

Health-Related Measurements from the Fresno Supersite

John G. Watson*, Judith C. Chow, John L. Bowen

Desert Research Institute, 2215 Raggio Pkwy., Reno, NV 89512

Susanne Hering

Aerosol Dynamics Inc., 2329 Fourth St., Berkeley, CA 94710

Peter Ouchida and William Oslund

California Air Resources Board, PO Box 2815, Sacramento, CA 95812

Keywords: supersite, PM_{2.5}, particle size, aerosol chemistry

Abstract

The Fresno Supersite intends to: 1) test and evaluate non-routine monitoring methods, with the intent to establish their comparability with existing methods and determine their applicability to air quality planning, exposure assessment, and health impact determination; 2) increase the knowledge base of aerosol characteristics, behavior, and sources so regulatory agencies can develop standards and strategies that protect public health; and 3) acquire measurements that can be used to evaluate relationships between aerosol properties, co-factors, and observed health end-points. Supersite observables include *in-situ*, continuous, short duration measurements of: 1) PM_{2.5}, PM₁₀, and coarse (PM₁₀ minus PM_{2.5}) mass; 2) PM_{2.5} sulfate, nitrate, carbon, light absorption, and light extinction; 3) numbers of particles in discrete size bins ranging from 0.005 to ~10 μm; 4) criteria pollutant gases (O₃, CO, NO_x); 5) reactive gases (NO_y, HNO₃, NH₃); and 6) single particle characterization by time of flight mass spectrometry. Field sampling and laboratory analysis are applied for: 1) gaseous and particulate organic compounds (light hydrocarbons, heavy hydrocarbons, carbonyls, polycyclic aromatic hydrocarbons [PAH] and other semi-volatiles); and 2) PM_{2.5} mass, elements, ions, and carbon. Observables common to other Supersites, including: 1) daily PM_{2.5} 24-hour average mass with Federal Reference Method (FRM) samplers; 2) continuous hourly and five minute average PM_{2.5} and PM₁₀ mass with Beta Attenuation Monitors (BAM) and Tapered Element Oscillating Microbalances (TEOM); 3) PM_{2.5} chemical speciation with an EPA speciation monitor and protocol; 4) coarse particle mass by dichotomous sampler and difference between PM₁₀ and PM_{2.5} BAM and TEOM measurements; 5) coarse particle chemical composition; and 6) high sensitivity and time resolution scalar and vector wind speed, wind direction, temperature, relative humidity, barometric pressure, and solar radiation. The Fresno supersite is coordinated with health studies that will use these data in establishing relationships with asthma, other respiratory disease, and cardiovascular changes in animal subjects.

* Corresponding author.

INTRODUCTION

The U.S. Environmental Protection Agency's (EPA) Supersites program (U.S. EPA, 1998a) intends to operate research-grade air monitoring stations to improve understanding of measurement technologies, source contributions and control strategies, and effects of suspended particles on health. Supersites are being established in seven urban areas within the continental United States: 1) New York, NY; 2) Pittsburgh, PA; 3) Baltimore, MD; 4) Houston, TX; 5) St. Louis, MO; 6) Fresno, CA; and 7) Los Angeles, CA. Supersites' guiding principles are that they: 1) test specific scientific hypotheses appropriate for the monitored airshed and suite of measurements; 2) provide measurements that can be compared and contrasted among the seven urban areas; 3) are integrated into larger monitoring networks and research studies; and 4) leverage EPA investments with contributions from other agencies. The information derived from these Supersites is expected to complement information from PM_{2.5} and PM₁₀ (particles with aerodynamic diameters less than 2.5 and 10 μm , respectively) measurement networks operated at Community Representative (CORE), transport, and background locations as part of the national PM_{2.5} monitoring network.

The Fresno Supersite is acquiring advanced air quality measurements related to suspended particulate matter to accomplish the following objectives:

- Test and evaluate non-routine monitoring methods, with the intent to establish their comparability with existing methods and determine their applicability to air quality planning, exposure assessment, and health impact determination.
- Increase the knowledge base of aerosol characteristics, behavior, and sources so regulatory agencies can develop standards and strategies that protect public health.
- Evaluate relationships between aerosol properties, co-factors, and observed health end-points.

Specific hypotheses have been formulated related to each of these objectives. Measurement methods have been selected to provide the variables needed to test these hypotheses. Supersite measurements are coordinated with health studies in the region, specifically a multi-million dollar effort by the state of California to better understand the relationships between air quality and asthma.

Previous studies (Ackermann, 1994; Arey et al., 1991; Barone et al., 1978; Baxter and Pederson, 1994; Blanchard et al., 1999; Blumenthal and Lurmann, 1994; Blumenthal and Watson, 1994; Bytnerowicz et al., 1991, 1992; Campbell and Shimp, 1998; Carroll and Baskett, 1979; Chow et al., 1992, 1993, 1994a, 1994b, 1996, 1997, 1998a, 1998b, 1999; Chu, 1995; Coe and Chinkin, 1998; Collett et al., 1999; Dabdub et al., 1999; Desjardins et al., 1995; Dickson et al., 1994, 1995; Dolislager and Motallebi, 1998; Douglas and Kessler, 1991; Easter and Pennell, 1994; Ewell et al., 1995; Feldstein et al., 1963; "Feldstein et al., 1963"; Flocchini et al., 1976; Fosberg and Schroeder, 1966; Fujita et al., 1995; Fung et al., 1994; Gertler and Coulombe, 1994; Glotfelty et al., 1987; Gordon et al., 1994; Grantz and McCool, 1992; Grantz et al., 1994, 1995, 1996; Green et al., 1992a, 1992b; Guo et al., 1995a, 1995b; Hackney et al., 1994; Hall et al., 1998; Harrington et al., 1993; Hoag et al., 1999; Hubbe and Pederson, 1994; Hughes et al., 1998; Jacob et al., 1985, 1986a, 1986b, 1987; Jassim et al., 1994; Jenkins et al., 1991; Kessler et al.,

1991; Kessler and Douglas, 1994; Lillis et al., 1999; MacPherson et al., 1995; Magliano, 1988, 1994; Magliano and Chinkin, 1994; Magliano et al., 1998, 1999; Mahrt et al., 1994a, 1994b, 1995; Mahrt and Sun, 1995, 1998; Mahrt, 1998; Massman et al., 1994, 1995; Massman and Grantz, 1995; Matsumura et al., 1992; Mitic et al., 1995; Moore et al., 1987; Morris et al., 1991, 1994; Motallebi, 1998; Niccum, 1994, 1995; Niccum et al., 1995; Oncley et al., 1993; Padro et al., 1994a, 1994b; Pai et al., 1995; Pedersen and Cahill, 1989; Pederson et al., 1994, 1995; Pielke, 1994; Pun and Seigneur, 1999; Quint et al., 1993; Ranzieri and Thuillier, 1994; Rappolt and Teuscher, 1994; Reible et al., 1982; Richards et al., 1999; Roberts et al., 1994; Roth and Smith, 1994; Roth et al., 1994; Rowe and Chestnut, 1985; Seaman and Stauffer, 1994; Seaman and Stauffer, 1994; Seaman et al., 1995; Seiber et al., 1993; Seigneur, 1994; Seigneur et al., 1994; Shimp et al., 1996; Smith, 1994; Smith and Lehrman, 1994; Smith et al., 1995; Solomon, 1994; Solomon and Magliano, 1998, 1999; Start, 1994; Strader et al., 1999; Sun and Mahrt, 1995; Tanner and Zielinska, 1994; Tanrikulu and Ranzieri, 1998; Tanrikulu et al., 1998; Temple et al., 1987; Thuillier, 1995; VanCuren, 1998; Watson et al., 1994a, 1994b; Williams et al., 1977; Wilshire et al., 1981; Winer et al., 1992; Ziman et al., 1994) show that emissions, aerosol composition, and meteorology change substantially over the course of a day, between seasons, and between different years in central California where Fresno is located. It is conjectured that relationships between different measurement methods, aerosol characteristics, and health endpoints depend on these changes. Evaluating these relationships requires frequent samples over short durations for a multi-year monitoring period.

Although all of the measurement methods applied at Fresno have been used in short-term programs, the Supersite represents the first application of these methods together for multi-year monitoring. The objectives of this paper are to: 1) describe the area represented by Supersite monitoring and the historical air quality context for current measurements; 2) specify the variables measured at the Supersite and at surrounding locations with respect to method, sampling period, sampling frequency, and sample duration; 3) state the hypotheses to be tested with measurements and data analysis methods needed for that testing; and 4) provide some examples of measurements acquired that are applicable to some of the hypotheses.

FRESNO STUDY AREA

Fresno and its sister city of Clovis are located in the center of California's San Joaquin Valley, which encompasses nearly 64,000 km² and contains a population in excess of three million people. The Fresno metropolitan area, is the largest population center for 150 km to the north and south. The more than 500,000 population is ethnically diverse, with ~51% White, ~36% Hispanic, ~5% African-American, and ~8% Asian. The Fresno area experiences frequent hospitalizations for asthma ranking second in California for African-American children, third for Hispanic children, and eighth for White children.

The San Joaquin Valley in which Fresno is situated is bordered on the west by the coastal mountain range and on the east by the Sierra Nevada range. These ranges converge at the Tehachapi Mountains in the southern end of the Valley, nearly 200 km south of Fresno. Weather changes with season throughout the year. Spring often experiences small frontal passages with low moisture content resulting in high winds. Summer meteorology is driven by heating over the Mojave desert that creates a thermal low pressure system and a large pressure gradient between the coast and the desert. Fall is influenced by the Great Basin High, with prolonged periods of

slow air movement and limited vertical mixing. Mixing depths and ventilation are low in the morning during all seasons and remain low throughout the day during the winter. Relative humidities are highest in the winter, with low relative humidities in the summer and fall. For spring, summer, and fall, the typical winds are northwesterly, directed along the Valley axis. This is the predominant non-winter wind flow pattern both during the day and night, although it is more sluggish during fall.

Central California emission source categories include: 1) small to medium sized point sources (e.g., power stations, incinerators, cement plants, and steam generators); 2) area sources (e.g., fires, wind blown dust, petroleum extraction operations, cooking, and residential fuel combustion); 3) mobile sources (e.g., cars, trucks, off-road heavy equipment, trains, and aircraft); 4) agricultural and ranching activities (e.g., fertilizers, herbicides, tilling and livestock); and 5) biogenic sources (e.g., oxides of nitrogen from biological activity in soils and hydrocarbon emissions from plants). Agriculture is the main industry surrounding Fresno, with cotton, alfalfa, corn, safflower, grapes, and tomatoes being the major crops. Cattle feedlots, dairies, chickens, and turkeys constitute most of the animal husbandry in the region. Oil and gas production, refining to the south, waste incineration to the northwest, electrical co-generation at various locations, transportation, commerce, local government and light manufacturing constitute the remainder of the economy.

PM_{2.5} levels measured from 1991 to 1996 with dichotomous samplers operating every sixth day show annual averages ranging from 18 to 24 µg/m³. The highest 24-hour averages ranged from 56 to 93 µg/m³ during this period. These are in excess of the annual (15 µg/m³) and 24-hour (65 µg/m³) National Ambient Air Quality Standards (NAAQS) for PM_{2.5}. The highest PM_{2.5} concentrations are typically found during winter and fall, with the lowest concentrations occurring during spring and summer (Watson et al., 1998). PM_{2.5} constitutes ~80% of PM₁₀ during winter and ~50% of PM₁₀ during the rest of the year (Chow et al., 1993, 1996, 1998a, 1998b).

Fresno experiences high ammonium nitrate levels during winter and sometimes in fall, large geological contributions during fall and spring, and medium to high carbon concentrations throughout the year. Organic carbon concentrations are enhanced by vegetative burning and cooking during winter (Schauer and Cass, 1999) when dispersion is poor. Ammonium sulfate levels average <2 µg/m³ throughout the year. Owing to multiday accumulation of organic precursors, Strader et al. (1999) hypothesize that up to 20% of wintertime organic material during some parts of the day may be of secondary origin, but organic to elemental carbon proportions are typically similar to those of primary emissions. This rich variability in aerosol concentration and composition found throughout the year, over multi-day episodes, and even within a day provides the contrasts and extremes needed to stress measurement methods and to evaluate changes in health end-points. The Fresno atmosphere presents substantial measurement challenges caused by multiple area sources, volatile aerosol, and fogs and rain during winter.

SITE DESCRIPTION

The California Air Resources Board (ARB) has operated the site at 3425 First Street (coordinates -119.7727725 °W, 36.78184232 °N), ~3 km north of the downtown commercial district, since 1990. Commercial establishments, office buildings, churches, and schools are

located north and south of the monitors. Medium-density single-family homes and some apartments are located in the blocks to the east and west of First St. Sampling inlets are located on a second story rooftop ~10 m above ground level and ~50 m from the west side curb of First St., a four-lane artery with moderate traffic levels. Other PM sites in the Fresno metropolitan area include the Clovis site, located ~10 km northeast of First St., the Drummond St. site located ~5 km south, and the N. Villa Ave. site in the southeastern part of the city.

Two satellite sites (Chow and Egami, 1997) are located in the vicinity of the First St. site to determine its zone of representation and the effects of local sources on chemical concentrations. A vehicle-dominated site at Shields Ave. and SR 41 is in a residential area near a freeway onramp ~1 km west-southwest of the Supersite and will quantify incremental carbon contributions from directly emitted vehicle exhaust. A residential site near a city park is located ~1 km north northeast of the Supersite on a lightly-traveled neighborhood street. For most of the year this site will represent a neighborhood similar to that around the First St. Supersite. During winter, however, Schauer and Cass (1998) attributed the large increment in organic carbon near this site to neighborhood wood combustion. A third satellite site located at the Selma Airport, ~30 km south southeast of the Supersite, is outside of the populated area and provides the ability to separate urban-scale from regional-scale PM contributions.

The Angiola Tower site operated as part of the California Regional PM₁₀/PM_{2.5} Air Quality Study (CRPAQS, Watson et al., 1998) is equipped with much of the same measurements as the First St. Supersite. The Angiola site is located in a flat field ~100 km south of Fresno with minimal influence from non-urban sources. A 100 m tower is instrumented with micrometeorological and particle monitors to evaluate the vertical mixing and transport of pollutants between major urban areas such as Fresno and Bakersfield. Angiola measurements will be compared with those from Fresno to evaluate hypotheses about urban- and regional-scale contributions to excessive PM_{2.5} and PM₁₀ concentrations.

SUPERSITE MEASUREMENTS

Table 1 specifies the measurements at the Fresno Supersite, the methods applied, sample durations and frequencies, and the measurement periods. Simultaneous measurements available from the Angiola Tower site are also indicated, as are measurements at the three satellite sites.

Emphasis is on *in-situ*, continuous, short duration measurements of: 1) PM_{2.5}, PM₁₀, and coarse (PM₁₀ minus PM_{2.5}) mass; 2) PM_{2.5} sulfate, nitrate, carbon, light absorption, and light extinction; 3) numbers of particles in discrete size ranges from 0.005 to ~10 μm; 4) criteria pollutant gases (O₃, CO, NO_x); 5) reactive gases (NO_y, HNO₃, NH₃); and 6) single particle characterization. Field sampling and laboratory analysis are applied for: 1) gaseous and particulate organic compounds (light hydrocarbons, heavy hydrocarbons, carbonyls, polycyclic aromatic hydrocarbons [PAH] and other semi-volatiles); 2) PM_{2.5} mass, elements, ions, and carbon; and 3) PM_{2.5} and coarse-particle bioaerosols such as endotoxins, pollens, molds, and fungi.

Observables common to other Supersites, including: 1) daily PM_{2.5} 24-hour average mass with Federal Reference Method (FRM) samplers; 2) continuous hourly and five minute average PM_{2.5} and PM₁₀ mass with Beta Attenuation Monitors (BAM) and Tapered Element Oscillating

Microbalances (TEOM); 3) PM_{2.5} chemical speciation with an EPA speciation monitor and protocol; 4) coarse particle mass by dichotomous sampler and difference between PM₁₀ and PM_{2.5} BAM and TEOM measurements; 5) coarse particle chemical composition; and 6) high sensitivity and time resolution scalar and vector wind speed, wind direction, temperature, relative humidity, barometric pressure, and solar radiation. Satellite sites are equipped with PM_{2.5} nephelometers operating continuously and with Minivol Teflon and Quartz filter samplers operating for 24-hours every 6th day to quantify mass, elemental, ion, and carbon concentrations.

Quality assurance (QA) (U.S. EPA, 1998a, 1999a, 1999b; Hook et al., 1998; Patterson et al., 1998) plans describe measurements, quality control (QC), and QA activities. They specify Data Quality Objectives (DQO, U.S. EPA, 1994) to the extent that they apply to a research study and are supported by Standard Operating Procedures (SOPs) describing each measurement process (U.S. EPA, 1995, 1998b).

QA activities include: 1) assembling, reviewing, and archiving SOPs; 2) summarizing QC and QA procedures with measurement descriptions in QA plans; 3) specifying primary, calibration, performance test, and audit standards; 4) specifying data reporting conventions; 5) conducting systems audits of field, laboratory, and data management systems; 6) conducting performance audits of field and laboratories; 7) preparing data qualification statements; and 8) reporting QA results.

Several types of standards are needed for calibration, auditing, and performance tests. Table 2 identifies primary and transfer standards and the frequency of application for calibration, performance testing, and auditing. Methods for presenting these standards to instruments depend on the instrument. Flow rates are relatively simple to verify, but evaluating continuous monitor response to particle size is impractical under field conditions. Gas and meteorological monitors used in compliance networks have common procedures and standards for calibration and auditing. Calibration, performance testing, and auditing methods for laboratory operations are largely based on the preparation of standard solutions from mineral salts. The National Institute of Standards and Technology (NIST) does not provide these types of standards. Standard solutions in a large range of concentrations are available commercially for inorganic monoatomic and polyatomic ions. Performance testing for particle size and chemical speciation methods are still under development, and one of the research goals is to devise practical standards and methods to evaluate accuracy, precision, and validity.

Each *in situ* instrument is interfaced to an analogue and serial data acquisition system that is accessible by modem for data review and archiving. This communication capability will be used by health researchers to time clinical and toxicological measurements of test subjects.

The Supersite data base is available over the internet where it is integrated with other particulate, air quality, visibility, and meteorological data bases throughout Central California and measurements from other Supersites (Christensen et al., 1999). Validated measurements are posted within one calendar quarter of the previous quarter. The following types of tables are included in the project database:

- **Measurement locations:** Each measurement location is identified with a unique alphanumeric site ID accompanied by its name and address, coordinates, elevation, its

primary operator, and a summary of measurements taken at the site for different monitoring periods. Coordinates are determined with global positioning systems (GPS) using map basis NAD-83 (Federal Aviation Administration convention). The GPS time stamp is recorded to correct coordinate deviations.

- **Variable definitions:** Each variable is assigned a unique code that is accompanied by its definition, units, averaging time, measurement method, applicable temperature and pressure adjustments, and data reporting format.
- **Data validation flags:** Flags specific to each measurement are translated into a common set of validation flags that are carried with each data point. These are currently being defined by EPA for its speciation program, and this will be a starting point for Fresno Supersite data validation flags.
- **Data tables:** Basic data tables are constructed in normalized formats that have the same structure for different types of data. Each record contains the site code, sample date (MM/DD/YYYY), sample time (HH:MM:SS PST), variable code, measurement value, measurement precision, validity code, and validation level. These files will be transparent to most users and can be easily manipulated into convenient data analysis forms. Missing or invalid measurements are omitted or contain a “NULL” value. Separate tables are produced for different averaging times and for non-uniform data sets.
- **Validation indicators:** Detailed information on specific samples indicating the nature of the data qualification. These tables also contain the validation level assigned to each data item.

Data validity levels are designated in the validation tables for different stages of data acquisition and interpretation. Level 0 designates data sets downloaded from a field instrument that have not been examined. These measurements are used to evaluate instrument performance and to forecast conditions for special experiments, but they are not used for interpretive purposes. Level 1 data has been evaluated by the measurement investigator prior to submission to the data base. Values are removed for instrument downtime and performance tests, adjustments for calibration deviations are applied, extreme values are investigated, internal comparisons are made, blanks are subtracted, precisions are estimated and propagated, and appropriate data qualification flags are assigned. For sequential measurements, jump tests, standard deviation tests, and extreme value tests often identify values that need to be investigated. Level 2 data have completed comparison tests between data sets. These tests often result in the investigation of several samples that do not follow the same pattern as other measurements. These samples are sometimes re-analyzed, and re-designated as valid, invalid, or suspect as a result of the investigation.

Level 3 validation occurs after measurements are used to test hypotheses and values that are found contradictory to other values have been investigated. The first assumption upon finding a measurement inconsistent with physical expectations is that the unusual value is due to a measurement error. If, upon tracing the path of the measurement, nothing unusual is found, the value can be assumed to be a valid result of an environmental cause. Unusual values are identified as: 1) extreme values; 2) values that would normally track the values of other

variables in a time series; and 3) values for observables that would normally follow a qualitatively predictable spatial or temporal pattern.

HYPOTHESES AND TESTING METHODS

Table 3 summarizes the hypotheses associated with each objective. These hypotheses take advantage of the longer than 3-year record that will be available. $PM_{2.5}$ and PM_{10} NAAQS require at least a three-year record to determine attainment (U.S. EPA, 1997). While the CRPAQS monitoring and data analysis will provide detailed understanding of source contributions, meteorology, and atmospheric chemistry for one year and several multi-day episodes, they cannot provide the multi-year perspective needed to evaluate compliance with current NAAQS. A multi-year data set is also needed to evaluate alternative forms and indicators for new standards that might be promulgated nationally and in California as a result of new knowledge gained by research on mechanisms for particle effects on cardiovascular health. The application and evaluation of advanced, continuous measurement technology over this extended period will provide knowledge needed by regulators when they consider particle health indicators and candidates for future Federal Reference Methods.

Methods testing and evaluation hypotheses are based on evidence that there is a climatology for the validity and comparability of measurements acquired by the same instruments. Meteorological conditions, source contributions, and aerosol chemical composition in central California are known to change substantially over a year and even between different parts of the day (Chow et al., 1992, 1993, 1994, 1996, 1998, 1999).

Emissions reduction plans need to determine source contributions to primary particles and the limiting precursors for secondary particles. Conclusions drawn from special, short-term studies need to be generalized over at least the three-year period used to determine compliance or non-compliance with NAAQS, and over a longer period (~10 years) during which control strategies are implemented. These hypotheses examine how well conclusions from special studies such as CRPAQS stand up during subsequent years. They also place the Supersite monitoring period within a long-term record by comparison with Fresno First St. $PM_{2.5}$, PM_{10} , light scattering, coefficient of haze, and meteorological measurements are available from 1990 onward.

Mauderly et al. (1998) identify the following potential indicators for adverse health effects: 1) PM mass; 2) PM surface area; 3) PM number (i.e., ultrafine concentration); 4) transition metals (especially soluble fraction); 5) acids (especially sulfuric acid); 6) organic compounds; 7) bioaerosols; 8) sulfate and nitrate compounds (typically neutralized in whole or in part by ammonia or sodium); 9) peroxides and other free radicals that accompany and help to form PM; 10) soot (elemental carbon and associated PAH); and 11) correlated co-factors (other pollutants and variation in meteorology). Long-term data records of these variables are needed to examine relationships to health end-points and to determine the range of concentrations to which humans might be exposed. Owing to the complexity and expense of measurement technology, such long-term records are lacking.

Measurements at the Fresno Supersite can be acquired to support health studies related to all but category 9, peroxides and free radicals. Although sulfuric acid (category 5) could be

quantified, there is sufficient evidence that available sulfate anions are completely neutralized by ammonia and alkaline species in Central California. Nitric acid could be related to health endpoints, and attempts at its continuous measurement are important.

Hypotheses 3.1 through 3.9 in Table 3 require measurements from other studies related to human respiratory health in the Fresno area and Central California (Schlesinger, 1999). The Particulate Air Pollution and the Natural History of Childhood Asthma Study sponsored by ARB at UC Berkeley will test panels of children for four years, with a variety of lung function tests and clinical examinations made throughout the period. Indoor and outdoor samples will be acquired and personal exposure monitors will be used to develop long term exposure estimates. These will be correlated with Supersite measurements.

The Health Effects of Concentrated Ambient Particles from the Central Valley of California sponsored by U.S. EPA at UC Davis will expose rats to different levels of Central Valley aerosol, then sacrifice the rats and examine damage to their respiratory system. Portable particle concentrators for ultrafine, fine, and coarse fractions will be located near the Supersite to take advantage of its measurements. Extremes will be sought in particle number, composition, surface area, and other variables by selecting times of day and times of the year where contrasts are largest. Real-time access to Supersite measurements will be used to schedule experiments.

The Indoor Exposure from Ambient Concentrations Study sponsored by U.S. DOE at Lawrence Berkeley National Laboratory will develop a mechanistic model for infiltration of outside air into buildings. The model requires a detailed understanding of particle size and chemical characteristics, infiltration characteristics of various buildings, resident behavior, and outdoor meteorological conditions. Occupants of buildings near the Fresno Supersite will be recruited for participation. Indoor and outdoor measurements will be taken for representative seasons to test the model. Supersite measurements will be used for detailed characterization and to extrapolate limited and integrated indoor/outdoor measurements to a range of aerosol characteristics and weather conditions.

SUMMARY

The Fresno Supersite will provide: 1) a long-term record of simultaneous advanced particle measurements that includes a large range of concentration levels, particle sizes, and aerosol compositions, suitable for many purposes; 2) supportable conclusions about specific hypotheses concerning measurement method performance, causes of excessive pollution levels, and effects on health; 3) linkages and collaboration among air quality scientists, toxicologists, epidemiologists, exposure specialists, and clinicians that better integrate and communicate their scientific findings; 4) a research infrastructure in Fresno and at the First St. site that can serve research needs during and after Supersite monitoring; and 5) publications and reports that support local, state, and national decision-making related to standard setting and pollution controls.

Subsets of Fresno Supersite measurements will be comparable to similar measurements from other Supersites established nationwide and to other measurements from additional sites and special studies in Central California. Specifically, a non-urban Angiola site located ~100 km south of Fresno will have nearly identical measurements that will allow differentiation of

regional from urban contributions. The three-year record at Fresno is likely to overlap shorter monitoring periods at other U.S. Supersites, making possible day-to-day correspondence between measurements.

Fresno Supersite measurements will establish relationships between complex and less comprehensive measurements such as those acquired from speciation monitors, FRMs, and Minivol monitors. These data will be available over a wider spatial scale, both in Central California and throughout the United States. A better understanding of where and when these more widely available measurements are adequate surrogates for more complex measurements will provide opportunities for comparisons and contrasts.

ACKNOWLEDGMENTS

The Fresno Supersite work is supported by a cooperative agreement with the U.S. Environmental Protection Agency. The California Air Resources Board supplies several of the measurement systems, on-site field support, space, utilities, and data management.

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Table 1. Observables, measurement methods, sample durations, frequencies and monitoring periods for the Fresno Supersite.

Observable and Method	Size Range	Avg Time	Frequency	Period
Gases				
NO/NO _x (TEI 42 chemiluminescence) ^c	gas	1-hr	daily	1990 onward ^a
Ozone (API 400 UV absorption) ^c	gas	1-hr	daily	1990 onward ^a
Carbon monoxide (Dasibi 3008 infrared absorption)	gas	1-hr	daily	1990 onward ^a
Non-methane hydrocarbons	gas	1-hr	daily	1990 onward ^a
NO _y (high sensitivity TEI 42 with external converters and denuders) ^c	gas	5-min	daily	12/15/99 to 3/31/03
HNO ₃ (high sensitivity TEI 42 or Ecophysics chemiluminescent monitor with external converters, denuders & sequencers) ^d	gas	5-min	daily	12/1/00 to 3/31/03
Ammonia (TEI 17C high sensitivity with NO _x scrubbers and oxidizers) ^d	gas	5-min	daily	12/1/00 to 3/31/03
Filter Mass and Chemistry				
TSP mass (hivol w/ quartz filters) and lead	TSP	24-hr	12th day	1990 onward ^a
PM ₁₀ mass, sulfate, nitrate, chloride, and ammonium (hivol SSI w/ quartz filters)	0 to 10 μm	24-hr	6th day	1990 onward ^a
PM _{2.5} and coarse mass, elements (dichotomous samplers with Teflon filters)	0 to 2.5 μm 0 to 10 μm	24-hr	6th day	1990-11/1/00 ^a
PM _{2.5} and coarse mass, elements. Coarse endotoxins, spores, molds, fungi (dichotomous samplers with Teflon filters)	0 to 2.5 μm 0 to 10 μm	24-hr	every day	11/1/00-12/3/05 ^{a,c}
PM _{2.5} mass (collocated Andersen sequential FRM w/ Teflon filters)	0 to 2.5 μm	24-hr	daily for primary 6th day collocated	3/1/99 onward ^a
PM _{2.5} mass, light absorption, elements, ions, and carbon (two single-channel FRMs w/ Teflon and quartz filters)	0 to 2.5 μm	24-hr	6th day	7/5/99 to 6/29/00 (method evaluation)
PM _{2.5} mass, elements, ions, and carbon (six-channel Andersen RAAS speciation sampler w/ denuders and backup filters)	0 to 2.5 μm	24-hr	6th day	7/5/99 to 6/29/00 (method evaluation)
Particle morphology (Airmetrics Minivol w/ polycarbonate filters and scanning electron microscopy)	0 to ~30 μm	24-hr	6th day	7/5/99 to 6/29/00 (method evaluation)
PM _{2.5} mass, elements, ions, and carbon (two-channel speciation sampler)	0 to 2.5 μm	24-hr	3 rd day	2001 onward ^a
PM _{2.5} mass, elements, ions, volatilized nitrate, carbon, and ammonia at three neighborhood (satellite) sites (six Airmetrics MiniVols w/ Teflon/citric acid cellulose and quartz/NaCl cellulose filter packs)	0 to 2.5 μm	24-hr	6th day	12/1/99 to 3/31/03

Table 1. (continued)

Observable and Method	Size Range	Avg Time	Frequency	Period
Filter Mass and Chemistry (continued)				
PM _{2.5} mass, elements, ions, carbon, and ammonia (two-channel sequential filter sampler w/ denuders and backup filters; mass on all, chemistry on 100 samples) ^c	0 to 2.5 μm	24-hr	daily	12/1/99 to 1/31/01 ^b
PM _{2.5} mass, elements, ions, and carbon (two-channel sequential filter sampler w/ denuders and backup filters) ^c	0 to 2.5 μm	3-, 5-, and 8-hr 5/day	daily on episode days	15 episode days 12/1/00 to 1/31/01 ^b
PM ₁₀ mass, elements, ions, carbon, and fugitive dust markers (methods to be specified by CRPAQS) ^c	0 to 10 μm	24-hr	daily sampling with selected characterization	9/15/00 to 11/15/00 ^b
Toxic species (metals, chromium VI, aldehydes) (Xontec 920)	0 to ~30 μm	24-hr	12th day	1996 onward ^a
Continuous Particle Mass and Chemistry				
PM _{2.5} mass (30 °C TEOM)	0 to 2.5 μm	1-hr	daily	7/5/99 to 3/31/03
PM ₁₀ mass (30 °C TEOM)	0 to 10 μm	1-hr	daily	7/5/99 to 3/31/03
PM _{2.5} mass (ambient temperature BAM) ^c	0 to 2.5 μm	1-hr	daily	5/15/99 onward ^a
PM ₁₀ mass (ambient temperature BAM) ^c	0 to 10 μm	1-hr	daily	5/15/99 onward ^a
PM _{2.5} nitrate and sulfate (ADI flash volatilization with TEI NO _x detector) ^d	0 to 2.5 μm	10-min	daily	9/23/99 to 3/31/03
PM _{2.5} nitrate and sulfate (ADI flash volatilization with TEI SO ₂ detector) ^d	0 to 2.5 μm	10-min	daily	2/1/00 to 3/31/03
PM _{2.5} organic and elemental carbon (R&P Series 5400 carbon monitor) ^c	0 to 2.5 μm	30-min	daily	12/15/99 to 3/31/03
PM _{2.5} organic and elemental carbon (MET ONE in situ analyzer)	0 to 2.5 μm	30-min	daily	4/1/01 to 3/31/03
Individual particle size and chemistry (UC Riverside time-of-flight spectrometer)	0 to 10 μm	5-min	daily on episode days	15 episode days 12/1/00 to 1/31/01 ^b
Organic Gases and Particles				
Toxic hydrocarbons (Xontec 910 canister sampler)	gas	24-hr	12th day	1995 onward
Carbonyls (Xontec 925 DNPH sampler) ^c	gas	24-hr summer 4/day	12th day 3rd day	1995 onward ^a 1995 onward ^a
Light hydrocarbons (canister & GC/FID) ^c	gas	5- to 8-hr, 4/day	daily for episodes	15 episode days 12/1/00 to 1/31/01 ^b

Table 1. (continued)

Observable and Method	Size Range	Avg Time	Frequency	Period
Organic Gases and Particles (continued)				
Heavy hydrocarbons (TENAX & GC/TSD/FID) ^c	gas	5- to 8-hr, 4/day	daily for episodes	15 episode days 12/1/00 to 1/31/01 ^b
Aldehydes (DNPH & HPLC) ^c	gas	5- to 8-hr, 4/day	daily for episodes	15 episode days 12/1/00 to 1/31/01 ^b
PM _{2.5} organic compounds (Teflon-coated glass-fiber/PUF/XAD filters and GCMS) ^c	0 to 2.5 µm	5- to 8-hr, 4/day	daily for episodes	15 episode days 12/1/00 to 1/31/01 ^b
PM _{2.5} organic compounds (Teflon-coated glass-fiber/PUF/XAD filters and GCMS)	0 to 2.5 µm	24-hr	6th day	6/1/00-9/30/00 ^b
PM _{2.5} organic compounds (Minivol w/ Teflon-coated glass-fiber filters and GCMS) (aggregated for 60 sample polycyclic aromatic hydrocarbon [PAH] analysis) ^c	0 to 2.5 µm	24-hr	6th day	2/1/00 to 1/31/01 ^b
Continuous particle-bound PAHs (EcoChem Analytics PAS2000 w/ UV radiation and photoelectric aerosol sensors)	0 to 1 µm	5-min	daily	9/30/99 to 3/31/03
Continuous Light Scattering				
Ambient particle light scattering (Optec NGN2 ambient-temperature nephelometer at 550 nm)	0 to ~30 µm	5-min	daily	5/15/99 to 3/31/03
Dry particle light scattering (Optec NGN3 heated nephelometer at 550 nm)	0 to 2.5 µm	5-min	daily	5/15/99 to 12/31/99 (method evaluation)
Total particle light scattering (Radiance M903 nephelometer with smart heater at 530 nm) ^c	0 to ~30 µm	5-min	daily	12/15/99 to 3/31/03
PM _{2.5} particle light scattering (Radiance M903 nephelometer with smart heater at 530 nm)	0 to 2.5 µm	5-min	daily	12/15/99 to 3/31/03
Light scattering (TSI- DUSTRACK photometer at 780 nm)	0 to 2.5 µm	5-min	daily	5/15/99 to 3/31/01
Light Absorption				
Coefficient of haze (AISI paper tape sampler)	0 to ~30 µm	2-hr	daily	1990 onward ^a
Light absorption (McGee aethalometer at 880 nm) ^c	0 to 2.5 µm	5-min	daily	5/15/99 to 3/31/03
Light absorption (McGee multi-color [450, 570, 590, 615, 660, 880, and 950 nm] aethalometer)	0 to 2.5 µm	30-min	daily	5/15/99 to 3/31/03

Table 1. (continued)

Observable and Method	Size Range	Avg Time	Frequency	Period
Particle Sizes				
Scanning mobility particle sizer (TSI 3936L10 with 3010S ultrafine condensation particle counter w/ TSI 3080L electrostatic classifier and differential mobility analyzer and TSI 3900087 software) ^c	10 to 1,000 nm	5-min	daily	12/15/99 to 3/31/03
Particle Sizes (continued)				
Fine particle size distribution in 8 size fractions (0.1, 0.2, 0.3, 0.4, 0.5, 0.7, 1.0, and 2.0 μm) (PMS Lasair 1003 optical particle counter) ^c	0.1 to 2 μm	5-min	daily	11/1/99 to 3/31/03
Aerodynamic particle sizer (TSI 3926)	0.3 to 10 μm	5-min	daily	2/1/01 to 3/31/03
Coarse particle size distribution in 16 size fractions (0.3, 0.4, 0.5, 0.63, 0.8, 1.0, 1.3, 1.6, 2.0, 2.5, 3.2, 4.0, 5.0, 6.3, 8.0, and 10 μm) (Climet CI-500 optical particle counter) ^c	0.5 to 10 μm	5-min	daily	12/15/99 to 3/31/03
Mass and ion size distribution in 9 size fractions (0.054, 0.105, 0.148, 0.37, 0.54, 1.0, 1.8, 3.2, 5.6, and 15 μm) (MOUDI with Teflon filters and IC and AC)	0.054 to 15 μm	5- to 8-hr	daily for episodes	15 Episode Days 12/1/00-1/31/01 ^b
Carbon size distribution in 9 size fractions (0.054, 0.105, 0.148, 0.37, 0.54, 1.0, 1.8, 3.2, 5.6, and 15 μm) (MOUDI with aluminum filters and TOR)	0.054 to 15 μm	5- to 8-hr	daily for episodes	15 Episode Days 12/1/00-1/31/01 ^b
Meteorology				
Wind speed/direction (Met One 05305L high-sensitivity wind vane and anemometer) ^c	NA	5-min	daily	5/15/99 onward ^b
Temperature (Met One CS500L high-accuracy sensor) ^c	NA	5-min	daily	5/15/99 onward ^b
Relative humidity (Met One CS500L high-accuracy sensor) ^c	NA	5-min	daily	5/15/99 onward ^b
Solar radiation (Met One LI200X-L) ^c	NA	5-min	daily	9/15/99 onward ^b
Barometric pressure sensor ^c	NA	5-min	daily	9/15/99 onward ^b
Data Acquisition and Processing				
Campbell Scientific 24-input analogue data logger with modem dialup	NA	All times	daily	5/15/99 onward ^b
PC-LABVIEW serial data logger with modem dialup ^c	NA	All times	daily	12/1/99 onward ^b

Table 1. (continued).

- ^a Part of the California Air Resources Board's compliance monitoring network.
- ^b Measurements from the California Regional Particulate Air Quality Study (CRPAQS) (Watson et al., 1998a). Three to five wintertime episodes of four to eight day duration will be monitored based on a forecast of high PM_{2.5} concentrations under clear sky stagnation and stagnation with fog conditions.
- ^c These ground-level measurements will also be taken at the non-urban Angiola site established by CRPAQS from 2/1/00 through 1/31/01 and during pollution episodes. This site is located 100 km south of Fresno in a flat area of the San Joaquin Valley surrounded by agricultural fields dominated by cotton and alfalfa. Simultaneous measurements from Angiola will be used with those from the Fresno site to evaluate hypotheses about measurement equivalence in the absence of fresh urban emissions and to separate urban from non-urban contributions to the concentrations of measured observables. CRPAQS episodic measurements at Angiola will be taken at the same time as those acquired at Fresno.
- ^d Measurements at Angiola are available from 12/1/00 through 1/31/01.
- ^e Part of Particulate Air Pollution and the Natural History of Childhood Asthma sponsored by ARB.

Table 2. Quality assurance activities at the Fresno Supersite.

	Observable (Method)	Percent Tolerance	Instrument	Primary Standard	Calibration Standard	Calibration Frequency	Performance Test Standard	Performance Test Frequency	Performance Audit Standard	Performance Audit Frequency	Audit by ^a
I. Gases											
	NO/NO _x (chemiluminescence)	±10%	TEI 42	NIST - traceable NO mixture	Certified NO mixture and dynamic dilution	Quarterly or when out of spec	Span with certified NO and zero with scrubbed air	Daily	Certified NO mixture and dynamic dilution	Yearly	ARB
	O ₃ (UV absorption)	±10%	API 400	ARB Primary UV Photometer	Dasibi 1003H UV photometer	Quarterly or when out of spec	Span with internal ozone generator and zero with scrubbed air	Daily	Dasibi 1008 with temperature and pressure adjustments	Yearly	ARB
	CO (infrared absorption)	±10%	Dasibi 3008	NIST - traceable CO mixture	Certified CO mixture and dynamic dilution	Quarterly or when out of spec	Span with certified CO and zero with scrubbed air	Daily	Certified CO mixture and dynamic dilution	Yearly	ARB
	NMHC (flame ionization)	±10%	TEI 55	NIST - traceable HC mixture	Certified HC gas dilution	Quarterly or when out of spec	Span with certified HC and zero with scrubbed air	Daily	Certified HC gas dilution	Yearly	ARB
	NO _y / HNO ₃ (chemiluminescence)	±20%	TEI 42CY ^b	NIST - traceable NO mixture	Certified NO mixture and dynamic dilution	Quarterly or when out of spec	Span with certified NO and zero with scrubbed air	Daily	Certified NO mixture and dynamic dilution	5 times over 3 years	CRPAQS/CE-CERT
	NH ₃ (chemiluminescence/oxidation)	±20%	TEI 17C or API 200A ^b	NIST - traceable NO mixture	Certified NO mixture and dynamic dilution	Quarterly or when out of spec	Span with certified NO and zero with scrubbed air	Daily	Certified NO mixture and dynamic dilution	5 times over 3 years	CRPAQS/CE-CERT
II. Filter Mass and Chemistry											
	TSP mass (high-volume sampler)	±5%	General Metal Works	Spirometer (>1,000 L/min)	Calibrated orifice/rootsmeter	Quarterly	Calibrated orifice	Monthly	Calibrated orifice/rootsmeter	Yearly	ARB
	PM ₁₀ mass (hivol SSI sampler)	±5%	Graseby Andersen	Spirometer (>1,000 L/min)	Calibrated orifice/rootsmeter	Quarterly	Calibrated orifice	Monthly	Calibrated orifice/rootsmeter	Yearly	ARB
	PM _{2.5} and PM ₁₀ mass and elements (collocated dichotomous samplers)	±5%	Graseby Andersen	NIST - certified bubblermeter (1-25 L/min)	Mass flowmeter/bubblermeter	Quarterly	Calibrated bubblermeter	Monthly	Mass flowmeter	Yearly	ARB
	PM _{2.5} mass (2 single-channel FRM samplers)	±5%	Graseby Andersen	NIST - certified bubblermeter (1-25 L/min)	Mass flowmeter/bubblermeter	Quarterly	Calibrated bubblermeter (Gillibrator)	Monthly	Mass flowmeter	Yearly	ARB
	PM _{2.5} mass (2 sequential PM _{2.5} FRM samplers)	±5%	Graseby Andersen	NIST - certified bubblermeter (1-25 L/min)	Mass flowmeter/bubblermeter	Quarterly	Calibrated bubblermeter	Monthly	Mass flowmeter	Yearly	ARB

Table 2. (continued)

	<i>Observable (Method)</i>	<i>Percent Tolerance</i>	<i>Instrument</i>	<i>Primary Standard</i>	<i>Calibration Standard</i>	<i>Calibration Frequency</i>	<i>Performance Test Standard</i>	<i>Performance Test Frequency</i>	<i>Performance Audit Standard</i>	<i>Performance Audit Frequency</i>	<i>Audit by^a</i>
II. Filter Mass and Chemistry (continued)											
	PM _{2.5} mass and chemistry (2 RAAS speciation samplers)	±5%	Graseby Andersen	NIST - certified bubblemeter (1-25 L/min)	Mass flowmeter/ bubblemeter	Quarterly	Calibrated bubblemeter	Monthly	Mass flowmeter	Yearly	ARB
	PM _{2.5} mass and chemistry (7 minivol portable samplers)	±15%	Airmetrics	NIST - certified bubblemeter (1-25 L/min)	Mass flowmeter/ bubblemeter	Quarterly	Calibrated bubblemeter	Monthly	Mass flowmeter	5 times over 3 years	CRPAQS/ CE-CERT
	PM _{2.5} mass and chemistry (sequential speciation sampler)	±5%	DRI SFS	NIST - certified Vol-U-Met (25-200 L/min)	Dry test meter	At the beginning and end of sampling episode	Calibrated dry test meter	Monthly	Dry test meter	At the beginning and end of sampling episode	CRPAQS
	PM ₁₀ mass and chemistry (fugitive dust characterization sampler)	±15%	CRPAQS	NIST - certified Vol-U-Met (25-200 L/min)	Dry test meter	At the beginning and end of sampling episode	Calibrated dry test meter	Monthly	Dry test meter	At the beginning and end of sampling episode	CRPAQS
	Trace metals, chromium VI, aldehydes (air toxic monitor and absorbent cartridge)	±10%	Xontec 920	NIST - certified bubblemeter (1-25 L/min)	Dry test meter	Quarterly	Calibrated dry test meter	Monthly	Mass flowmeter	Yearly	ARB
III. Continuous Particle Mass and Chemistry											
	PM _{2.5} mass (TEOM)	±10%	R&P 1400A	NIST - certified bubblemeter (1-25 L/min)	Mass flowmeter/ bubblemeter	Quarterly	Internal flow check	Weekly	Mass flowmeter	5 times over 3 years	CRPAQS/ CE-CERT
	PM ₁₀ mass (TEOM)	±10%	R&P 1400A	NIST - certified bubblemeter (1-25 L/min)	Mass flowmeter/ bubblemeter	Quarterly	Internal flow check	Weekly	Mass flowmeter	5 times over 3 years	CRPAQS/ CE-CERT
	PM _{2.5} mass (BAM)	±10%	Met One 1020	NIST - certified bubblemeter (1-25 L/min)	Standard aluminum filter	Quarterly	Calibrated bubblemeter	Weekly	Mass flowmeter	5 times over 3 years	CRPAQS/ CE-CERT
	PM ₁₀ mass (BAM)	±10%	Met One 1020	NIST - certified bubblemeter (1-25 L/min)	Standard aluminum filter	Quarterly	Calibrated bubblemeter	Weekly	Mass flowmeter	5 times over 3 years	CRPAQS/ CE-CERT

Table 2. (continued)

	Observable (Method)	Percent Tolerance	Instrument	Primary Standard	Calibration Standard	Calibration Frequency	Performance Test Standard	Performance Test Frequency	Performance Audit Standard	Performance Audit Frequency	Audit by ^a
III. Continuous Particle Mass and Chemistry (continued)											
	PM _{2.5} nitrate (ambient particulate nitrate monitor, flash volatilization w/ TEI NO _x detector)	±15%	ADI/R&P	NIST - traceable nitrate	Nitrate standard	Weekly	Calibrated bubblemeter	Weekly	NO gas dilution	5 times over 3 years	CRPAQS/CE-CERT
	PM _{2.5} sulfate (ambient particulate sulfate monitor, flash volatilization w/ TEI SO ₂ detector)	±15%	ADI/R&P	NIST - traceable sulfate	Sulfate standard	Weekly	Calibrated bubblemeter	Weekly	SO ₂ gas dilution	5 times over 3 years	CRPAQS/CE-CERT
	PM _{2.5} organic and elemental carbon (ambient particulate carbon monitor, flash volatilization w/ NdIR CO ₂ detector) ^c	±15%	ADI or MetOne	NIST - traceable carbon	Oxalic acid	Weekly	Collocated comparison with continuous thermal analyzer	Every sample	CO ₂ gas dilution	5 times over 3 years	CRPAQS/CE-CERT
	PM _{2.5} organic and elemental carbon (ambient carbon particulate monitor, combustion)	±15%	R&P 5400 or MetOne	NIST - certified CO ₂ canister	Carbon dioxide	Quarterly	Collocated comparison with continuous thermal analyzer	Weekly	Mass flowmeter	5 times over 3 years	CRPAQS/CE-CERT
	Individual particle size and chemistry (time-of-flight mass spectrometer)	±20%	U.C. Riverside	NIST - certified bubblemeter (1-25 L/min)	Known particle size standard	Weekly	Calibrated bubblemeter	Weekly	Mass flowmeter	At the beginning and end of sampling episode	CRPAQS
IV. Organics											
	Hydrocarbons (canister)	±10%	Xontec 910	Primary Flow Standard	NIST - certified bubblemeter (1-25 L/min)	Quarterly	Calibrated bubblemeter	Once every 12 days	Mass flowmeter	Yearly	ARB
	Carbonyls (absorbent cartridge)	±10%	Xontec 925	Primary Flow Standard	NIST - certified bubblemeter (1-25 L/min)	Quarterly	Calibrated bubblemeter	Once every 12 days	Mass flowmeter	Yearly	ARB
	Light hydrocarbons (canister and GC/FID)	±10%	CRPAQS	NIST - certified bubblemeter	Mass flowmeter/ bubblemeter	At the beginning and end of each sampling episode	Mass flowmeter/ bubblemeter	Once every 15 winter episode days	Mass flowmeter	At the beginning and end of sampling episode	CRPAQS
	Heavy hydrocarbons (Tenax and GC/TSD/FID)	±10%	CRPAQS	NIST - certified bubblemeter	Mass flowmeter/ bubblemeter	At the beginning and end of each sampling episode	Mass flowmeter/ bubblemeter	Once every 15 winter episode days	Mass flowmeter	At the beginning and end of sampling episode	CRPAQS

Table 2. (continued)

	Observable (Method)	Percent Tolerance	Instrument	Primary Standard	Calibration Standard	Calibration Frequency	Performance Test Standard	Performance Test Frequency	Performance Audit Standard	Performance Audit Frequency	Audit by ^a
IV. Organics (continued)											
	Aldehydes (DNPH and HPLC)	±10%	CRPAQS	NIST - certified bubblermeter	Mass flowmeter/ Bubblermeter (Gillibrator)	At the beginning and end of each sampling episode	Mass flowmeter/ bubblermeter	Once every 15 winter episode days	Mass flowmeter	At the beginning and end of sampling episode	CRPAQS
	PM _{2.5} organic compounds (Teflon-coated glass fiber/PUF/XAD and GCMS)	±20%	DRI organic sampler	NIST - certified vol-u-met	Dry test meter	At the beginning and end of each sampling episode	Calibrated dry test meter	Once every 15 winter episode days	Mass flowmeter	At the beginning and end of sampling episode	CRPAQS
	PM _{2.5} organic components (Teflon-coated glass fiber)	±20%	Airmetrics	NIST - certified bubblermeter	Mass flowmeter/ bubblermeter	At the beginning and end of each sampling episode	Mass flowmeter/ bubblermeter	Once every 6 days	Mass flowmeter	At the beginning and end of sampling episode	CRPAQS
	Particle-bound polycyclic aromatic hydrocarbons (PAHs) (photooxidation)	±20%	EcoChem PAS2000	NIST - certified bubblermeter	Mass flowmeter/ bubblermeter	Quarterly	Mass flowmeter/ bubblermeter	Weekly	Collocated comparison with PUF filter/XAD sample PAH analyses	5 times over 3 years	CRPAQS/ CE-CERT
V. Light Scattering											
	PM _{2.5} Dry Particle Nephelometer (530 nm) ^b	±10%	Radiance M903	SUVA 134a refrigerant	Clean air/SUVA 134a refrigerant	Monthly	Clean air/SUVA 134a refrigerant	Weekly	Clean air/SUVA 134a refrigerant	5 times over 3 years	CRPAQS/ CE-CERT
	PM _{2.5} Open-Air Nephelometer (550 nm)	±10%	Optec NGN-2	SUVA 134a refrigerant	Clean air/SUVA 134a refrigerant	Monthly	Clean air/SUVA 134a refrigerant	Weekly	Clean air/SUVA 134a refrigerant	5 times over 3 years	CRPAQS/ CE-CERT
	Ambient Particulate Monitor (photometer) ^b	±20%	Greentek GT-640A or DUSTRAK	SUVA 134a refrigerant	Clean air/SUVA 134a refrigerant	Monthly	Clean air/SUVA 134a refrigerant	Weekly	Clean air/SUVA 134a refrigerant	5 times over 3 years	CRPAQS/ CE-CERT
VI. Light Absorption											
	Coefficient of Haze	±20%	Research Appliance AISI	Neutral density filter	Neutral density filter	Quarterly	Optical Check	Weekly	Mass flowmeter	Yearly	ARB
	Aethalometer (880 nm)	±5%	Magee Scientific AE14U	Neutral density filter	Neutral density filter	Quarterly	Neutral Density filter	Weekly	Mass flowmeter	5 times over 3 years	CRPAQS/ CE-CERT

Table 2. (continued)

	Observable (Method)	Percent Tolerance	Instrument	Primary Standard	Calibration Standard	Calibration Frequency	Performance Test Standard	Performance Test Frequency	Performance Audit Standard	Performance Audit Frequency	Audit by ^a
VI. Light Absorption (continued)											
	Multiwavelength Aethalometer ^b (450, 570, 590, 615, 660, 880, 950 nm)	±5%	Magee Scientific AE30S	Neutral density filter	Neutral density filter	Quarterly	Neutral Density filter	Weekly	Mass flowmeter	5 times over 3 years	CRPAQS/CE-CERT
VII. Particle Sizes											
	Scanning Mobility Particle Sizer (0.01 to 1.0 µm)	±15%	TSI 3936L10	Collocated differential mobility analyzer	Small particle mist	Yearly	Known particle size standard and voltage tests	Weekly	Certified particle sizes and voltage tests	5 times over 3 years	CE-CERT
	Optical Particle Counter (0.5 to 10 µm)	±15%	Climet CI-500	Vibrating orifice aerosol generator	Polystyrene latex suspension	Yearly	Polystyrene latex suspension	Weekly	Polystyrene latex suspension	5 times over 3 years	CE-CERT
	Optical Particle Counter (0.1 to 2 µm)	±15%	PMS LASAIR 1003	Vibrating orifice aerosol generator	Polystyrene latex suspension	Yearly	Polystyrene latex suspension	Weekly	Polystyrene latex suspension	5 times over 3 years	CE-CERT
	Aerosol Particle Sizer ^c (0.3 to 10 µm)	±20%	TSI 3296	Vibrating orifice aerosol generator	Polystyrene latex suspension	Yearly	Small particle mist	Weekly	Polystyrene latex suspension	5 times over 3 years	CE-CERT
	Rotating MOUDI w/ accessories (4 units) for mass, ions, and carbon size distributions	±10%	MSP 100	NIST - certified Vol-U-Met	Dry test meter	At the beginning and end of each sampling episode	Calibrated dry test meter	Once every 6-hour sample run	Mass flowmeter	At the beginning and end of each sampling episode	CRPAQS
VIII. Meteorology											
	High-Sensitivity Anemometer (wind speed)	±0.5 m/s	Met One	Certified wind tunnel	Certified wind tunnel synchronized motor	Quarterly	Visual check, synchronize motor when out of spec	Weekly	Synchronized motor	Yearly	ARB
	High-Sensitivity Windvane (wind direction)	±10° from North	Met One	Surveyor compass, solar azimuth	Surveyor compass, solar azimuth	Quarterly	Visual check, realignment when out of spec	Weekly	Surveyor compass, solar azimuth	Yearly	ARB
	High-Accuracy Temperature Sensor / Thermocouple	±0.1 °C	Met One	NIST thermometer and water bath	NIST thermometer and water bath	Quarterly	On-site psychrometer	Weekly	NIST thermometer and water bath	Yearly	ARB
	High-Accuracy Relative Humidity Sensor / Lithium Chloride	±2%	Met One	NIST thermometer and dew cups	NIST thermometer and psychrometer	Quarterly	On-site psychrometer	Weekly	Collocated chilled mirror sensor	Yearly	ARB

Table 2. (continued)

	<i>Observable (Method)</i>	<i>Percent Tolerance</i>	<i>Instrument</i>	<i>Primary Standard</i>	<i>Calibration Standard</i>	<i>Calibration Frequency</i>	<i>Performance Test Standard</i>	<i>Performance Test Frequency</i>	<i>Performance Audit Standard</i>	<i>Performance Audit Frequency</i>	<i>Audit by^a</i>
VIII. Meteorology (continued)											
	Solar Radiation Sensor / Pyranometer	±20 w/m ²	Met One	NIST standard luminance	NIST standard luminance	Quarterly	Visual inspection of max and min	Weekly	Collocated pyranometer	Yearly	CE-CERT
	Barometric Pressure Sensor / Barometer	±3 mm Hg	MetOne	Mercury barometer	Mercury barometer	Quarterly	Visual inspection of max and min	Weekly	Mercury barometer	Yearly	CE-CERT
IX. Laboratory Chemical Analysis											
	Mass (electrobalance)	±10%	Mettler MT5	NIST Class 1.1 weights	NIST Class 1.1 weights	3 months	NIST weights	10 samples	NIST Class 1.1 weights	Yearly	CE-CERT
	Total elements (x-ray fluorescence)	±5%	KeveX 700/800	EPA polymer films, NIST impregnated glass	Micromatter film deposits	6 months or when out of spec	Multi-element impregnated glass	15 samples	Micromatter film deposits	Yearly	CE-CERT
	Soluble metals (ICPMS)	±0.005 to ±0.05 µg/mL	Varian Ultramass 700	Mineral salt solutions	Salt solution	3 months or when out of spec	Mixed salt solution	10 samples	Mixed salt solution	Yearly	CE-CERT
	Anions and cations (ion chromatography)	±0.05 µg/mL	Dionex 500DX	Mineral salt solutions	Salt solution	100 samples	Mixed salt solution and distilled water	10 samples	Mixed salt solution	Yearly	CE-CERT
	Carbon (TOT or TOR)	±0.2 µg/cm ²	DRI/Met One thermal/optical analyzer	NIST CO ₂ and CH ₄	Phthalate and sucrose solutions	3 months or when out of spec	CH ₄	Every sample	Phthalate and sucrose solutions on filters CO ₂ and CH ₄	Yearly	CE-CERT

^a Audited as part of California Air Resources Board's QA program for compliance network.
 Audited as part of California Regional Particulate Study Air Quality Study special study between 11/15/99 and 1/31/01.
 Audited by Fresno Supersite QA group at University of California, Riverside, between 2/1/01 and 3/31/03.
^b Under development and evaluation.
^c Available 4/1/01 to 3/31/03.

Table 3. Fresno Supersite hypotheses.

1. Measurement Evaluation Hypotheses

- 1.1 Mass and chemical (elements, ions, and carbon) measurements from compliance filter samplers with Teflon-membrane filters (from Federal Reference Method [FRM] or Minivol monitors) represent actual PM_{2.5} mass within the spatial zone of representation of a community representative sampling site.
- 1.2 Elemental analysis of Teflon-membrane filters under helium and vacuum atmospheres does not result in a significant (>10%) loss of volatile nitrate.
- 1.3 Carbon gases absorbed on quartz-fiber filters are a small (<15%) fraction of organic carbon measured on these filters.
- 1.4 Volatilized particulate nitrate is a minor (<10%) part of particle nitrate during winter, but a major fraction of particle nitrate during other seasons.
- 1.5 Volatilized particulate nitrate is a minor (<10%) part of actual PM_{2.5} during all seasons.
- 1.6 PM_{2.5} mass concentrations estimated from particle size, weighted sums of chemical components, light scattering, light absorption, and light extinction, are equivalent to gravimetric mass of samples taken with a PM_{2.5} FRM sampler.
- 1.7 PM_{2.5} and PM₁₀ mass measurements are comparable for all measurement methods during spring and summer when the sampled aerosol is stable. Mass measurements diverge during winter and part of the spring when volatile nitrate and organics constitute a large mass fraction.
- 1.8 Particle number counts in integrated sub-ranges of the 0.01 to ~10 μm size distribution are comparable to PM_{2.5} and PM₁₀ mass measurements with definable assumptions of constant shape and density.
- 1.9 Differences between continuous PM₁₀ and PM_{2.5} monitors are comparable to coarse particle mass concentrations on dichotomous samplers.
- 1.10 The PM_{2.5} geological component is comparable to the difference between continuous PM_{2.5} mass measurements and the sum of continuous nitrate, sulfate, and carbon concentrations (adjusted for ammonium, hydrogen, and oxygen).
- 1.11 Bioaerosols and endotoxins constitute a constant fraction of coarse particle mass.
- 1.12 Photoionization and wavelength-specific light absorption are correlated with organic compound concentrations.

Table 3. (continued).

2. *Aerosol Characterization and Control Strategy Hypotheses*

- 2.1 Short duration (~5 min) spikes in particle measurements represent contributions from nearby (<500 m) emitters.
- 2.2 Nearby emitters represent a small (<15%) fraction of PM_{2.5} measured at a community representative sampling site.
- 2.3 The majority of ultrafine particles (< 0.1 μm) are from nearby (<500 m) fresh emissions sources.
- 2.4 Ammonium nitrate reductions are limited by available nitric acid rather than available ammonia in urban areas during all seasons and all hours of the day.
- 2.5 Advanced gas and particle organic speciation measurements, coupled with elements, ions, and organic and elemental carbon fractions, consistently and accurately distinguish contributions from different types of suspended dust, secondary sulfate and nitrate, wood combustion, field burning, meat cooking, gasoline engine exhaust from cold starts, high emitters, and hot stabilized operations, diesel exhaust, and primary industrial emissions.
- 2.6 Commonly measured elements, ions, and organic and elemental carbon fractions consistently and accurately distinguish contributions from suspended dust, secondary sulfate and nitrate, vegetative burning (wood and field combustion and meat cooking), gasoline engine exhaust (cold starts, high emitters, and hot stabilized), diesel exhaust, and primary industry contributions.
- 2.7 Gasoline engine cold starts and high emitters are the major causes of gasoline-fueled vehicle contributions to PM_{2.5}, and they cause gasoline exhaust contributions to exceed diesel exhaust contributions.
- 2.8 Statistical aggregates of concentration indicators for a single year deviate by less than sampling error from a three-year distribution.
- 2.9 Concentrations in continuously measured carbon fractions can be associated with different proportions of gasoline vehicle exhaust, diesel vehicle exhaust, and wood burning.
- 2.10 Annual average, seasonal average, and 98th percentile source contributions from fugitive dust, wood burning and cooking, vehicle exhaust, secondary ammonium sulfate, and secondary ammonium nitrate differ by less than ±10% over a three year period.
- 2.11 Particle size fraction, number, surface area, and major chemical component indicators of particle concentrations are highly correlated; one indicator is equivalent to other indicators that might be specified by future air quality standards.
- 2.12 Large reductions in PM_{2.5} and PM₁₀ mass concentrations in Central California after 1992 are due to the end of a seven-year drought rather than due to emissions reductions.

Table 3. (continued).

3. *Health- and Exposure-Related Hypotheses*

- 3.1 PM_{2.5} mass concentration, surface area, and number counts are highly correlated ($R^2 > 0.8$) and a measure of one is a good indicator of the other two.
- 3.2 Soluble transition metals are a small fraction (<15%) of total metal concentrations in PM_{2.5}.
- 3.3 Measurements at a community representative sampling site represent the minimum to which people are exposed in their neighborhoods within an urban area.
- 3.4 Hospital and physician diagnoses of respiratory and cardiovascular ailments are as equally sensitive to changes in PM_{2.5} mass concentrations as they are to other air pollution indicators.
- 3.5 There is a discernible lower threshold for single and combined air quality indicators, below which no relationships with health end-points are statistically significant.
- 3.6 Different particle chemical characteristics have different and identifiable immuno-enhancing properties that affect the symptom onset and severity of short-term reductions in lung function, asthma attacks, and cardiovascular ailments.
- 3.7 Coarse particle concentrations and biologically active components show relationships to health end-points.
- 3.8 Animal (rats) exposures to different combinations of concentrated amounts of particle size, surface area, chemical, and mass characteristics result in similar indications of respiratory and cardiovascular distress.
- 3.9 Particles found in healthy human lungs have characteristics similar to those found in urban air over long periods of exposure.