Draft Technical Proposal

ROADWAY POLLUTANT MITIGATION STRATEGIES

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Check if applicable:
Animal subjects ______
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ABSTRACT

While California has made tremendous progress in reducing vehicular emissions, evidence of the dangers of roadway pollutant exposure is growing, highlighting the need to protect populations from elevated concentrations of roadway pollution. A large number of pollutants are elevated around roadways, including black carbon, carbon monoxide, ultrafine particles, NO_x, and gasses such as benzene. Vegetation planted in combination with solid barriers along the sides of freeways, whose primary purpose is to reduce freeway noise, can potentially reduce downwind pollutant concentrations. However, to date, studies of the effect of sound/vegetation walls have not yet produced definitive results and few studies have been performed for California's roadway styles and Mediterranean climate. The proposed project will characterize the effectiveness of sound and vegetative barriers in dispersing and removing pollutants under conditions common in California. Three sites in two different air basins will be selected for study. Traffic related pollutants including fine particulate matter (PM2.5), ultrafine particles, black carbon, oxides of nitrogen, carbon dioxide, and carbon monoxide will be measured in both summer and winter and during both nighttime and daytime hours. Stationary monitoring at up to six locations around sound walls will be employed combined with repeated mobile monitoring to provide a two-dimensional map of pollutant concentrations in the vicinity of the sound barrier. Efforts will be made to find sites with a sound barrier, part of which includes vegetation, adjacent to a segment of freeway without a sound barrier. Micrometeorology (e.g., wind speed and direction, temperature, and humidity) will be characterized both at ground level and at up to 100 meters using a portable tower and tethered balloon. Traffic volumes, speeds and fleet mix on the roadway, as well as noise levels will also be determined. Vegetation will be documented and characterized using key plant parameters. The proposed project will yield a comprehensive data set that can be used for development of mechanistic models to estimate the impact of barriers on near-road air quality in future studies. The results will provide insights into the value and best practices for siting and design of sound walls, and vegetation in combination with sound walls, to reduce downwind pollution from roadways.

1. Introduction

1.1 Background and similar work by others.

The impact of roadway emissions on air quality has been studied since the 1970s. Recently, a number of epidemiological studies have reported associations between living within a few hundred meters of high-traffic roadways and adverse health effects such as asthma and other respiratory impacts, birth and developmental effects, premature mortality, cardiovascular effects, and cancer (Hoek et al. 2002; Wilhelm and Ritz 2003; Beelen et al. 2008; Gehring et al. 2010; Wellenius et al. 2012). Air quality monitoring studies conducted near major roadways suggest these health effects are associated with elevated concentrations, compared with overall urban background levels, of various motor-vehicle-emitted compounds. Roadway combustion emissions include carbon monoxide (CO); nitrogen oxides (NOx); coarse (PM10-2.5), fine (PM2.5), and ultrafine (PM0.1) particle mass; particle number; black carbon (BC), polycyclic aromatic hydrocarbons (PAHs), and a suite of volatile organic compounds including benzene (Kim et al. 2002; Zhu et al. 2002; Zhu et al. 2002a; Kittelson et al. 2004).

Several approaches have been suggested to mitigate the near road impact of vehicle emissions. These include optimized noise barriers, roadside vegetation, road canopies in combination with methods to treat the pollutants trapped in the canopies, catalytic coatings on barriers to convert NO_2 to nitrate, and dynamic traffic management based on forecasts of conditions that might lead to poor air quality (McCrae 2010).

The removal of pollutants using methods such as electrostatic precipitation of particles are expensive and less than reliable. Catalytic coatings on barriers to absorb or convert pollutants such as NO_2 have not been effective because the contact time between the pollutants and the coated surface is not large enough (Hooghwerff et al. 2010). Dynamic traffic management, which is reducing traffic flows when the meteorology is conducive to high air pollution levels, is difficult to implement even if adverse meteorological conditions could be forecast accurately. The most practical and consistently successful mitigation strategy is based on physical barriers and roadside vegetation.

1.1.1 Physical Barriers

Physical barriers affect concentrations associated with vehicle emissions by modifying the flow field and turbulence in the vicinity of the barrier. The pollutant plumes from vehicles are carried over the barrier by the mean flow that is deflected upwards by the barrier, as indicated in **Figure 1.** A circulating region forms behind the barrier, in which the near surface flow is opposite to that in the mean flow aloft. Above the cavity, the flow is deflected downwards, and

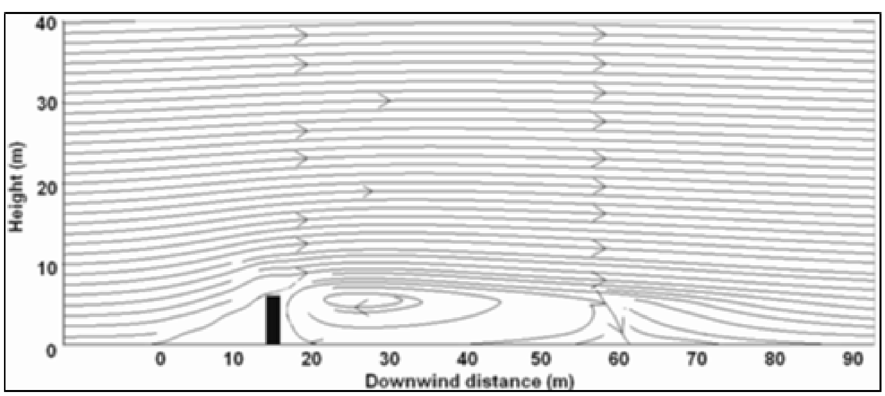


Figure 1: Flow induced by physical barrier (Bowker et al. 2007).

turbulence levels are enhanced in a vertically expanding wake whose effects extend to a distance of about 10-20 times the height of the barrier.

Physical barriers raise the height of emissions from near ground-level to the approximate height of the barrier. A fraction of these elevated emissions is entrained into the recirculating cavity and then reemitted into the wake region of the flow. The material entrained into the cavity represents a ground-level source with an initial vertical spread proportional to the barrier height. In general, the combination of all these barrier induced effects leads to a reduction in concentrations relative to those without the barrier.

Figure 2: Mock straw bale sound barrier, 6 m high and 90 m long (Finn et al. 2010).

Some of the most definitive information on the impact of barriers is provided by a tracer study (Finn et al. 2010) conducted at the Department of Energy's Idaho National Laboratory (INL). A 6 m high (1H = 6 m) by 90 m long (15H) straw bale stack, shown in **Figure 2**,

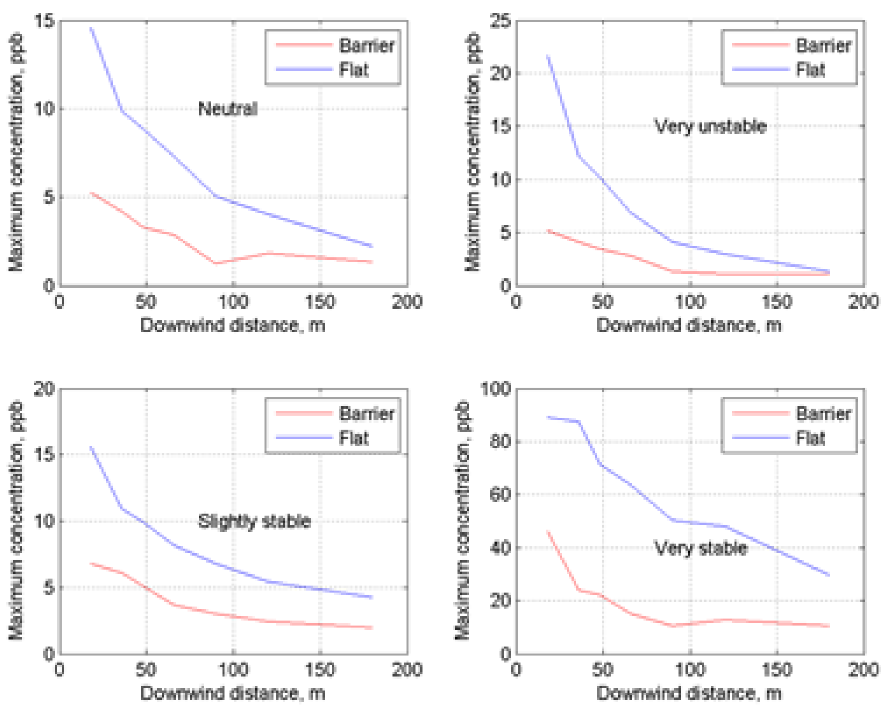


Figure 3: Spatial variation of SF_6 concentrations measured in the Idaho Falls experiment. The barrier height is 6 m. Points represent averages over maximum concentrations measured over the 3 hours of each experiment. Upper lines (blue) indicate concentrations in the absence of the barrier, and lower (red) with the barrier.

represented a roadway barrier for the primary experiment. The "roadway" was an access track through the sagebrush adjacent to the barrier. The primary and reference control experiments both had a 54 m long (9H) SF_6 tracer line source release positioned 1 m above ground level (AGL) representing pollution sources from a roadway. In the primary experiment, the line source was positioned 6 m upwind of the 6 m high barrier with a gridded array of 58 bag samplers downwind of the line source and barrier for measuring mean 15-min concentrations. The control experiments (conducted at an adjacent location and simultaneous to the primary) included identical source and concentration sampling but without the barrier in the array. An array of six 3-d sonic anemometers was deployed for making wind and turbulence measurements, six on the primary experiment and one on the control experiment. Five tests, each lasting 3 hours, were conducted in October, 2008 under the different atmospheric stabilities.

Figure 3, which summarizes the concentration measurements, in terms of averages over 3 hours of each test, shows that the barrier reduced concentrations (red line) by about 20-50%, relative to open terrain (blue line), out to a distance of 20 barrier heights under different meteorological conditions, including very stable, light wind conditions (See bottom right panel of **Figure 3**).

The US Environmental Protection Agency conducted several experiments (Heist et al. 2009) in its wind tunnel laboratory in Research Triangle Park, NC, to examine the effect of roadway configurations on the dispersion of traffic-related pollutants at distances up to several hundred meters. All of the configurations reduced downwind concentrations relative to the flat terrain case. The study found that the ground-level concentrations beyond a distance of about 10 times the height of the barrier could be modeled as a ground-level source with two modifications: 1) the source is shifted upwind, and 2) and the effective rate of vertical plume spread is enhanced in the presence of a barrier. The upwind shift in source location depends on the particular geometry, with larger shifts necessary when multiple physical effects are combined.

Tracer and wind tunnel studies have provided some of the most useful information on the impact of barriers on near-road concentrations. However, this information has to be validated under real world conditions before it can be used for regulatory guidance. A number of studies have been conducted within the past ten years to examine the impact of in-use roadside barriers on near-road concentrations of vehicular emissions. Baldauf and colleagues (Baldauf et al. 2008) reported that spatial concentrations patterns in the presence of barriers were similar to those in the absence of barriers: concentrations decreased with downwind distance from the barrier. But these concentrations were about 20% lower than the corresponding values for the open terrain road. This behavior was contradicted by a measurement program conducted next to two freeways in Los Angeles (Ning et al. 2010). The results of this study are notable because, unlike in other studies, mass and number concentrations of particulate matter were small immediately behind the barrier, increased with distance from the barrier, reaching peaks at distances of 80-100 m, and then decreasing. These peaks were about twice those observed at the same distance in the absence of the barrier. The occurrence of this peak concentration is attributed to the effective elevation of the emissions by the barrier. This spatial pattern is not consistent with a tracer experiments (Finn et al., 2009), in which concentrations always decreased with distance from the barrier.

1.1.2 Effects of Vegetative Barriers

Considerable attention has been focused in recent decades on the question of whether trees and shrubs planted along major roadways can help mitigate the impacts of vehicle-related emissions through enhanced surface deposition of certain pollutants (Heichel and Hankin 1976; Munch 1993; Bussotti et al. 1995; Heath et al. 1999; Beckett et al. 2000; Raupach et al. 2001; Fuller et al. 2009; Ning et al. 2010). In a modeling analysis of the Raleigh measurements, Bowker et al. (2007) found the combination of sound barriers and tall trees led to enhanced mixing and pollutant dispersion leading to lower downwind pollutant concentrations.

The likely impact of a vegetation barrier can be understood by considering the solid barrier as a very dense vegetation barrier with added ability to process and take up gasses and small particles. If the solid barrier is made porous, its effect on vertical mixing has to be reduced. This would suggest that vegetation barriers would be less effective than solid barriers in reducing concentrations. However, vegetation can compensate for this by reducing the concentration of particles and gases in the air passing through the vegetation through deposition and impaction (Raupach et al. 2001). The entrapment of particles by windbreaks (Raupach et al. 2001) show that this removal is a function of the optical porosity of the vegetative barrier, leaf area index, the mass transfer coefficient, and the 'bleed' velocity through the barrier. In principle, we can estimate this removal rate through modeling. Results from Steffens et al. (2012) suggest that the vegetation filtration effect is small compared to the vertical mixing effect induced by solid barriers. Filtration can be increased by increasing the thickness of the vegetation barrier (Steffens et al. 2012). However, this has a limit because beyond a certain thickness there is no flow through the vegetation, which then effectively becomes a solid barrier. It is clear that vegetation can enhance the effectiveness of a solid barrier if tall vegetation is planted behind the barrier to enhance vertical dispersion.

A small number of field studies have investigated the effects of vegetation barriers on vehicle related concentrations. **Figure 4** shows that the mitigation effects of a vegetative barrier can be significant. A field study conducted next to interstate I-440 in Raleigh, North Carolina

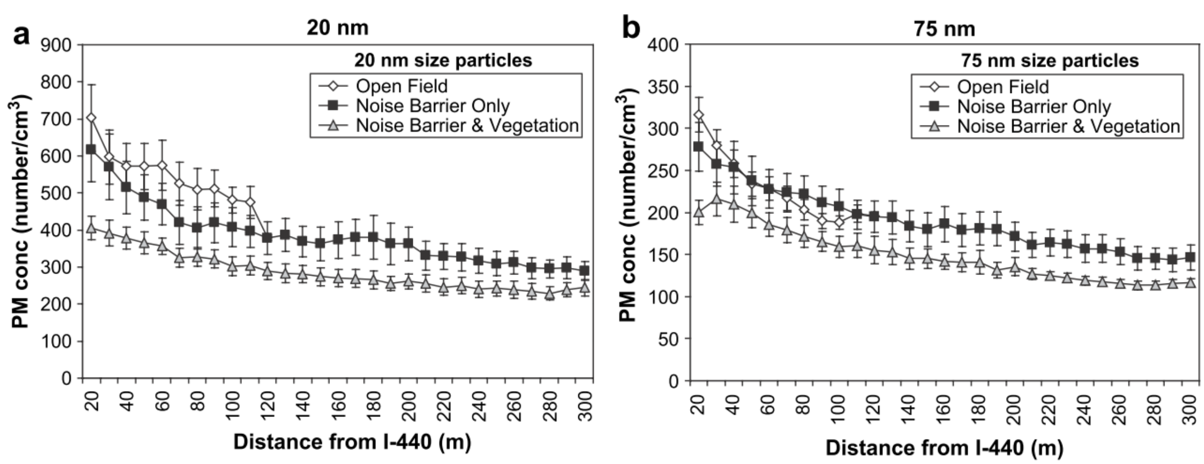


Figure 4: Mobile monitoring measurements of (a) 20 nm and (b) 75 nm size particles using the DMA–CPC units at varying distances from the road for open terrain, behind a noise barrier only, and behind a noise barrier with vegetation. Bars represent 95% confidence intervals for each distance (Baldauf et al. 2008).

(Baldauf et al. 2008) investigated the impact of vegetative barriers on roadside PM and found that concentrations of smaller diameter particles were decreased slightly more than concentrations of larger particles (**Figure 4**). Concentrations of both 20 nm and 75 nm particles were decreased only slightly by the barrier by itself. Concentrations were decreased much more significantly for the section of barrier that had mature vegetation (trees taller than 10m with leaves) next to it. In contrast, in field studies conducted at three locations in North Carolina, Hagler et al. (2012) found that the impact of vegetation barriers is small compared to solid barriers. In some cases, they found that UFP concentrations behind the vegetation barrier were higher than those in the open area. Furthermore, on-road UFP concentrations behind the barrier were not always higher than those in the open area. These results are preliminary because they are based on measurements made at single locations next to roads and barriers, and thus might be influenced by local flows.

It is necessary to conduct more comprehensive measurements with monitors at several distances to obtain more definitive understanding of effects of vegetation on concentrations. A mobile monitoring platform (MMP) in combination with fixed monitors will provide the spatial coverage required to evaluate a physically based model that can be used to design mitigation measures. The major advantage of using a MMP is that we can measure concentrations at varying distances from the road without the need for power or security. The fact that a MMP can provide an average concentration profile is an advantage for a line source such as a road because variations of concentrations parallel to the road are not relevant to the understanding of the problem. It is the gradient perpendicular to the road that is important.

1.2 Current Research Relevant to Proposal

In a project sponsored by the South Coast Air Quality Management District (AQMD), Co-PI A. Venkatram and his research group have analyzed data from the EPA field study and wind tunnel to develop models to explain the impact of sound barriers on near-road dispersion. We focused on the Idaho Falls field study (Finn et al. 2010) because it was designed to provide the comprehensive data set required to model dispersion in the presence of obstacles.

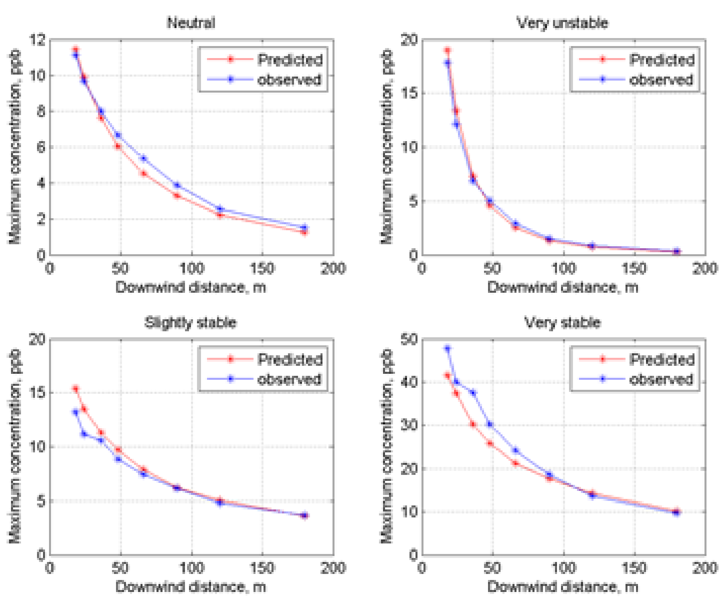


Figure 5: Comparison between modeled and observed maximum concentrations at different downwind distances. The maximum concentrations are averaged over the 3 hours of each experiment.

In order to understand the impact of the barrier, we first modeled the concentrations measured by the samplers corresponding to the flat terrain release. As **Figure 5** shows, we were successful in describing the variation of concentrations under a variety of atmospheric stabilities. However, this required us to modify our current understanding of dispersion in the surface boundary layer.

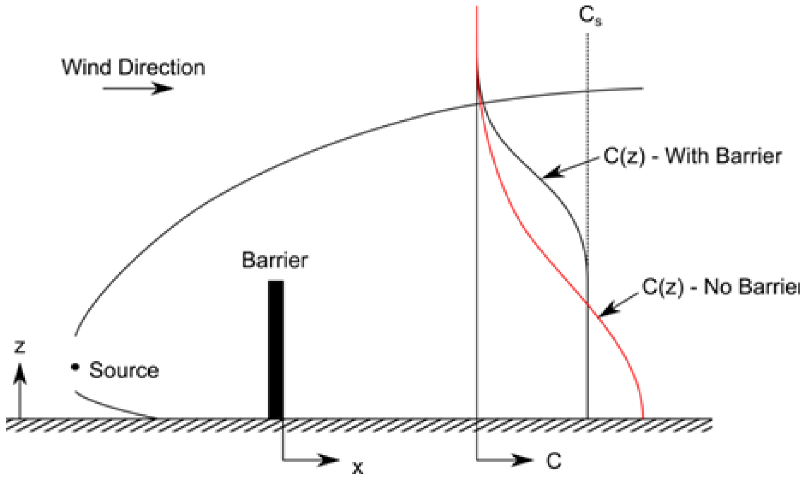


Figure 6: Schematic of the mixed-wake model. The “No Barrier” vertical concentration profile represents the profile that the Gaussian plume formulation predicts and the “With Barrier” profile is used in the mixed-wake model. The pollutant mass is well-mixed below the barrier height in the mixed-wake model.

We have developed several models to describe the impact of the barrier on near road concentrations. They include two models based on the Gaussian dispersion equation, one on the numerical solution of the eddy diffusivity equation, and one based on computational fluid dynamics (CFD). Although none of them explain all the features of the observed concentrations, their results lead to some important conclusions: the material released behind the barrier is well mixed at heights below the barrier, and the maximum concentration is elevated. These features are also apparent in the results obtained through CFD modeling (Hagler et al. 2011).

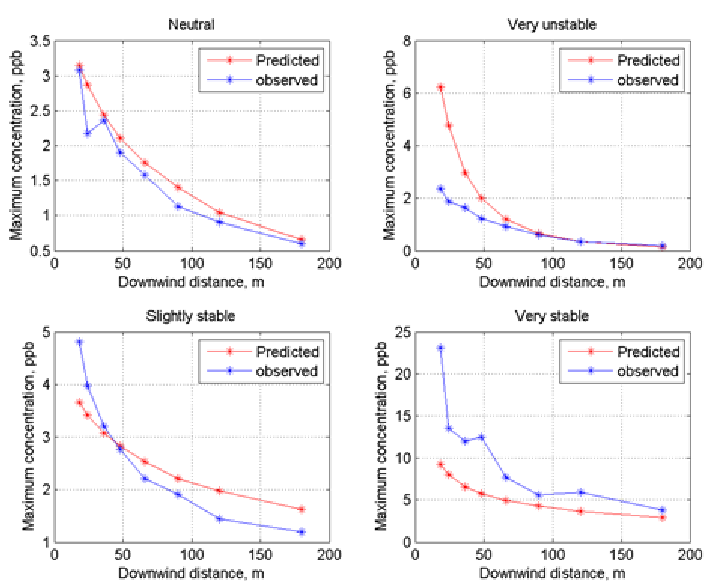


Figure 7: Comparison between modeled using the mixed wake model and observed maximum concentrations at different downwind distances. The maximum concentrations are averaged over the 3 hours of each experiment.

To the first order, the effect of the barrier can be simulated using the mixed wake model depicted in **Figure 6**. Concentrations below the barrier height can be estimated by simply adding the barrier height to the vertical plume spread and increasing the turbulence levels behind the barrier. **Figure 7** shows the results obtained using this model. The turbulence levels behind the barrier were obtained from sonic measurements made during the study. As expected, the results are not as good as those for the flat terrain case (Figure 5). The neutral and slightly stable cases are described well by the model. However, in the very unstable case, the model overestimates concentrations close to the barrier. In the very stable case, the model underestimates the observations. Both these cases corresponded to low wind speeds when the tracer can flow around the barrier, which is not accounted for in the simple model. At this stage, this is only speculation, and only more field measurements can resolve the type of discrepancies seen in **Figure 7.**

2. OBJECTIVES

The goal of this project is to provide information that can be utilized by the Air Resources Board (ARB) to advise local planners, agencies, and developers on effective measures to mitigate exposures for residents near highly trafficked roadways. Specific research objectives are to obtain field measurement data in California to evaluate the impacts of sound walls alone, and sound walls in combination with vegetation, on levels of traffic-related pollutants. The second objective is to develop a comprehensive data base that can be used for modeling studies in the future. Target pollutants include fine particular matter (PM2.5), ultrafine particles, black carbon, oxides of nitrogen, carbon dioxide, and carbon monoxide. Measurements will be made at varying downwind distances from the roadways, to carefully characterize any potential increased or decreased concentrations resulting from the use of the barriers and vegetation.

We will measure the variables that govern the impact of sound wall-vegetation combination barriers on near-road pollutant concentrations. These include the geometry of the sound wall and freeway, micrometeorology in the vicinity of the road, and traffic activity patterns including traffic volume and speed, and fleet mix. The role of vegetation in deposition, dispersion and filtration of pollutants will be characterized using species and physical characteristics as well as leaf area index (LAI), optical porosity, and possibly stomatal conductance. We will capture the full range of micrometeorological variables that govern dispersion by making measurements at several sites during different times of the day in winter and in summer, as well with tethered balloon and tower meteorological measurements to characterize stability in the lowest layer of the atmosphere.

We expect to develop a comprehensive data base that provides guidance in designing optimum mitigation strategies based on sound and vegetative barriers.

3. TECHNICAL PLAN

3.1 Tasks

1. **Literature Review, Site Selection, detailed design**

Analyze existing literature to develop an understanding of the ability of earlier and on-going studies to describe the impact of sound/vegetation walls in California. The starting point for the literature review will be the research team’s own considerable resources of documents dealing with sound wall-vegetation barriers as demonstrated in the Introduction section. In addition to the use of the team’s resources, searches will be conducted in the peer-reviewed literature and gray literature to identify relevant publications. This will include standard keyword searches, following cited references, and outreach to authors. The research team will focus on extracting the experimental methods, data analysis, findings, and conclusions from each document. The goal is to identify critical information and data gaps to help us better design the sampling plan.

Sites will be selected in close collaboration with ARB staff. Next, we will use the mobile monitoring platform and/or rental car with portable instruments to characterize the "short list" of sites and make final site selection. This task represents 12% of total effort.

2. Pilot Testing and Standard Operating Procedure (SOP) Development

Pilot measurements, planning and logistics preparation and deployment for 6-8 months over the course of the project. Logistics preparation will be divided among the research groups overseen by Paulson, Zhu and Venkatram, so that each groups will each take the logistics lead for one site. The MMP, or portable instruments in an electric or hybrid car if the MMP is not available, is proposed for pilot studies as it allows examination of the area without the large investment required to set up stationary measurements. Pilot measurements will be used to identify confounding pollutant sources, which can sometimes be difficult to predict based purely on examination of maps, and to provide preliminary meteorological data to verify the wind regimes are in the desired configurations. Based on these pilot measurements, SOPs will be developed for the full scale study at each site. Effort represents 9% of total effort.

3. Conduct Field Campaigns

Measurement campaigns, including planning and logistics preparation and deployment. A total of about 6 - 8 weeks of intensive sampling, combined with 6 - 8 additional weeks of stationary monitoring, divided among three sites and four measurement periods, as follows: site 1, summer and winter, site 2, summer or fall, site 3, winter or spring. During the intensive periods, measurement time will be varied over the hours of 5 AM and 11 PM in attempts to capture the complete range of meteorological/traffic conditions. During the stationary part of the period, as many low-maintenance instruments as possible will be deployed, subject to security and power constraints, and instruments available. The purpose of these measurements will be primarily to determine if the intensive periods are representative of the range of conditions experienced at the site. Because we will be measuring in several seasons and importantly, several times of day, we will produce a thorough analysis of the full range of meteorological, traffic, vegetation and other conditions commonly encountered.

On each measurement day, continuous measurements will be performed at the stationary meteorological sites. The 10 m tower will be stationary for at least an hour at a time, and may be moved based on insights from the model, pilot runs, and accumulating data as the measurement intensives progress. The mobile platform will make measurements for 3-4 hours in the morning, capturing the morning commute from about 5:30 – 9 AM, followed by a break for 3-4 hours to recharge the vehicle and instrument batteries, and a second 3-4 hour measurement period in the afternoon.

Within each 3-4 hour mobile measurements platform sampling period, we anticipate collecting measurements using a mixture of driving along a transect perpendicular to the freeway, on a grid in nearby neighborhoods, and at stationary stops of ~5 minutes each. Effort represents 35% of total effort.

4. Data Analysis and Preparation of Results

Data preparation, QA/QC, preparation, and interpretation using statistical analysis techniques and analytical models. The rich data set generated by the measurements will be interrogated in multiple ways.

- First, data will undergo preparation including time synching, QA/QC, and needed calibration adjustments. Days will undergo meteorological classification using classification and regression trees [31] to determine which data, if any, can be reasonably averaged. For some analyses and measurements, data filters will be applied to remove the influence of various levels of high emitters, defined using various approaches.
- Data will be subjected to various statistical interrogation methods, with aim to determine the most important factors determining downwind pollutant concentrations at each site and for different time of day/atmospheric stability/wind speed and direction/season etc. Manuscripts and reports summarizing descriptive results and results from statistical models.
- Data will be interpreted and summarized using the semi-empirical models described earlier; see Figures 6 and 7.

Task represents 39% of time.

5. Prepare Quarterly Reports and Final Report

Preparation of progress reports on a quarterly basis, and preparation of draft final report and final report. This task represents 5% of the total effort.

3.2 Measurements

3.2.1 Selecting the ideal field environments for measurements

Several potential suitable sample sites were identified for this project in the South Coast (Los Angeles), San Joaquin Valley (Bakersfield), and Sacramento Valley (Sacramento) air basins. Sites were identified based upon the following criteria:

- The freeway section passes through a residential area with sound barrier wall and vegetation. Ideally vegetation is combined with the sound wall for part but not all of the wall, and there is a nearby “control” area with no sound barriers installed.
- The freeway section is roughly perpendicular to the prevailing wind direction. Perpendicular configurations are expected to impact larger downwind populations.
- Reasonable likelihood that stationary sampling sites might be located at varying distances downwind from the freeway.
- Stationary sampling sites are available at upwind locations.

Major freeways in each air basin were visually surveyed using the Google Earth program. In the South Coast air basin the I-405, I-110, I-710, I-5, I-605, I-15, I-215, US-101 and US-91 were surveyed. In the San Joaquin Valley air basin US-99, US-58, and US-178 were surveyed. In the Sacramento Valley air basin, the I-5, I-80, US-99, and US-50 were surveyed. Once a potential site (i.e., a residential area with visible green vegetation) was identified in the satellite view, the street level view was used to verify the presence of a sound barrier wall and vegetation (trees, vines, and bushes). Meteorological data from nearby stations were used to confirm the prevailing wind direction is roughly perpendicular to the freeway section.

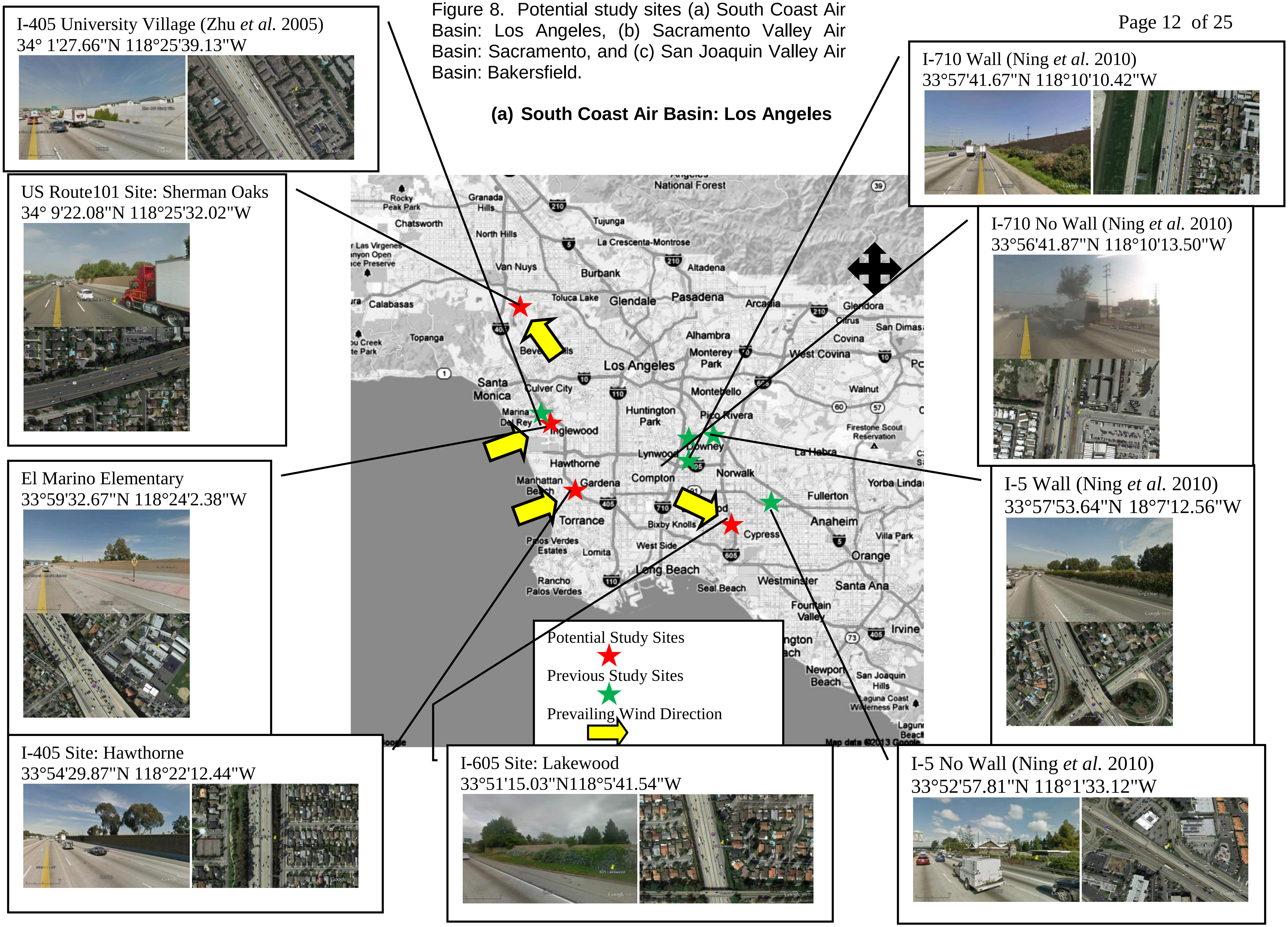
An area map of each basin is presented with red stars marking potential sites (**Figure 8**). Green stars mark the sites at which two previous studies were performed (Zhu et al. 2005; Ning et al. 2010), which can also serve as potential sites. The yellow arrows indicate the prevailing wind directions obtained from nearby monitoring stations. The callout boxes give more detail about each site including a closer aerial view of the area and a freeway view of the sound barrier wall. The longitude and latitude of the each site are also provided.

In the SoCAB two potential sites were identified along the I-405, one along the I-605, and one along US-101. The two I-405 sites represent the coastal region of the air basin. The I-605 and the US-101 sites represent more inland regions. In addition, study sites used in previous near-roadway studies in SoCAB were also indicated. The study by Zhu *et al.* (2005) was on the penetration of ultrafine particles into indoor environments. The study site is located downwind of the I-405 inside of an apartment complex. A portion of this wall has a thick covering of vines. The sample sites used by Ning *et al.* (2010) study also have vegetation along the sound barrier. The two sites in Bakersfield are approximately one mile apart and have sparse vegetation along the sound barrier wall. The two sites in Sacramento are also about one mile apart and have dense vegetation on the residential side.

The sites presented in this proposal have been selected as examples based only upon the listed criteria, and are not an exhaustive review of available sites. Other key factors such as access, power availability, and security were not considered. These factors will be further reviewed with consultation from ARB to determine the most suitable sites. When a "short list" of sites is finalized, preliminary experiments will be conducted via the mobile measurements, to further determine the suitability of sites, especially to rule out potential emissions other than the freeway that could confound the measurements.

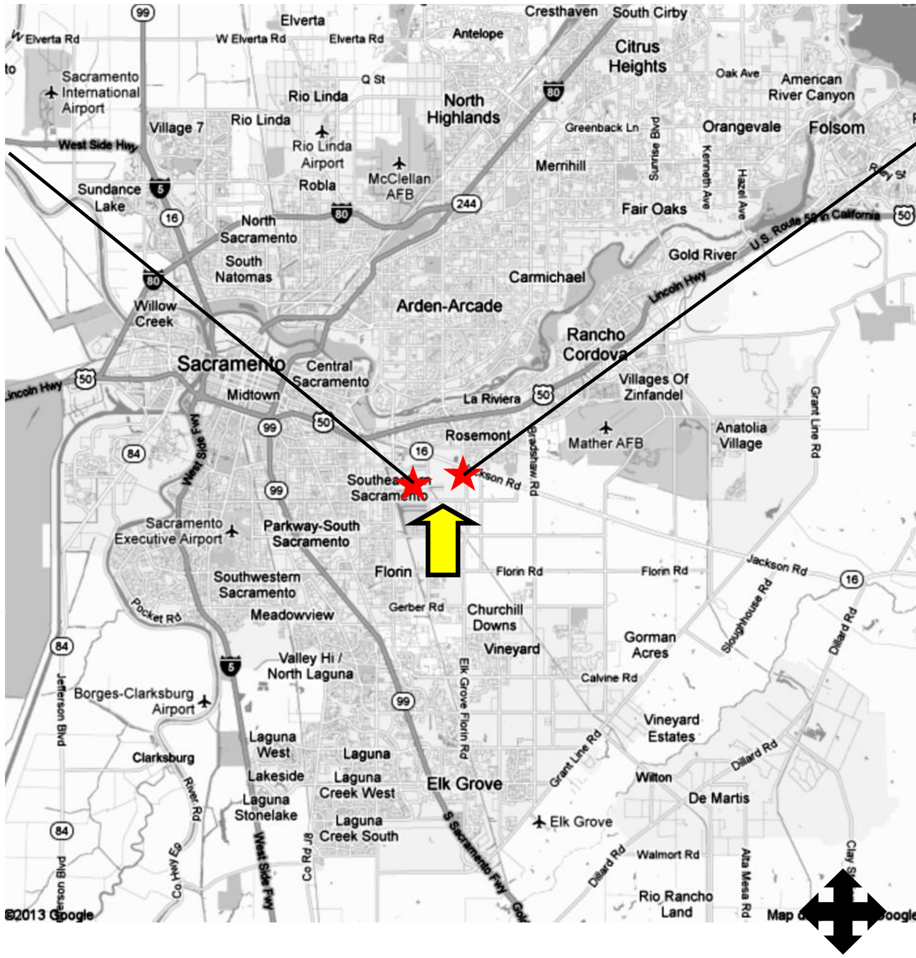
Figure 8. Potential study sites (a) South Coast Air Basin: Los Angeles, (b) Sacramento Valley Air Basin: Sacramento, and (c) San Joaquin Valley Air Basin: Bakersfield.

(a) South Coast Air Basin: Los Angeles

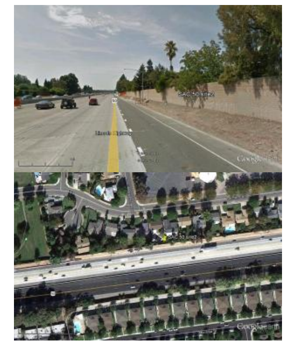


(b) Sacramento Valley Air Basin: Sacramento

US Route 50: College/ Glen
38°33'27.19"N 121°23'35.58"W

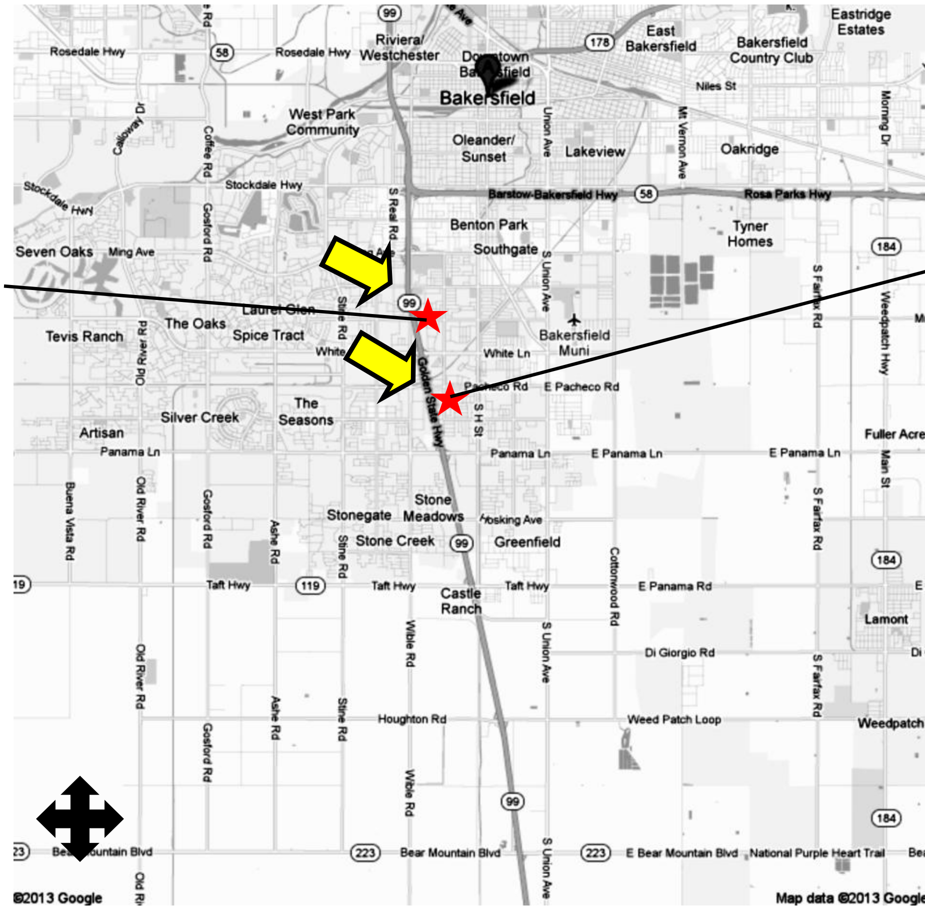


US Route 50: Rosemont
38°33'36.20"N 121°22'11.45"W

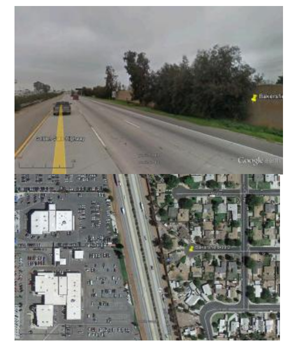


(c) San Joaquin Valley Air Basin: Bakersfield

Route 99: Bakersfield 1
35°19'20.13"N 119° 2'12.72"W



Route 99: Bakersfield 2
35°18'23.15"N 119° 1'56.93"W



3.2.2 Study design: stationary and mobile measurements

We propose to perform a combination of stationary and mobile measurements to effectively determine the effect of the sound walls-vegetation combination barriers in reducing pollutant levels downwind from roadways. Ideally, a dense matrix of ground and elevated stationary measurements (ten or more) could be deployed to fully characterize dispersion of freeway emissions in the presence and absence of sound-walls, and with and without vegetation. In practical terms, this is not possible due to the large quantity of monitoring instrumentation, and importantly secures sites required. To get a complete as possible data set in a reasonably cost effective and timely way, a mobile platform repeatedly sampling in a modified transect pattern can be used in combination with a more limited set of stationary measurements.

For stationary measurements, we have available already in our combined research group sufficient instrumentation to fully equip two monitoring stations, with the exception of NO_x and black carbon (Table 2). Funds for a NO_x instrument and an Aethelometer for black carbon measurements are requested as part of this proposal. In addition to two full sites, we have the ability to monitor particle number at least at three additional locations, for a total of five sites. Optimal configurations will be determined as part of the study, however it is anticipated that the two fully instrumented sites would be located at the same distance from the barrier, downwind of the sections with and without vegetation, respectively. The three additional particle number measurements will be placed one downwind of the barrier-free control area and at larger distances downwind of the barrier with and without vegetation. Ideally, a sixth sampler can be obtained so that there are two stationary monitors downwind of each of the no barrier, barrier only, and barrier with vegetation sections. We note that a dominant factor in determining stationary monitoring locations is the availability of power and security. Section 8.2 provides a cost estimate for additional instrumentation at the additional sites, as well as for additional weeks of stationary measurements.

Mobile measurement platforms can be used in one of two modes: 1) as a movable stationary monitor, where the platform is stopped repeatedly for multiple minutes, 2) or in traditional mobile mode where the platform is moving mostly continuously, sampling a route designed to make a detailed map of pollutant concentrations. A movable stationary monitor may be the best choice for variable and/or intermittent sources such as aircraft emissions and plume monitoring. For reasonably continuous line sources such as freeways, using the mobile platform in mobile mode and repeatedly following a set sampling route provides a method in which to make continuous profiles and partial two-dimensional maps. Such profiles are particularly useful because they make potential contamination from sources other than the freeway much more obvious and easy to determine; for example if suspiciously high measurements are observed at a stationary site it is almost impossible to know if they arise from the direction of the freeway or somewhere else. Mobile monitoring on the other hand has the potential to provide at a minimum, a continuous one-dimensional profile. Additionally, provided the emissions line source is reasonably steady, repeated mobile monitoring has the potential to effectively provide data that approaches the true ideal, which is a grid or two dimensional map.

Mobile monitoring is arguably the most effective method to characterize plume decay from freeways, regardless of the configuration and it has been used to produce strong results in earlier studies by us (Hu et al. 2009; Choi et al. 2012b). Mobile monitoring allows collection of continuous gradient data, perpendicular to the freeway “line” source. Mobile monitoring can also provide measurements in a grid in the area. Mobile monitoring has two significant drawbacks in this application. It is labor-intensive and can only be performed for several hours at one time, thus limiting the amount of data it is practical to obtain. It can be contaminated by high-emitting vehicles in the immediate vicinity of the measurement instruments, although this problem can also influence stationary measurements. Nevertheless, the advantages of continuous monitoring in its ability to determine the gradient shape, as well as potential anomalies such as unanticipated pollutant sources unrelated to the freeway of interest, far outweigh disadvantages associated with the limitations on the time spans over which it is practical to acquire data.

For this project we propose to deploy the mobile measurements platform (ARB MMP) owned by the California Air Resources Board. The mobile sampling platform is a non-polluting electric Toyota RAV4 sub-SUV; Table 1 summarizes the instruments available on the mobile platform, together with the parameters to be measured and the time resolution of each instrument. The instruments have been selected for their ability to report useful physical and chemical data at high time resolution, for their compact size and robust operation while on roadways, and for their low power consumption. Special emphasis is placed on measurements of pollutants relating to emissions from diesel and gasoline powered vehicles, although several additional area wide pollutants, such as $PM_{2.5}$ are also measured. The vehicle has a range of approximately 75 miles, and is normally housed at a secure facility near downtown Los Angeles, although alternate charging facilities may often be found if needed. For sites where the ARB MMP cannot be made available, we propose to instrument a private or rental electric car using a subset of portable instrumentation, including a Discmini, DusTrak and Q-Trak.

For this study, we propose approximately 50 hours of mobile sampling at each site, between 200 and 300 repetitions of a sampling route. The measurements will be made over the course of a day, and thus over a range of atmospheric conditions, and will be binned into several stability/windspeed groups. As a result, for a given set of meteorological conditions, we may have between 30 and 80 measurements that can be averaged to provide a robust view of the ground level pollutant concentrations in the vicinity of the sound barrier wall, and the influence of vegetation.

3.2.3 Influence of high emitters

A potential issue with all measurements, both stationary and mobile, is the impact of nearby high emitters, which can, when they come in very close proximity of the measurement site, create spurious high concentrations that mask the freeway emissions and the influence of sound barriers. We have recently examined methods to address the impact of high emitters (Choi et al. 2012b; Choi et al. 2013). In short, we have shown that using a running low-quintile filter with a variable width window is effective at removing spikes from high emitters on the surface streets used for mobile measurements. As the MMP approaches the freeway, where pollutant concentrations change rapidly due to the influence of the freeway itself, a narrow window is used so that the strong feature(s) of the freeway are not removed. When the MMP is further away, the window width is increased, to effectively establish the background. The mobile monitoring platform proposed for this study is equipped with a video camera so that presence of high emitters may be verified. Stationary monitors will also be equipped with video cameras to capture traffic patterns on the roadway.

3.2.4 Ultrafine Particle Measurements at Multiple Stationary Sites

While the ideal for a study such as this is to make a full suite of pollutant measurements at many stationary sites, because the instrumentation is expensive to acquire and operate, and because in rough terms, roadway pollutants are diluted together (Karner et al. 2010), much can be learned from making measurements of one or two pollutants at a larger number of stationary sties, arranged in an array. The most desirable choice for pollutants to be measured at multiple sites are ultrafine particles and NO and or NO_2. NO_2 is a criteria pollutant, but NO is the dominant form of NO_x emitted from vehicles. Ultrafine particles are the focus of much of the study in the toxicological community, and appear to be among the active of the pollutants that are elevated around roadways (Knol et al. 2009; Stewart et al. 2010; Kraus et al. 2011). Ultrafine particles are in the same size range as viruses, and thus appear to have a special ability (which larger particles do not have) to transfer from the respiratory system into other human tissues, including the cardiovascular system and brain (Li et al. 2003; Veronesi et al. 2005; Araujo and Nel 2009; Oszlanczi et al. 2010). Because ultrafine particles quickly (within ~30 minutes) coagulate with one another and with larger particles, their background concentrations are low relative to the fresh emissions we need to measure. For other pollutants, the roadway signal may be only 30-100% larger than the background, while for ultrafine particles the roadway levels are typically 100-1000 % or more above than the background (Hu et al. 2012).

We have several instruments that can produce particle number measurements (a good metric for ultrafines) or particle size distributions, up to seven depending on use in other projects (Table 2). We plan to deploy a much larger array of these instruments to the study sites.

Table 1. Instrumentation available for the study

Stationary Monitoring Instrumentation **** Indicates portable, battery powered instrument**			
Instrument and manufacturer	**Measurement Parameter and resolution**	**Time Resolution**	**Research Group**
UFP/Fine Particle Size Distribution			
(2) SMPSs (TSI)	Particle size distributions, range selectable between 10 and 1000 nm	1 min	Paulson & Zhu
Particle Number Concentration			
(at least 2)[1] **Testo Discmini[1]	Ultrafine particle count and average size	1 sec	Paulson
**CPC 3007	Particle number concentration, 0 – 100,000 particles/cm^3	1 sec.	Zhu
WCPC 3785 (TSI)	Particle number concentration, 0 – 100,000 particles/cm^3	1 sec.	Zhu
Black Carbon			
Aethelometer (Magee Scientific)	Black carbon ($\mu g/m^3$)	1 min	Zhu
Micro-Aeth (Aeth Labs)	Black carbon ($\mu g/m^3$)	~5s – 1min	Funds Req.
PM2.5			
(2) **DustTrak (TSI)	PM2.5 ($\mu g/m^3$)	1 min	Zhu

Gasses			
**(2) ****Q-Trak (TSI)	CO_2 (1 ppm), Temp, RH & CO (1 ppm)	1 min	Zhu
**CO_2 Analyzer (Bacharach 2815)	CO_2 (10 ppm spec. but better in practice)	1 min	Paulson
NO_2, Thermo Scientific[2]	1 ppb NO_2 (also NO, but requires on-site operator)	3 min	Paulson
NO_x, Teledyne API T200	0.5 ppb	1 min	Funds req.
Noise			
Quest 2900	dB	1 min	Zhu
Meteorological Instrumentation			
Balloon Tethersonde (Anasphere)[3]	Digital temperature, RH, wind speed in lowest 100 m above ground level	One to three times per day	Paulson
(3) Sonic Anemometer (Campbell Scientific CSAT3)	3-D wind fields	1 – 60 Hz	Venkatram
Portable 10 m Tower			Venkatram
Mobile Measurements Platform instruments			
TSI CPC, model 3007	UFP Count 10 nm-1μm	<5 s	ARB
TSI Model 8520 DustTrak	$PM_{2.5}$, PM_{10}	<5 s	ARB
TSI FMPS	Particle size distribution, 5.6-560 nm	1-60 s	ARB
Magee Scientific Aethalometer	Black Carbon	5 s	ARB
LI-COR, LI-820 CO_2 Gas Analyzer	CO_2	10 Hz	ARB
Teledyne API 300eu	CO	20 s	ARB
Teledyne-API 200e NO_x analyzer	NO, NO_x, NO_2	20 s	ARB
Garmin GPSMAP 76CS	GPS	±3 meters	ARB
Visalia 2-D Sonic Anemometer	Local Wind Speed and Direction	10 Hz	ARB
Eurotherm Chessell Graphic DAQ	Data Logger	N/A	ARB
Stalker Video System	Traffic Documentation	N/A	ARB
DryCal DC-lite, Model M	Gas Flow Calibrator	N/A	ARB
Particle Bound PAHs	Ecochem PAS 2000	5 s	ARB

[1]Availablility of the second instrument is not guaranteed, but there is also the possibility we may be able to deploy up to four portable particle counters. One may be a CPC-type instrument such as the Kanomax portable instrument.

[2]Instrument is very old so its ability to perform in the field is far from guaranteed.

[3]Cannot be deployed within 5 miles of an airport, must be deployed in open area such as large parking lot or park. Will be deployed nearby but not at exact site.

3.2.6 Meteorology and vertical pollutant concentration measurements

Meteorological variables are critical to interpreting concentrations measured during the field studies. At each location of interest, we will make measurements with at least two sonic anemometers. The sonic anemometers will measure all three components of wind velocity and virtual temperature with a sampling rate of 10 Hz to enable characterization of turbulent transport and sensible heat fluxes near the ground. Measurements from sonic anemometer placed next to the road will examine the impact of traffic-induced turbulence on dispersion (Kalthoff et al. 2005). The 2-D sonic anemometer mounted on the instrumented van will provide additional data on wind speed and direction. We will use a fixed video camera to record traffic flows on the arterial roadway to augment traffic data collected with the mobile platform. A 10m mobile tower, set up for rapid deployment on a trailer, will provide characterization of meteorological variables up to the height of 10 m. We will add to the tower the ability to measure particle concentrations at 5 and 10 meters, providing a critical test for model refinement.

3.2.7 Characterize vegetation

The effect of vegetation clearly depends on its physical characteristics, as well as its activity (Fuller et al. 2009). The outcomes from our study with regard to the details of the ability of vegetation to mitigate pollution are difficult to predict. With only three sites and so many other requirements in site selection (presence of nearby control areas, power and security for stationary measurements and so on) we may not be able to find sites with the correct variables in terms of vegetation (such as the same height and geometry with respect to other aspects of the freeways, but significantly different leaf area index). However, depending on the magnitude of the effect of vegetation and the sites we select, the study may be able to produce clear results for some vegetation metrics. Regardless, for our study to be able to contribute to the body of knowledge surrounding the effectiveness of vegetation at mitigating pollutant concentrations, vegetation properties must be well characterized.

Vegetation will be characterized in terms of its type and physical characteristics, including genus and species, height, width, spacing, optical porosity, leaf shape and clumping, leaf area index, and stomatal conductance. Leaf area index is likely the dominant parameter for particle deposition and stomatal conductance a significant contributor to impacts on gaseous pollutants, while characteristics of leaf shape and clumping contribute to optical porosity. Optical porosity can be obtained with a photographic image and various post processing schemes. Leaf area index will be estimated using a Plant Canopy Analyzer (such as the LAI 2000, Li-cor, or CI-110, CID Inc.) or Hemispheric Image Analysis System (HemiView, Dynamax), or if necessary by scaling up from manual branch-scale measurements. Stomatal conductance will be measured using a Leaf Porometer (SC-1, Decagon). In any cases where measurements are not possible, we will use published literature for these properties when available. Because we need these instruments only briefly, we anticipate being able to borrow sufficient instrumentation to perform the measurements.

3.2.8 Noise measurements

Sound levels will be measured using the Quest 2900 meter which performs a wide variety of acoustical measurements. The Quest 2900 has the capability of internal data logging to provide time integrated measurements for noise. It has been used in a wide-range of laboratory, industrial, and community settings. The sound level meter will be used to collect data to ensure that the sound walls are achieving their intended purpose.

3.2.9 Traffic activity patterns

Traffic activity patterns (i.e., traffic volume and speed, and fleet mix) will be obtained through two methods. We will download traffic data from the Performance Management System (PeMS) which provides historical and real-time traffic flow and speed via Caltrans loop detectors from traffic management centers statewide. The PeMS data are generally regarded as the gold standard for estimating traffic flow. However, our recent study (Quiros et al., 2013) found at certain sites, there were substantial discrepancies in truck flow between PeMS data and video records which undermines the robustness of the PeMS data base. Thus, in the proposed study, traffic collected on the video cameras will also be quantified in terms of traffic volume and speed, and fleet mix and compared to PeMS.

3.3 Alternate Task Plans

In the cost proposal section we provide estimates of costs for additional studies, specifically costs of additional instrumentation and costs associated with additional weeks of field measurements at the three sites selected and the additional analysis required to do basic processing of the resulting data.

3.4 Data Management Plan

3.4.1 Data Acquisition

Critical measurements include (1) total particle number concentration, (2) ultrafine particle size distribution, (3) $PM_{2.5}$ mass concentration, (4) black carbon concentration, (5) NO, NO2, NOx concentration, (6) carbon monoxide, carbon dioxide concentrations, (7) local meteorological data, (8) noise level, (9) traffic activity patterns and (10) fleet mix (see Table 2). Measurements will be taken simultaneously at the stationary site and at increasing downwind distances from the freeway.

All real-time continuous air quality instruments will sample continuously during the course of the study. All the instruments that are listed below will be synchronized beforehand to a satellite-signaled clock and data will be archived into a designated data collection laptop computer at the experiment site.

- TSI WCPC: total particle number concentration
- TSI SMPS system: ultrafine particle size distribution
- NOx analyzer: NO, NO2, and NOx
- TSI DustTrak: real-time particle mass $PM_{2.5}$
- Magee Scientific Aethelometer: real-time black carbon concentration
- TSI Q-Trak: CO and CO_2 concentration, temperature, and relative humidity
- Matter Aerosol Discmini: particle number concentrations and average particle size

3.4.2 Data Validation

Data validation will follow guidelines described by the U.S. Environmental Protection Agency (U.S. EPA, 1978, 1980). This includes the following steps: (1) flag data when significant deviations from measurement expectations occur; (2) verify computer file entries; (3) eliminate values for measurements that are known to be invalid because of instrument malfunctions; (4) adjust measurement values for quantifiable calibration or interference biases. Data will not be removed unless there is an identifiable problem or the measurement result is physically impossible.

Partial data validation will also be conducted between runs as a preliminary validation step. Partial data validation is the process of scanning data in real-time, and noting anomalous data. Performing preliminary validation steps serves as a check to ensure the instruments are functioning correctly and also will allow us to develop an initial understanding of the data from our measurements, thus laying the groundwork for subsequent more detailed data analysis, as well as the possibility of "mid-course" corrections in our study design.

Synchronization is used to provide time consistency. The SMPS system will be operated by a laptop computer and particle size distribution will be generated by Aerosol Instrument Manager software (version 9.0, TSI Inc., St. Paul., MN) in real time and logged by the laptop. Temperature and relative humidity will be collected and logged internally by Q-Trak. All data will be transferred to the designated laptop PC for storage and backup right after each run on site. The data collection laptop will be brought back to UCLA on a daily basis to back up all data into Drs. Paulson and Zhu's computers. Meteorological data stored on data recorders associated with the sonic anemometers will be downloaded daily on laptop PCs for subsequent processing. All the instruments that will be used in this study provide continuous or near-continuous data. After data validation following the guidelines described by the U.S. Environmental Protection Agency (US EPA 2002), all data will be imported into the Statistic Analysis System (SAS 9.2) for archive and future analysis. All data will be screened for outliers that are not within the physically reasonable (normal) ranges. We will take the following steps:

1) Flagging data when significant deviations from measurement assumptions have occurred.
2) Verifying computer file entries.
3) Eliminating values for measurements that are known to be invalid because of instrument malfunctions.
4) Adjustment of measurement values for quantifiable calibration or interference biases.

Real-time continuous data will be reviewed as time series plots during the measurement and after each sampling day. Rapidly changing, anomalous or otherwise suspect data will be examined with respect to other data. Data values below detection limits will be entered into the database as the detection limit and flagged as non-detect. Data will not be removed unless there is a good reason or the measurement result is physically impossible.

3.4.3 Data Archiving

There will be two computers designated for data management, a data acquisition laptop and a central server-type computer located at UCLA. The data acquisition computer will be used to continuously collect primary environmental data during the study. This laptop computer will be backed up to assure the original data are preserved. It will also be equipped with the capability of transferring data through the Internet or other data transfer protocols to the central server computer. The primary role of the central server-type computer is to house all secondary processed and publication-ready data from the study.

3.5 Facilities

3.5.1 Paulson Laboratory

Prof. Paulson's laboratory facilities include a 1600 sq. ft. facility on the first floor of the Math Sciences building and an additional 500 sq. ft. laboratory on the roof of the math sciences building, together with adjacent roof space, with elevator service. Adjacent to the penthouse laboratory is an outdoor 24 m^3 Teflon chamber facility equipped with clean air generators a padded frame to support the chamber and covers, surrounded by a locked fence.

Instrumentation available in Prof. Paulson's laboratory includes a Scanning Mobility Particle Sizer (TSI), an Aerodynamic Particle Sizer (TSI 3321), a Sartorius microbalance (1 µg) in a T and RH controlled weighing room, an integrating nephelometer (Ecotech), a liquid wave guide capillary cell absorption spectrometer (Avantes), a fluorescence spectrophotometer (thermo scientific), four gas chromatographs (Varian, Hewlett Packard (2), SGI) each with flame ionization detectors, one with ion trap mass spectrometer (Varian Saturn), NO_x (Thermo Environmental) and O_3 (Dasibi Corp) analyzers, a high performance liquid chromatograph (Shimadzu) capable of measuring hydroperoxides collected from the gas- and aerosol phase. We have two laboratory-built polar nephelometers, which measure angularly resolved scattering at 532 and 980 nm. An additional laser at 670 nm can be substituted in for one of the other wavelengths. Additional equipment includes 2 Collison nebulizers, a Teflon heat sealer, two virtual impactors, 8 flow controllers, ozone generators, a tube furnace (Thermolyne) and conventional oven, water baths, pumps, flow meters, cylinder regulators, a hood, and vacuum line. The laboratory also has a fully equipped and well-characterized indoor 1.3 m^3 Teflon chamber facility with controlled temperature and humidity, supplied with purified air and illuminated with either with black lights or UV lights, several additional Teflon chambers, a flow tube apparatus and an evacuable white cell with attached Fourier Transform Infrared Spectrometer (Bruker).

3.5.2 Zhu Laboratory

Dr. Zhu has one laboratory (600 ft2, 51-295 CHS) dedicated to ultrafine particle exposure and dynamic studies. Her laboratory is equipped with two fume hoods, line vacuum; compress air, and wireless connections. This laboratory is available to Dr. Zhu at 100% time. Major equipment in this space includes two Scanning Mobility Particle Sizers to measure real-time ultrafine particle concentrations and size distributions; two Water-based Condensation Particle Counters that count total particle number concentrations every second; and one Aethelometer to measure near real-time BC concentrations. Minor equipment in this space includes: two units of TSI DustTrak monitor that measures $PM_{2.5}$ in real-time, two Sioutas personal cascade impactors that classify particulate matter (PM) in 5 size ranges (<0.25; 0.25 – 0.50; 0.5 – 1.0; 1.0 - 2.5; 2.5 – 10 μm); two units of TSI Q-Trak monitors that measures CO, CO_2, temperature and relative humidity in real-time; and two Garmin GPS-18 global positioning system that track vehicle time-location patterns. These laboratory facilities were specifically designed and equipped to support the proposed research.

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Stewart, J. C., D. C. Chalupa, R. B. Devlin, L. M. Frasier, L. S. Huang, E. L. Little, S. M. Lee, R. P. Phipps, A. P. Pietropaoli, M. B. Taubman, M. J. Utell and M. W. Frampton (2010). "Vascular Effects of Ultrafine Particles in Persons with Type 2 Diabetes." Environmental Health Perspectives **118**(12): 1692-1698.

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Veronesi, B., O. Makwana, M. Pooler and L. C. Chen (2005). "Effects of subchronic exposure to concentrated ambient particles: VII. Degeneration of dopaminergic neurons in Apo E-/- mice." Inhalation Toxicology **17**(4-5): 235-241.

Wellenius, G. A., M. R. Burger, B. A. Coull, J. Schwartz, H. H. Suh, P. Koutrakis, G. Schlaug, D. R. Gold and M. A. Mittleman (2012). "Ambient Air Pollution and the Risk of Acute Ischemic Stroke." Archives of Internal Medicine **172**(3): 229-234.

Wilhelm, M. and B. Ritz (2003). "Residential proximity to traffic and adverse birth outcomes in Los Angeles County, California, 1994-1996." Environmental Health Perspectives **111**(2): 207-216.

Zhu, J. Y., K. O. Lee, A. Yozgatligil and M. Y. Choi (2005). "Effects of engine operating conditions on morphology, microstructure, and fractal geometry of light-duty diesel engine particulates. ." Proceedings of the Combustion Institute **30**: 2781-2789.

Zhu, Y. F., W. C. Hinds, S. Kim, S. Shen and C. Sioutas (2002). "Study of ultrafine particles near a major highway with heavy-duty diesel traffic." Atmospheric Environment **36**(27): 4323-4335.

Zhu, Y. F., W. C. Hinds, S. Kim and C. Sioutas (2002a). "Concentration and size distribution of ultrafine particles near a major highway." Journal Of The Air & Waste Management Association **52**(9): 1032-1042.

5.0 PROJECT SCHEDULE

5.1 Schedule

Task	Year 1 Qtr. 1	Year 1 Qtr. 2	Year 1 Qtr. 3	Year 1 Qtr. 4	Year 2 Qtr. 1	Year 2 Qtr. 2	Year 2 Qtr. 3	Year 2 Qtr. 4	Year 3 Qtr. 1	Year 3 Qtr. 2	Year 3 Qtr. 3	Year 3 Qtr. 4
1. Study Design and Site Selection												
2. Pilot Studies and SOP Development												
3. Measurement Campaigns												
4. Data Analysis and Preparation of Results												
5. Reports	Quart-erly	Quart-erly	Quart-erly	Quart-erly	Quart-erly	Quart-erly	Quart-erly	Quart-erly	Quart-erly	Quart-erly	Draft Final Rpt	Final Report

*Depends on start date; sampling is targeted primarily for winter when pollutant concentrations tend to be highest.

6.0 REPORTING

Quarterly progress reports will be written to review the work conducted and describe any problems encountered during the reporting quarter; discuss the work to be conducted in the next quarterly period; and to present the funds expended and assess the status of the project with respect to being on time and within budget.

A draft final report will be written in accordance with the ARB guidelines. This will consist of the following main components:

- Description of the objective and approach.
- A summary and discussion of the data collected and estimates of precision and accuracy.
- Summary and conclusions.

The final report will include a summary of all of the data. In addition all data will be provided on magnetic media in a format specified by the ARB

The final report will address any comments provided by the ARB after reviewing the draft final report.

The investigators will also present the study results to interested ARB staff and scientists at a Chairman's Technical Seminar at the end of the project. Furthermore the intent of the investigators is to publish at least one article regarding this study in a peer-reviewed journal.

7.0 PROJECT MANAGEMENT PLAN

7.1 Staff and Responsibilities

UCLA Staff – Paulson Group

1. PI: Suzanne Paulson: General oversight of project, day-to-day management of the project and coordination with other investigators, field site planning and coordination, assistance with measurements, data analysis, and primary responsibility for written presentation of results related to measurement data, primary responsibility for reporting and budgeting of UCLA portion of project. Group is responsible for logistics at one of the three sites.
2. Prof. Emeritus Arthur M. Winer (without salary): Contributions to study and data analysis design, contributions to manuscript preparation.
3. Postdoctoral researcher, UCLA: Dr. Wonsik Choi. Dr. Choi has extensive experience with the ARB mobile measurement platform instrumentation and with producing insightful analyses of its data. He will have primary responsibility for field measurements, data analysis, QA/QC, draft reports and manuscripts.
4. Part time GSR will assist Dr. Choi in field measurements and data analysis.

UCLA Staff – Zhu Group

1. PI: Yifang Zhu: Assist Paulson with field site planning and coordination, responsible for field measurements, data collection and analysis. Assist Paulson with written presentation of results related to measurement data, and reporting and budgeting of UCLA portion of project. Group is responsible for logistics at one of the three sites.

2. Part time GSR (49% in academic year and 100% in summer) will be responsible in maintaining and operating instruments from Zhu's lab and assist in the field measurements and data analysis.

UCLA Staff – Seibt Group

1. Co-I: Ulrike Seibt: Plan, coordinate and lead efforts to characterize vegetation at all sites.

UCR Staff

1. PI: Akula Venkatram: Primary contact with UCLA. Responsible for literature review, data analysis, and interpretation of concentration data using semi-empirical dispersion models. Report writing and budgeting. Group is responsible for logistics at one of the three sites.
2. GSR will conduct micrometeorological measurements and assist in data analysis and modeling.

7.2 Management and Coordination

The nature of this project is such that it must be undertaken as a close collaborative effort between the UCLA and UCR investigators. All groups will participate in designing a detailed and evolving framework for sampling and sample analysis to achieve the objectives discussed in this proposal. Weekly research group meetings will be held separately for the researchers at each University. In addition, all three groups (PIs and postdoc, and students as appropriate and practical) will have meetings at least monthly by conference call throughout the duration of the project, and at much higher frequency during the planning, implementation and analysis of the field measurement intensives.

UCLA and UCR staff will jointly choose the field site and designing the measurements. UCLA and UCR will collaborate closely on the field measurements, communicating closely on at least twice per week or more frequent communications, by telephone or in person when practical. The UCLA postdoc will serve as the field captain, with primary responsibility for maintaining consistent, high quality field sample collection.

8.0 PRELIMINARY COST PROPOSAL

Task	UCLA Labor	UCLA Benefits	UCR Sub (includes OH)	UCLA Equip	UCLA Travel Subsist	EDP	UCLA Copy Print	UCLA Mail Phone Fax	UCLA Materials and Supplies	Anal.	UCLA Misc.	UCLA Overhead	Total
1	$ 22,804	$ 4,091	$ 18,759	$ -	$ 300	$ -	$ 133	$ 133	$ -	$ -	$ 3,840	$ 2,788	$ 52,848
2	$ 17,103	$ 3,068	$ 14,069	$ -	$ 1,000	$ -	$ 100	$ 100	$ 300	$ -	$ 2,880	$ 2,199	$ 40,819
3	$ 70,942	$ 12,493	$ 54,715	$ 16,000	$ 4,200	$ -	$ 387	$ 387	$ 7,000	$ -	$ 11,199	$ 9,663	$ 179,986
4	$ 74,114	$ 13,295	$ 60,969	$ -	$ 2,000	$ -	$ 431	$ 432	$ -	$ -	$ 12,478	$ 9,164	$ 172,883
5	$ 9,501	$ 1,705	$ 7,818	$ -	$ -	$ -	$ 55	$ 55	$ -	$ -	$ 1,599	$ 1,149	$ 21,882
	$ 194,464	$ 34,652	$ 156,330	$ 16,000	$ 7,500	$ -	$ 1,106	$ 1,107	$ 7,300	$ -	$ 31,996	$ 24,963	$ 475,418

Tasks:

1. Site Selection, detailed design.

2. Pilot Testing and Standard Operating Procedure (SOP) Development.

3. Conduct Field Campaigns

4. Data Analysis and Preparation of Results

5. Prepare Quarterly Reports and Final Report

8.1 Cost Sharing

To date we have secured modest cost sharing for the equipment required for the proposal. The UCLA Institute of the Environment has agreed to provide $4,000 toward purchase of instrumentation. Currently we have this budgeted toward the NO_x or BC analyzers, which, consistent with ARB's priorities are the highest priority instruments needed. If an alternate source of a NO_x and BC analyzers is found, the next priority is probably an additional particle counter. The research team is also planning to put in a proposal to response to the Health Effects Institute's upcoming RFA on near roadway pollution. If this proposal is successful we will work together with both agencies to develop a more extensive and comprehensive project. Finally, we will work together with the South Coast Air Quality Management District to determine if there is the potential that they could collaborate to augment our measurements, data analysis and/or modeling efforts.

8.2 Alternative Cost Proposals

The above cost proposal covers costs for conducting the studies at three sites for a total of 8 weeks, divided as follows: Site 1, three-four weeks each in summer and winter, site 2, three – four weeks in summer or fall, site 3, three - four weeks in winter or spring. Planned for each site is 10 days to two weeks of intensive sampling with all measurements including mobile measurements, and 10 days to two weeks of additional measurements with only stationary sampling.

- Cost for additional weeks of stationary sampling at any site already included in the study, including basic data work up is about $4000/week.
- Additional sites would be much more expensive due to the large amount of additional logistics, pilot studies, and so on.
- Costs for additional instrumentation for each additional stationary site are approximately $70,000 for instrumentation, including particle number, NO, NO_2, black carbon, CO, CO_2 and PM2.5
- Cost for additional minimally instrumented stationary sites is about $8800 per site for instruments to monitor particle number (such as a Kanomax handheld) and carbon dioxide (inexpensive sensor), together with minimal materials for power and security.

9.0 CURRICULUM VITAE FOR KEY PERSONNEL

SUZANNE E. PAULSON August, 2012
email: paulson@atmos.ucla.edu

CURRENT POSITION

Vice Chair & Professor, Department of Atmospheric and Oceanic Sciences
& Professor, UCLA Institute of the Environment
University of California at Los Angeles 90095-9565

PROFESSIONAL HISTORY
Assistant & Associate Professor of Atmospheric Chemistry 1994-2005
Department of Atmospheric Sciences, University of California at Los Angeles

Advanced Study Program Post-Doctoral Fellow, National Center for Atmospheric Research
10/1991-2/1994

EDUCATION
Ph.D., Environmental Engineering Science, June 1991, California Institute of Technology. Course Concentration in Chemistry and Chemical Engineering.
Thesis: "Contributions of Biogenic and Anthropogenic Hydrocarbons to Photochemical Smog Formation." Advisor: Professor John H. Seinfeld.
M.S., Environmental Engineering Science, June 1987, California Institute of Technology.
M.S., Plant Biology, August 1986, University of Illinois, Urbana-Champaign.
B.A., Chemistry, December 1983, University of Colorado at Boulder.

TEACHING AND EDUCATIONAL ACTIVITIES
Degree Development
Founding Chair, Interdepartmental Advisory Committee for the New Environmental Science Degree 06-10
Committee to Develop Environmental Science Degree, Member 04-06
Committee to Administer UCLA/Getty Conservation Program Masters of Arts 04-
New Course Development
Introduction to Environmental Science: the Earth and Atmosphere (Undergraduate) 07
Transportation Alternatives: Air Pollution and Climate Impacts (Undergraduate) 11, 12
Topics in Advanced Atmospheric Chemistry-The Troposphere (Graduate) 94, 99, 09-12
Environmental Chemistry Laboratory (Undergraduate/Graduate) 94-98
Courses Taught
Environment 1 & 2 (Non-Scientist General Education) 04-07, 12
Air Pollution (Non-Scientist General Education) 09, 10, 12
Science of the Environment (Undergraduate Non-Scientist/Engineers) 01
Air and Water Pollution (Upper Division Undergraduate) 00-04
Introduction to Atmospheric Chemistry (Undergraduate/Graduate) 94-99, 02-06, 08-10, 12
Environmental Chemistry Laboratory (Undergraduate/Graduate) 94-98
Advanced Atmospheric Chemistry-The Troposphere (Graduate) 94, 95, 99, 09-12
Undergraduate Research Mentoring

A total of 21 undergraduates have participated in our research program during 95-12.

HONORS AND AWARDS

2001 Guest Professor, University of Innsbruck, Austria
1999 University of California Regents Faculty Fellowship
1999 Who's Who in American Women in Science
1996 NSF CAREER Award
1995 Award for Excellence in Teaching and Education, UCLA Dept. of Atmospheric Sciences.
1991-1993 National Center for Atmospheric Research Advanced Study Program Post-Doctoral Fellowship.
1990-1991 Dissertation Fellowship, American Association of University Women.
1986-1989 Switzer Scholarship for Environmental Chemistry, Hewlett-Environmental Quality Laboratory Summer Fellowship, Earl C. Anthony Fellowship, Caltech.

PROFESSIONAL. EXPERIENCE-Past 5 Years

Director, Air Pollution Research Center, UCLA Institute of the Environment and Sustainability	2012-
Science Advisory Board member, EPA Clean Air Research Center, Georgia Tech	2011-
American Association of Aerosol Research Publications Committee	2009-2012
Chair	2010-2012
Research Screening Committee Appointee, California Air Resources Board	2008-
Expert, Hydrocarbon Reactivity Case, Fish & Richardson P.C.	2007

PUBLIC SERVICE & SELECTED PRESS

-Press Interviews, Public Education Talks and Fora, General Air Pollution 1999-
NY Times, NPR, Wall Street Journal, Christian Science Monitor, Discovery Channel Canada, Prop 23 Documentary, IMPACT cable TV biodiesel documentary, NY Times business section June 30, 2010, KCET TV 11/10, 2009 – 2010: ~50 other print and radio interviews, including several articles in African, European and Asian Publications; LA City View 35 Dec. 3, 2011, NPR California report May 16, 2012, National Academies of Science/Entertainment Executive Salon (7/12).

-Airport Pollution: North Westdale Community (1/10), Los Angeles City Councilman Rosendahl (2/10), Santa Monica Airport Commission (2010, 2012), Congressman Henry Waxman (9/10), Congresswoman Jane Harmon, District 9 EPA administrator (10/10), Congressman Henry Waxman, CA Senator Ted Liu; CA Senate Select Committee on Air Pollution Nov. 30, 2011, National Academies of Science's Science-Entertainment Salon July 31, 2012, Sept. 2012: NPR, Los Angeles Times

-Climate Education

UCLA Sociology Class (4/00), Loyola Mary Mount University Biology (9/2000), USC Geography (11/00), Loyola Mary Mount University Chemistry (5/01), Univ. of Innsbruck Department of Physics (9/01) UCLA Civil Engineering (11/02), Cal State Fresno (4/04), Malibu (3/05), CA Legislature (4/05), UCLA "Professor in the Union" (11/05), Union of Concerned Scientists Web video (4/06), Manhattan Beach HS (4/07), Lake Arrowhead Bruin Woods (3/08, 8/08, 7/09, 8/09, 3/10, 4/10, 1/12), Prop. 23 Documentary interview (9/10).

PUBLICATIONS: 68 and 1 Submitted (list in Section 5).

Yifang Zhu, Ph.D.
Department of Environmental Health Sciences
University of California Los Angeles (UCLA), Fielding School of Public Health
650 Charles Young Drive South, 51-295 CHS
Los Angeles, CA 90095
Phone (310) 825-4324
Fax (310) 794- 2106
Email: yifang@ucla.edu

EDUCATION

1999-2003	Ph.D.	UCLA, PI: William C. Hinds
1997-1999	M.S.	Kwangju Institute of Sci. & Tech (South Korea), PI: Ken W. Lee
1992-1997	B.Eng.	Tsinghua University (China)

PROFESSIONAL EXPERIENCE

2012-present	Associate Professor (with tenure), UCLA
2010-2012	Assistant Professor, UCLA
2006-2010	Assistant Professor, Texas A&M University-Kingsville
2005-2006	Assistant Professor in Residence, UCLA
2003-2005	Post-Doctoral Researcher, UCLA, PI: William C. Hinds

HONORS AND SPECIAL AWARDS

Haagen-Smit Prize – Atmospheric Environment (2011)
National Science Foundation Faculty Early Career Development (CAREER) Award (2009)
The Health Effects Institute Walter A. Rosenblith New Investigator Award (2007)
Texas A&M University – Kingsville (TAMUK), University Research Award (2007)
Delta-Omega Honorary Society for Graduate Studies in Public Health (2003)
UCLA Samuel J. Tibbitts Award (2002)
UCLA Chancellor's Fellowship (1999 – 2002)

Selected Peer-reviewed Publications (Selected from 46 peer-reviewed publications)

Five most relevant to the current application

1. **Yifang Zhu**. Hinds, W.C., Kim, S., and Sioutas, C., "Concentration and size distribution of ultrafine particles near a major highway" (2002) J. Air Waste Management Assoc., 52, 1032-1042.
2. **Yifang Zhu**, Thomas Kuhn, Paul Mayo, and William C. Hinds "Comparison of daytime and nighttime concentration profiles and size distributions of ultrafine particles near a major highway" (2006) Environmental Science and Technology 40: 2531-2536.
3. **Yifang Zhu**, Arantza Eiguren-Fernandez, William C. Hinds, Antonio H. Miguel, "In-cabin commuter exposure to ultrafine particles on Los Angeles freeways" (2007) Environmental Science and Technology. 41: 2138-2145.
4. Bin Xu and **Yifang Zhu** "Quantitative analysis of the parameters affecting in-cabin to on-roadway (I/O) ultrafine particle concentration ratios" (2009) Aerosol Science and Technology, 43: 400-410.

5. Qunfang Zhang and **Yifang Zhu** "Performance of School Bus Retrofit Systems: Ultrafine Particles and Other Vehicular Pollutants" (2011) Environmental Science and Technology, 45: 6475–6482.

Additional 10 recent publications of importance to the field (in chronological order)

6. **Yifang Zhu**, Hinds, W.C., Kim, S., Shen, S., and Sioutas, C. "Study on ultrafine particles near a major highway with heavy-duty traffic" (2002) Atmospheric Environment, 36, 4323-4335
7. **Yifang Zhu**, Hinds, W.C., Shen, S., and Sioutas, C., "Seasonal trends of concentration and size distribution of ultrafine particles near major highways in Los Angeles" (2004) Aerosol Science and Technology, 38 (S1), 5-13
8. **Yifang Zhu** and William C. Hinds "Predicting particle number concentrations near a highway based on vertical concentration profile" (2005) Atmospheric Environment, 39: 1557-1566
9. **Yifang Zhu**, William C. Hinds, Margaret Krudysz, Thomas Kuhn, John F. Froines, and Constantinos Sioutas "Penetration of freeway ultrafine particles into indoor environments" (2005) Journal of Aerosol Science, 36: 303-322.
10. **Yifang Zhu**, David Fung, Arantza Eiguren-Fernandez, William C. Hinds, "Measurements of ultrafine particles and other vehicular pollutants inside a mobile exposure system on Los Angeles freeways" (2008) J. of Air and Waste Management Association, 58: 424-434.
11. Teresa L. Barone and **Yifang Zhu** "Morphology of ultrafine particles on and near freeways" (2008), Atmospheric Environment, 42: 6749-6758.
12. Longwen Gong, Bin Xu and **Yifang Zhu** "Ultrafine particles deposition inside passenger vehicles" (2009) Aerosol Science and Technology, 43: 544-553.
13. Qunfang Zhang and **Yifang Zhu** "Measurements of Ultrafine Particles and Other Vehicular Pollutants inside School buses in rural South Texas roadways" (2010) Atmospheric Environment, 44 (2) 253-261.
14. Bin Xu, Shusen Liu, and **Yifang Zhu** "Ultrafine particle penetration through idealized vehicle cracks" (2010) Journal of Aerosols Science, 41(9) 859-868.
15. Bin Xu, Shusen Liu, Junjie Liu and **Yifang Zhu** "Effects of vehicle cabin filter efficiency on ultrafine particle concentration ratios measured in-cabin and on-roadway" (2011) Aerosol Science and Technology, 45:215–224.

Akula Venkatram
Professor of Mechanical Engineering
University of California, Riverside 92521
venky@engr.ucr.edu

Phone: 951-827-2195

Educational Background:

PhD, Mechanical Engineering, Purdue University, 1976.
MS, Mechanical Engineering, Brigham Young University, 1973.
BTech, Mechanical Engineering, Indian Institute of Technology, 1971.

Recent Professional Positions:

Professor, Mechanical Engineering, University of California, Riverside, CA - 1993-present
Vice President (Last Position), Air Sciences, ENSR Consulting and Engineering, CA – 1981-1993
Head (Last position), Atmospheric Model Development Unit, Ontario Ministry of the Environment – 1977-1981
Research Scientist, Atmospheric Environment Service, Canada, - 1976-1977

Memberships, etc.:
Associate Editor, Journal of Applied Meteorology, 1991-1996
Member, AMS Committee on Meteorological Aspects of Air Pollution, 1984-1989, 1997-2000
Member, South Coast Advisory Council, 1990-1994
Member, AMS/EPA Committee on Regulatory Model Development, 1987- 2000
Member, USEPA Committee on Regulatory Model Improvement, 2005- 2010
Chair, FAA Committee on Airport Modeling, 2009-2010
Member, USEPA Committee on Exposure Modeling, 2011-

Professional Honors and Awards

United States Environmental Protection Agency, **Scientific and Technological Achievement Award** for "expanding and improving the scientific and regulatory communities' ability to assess the impacts of mobile source emissions", 2010.

Award from the Committee on Meteorological Aspects of Air Pollution of the American Meteorological Society for "contributions to the field of air pollution meteorology through the development of simple models in acid deposition, ozone photochemistry and urban dispersion" , 2011

Consulting Experience

I have consulted on all aspects of air quality and meteorological modeling. My clients include 1) Envirocomp, 2) ERM, 3) USEPA, 4) Louisiana Pacific Paper, 5) CH2M Hill, and 6) ENSR.

Arthur M. Winer, Ph.D.

Academic Title:	Distinguished Professor Emeritus
Business Address:	Environmental Health Sciences Department School of Public Health University of California Los Angeles, CA 90095-1772 E-mail: amwiner@ucla.edu

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EDUCATION

B.S. Chemistry, University of California, Los Angeles, l964
Ph.D. Physical Chemistry, The Ohio State University, l969
Post-Doctoral Fellow, University of California, Berkeley, 1970-71

HONORS

NSF Undergraduate Research Fellowship, UCLA, l964
Sigma Xi
Clean Air Award, Coalition for Clean Air, l984
Commendation from South Coast Air Quality Management District, 1986
Commendations from President Clinton and Congress, 1998
Faculty Member of the Year Award from UCLA School of Public Health, 2000
ISI Highly Cited Researcher in Environmental Field, 2003
Carl Moyer Award for Scientific Leadership and Technical Excellence, Coalition for Clean Air, 2004
American Lung Association Clean Air Award, 2004
Haagen-Smit Award, 2006
Luskin Scholar, 2009-2010

PROFESSIONAL EXPERIENCE

2010-Present	Distinguished Professor Emeritus
2009-2010	Luskin Scholar, UCLA Luskin Center for Innovation
2005-2010	Distinguished Professor Environmental Health Sciences Department UCLA School of Public Health
2005-2006	Associate Director, UCLA Institute of the Environment
1995-2002	Associate Director, University of California Toxic Substances Research & Teaching Program (for the five southern campuses)
1990-1998	Director and Chair, Environmental Science and Engineering Program UCLA School of Public Health
1989-2005	Professor Environmental Health Sciences Department, UCLA SPH
1985-1989	Co-Director, UC Riverside Toxic Substances Research and Training Program
1971-1989	Research Chemist, Statewide Air Pollution Research Center, UC Riverside
1978-1986	Assistant Director, Statewide Air Pollution Research Center, UC Riverside

1970-1971 Postdoctoral Fellow with Professor George C. Pimentel
Department of Chemistry, University of California, Berkeley

RESEARCH INTERESTS

Air pollutant exposure assessment field measurements, with an emphasis on children's exposure in key microenvironments, including diesel school buses, portable classrooms, personal residences and vehicles. Application of an instrumented electric vehicle to measure air pollution concentrations and gradients in communities adjacent to the Ports of Long Beach and Los Angeles, as well as in west- and downtown Los Angeles, with an emphasis on emissions from heavy-duty diesel trucks and high-emitting gasoline vehicles. Atmospheric transformations of airborne chemicals. Measurements of vehicle exhaust constituents, including greenhouse gas emissions from mobile sources.

PROFESSIONAL SERVICE

1980-81 Member, Environmental Impacts Panel, Diesel Impacts Study Committee, HEI
1981-86 Member, Advisory Council of the South Coast Air Quality Management District
1983-84 Member, Review Panel on Epidemiologic Investigation of Effects of Automotive Emissions, Health Effects Institute
1983-85 Member, Stringfellow Toxic Waste Site Scientific Advisory Panel
1983-86 Member, City of Riverside, Environmental Protection Commission
1984-95 Research Consultant to Health Effects Institute
1985-86 Research Consultant to U.S. Environmental Protection Agency
1985-87 Member, Health Effects Institute's Exposure Analysis Subcommittee
1986-94 Member, Environmental and Occupational Health Committee, ALA of California
1988-89 Consultant to California Assembly Office of Research
1989-96 Member, Modeling Working Group, SCAQMD
1989-97 Atmospheric Sciences Comm., Advisory Council, SCAQMD (Chair 1989-1994)
1990-97 Founding Member, The Environmental Institute, California State Univ., Fullerton
1990 Member, Health Effects Institute, Diesel Working Group
1991 Member, U.S. EPA Peer Review Panel, Extramural Grants Program
1991-94 Consultant to Regional Citizen Advisory Committee, Valdez, Alaska
1995-2002 Associate Director, UC Toxic Substances Research and Teaching Program
1999-2001 Member, National Academy of Sciences/National Research Council Committee to Evaluate the Federal Congestion Mitigation and Air Quality Program
2002-2005 Member, Advanced Air Pollution Research Plan Steering Committee, SCAQMD
2002-2006 Member, External Advisory Committee, Vulnerable Populations Research Program, California Air Resources Board
2005-2006 Associate Director, UCLA Institute of the Environment
2004-2005 Consultant to National Highway Administration
2008 Interim Chair, Environmental Health Sciences Department, SPH
2008-2010 Member, Expert Advisory Committee for Oil and Gas Platform Decommissioning Alternatives Study" California Ocean Science Trust

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Department of Earth & Space Sciences
University of California, Los Angeles, CA 90095
phone: (310) 206-7428, email: ulli@atmos.ucla.edu

Education

PhD, 2003, Geosciences, University of Hamburg, Germany, PhD thesis at Max Planck Institute for Biogeochemistry, Jena, Germany, and Scripps Institution of Oceanography, San Diego, CA, USA
Diploma, 1997, Physics, Eberhard Karls University Tübingen, Germany, diploma thesis at Max Planck Institute for Meteorology, Hamburg, Germany

Professional Experience

Assistant Professor, UCLA, Dept. of Atmospheric & Oceanic Sciences, 2009–present, Dept. of Earth & Space Sciences, 2010–present
ERC Starting Investigator, Bioemco, Université Pierre et Marie Curie Paris 6, France, 2008–present
Postdoctoral Research Associate, EU Marie Curie International Fellowship,
Department of Plant Sciences, University of Cambridge, UK, 2006–2007, and
Department of Global Ecology, Carnegie Institution, Stanford, USA, 2004–2006

Awards and Fellowships

- ERC Starting Independent Investigator, European Research Council, 2008–2014
- UCLA New Scholars program grant, Elsevier Foundation, 2011
- Marie Curie International Fellowship, European Commission, 2004–2007
- Max Planck Society scholarship for doctoral research, 1999–2000
- Max Planck Society scholarship for US research visit, 1998–1999
- ERASMUS scholarship, European Commission, Queen Mary, University of London, UK, 1993–1994

Teaching

- AOS1 "Climate Change", Fall 2012, Spring 2012
- AOS100/ENV111 "Earth and Its Environment", Fall 2012, Winter 2012, Winter 2010
- AOS281 Special Topics "The Carbon Balance of Terrestrial Ecosystems", Spring 2010
- graduate students: Yifan Yu, Wu Sun, AOS
- summer research project for two undergraduate students: Chris Bentley, Ning Zhao, Summer 2010
- guest lecturer, University of Cambridge, UK, 2007, University of Edinburgh, UK, 2006
- postgraduate advisor for: Kadmiel Maseyk, Bioemco, Paris, France, 2010-present, and Markus Schmidt, Bioemco, Paris, France, 2009-2011

Service

- Academic Senate Legislative Assembly representative, AOS, UCLA, since 2011
- member, Graduate Advising committee, AOS, UCLA, 2011-2012
- member, Graduate Admissions committee, AOS, UCLA, since 2011
- co-organizer, session on Isotopic Tracers in the Atmosphere, AGU Fall meeting, 2012
- co-organizer, session on Terrestrial Gross Fluxes, AGU Fall meeting, 2011
- co-organizer, session on High-Resolution Instrumentation, AGU Fall meeting, 2010

Synergistic activities

- member of scientific advisory committee, European Fleet for Airborne Research, since 2008
- associate editor, *Biogeosciences*, since 2009
- reviewer for *Geochimica Cosmochimica Acta*, *Global Biogeochemical Cycles*, *New Phytologist*, *Plant Cell & Environment, Plant Physiology, Tree Physiology, Atmospheric Environment*, NSF

- session co-convener, AGU Fall Meeting 2010, 2011, 2012
- invited speaker, discussion panel: “Attracting young researchers – educating the next generation of scientists”, Science Policy Conference, European Science Foundation (ESF), Stockholm, Sweden, 2008
- developed web-based modeling framework for water use efficiency and carbon isotopes for tree rings and other organic samples, available at sites.google.com/site/carbon isotopes, since 2007
- scientific presenter on carbon cycle research for public audiences, Germany (TV documentaries, laureates of EU science youth programs), 2000, 2002, UK (scientific documentary), 2003, and USA (www.America.gov), 2009
- memberships: American Geophysical Union (AGU), European Geosciences Union (EGU)

WON SIK CHOI

Atmospheric & Oceanic Science
University of California, Los Angeles
405 Hilgard Ave.,
Los Angeles, CA 90095

E-mail: wschoi@atmos.ucla.edu
Phone: 310–206–1941 (office)

Education

Institution	Degree	Year	Field of Study
University of California, Davis, CA, USA	Ph.D.[a]	2010	Atmospheric Science
Seoul National University, Seoul, Korea	M.S.[b]	2003	Earth and Environmental Science
Seoul National University, Seoul, Korea	B.S.	1997	Oceanography

a. Dissertation: A Study on Dimethyl Sulfide in a Coastal Upwelling Region, Formaldehyde in a Coniferous Forest, and Estimating Boundary Layer Height Over Mountainous Terrain
Advisor: Professor Ian C. Faloona
b. M.S. thesis: Photochemical Processes in Seoul and Incheon, Korea and Yanji, China Based on Observations of NO, NO_2, NOy, O_3, PAN, CO, and $J(NO_2)$
Advisor: Professor Kyung-Ryul Kim

1. Positions

Period	Position	Institution and location
2010 - current	Postdoc Scholar	University of California, Los Angeles, CA, USA
2004 - 2010	PhD student	University of California, Davis, CA, USA
Feb.~May, 2003	Visiting student	Laboratoire de Météorologie Physique (LaMP) of the University of Clermont-Ferrand, France
2000-2003	M.S. student	Seoul National University, Seoul, Korea
1997 – 2000	Intelligence Officer	Maritime Tactical Intelligence Center, Republic of Korea Navy

2. Experience
2.1. Additional Education

Period	Title (Subtitle)	Organizing Institutions

22~26 Sep. 2008	International Summer School on Atmospheric and Oceanic Sciences (Aerosols and Climate Change)	Center of Excellence for the Forecast of Severe Weather by Remote Sensing and Numerical Modelling (CETEMPS) University of L'Aquila, Italy
Aug. 2006 ~ Aug. 2008	Graduate Academic Certificate: Air Quality and Health	University of California, Toxic Substances Research and Teaching Program (TSR&TP) through the Atmospheric Aerosols and Health Lead Campus Program

2.2. Research

Period	Position	Project (supporter)
2010 - current	Postdoc scholar	Mobile Platform III: Characterizing Spatially Inhomogeneous Non-Criteria Pollutants in the Los Angeles Air Basin (California Air Resources Board)
2007 and 2009	Graduate Researcher	Biosphere Effects on Aerosols and Photochemistry Experiment (BEARPEX)
2005	Graduate Researcher	A pilot study for the measurements of atmospheric DMS
2001 - 2003	Research assistant	Investigation of photochemical pollution processes for establishment of pollution reducing strategy (Ministry of Environment, Korea)

3. Fellowships and Awards

2009	Henry A. Jastro Graduate Research Scholarship Awards ($3,000)
2008–2009 and 2006–2007	Atmospheric Aerosols and Health Lead Campus Program funded by University of California Toxic Substances Research & Teaching Program (TSR&TP)
2007 – 2008	Aligned Research Program funded of the NASA-UCSC University Affiliated Research Center (Grant #NAS2-03144)
2005 – 2006	Kearney Foundation of Soil Science

10.0 RELATED RESEARCH

10.1 Funded Projects and Related Activities

10.1.1 Paulson/Venkatram/Winer Related CARB Project (with DeShazo)

Drs. Paulson, Venkatram and Winer, as well as DeShazo at UCLA have a project entitled *"Identifying Urban Designs and Traffic Management Strategies for Southern California that Reduce Air Pollution Exposure*". This project requires an average of 0.6 summer months of SEP's time for the period 2013-2016

10.1.2 Venkatram/Paulson/Winer Related UCTC Project (with DeShazo)

Drs. Paulson, Venkatram and Winer, as well as DeShazo at UCLA have a project entitled: *"Air Quality in Transit Oriented Developments*" This project requires 0.3 summer months of SEP's time for the period 2013-2015.

10.1.3 Paulson/Winer Related NSF Project

Drs. Paulson and Winer are engaged Co-Is on an NSF funded project developing sampling, data collection and analysis methods for instrumented UCLA commuter vans. The UCLA portion of this three year project, entitled "*Closing the loop between traffic/pollution sensing and vehicle route control using traffic lights and navigators*.", is funded at $ 224,371, (Paulson portion only, Co-investigator with Liviu Iftode as PI, several other Co-I's; Winer draws no salary.) Project requires 0.5 summer months of SEP's time for the period 2012-2015.

10.1.4 Zhu Funded Projects and Related Activities

Title: Assessing and Reducing Taxi Drivers' Exposure to Ultrafine Particles
Project Period: June 2012 - May 2014
Funding Source: Center for Disease Control (CDC)
Total Award Amount: $423,501

Objectives: The major goals of this project are to develop ultrafine particle exposure assessment instrument and explore novel low-cost ultrafine particle exposure mitigation strategies for taxi drivers.

Title: Effects of Complete Streets on Travel Behavior and Exposure to Vehicular Emissions
Project Period: June 2012 - May 2015
Funding Source: California Environmental Protection Agency (EPA)/California Air Resource Board (ARB)
Total Award Amount: $250,000

Objectives: The objectives of this project are to 1) understand the extent to which complete streets affect travel behavior of local residents; 2) assess how such effects may differ among subgroups with different demographic and socio-economic characteristics; 3) illustrate how such effects may vary across different typical land use contexts and road types; and 4) explore potential barriers preventing people from using complete streets.

Title: Reducing Air Pollution Exposure in Passenger Vehicles and School Buses.
Project Period: April 2012 - September 2014
Funding Source: California Environmental Protection Agency (EPA)/California Air Resource Board (ARB)
Total Award Amount: $150,000

Objectives: Explore the application of high efficiency filtration to reduce exposure to particles in vehicle.

Title: CAREER: Effects of Volatility and Morphology on Vehicular Emitted Ultrafine Particle Dynamics.
Project Period: January 2009 – December 2013
Funding Source: National Science Foundation (NSF)
Total Award Amount: $400,014
Objectives: Investigate how volatility and morphology affect fundamental mechanisms that govern ultrafine particles' fate from vehicle tailpipe into the cabin where human exposure occurs.

10.1.5 Additional Venkatram Related Activities

Dr. Venkatram is involved in a one-year project funded ($ 70K) by the South Coast Air Quality Management District, Los Angeles to develop a model to estimate the impact of physical barriers on near road air quality.

Dr. Venkatram is also collaborating with scientists from the US Environmental Protection Agency on analyzing data relevant to dispersion from roads, and developing models to estimate the impact of vehicular emissions on near road air quality. He is currently a member of an USEPA group that is developing a new dispersion model to estimate exposure to pollutants emitted within urban areas.

10.1.6 Seibt Related Activities

- European Research Council (ERC) Starting Grant, "Investigating the terrestrial carbon and water cycles with a multi-tracer approach", 2008-2014, $2,600,000 (PI)
- DOE DE-SC0007094 (exploratory grant), "Quantifying climate feedbacks at the regional scale using atmospheric carbonyl sulfide", 2011-2012, $24,856 (co-PI, with E. Campbell, J. Berry, M. Torn)
- pending: DOE, "Carbonyl sulfide measurements to constrain gross carbon fluxes of a tropical rainforest", 2013-2014 (co-PI, with E. Campbell, J. Berry, D. Billesbach, M. Torn)

11.0 PUBLICATION LISTS

11.1 S. E. Paulson

Most Recent 25 Publications

67. K.M. Shakya, S. Liu, S. Takahama, L. M. Russell, F.N. Keutsch, J.E. Shilling, N. Hiranuma, Chen Song, Lisa Pfaffenberger, Jay Slowik, A. Prévôt, J. Dommen, U. Baltensperger, W.R.

Leaitch, H. Kim, S.E. Paulson, J.S. Craven, C.L. Loza, J.H. Seinfeld. (2013) Similarities in STXM-NEXAFS Spectra of Atmospheric Particles and Secondary Organic Aerosol Generated from Glyoxal, α-Pinene, Isoprene, 1,2,4-Trimethylbenzene, and d-Limonene. Accepted for publication in *Aerosol Sci. & Technol.*

66. Quiros, D.C, Q. Zhang, W.S. Choi, M. He, S.E. Paulson, A.M. Winer, R. Wang, and Y. Zhu (2013) Near-Roadway Air Quality Impacts of a Scheduled 36-hour Closure of a Major Highway. http://dx.doi.org/10.1016/j.atmosenv.2012.10.020 *Atmos. Environ.* (March) **67**: pps. 404-414.
65. Choi, W., S.E. Paulson, J. Cassmassi and A.M. Winer (2013) Development of a classification system for air pollution meteorology applied to primary pollutants in the Los Angeles Air Basin. http://dx.doi.org/10.1016/j.atmosenv.2012.09.049. *Atmos. Environ.* (Jan.) **64**: pps. 150-159.
64. Choi, W.S., M. He, V. Barbesant, K. Kozawa, S. Mara, A.M. Winer and S.E. Paulson (2012) Prevalence of Wide Area Impacts Downwind of Freeways under Pre-sunrise Stable Atmospheric Conditions. http://dx.doi.org/10.1016/ j.atmosenv.2012.07.084 (Dec.) *Atmos. Environ.* **62:** pps. 318-327**.**
63. Kim, H.J., B. Barkey and S.E. Paulson (2012) Real refractive indices of secondary organic aerosol generated from photooxidation of limonene and α-pinene: the effect of the HC/NO_x ratio. *J. Phys. Chem. A*, **2012**, *116* (24), pp. 6059–6067 doi: 10.1021/jp301302z.
62. Hu, S., Paulson, S.E., K. Kozawa, S. Mara, S. Fruin, and A.M. Winer (2012) Measurements of highly elevated pollution in a Los Angeles neighborhood: Boyle Heights. *Atmos. Environ.*, http://dx.doi.org/10.1016/j.atmosenv.2011.12.055.
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60. Wang, Y., C. Arellanes, C. and S.E. Paulson (2012) Hydrogen Peroxide Associated with Ambient Fine Mode, Diesel and Biodiesel Aerosol Particles in Southern California. *Aerosol Sci.& Technol.* 10.1080/02786826.2011.633582.
59. Wang, Y., H. Kim and S.E. Paulson (2011) Hydrogen Peroxide Generation from α- and β-pinene and Toluene Secondary Organic Aerosols. *Atmos. Environ.* 45(18):3149-3156 doi:j.atmosenv.2011.02.060.
58. Barkey, B., S.E. Paulson and K.N. Liou (2011), Polar nephelometer: Design and measurements. Light Scattering Reviews. Vol. 6. ISBN 978-3-642-15530-7.
57. Wang, Y., A. Chung, and S.E. Paulson (2010), The Effect of Metal Salts on Quantification of Elemental and Organic Carbon in Diesel Exhaust Particles using Thermal-Optical Evolved Gas Analysis. *Atmos. Chem. Phys.* 10: 11447-11457, 2010 doi:10.5194/acp-10-11447-2010.
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45. Paulson, S.E., D-L. Liu, G. Orzechowska, L.M. Campos and K.N. Houk (2006), Photolysis of Heptanal. *J. Org. Chem.* 71 (17): 6403-6408 DOI: 10.1021/jo060596u.
44. Arellanes, C., S.E. Paulson, P.M. Fine and C. Sioutas (2006), Exceeding of Henry's Law by Hydrogen Peroxide Associated with Urban Aerosols. *Envir. SciTech.* DOI: 10.1021/es0513786.

11.2 Y.F. Zhu

25 MOST RECENT ARTICLES

1 Qunfang Zhang, Heidi Fischer, Robert E. Weiss, and **Yifang Zhu** “Ultrafine Particle Concentrations in and around Idling School Buses”, 2013, *Atmospheric Environment.* 69: 65-75.
2 Bin Xu and **Yifang Zhu** “Investigation on lowering commuters’ in-cabin exposure to ultrafine particles”, 2013, *Transportation Research Part D: Transport and Environment.* 18: 122-130.
3 Eon S. Lee, Andrea Polidori, Michael Koch, Philip M. Fine, Ahmed Mehadi, Donald Hammond, Jeffery N. Wright, Antonio. H. Miguel, Alberto Ayala, and **Yifang Zhu** “Water-based Condensation Particle Counters Comparison near a Major Freeway with Significant Heavy-Duty Diesel Traffic”, 2013, *Atmospheric Environment.* 68: 151-161.

4 David Quiros, Qunfang Zhang, Wonsik Choi, Meilu He, Suzanne Paulson, Arthur Winer, Rui Wang, and **Yifang Zhu** "Air Quality Impacts of a Scheduled 36-hour Closure of a Major Highway", 2013, *Atmospheric Environment.* 67:404-414.

5 X. Max. Shao, Bin Xu, J Liang, **Yifang Zhu**, J. L. Feldman, and X. M. Xie "Nicotine delivery to rats via lung alveolar region-targeted aerosol technology produces blood pharmacokinetics resembling human smoking", 2012, *Nicotine & Tobacco Research. nts261v1-nts261.*

6 Eon S. Lee, Bin Xu, and **Yifang Zhu** "Measurements of Ultrafine Particles Carrying Different Number of Charges in On- and Near-Freeway Environments", 2012, *Atmospheric Environment.* 60: 564-572.

7 Qunfang Zhang and **Yifang Zhu "**Characterizing Ultrafine Particles and Other Air Pollutants at Five Schools in South Texas", 2012, *Indoor Air,* 22: 33–42.

8 **Yifang Zhu,** Elinor Fanning, RC Yu, Qunfang Zhang, and John Froines "Aircraft emissions and local air quality impacts from takeoff activities at a large International Airport", 2011 *Atmospheric Environment,* 45: 6526-6533.

9 Qunfang Zhang and **Yifang Zhu** "Performance of School Bus Retrofit Systems: Ultrafine Particles and Other Vehicular Pollutants", 2011, *Environmental Science and Technology*, 45: 6475–6482.

10 Yungang Wang, Philip K. Hopke, Oliver V. Rattigan and **Yifang Zhu** "Characterization of ambient black carbon and wood burning particles in two urban areas", 2011, *Journal of Environmental Monitoring*, 13:1919-1926.

11 Yuan Yuan, **Yifang Zhu** and Jun Wu "Modeling Traffic-Emitted Ultrafine Particle Concentration and Intake Fraction in Corpus Christi, Texas," 2011, *Chemical Product and Process Modeling*: Vol. 6: Iss. 1, Article 8. (invited contribution).

12 Bin Xu, Shusen Liu, Junjie Liu and **Yifang Zhu** "Effects of vehicle cabin filter efficiency on ultrafine particle concentration ratios measured in-cabin and on-roadway", 2011, *Aerosol Science and Technology*, 45:215–224.

13 Chengjue Li, Shusen Liu and **Yifang Zhu** "Determining Ultrafine Particle Collection Efficiency in a Nanometer Aerosol Sampler", 2010, *Aerosol Science and Technology*, 44: 11, 1027-1041.

15 Qunfang Zhang, Roja Haritha, David Ramirez, and **Yifang Zhu** "Measurement of Ultrafine Particles and Other Air Pollutants Emitted by Cooking Activities", 2010, *International Journal of Environmental Research and Public Health*, 7: 1744-1759. (invited contribution)

16 Bin Xu, Shusen Liu, and **Yifang Zhu** "Ultrafine particle penetration through idealized vehicle cracks", 2010, *Journal of Aerosols Science*, 41(9) 859-868.

17 Qunfang Zhang and **Yifang Zhu** "Measurements of Ultrafine Particles and Other Vehicular Pollutants inside School buses in rural South Texas roadways", 2010, *Atmospheric Environment*, 44 (2) 253-261.

18 Andrea Clements, Yuling Jia, Allison Denbleyker, Elena McDonald-Buller, Matthew P. Fraser, David T. Allen, Edward Michel, Donald R. Collins, Jayanth Pudota, and **Yifang Zhu** "Air Pollutant Concentrations near Three Texas Roadways, Part II: Chemical Characterization and Transformation of Pollutants", 2009, *Atmospheric Environment*, 43: 4523-4534.

19 **Yifang Zhu**, Jayanth Pudota, Allison DenBleyker, Edward Michel, Matthew P. Fraser, Donald Collins, Elena McDonal-Buller, Yuling Jia, Andrea Clements and

David Allen "Air Pollutant Concentrations near Three Texas Roadways, Part I: Ultrafine Particles", 2009, *Atmospheric Environment*, 43: 4513-4522.

20 Longwen Gong, Bin Xu and **Yifang Zhu** "Ultrafine Particles Deposition inside Passenger Vehicles", 2009, *Aerosol Science and Technology*, 43: 544-553.

21 Bin Xu and **Yifang Zhu** "Quantitative analysis of the parameters affecting in-cabin to on-roadway (I/O) ultrafine particle concentration ratios", 2009, *Aerosol Science and Technology*, 43: 400-410.

22. Yungang Wang, **Yifang Zhu**, Robert Salinas, Saritha Karnae, David Ramirez, and Kuruvilla John "Roadside Measurements of Ultrafine Particles at a Busy Urban Intersection", 2008, *J. of Air and Waste Management Association*, 58: 1449-1457.

23 Teresa L. Barone and **Yifang Zhu** "Morphology of ultrafine particles on and near freeways", 2008, *Atmospheric Environment*, 42: 6749-6758.

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13. Isakov, V., and A. Venkatram, "Resolving neighborhood scale in air toxics modeling: A case study in Wilmington, CA," Journal of the Air and Waste Management Association, 56, 5, 559-568, 2006.

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11.4 A.M. Winer

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12.0 APPENDIX: Detailed Mobile Platform Measurements

Ultrafine Particles

Ultrafine particles are a primary focus of this study, and the mobile platform has partially duplicative instruments to monitor them; a condensation particle counter (CPC) and a Fast Mobility Particle Sizer (FMPS). The TSI, Inc. Condensation Particle Counter Model 3007 measures particle counts in the size range from 10 nm to 1 μm. This instrument adds vapor to the aerosol sample, and then cools the sample stream, causing the particles to grow by condensation. The resulting larger particles can be counted using light scattering.

The FMPS spectrometer (TSI 3091) makes an electrical mobility measurement of particles in the range from 5.6 to 560 nm, with 32 channels of resolution and a time resolution of 1s. It uses multiple low-noise electrometers to detect size-segregated particles, allowing much higher time resolution than CPC detectors.

PM2.5 Mass

PM2.5 measurements will be made using a Thermo Systems Inc. Model 8520 DustTrak Aerosol Monitor. The DustTrak is a nephelometer that senses particle scattering of a laser beam and converts signals into a particle mass reading. Impactors are used to perform the necessary size cuts. The PM concentration circumventing the impactor is determined by measuring the intensity of the 90° scattering of light from a laser diode. The DustTrak has utility in its small size, low power consumption and high time resolution. It is well known to produce data best used for relative comparisons rather than absolute quantitative measurements (Fitz et al. 2003).

Black Carbon

Black carbon concentrations will be measured using a Magee Scientific aethalometer. The aethalometer draws sample air through a 0.5 cm^2 spot on a quartz fiber filter tape, and measures filter darkening with an infrared laser. The concentration of black carbon in units of mass of BC per volume of air (e.g. $\mu g/m^3$) is determined by the instrument from the flow rate and change in light transmittance data. Aethalometers have well-known problems, including filter loading correction and uncertainties in the conversion factor from absorption to mass, but these together lead to an uncertainty of ~± 30% in absolute terms, and ~± 15% in relative terms, which are acceptable in the context of this application.

Particle Bound Poly Aromatic Hydrocarbons

Poly aromatic hydrocarbons (PAHs) associated with particles will be monitored using an EcoChem Photoelectric Aerosol Sensor (PAS) model 2000. The instrument uses a high efficiency UV excimer lamp for excitation of PAHs, and detects their fluorescence emissions. The response time is adjusted to 5 s. For highly accurate measurements, the instrument needs to be calibrated for the particular PAHs on the particles, which is not practical in the current application. The instrument does have value in its rapid response, which can be used as a check for other instrument responses.

Gas Phase Measurements: Oxides of Nitrogen, Carbon Dioxide and Carbon Monoxide

An API-Teledyne Model 200e instrument will be used to measure oxides of nitrogen. This device utilizes chemiluminesence to detect nitric oxide (NO). The Model 200e unit is designed for routine ambient air monitoring applications, and was shown by Westerdahl et al. (2005) to perform well in mobile operations

Carbon dioxide (CO_2) will be measured with a LI-COR CO_2 Gas Analyzer, Model LI-820. This instrument uses an absolute, non-dispersive, infrared gas analyzer based on a single path, dual wavelength infrared detection subsystem. CO will be measured with a Teledyne API model 300eu, an EPA approved CO monitor has a time resolution of 30 seconds.

Mobile Platform Meteorological Data

Local meteorological data conditions will be collected on-board the platform with a Visalia sonic anemometer, and temperature and relative humidity monitors. This instrument transmits two horizontal component (u and v) wind velocities and temperature once per second. Only measurements made at stationary stops are used.

Verification of Vehicle Location using GPS

Vehicle location and speed will be determined with a Garmin GPS MAP 76CS global positioning system with a Wide Area Augmentation System (WAAS) corrections system with a roof-mounted antenna. The system provides position accuracy of about 2-3 m and velocity accuracy of 0.05 m s^{-1} while moving at steady state. The GPS has a 12 parallel channel receiver to continuously track and use data from up to twelve satellites. The WAAS system is a broadcasted “signal integrity” signal that is determined by fixed ground-based reference stations. The GPS uses the WAAS correction information to increase the accuracy of the positioning information. In addition to horizontal position (e.g. latitude and longitude or UTM coordinates), the corrected GPS system also provides elevation and velocity data. The GPS unit will also be used as a time reference during this study. The clocks on all other devices will be set to the GPS time on a daily basis.

Traffic Documentation

A Stalker Vision Digital System is mounted at the front of the vehicle to record traffic conditions in the lane in which the vehicle is traveling during all measurement periods, as well as the adjacent lanes. The camera will be set to a wide angle to view as much of the scene as possible. The camera includes a “time stamp” feature for adding date and time information to the video. The video camera will also serve to help identify emission sources and serve as an oral record of driver observations. The clock in the video camera will be synchronized with the GPS master clock time prior to each run.

Calibrations

Flow measurements will be made several times each week with a NIST traceable rotometer or a DryCal DC-lite flow meter. The API NOx and API 300e CO analyzers will be connected to the calibrator system of the Particle Instrumentation Unit and will be challenged with zero and span gases at least bi-weekly. Zero and leak checks will be made on a weekly basis for the CPC, DusTrak, and other instruments. All instruments and data logging devices will be synchronized to the GPS clock.

Data Logger and Power Supply

A Eurotherm Chessell 6100A graphic data acquisition recorder will be used for data collection. The 6100A has a 5.5” color touchscreen display with 18 universal inputs and 16 relay outputs. The 6100A has 96Mb flash memory for secure, short term, data storage and has a removable PC Flash Card slot accessible from the front. Instruments will be powered by a 2-kW/115-V inverter connected to sealed lead-acid batteries, providing for up to 6 hours of continuous instrument operation.