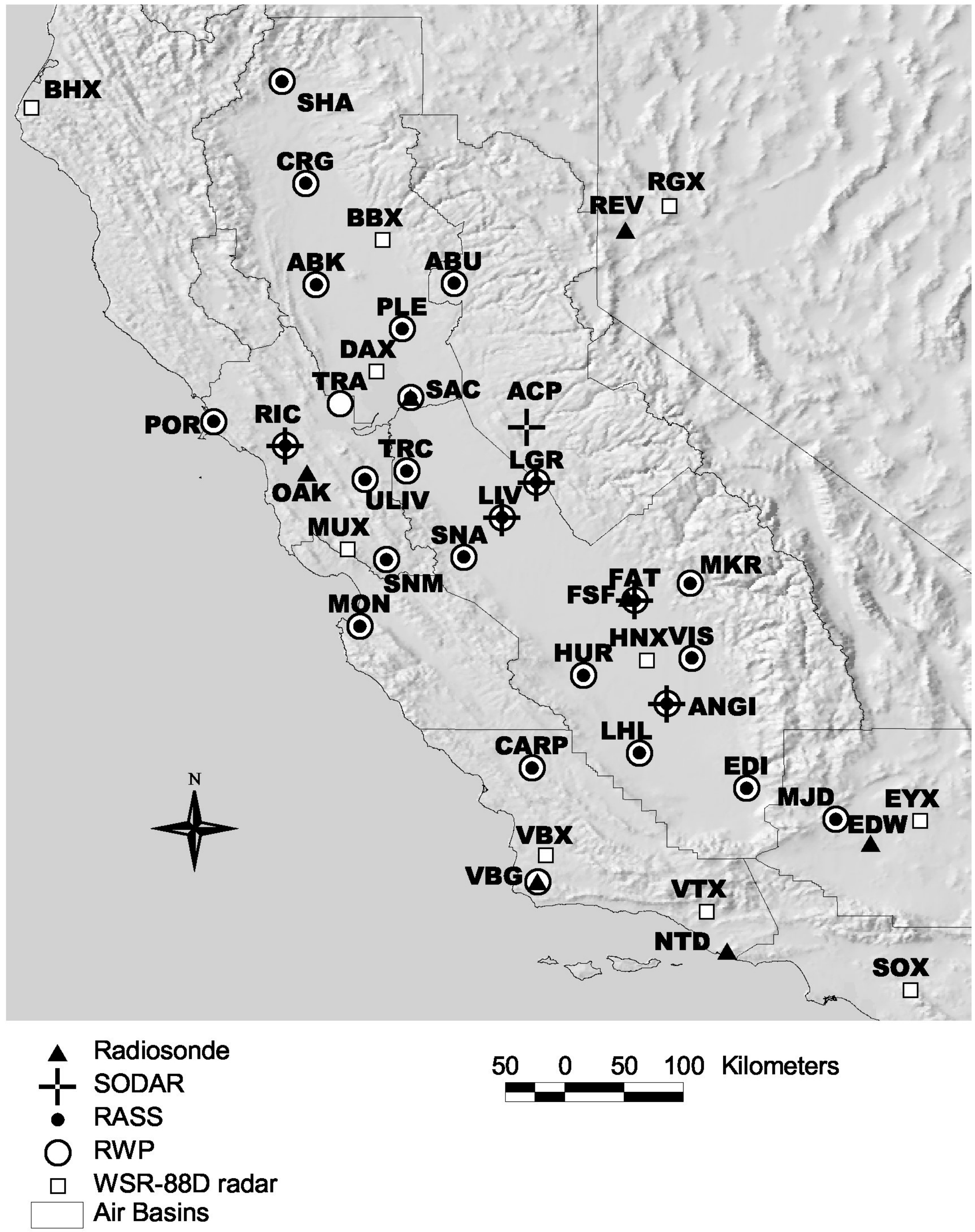

Figure 4.6-1. Upper air meteorological measurements during the summer campaign, including annual average study sites and NEXRAD (WSR-88D) profilers.

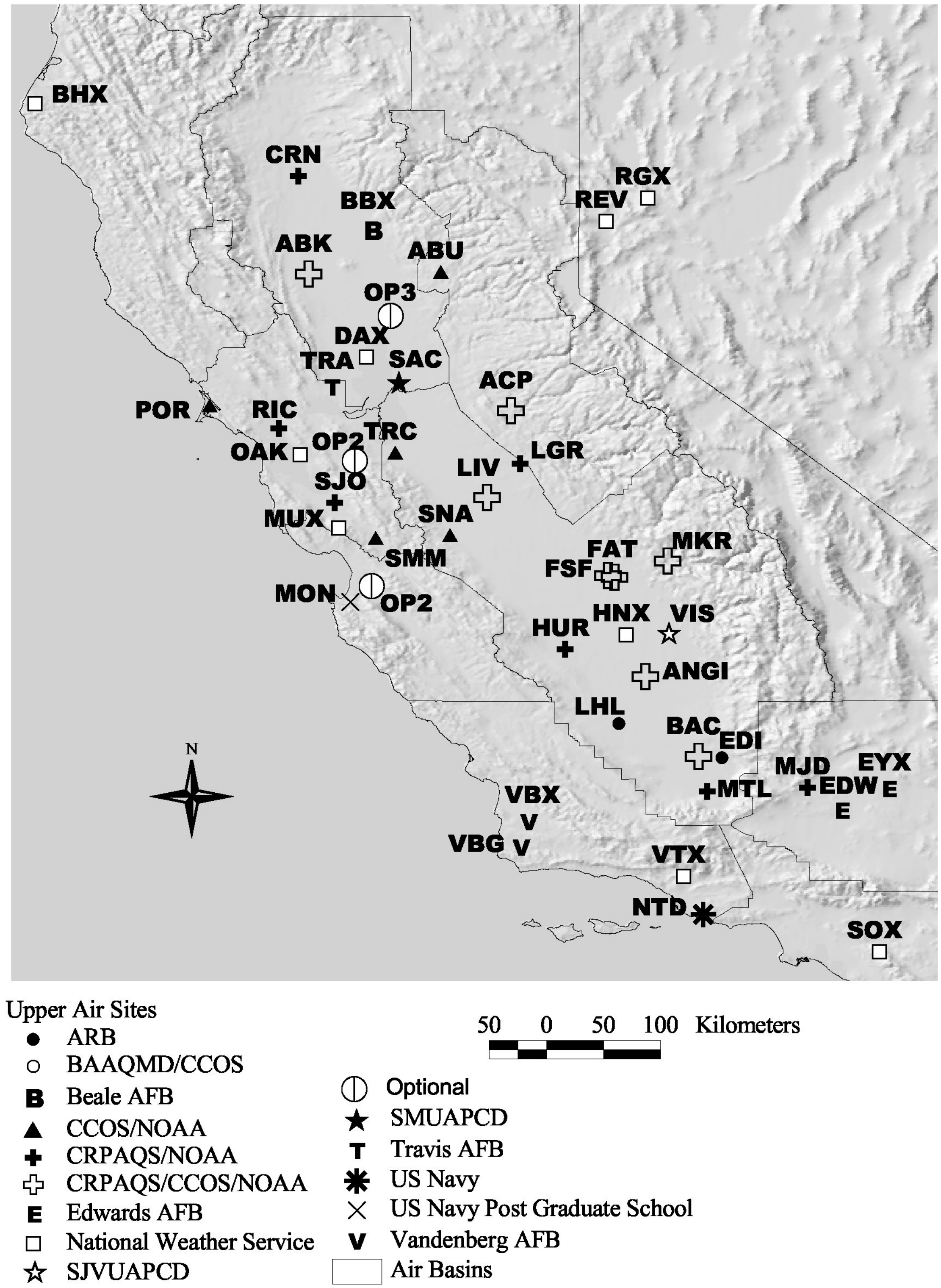

Figure 4.6-2. Upper air meteorological measurement network indicating operating agency.