SCOPE OF WORK

☒ Contract ☐ Grant

Does this project include Research (as defined in the UTC)? ☒ Yes ☐ No

PI Name: Qi Zhang

Project Title: Long-term Chemical Characterization and Source Apportionment of $PM_{2.5}$ in the San Joaquin Valley

Project Summary/Abstract

The San Joaquin Valley (SJV) in California consistently encounters air quality issues associated with particulate matter (PM) and frequently violates the 24-hr $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS). The SJV is currently implementing several $PM_{2.5}$ control strategies to achieve air pollution reduction goals as laid out in the latest State Implementation Plan (SIP) that guides the SJV to achieve $PM_{2.5}$ reduction milestones by the end of 2025. The Senate Bill (SB) 1383 also mandates the reduction of anthropogenic black carbon (BC) emissions, a component of $PM_{2.5}$, by 50% below 2013 levels by 2030. To evaluate the progress of ongoing air pollution mitigation strategies, it is important to link continuous, long-term measurements of ambient $PM_{2.5}$ concentration and chemical composition in the SJV with the changing influences of primary emission sources, chemical pathways, and meteorological conditions.

The overarching goal of this project is to gain a comprehensive understanding of the primary emission sources, chemical pathways, and meteorological conditions that affect ambient $PM_{2.5}$ levels in the SJV. To achieve this goal, the University of California, Davis research team (UCD) will collect sub-hourly measurements of non-refractory $PM_{2.5}$ (NR-$PM_{2.5}$) concentration and chemical composition using an Aerosol Chemical Speciation Monitor (ACSM; Aerodyne Research Inc.) at Fresno, CA for the next three consecutive years. UCD will also carry out parallel ACSM measurements at Bakersfield, CA during the same period. The project will combine the ACSM data with co-located measurements of BC, volatile organic compounds (VOC), and meteorological conditions (e.g., aerosol layer height) collected by the California Air Resources Board (CARB), to conduct advanced analyses that will help elucidate $PM_{2.5}$ characteristics in the SJV and identify the major drivers affecting ambient $PM_{2.5}$ levels and their constituents. Furthermore, UCD will conduct a month-long intensive measurement campaign in Fresno during the fall/winter of 2023 using two state-of-the-science real-time aerosol mass spectrometers – an Aerodyne high-resolution Soot Particle Aerosol Mass Spectrometer (SP-AMS) and a Long Time-of-Flight Chemical Ionization Mass Spectrometer (LTOF-CIMS). The project will use this data to study the contribution of various primary emission sources (e.g., mobile, biomass burning, cooking, and agricultural activities) to ambient $PM_{2.5}$. UCD will also examine the influence of secondary formation pathways and nocturnal residual-layer chemistry on the ambient concentrations and temporal patterns of critical secondary inorganic and organic PM species in the SJV. Lastly, this project will synergistically compare these results to the findings from CARB-funded contract #17RD008 to inform CARB, the local government, and the community of the effects of ongoing $PM_{2.5}$ control strategies in the SJV. Through these endeavors, the project will significantly advance the understanding of the complex mechanisms that contribute to elevated ambient $PM_{2.5}$ levels in the region. Ultimately, the outcomes of this project will aid in the development and refinement of future SJV SIPs and SB1383 initiatives.

If Third-Party Confidential Information is to be provided by the State:

☐ Performance of the Scope of Work is anticipated to involve use of third-party Confidential Information and is subject to the terms of this Agreement; ***OR***

☐ A separate CNDA between the University and third-party is required by the third-party and is incorporated in this Agreement as Exhibit A7.

I. Background and Identification of Problems / Statement of Significance

The San Joaquin Valley (SJV) in California continues to experience persistent air quality problems and remains one of the most polluted regions in the United States despite extensive regulatory control efforts over the years (Chen et al., 2020). During late fall and winter, the region frequently exceeds the 24-hour $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS) of 35 $\mu g\ m^{-3}$.

Previous studies have established that $PM_{2.5}$ in the SJV primarily consists of organic aerosols (OA) and ammonium nitrate, with various anthropogenic sources, such as vehicles, residential wood burning, food cooking, and agricultural activities, contributing to its elevated ambient concentrations (Ge et al., 2012a; Chow et al., 2007; Chen et al., 2018; Young et al., 2016; Sun et al., 2022). Additionally, wildfires in California have increased in frequency and intensity in recent years, increasing ambient $PM_{2.5}$ levels and causing more frequent episodes of severe PM pollution across the state, particularly during the summer and fall seasons (Jaffe et al., 2020; Altshuler et al., 2020). Wildfires release large amounts of primary organic aerosols (POA) and volatile organic compounds (VOCs) that can serve as effective precursors for secondary organic aerosol (SOA), which significantly affects the concentration of OA in the atmosphere that add to ambient $PM_{2.5}$ pollution (Zhang et al., 2018). Incomplete combustion of biomass and fossil fuels also produces black carbon (BC) – an important component of $PM_{2.5}$ in the SJV that is typically elevated in urban centers like Fresno and Bakersfield (Chow et al., 2006; Cappa et al., 2019). BC strongly absorbs solar radiation and is considered the second-largest contributor to global warming after carbon dioxide (CO_2) (Bond et al., 2006; Ipcc, 2013; Ramanathan and G., 2008). Moreover, BC influences regional and global climate by altering cloud properties, modifying cloud evaporation rates, and further affecting atmospheric mixing (Ding et al., 2016; Bond et al., 2006; Koch and Del Genio, 2010, Bond and Bergstrom, 2006; Koch and Del Genio, 2010; Petäjä et al., 2016). Ambient $PM_{2.5}$ concentration and composition in the SJV also exhibit significant temporal variability, characterized by diurnal and seasonal fluctuations that stem from changes in anthropogenic emission sources and meteorological conditions (Ge et al., 2012a; Ge et al., 2012b; Chen et al., 2010; Collier et al., 2018; Chen et al., 2018; Betha et al., 2018; Young et al., 2016; Pusede et al., 2016; Parworth et al., 2017; Sun et al., 2022). The region often experiences multi-day episodes of severe pollution caused by a multitude of factors, including meteorological conditions that restrict the dispersion of pollutants (e.g., stagnation, poor ventilation), increased primary emissions, nocturnal boundary layer inversion, and enhanced secondary aerosol formation processes (Ge et al., 2012a; Ge et al., 2012b; Young et al., 2016; Parworth et al., 2017; Sun et al., 2022; Chen et al., 2018, Prabhakar et al., 2017; Lurmann et al., 2006; Young et al., 2016; Brown et al., 2006). The diversity of sources and the complexity of the atmospheric processes in the SJV makes air pollution control extremely challenging. These findings also underscore the importance of implementing targeted air pollution control strategies in the SJV that focus on individual $PM_{2.5}$ components and specific emission sources. But to develop effective strategies, it is important to gain a comprehensive understanding of the key emission sources, chemical pathways, and atmospheric processes that influence the ambient $PM_{2.5}$ in the region.

The latest State Implementation Plan (SIP) (i.e., the 2018 Plan for 1997, 2006, and 2012 $PM_{2.5}$ standards) guides the SJV to achieve $PM_{2.5}$ reduction milestones by the end of 2025 and the Senate Bill (SB) 1383 further mandates the reduction of anthropogenic BC emissions by 50% below 2013 levels by 2030. To achieve these air pollution reduction goals, the SJV is implementing a range of strategies to control $PM_{2.5}$ emissions, such as the phase-out of agricultural burning and the provision of financial incentives to replace high-emitting agricultural equipment. It is important to evaluate the progress of these air pollution mitigation efforts, which can be accomplished through continuous, long-term monitoring of ambient $PM_{2.5}$ concentrations and chemical

compositions in the SJV. A recent study conducted by Sun et al. (2022), funded through CARB contracts #17RD008 and #20AQP007, has demonstrated the utility of long-term, highly time-resolved measurements of ambient $PM_{2.5}$ in assessing the sources and formation processes of $PM_{2.5}$ pollution in the SJV. Specifically, this study used an ACSM to measure the concentrations and chemical compositions of non-refractory components in $PM_{2.5}$ (NR-$PM_{2.5}$) at sub-hourly time resolution between 2018 and 2020 in Fresno. The measurements yielded a comprehensive understanding of the region's main $PM_{2.5}$ components, such as organics, nitrate, sulfate, ammonium, and chloride, including their diurnal, weekday/weekend, seasonal, and annual variation patterns. Additional advanced source apportionment analysis of the ACSM mass spectral data will provide valuable insights into major emission sources contributing to seasonal $PM_{2.5}$ pollution episodes and help track the progress of various $PM_{2.5}$ control strategies that are currently being implemented in the SJV. These findings can serve as a robust framework for evaluating future changes in emission sources and their potential impacts on ambient $PM_{2.5}$ levels in the SJV.

II. Objectives

This project aims to build on the success of Sun et al. (2022) by continuing the sub-hourly ACSM measurements of NR-$PM_{2.5}$ concentration and chemical composition at Fresno, CA, for the next three consecutive years. Parallel ACSM measurements will be collected simultaneously at Bakersfield, CA, by UCD during the same period. The ACSM data will be combined with co-located measurements of black carbon, VOCs, and meteorological conditions (e.g., aerosol layer height) collected by CARB to conduct advanced source apportionment analyses.

To enhance the long-term ACSM measurements, UCD will carry out a month-long intensive measurement campaign in Fresno during the fall/winter of 2023 using two state-of-the-science real-time aerosol mass spectrometers – SP-AMS and LTOF-CIMS. The data from this month-long campaign will improve the characterization of a broad range of gas-phase and particle-phase air pollutants in the SJV. Advanced and integrated analyses will be performed on the SP-AMS and LTOF-CIMS data to obtain unprecedented insights into the sources and characteristics of air pollution in the region.

UCD will use all of the data collected throughout the three years to advance the understanding of the intricate mechanisms responsible for ambient $PM_{2.5}$ pollution in the SJV by studying 1) the contribution of various primary emission sources (e.g., mobile, biomass burning, cooking, and agricultural activities) to ambient $PM_{2.5}$ pollution and 2) the influence of secondary formation pathways and nocturnal residual-layer chemistry on the concentration and temporal patterns of critical secondary inorganic and organic PM species in the SJV. Such knowledge is important for informing the development of effective and targeted measures to control air pollution. Furthermore, the progress of ongoing $PM_{2.5}$ control strategies will be examined by comparing the findings of this project to those of CARB contract #17RD008.

III. Tasks

The overall goal of this project is to improve the understanding of the emission sources, chemical pathways, and meteorological conditions that affect ambient $PM_{2.5}$ pollution in the SJV. To achieve this goal, UCD will perform the following tasks:

- Task 1: Conduct continuous, sub-hourly measurements of NR-$PM_{2.5}$ concentration and chemical composition using ACSMs at two locations in the SJV for three consecutive years. Process these measurements using rigorous quality control procedures to generate finalized data products.
- Task 2: Conduct a month-long intensive measurement campaign in Fresno during the fall/winter of 2023 using SP-AMS and LTOF-CIMS. Perform advanced and integrated data analyses to gain in-depth knowledge about the sources, processes, and characteristics of air pollution in the SJV region.
- Task 3: Perform advanced analyses on the data collected from Task 1, Task 2, and co-located measurements (e.g,. BC, VOCs, meteorological data) collected by CARB to understand the

current ambient $PM_{2.5}$ characteristics in the SJV. Identify the major drivers affecting $PM_{2.5}$ and its constituents, including primary and secondary sources, as well as meteorological conditions. These analyses will include:

a. rolling-window Multilinear Engine version 2 (ME-2) source apportionment analysis of the ACSM mass spectral data;
b. quantitative evaluation of inorganic and organic fractions of measured particulate nitrate, their temporal trends, and the impact of nighttime chemistry on their behavior;
c. examination of the diurnal, seasonal, and annual variations of $PM_{2.5}$ concentration and composition;
d. evaluation of the impact of meteorological conditions on aerosol mass loading and composition, particularly BC;
e. assessment of the progress of $PM_{2.5}$ control measures implemented in the SJV since 2018 that affect ambient $PM_{2.5}$ levels and their chemical components; and
f. comparison of ambient $PM_{2.5}$ concentration and chemical composition between Fresno and Bakersfield to understand the implications of the differences within the framework of future air quality modeling and emission reduction strategies.

Task 4: Conduct meetings and disseminate scientific findings.

Task 1: ACSM Data Collection and Finalization

UCD will install, operate, and maintain two ACSMs, equipped with capture vaporizers and $PM_{2.5}$ aerodynamic lenses, at two locations in the SJV: Fresno and Bakersfield. These ACSMs will continuously measure the NR-$PM_{2.5}$ concentrations and composition at sub-hourly time intervals over the next three consecutive years. UCD has been operating the ACSM at the Fresno-Garland Air Quality Monitoring Site (AQMS) of CARB since October 2018 and will install and operate a new ACSM (CARB owned) in Bakersfield at the beginning of this project.

The ACSM is an instrument that uses an aerodynamic lens to sample particles into a vacuum, where the NR-PM components are evaporated on a vaporizer that is maintained at approximately 550^{o}C. The resulting gaseous molecules are analyzed using 70 eV electron impact ionization mass spectrometry (Ng et al., 2011). The ACSM can provide highly time-resolved and continuous measurements of NR-$PM_{2.5}$ concentrations and composition, including organics, sulfate, nitrate, ammonium, and chloride, that evaporate at the vaporizer temperature in a high vacuum environment of 10^{-7} torr (Ng et al., 2011; Frohlich et al., 2013). The ACSM is traditionally considered a submicrometer aerosol (PM_1) instrument because its standard aerodynamic lens transmits particles in the 30 - 1000 nm size range. However, recent advances have led to the development of a $PM_{2.5}$ lens that can transmit particles with aerodynamic diameters up to 2.5 μm (Peck et al., 2016), as well as a capture vaporizer (CV) that eliminates the particle bounce issue associated with the standard vaporizer (SV) and has a collection efficiency (CE) of ~ 1 for NR-PM components (Xu et al., 2017). The combination of the $PM_{2.5}$ lens and the CV has successfully transformed the ACSM into an instrument capable of measuring $PM_{2.5}$ mass concentration for monitoring purposes (Sun et al., 2022; Zhang et al., 2017; Zheng et al., 2020).

As part of CARB-funded research contract #17RD008, UCD conducted a comprehensive evaluation of the performance of the ACSM currently operating at Fresno-Garland AQMS. This evaluation involved analyzing $PM_{2.5}$ and PM_{10} mass concentration readings obtained from the collocated Beta Attenuation Monitors (BAM), as well as data collected during an intensive field campaign that took place at the same site between Dec. 15, 2018, and Feb. 16, 2019. Figure 1 illustrates the excellent agreements between the ACSM measurement and those obtained from SP-AMS, a Scanning Mobility Particle Sizer (SMPS), a Multi-Angle Absorption Photometer (MAAP), and IMPROVE $PM_{2.5}$ Sampler (Sun et al., 2022). The Pearson's r^2 values for these comparisons ranged between 0.92 and 0.97, and the orthogonal regression slopes were close to 1 (Figures 1b – 1e). Since the method for IMPROVE $PM_{2.5}$ measurement was an EPA Federal Reference Method (FRM) and BAM-$PM_{2.5}$ measurement was an Equivalent Method (FEM), these agreements validate the effectiveness of ACSM as a monitoring tool for $PM_{2.5}$.

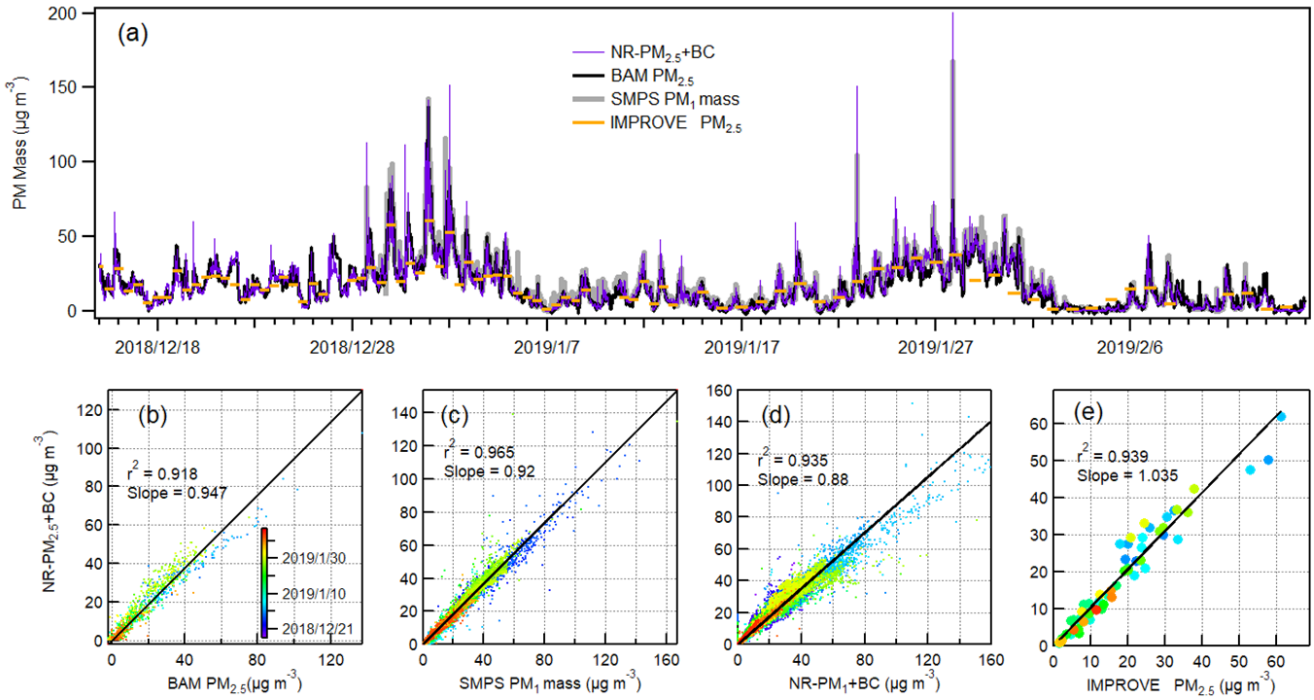

Figure 1. Inter-comparisons of PM mass measurements by a ACSM (10-min average), a $PM_{2.5}$-BAM (1 hr average), an SMPS (5-min average), an HR-AMS (2-min average), and gravimetric analysis of filters collected using an IMPROVE $PM_{2.5}$ Sampler (12-hr average) during the 2018/2019 winter intensive campaign in Fresno: (a) time-series of PM mass concentrations measured by different instruments; scatter plots that compare the sum of NR-$PM_{2.5}$ and BC mass concentration versus (b) total $PM_{2.5}$ mass concentration from BAM, (c) PM_1 mass concentrations calculated from the SMPS measurements, (d) mass concentration of NR-PM_1 + BC, and (e) filter-based 12-hr $PM_{2.5}$ mass concentrations measured gravimetrically. The Pearson's r^2 and the slope determined through linear orthogonal fit for each pair of the comparison are reported on (b) – (e).

The comparisons between the NR-$PM_{2.5}$ concentration measured by the ACSM and the $PM_{2.5}/PM_{10}$ mass concentration readings obtained from the collocated BAM instrument can also provide valuable insights into the sources of ambient $PM_{2.5}$ pollution (Sun et al., 2022). For instance, as shown in Figure 2, the time series of NR-$PM_{2.5}$ and BAM-$PM_{2.5}$ concentrations exhibit a strong correlation with a slope close to 0.9 during the winter and spring of 2018/2019. This indicates that $PM_{2.5}$ in Fresno is primarily composed of organics and ammonium salts of sulfate, nitrate, and chloride, while refractory species such as dust particles, BC, and metal salts contribute only ~10% of $PM_{2.5}$ mass. The substantial discrepancies between NR-$PM_{2.5}$ and $PM_{2.5}$ during October and November 2018 are linked to the presence of substantially elevated coarse mode particles composed predominantly of refractory dust or crustal materials. An analysis of the source regions of these refractory PM suggested that they mainly originated from the orchards close to Fresno, where agricultural activities, such as the harvesting of almonds, were a significant source of coarse mode particles in autumn (Sun et al., 2022).

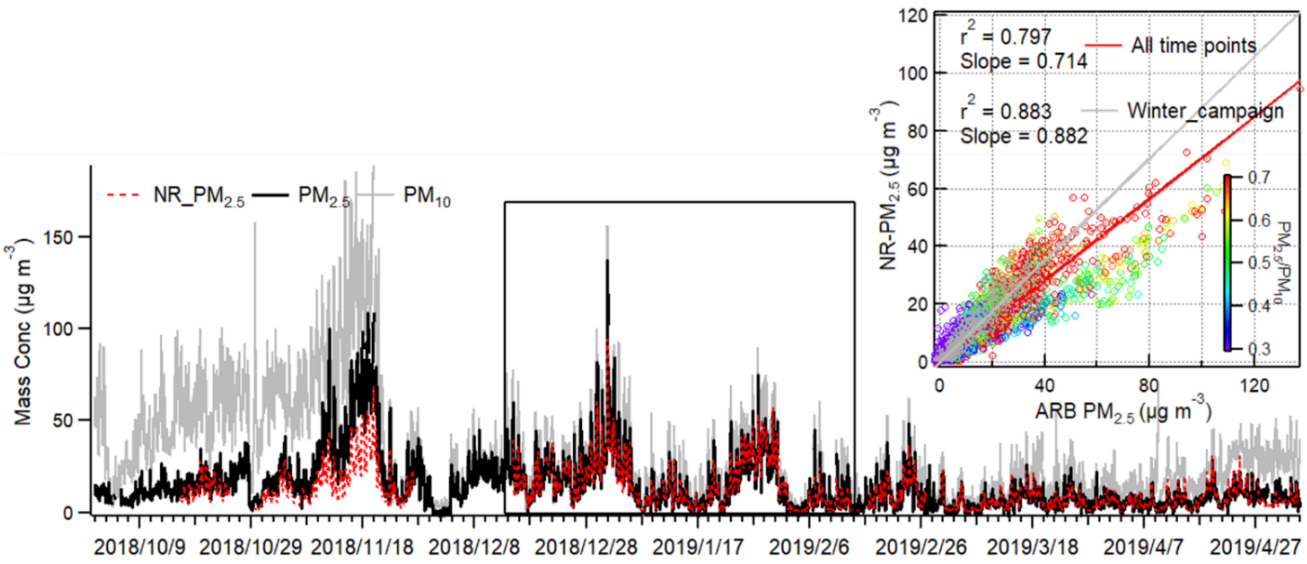

Figure 2. Mass concentration time series of NR-$PM_{2.5}$ measured by ACSM and $PM_{2.5}$ and PM_{10} measured by BAMs at the Fresno-Garland site. The inset shows the scatter plots of NR-$PM_{2.5}$ vs $PM_{2.5}$ with the points color by the $PM_{2.5}$-to-PM_{10} mass ratio.

In this project, UCD will install, operate, and maintain two ACSMs continuously for 36 months, with daily monitoring of their performance through remote-access software (e.g., Teamviewer). The ACSMs will undergo on-site calibrations every three months, in order to determine the ionization efficiency (IE) and the relative ionization efficiencies (RIE) of ammonium and sulfate. For the calibrations of the IE and the RIE for ammonium, UCD will use pure monodispersed ammonium nitrate particles of known sizes (Canagaratna et al., 2007; Ng et al., 2011). Pure ammonium sulfate particles will be used to calibrate the RIE for sulfate (Setyan et al., 2012). These measures will significantly improve the accuracy of the measurements.

UCD will configure both ACSMs to operate with a time resolution of 20 min, a significant increase from the typical hourly operation of ACSMs for long-term monitoring. This higher time resolution will allow for the capture of more dynamic variations in both ambient $PM_{2.5}$ concentration and composition, thereby facilitating a more accurate source apportionment analysis. To ensure data security, UCD will set up an automatic daily data backup to an external hard drive located on-site. In addition, UCD will create another copy of the data remotely on a computer at the UCD campus via Teamviewer on a weekly basis to ensure redundancy.

The ACSM data will be batch-processed weekly using the Tofware software from Tofwerk within the Igor Pro environment (Wave-Metrics, Inc., Oregon USA). UCD will ensure the proper application of IE and RIE values and subject the resulting NR-$PM_{2.5}$ data to thorough quality control and assurance (QA/QC) assessments. The QA/QC evaluations will include estimation and documentation of 1) detection limits for species, 2) diagnostic examination of mass spectral signals, and 3) quantification uncertainties based on electronic and ionic noise, particle sampling statistics, and mass spectral signals in particle-free air (Canagaratna et al., 2007; Ng et al., 2011). To assess the accuracy, precision, and performance of the ACSMs, UCD will compare their NR-$PM_{2.5}$ mass concentrations with $PM_{2.5}$ mass concentration readings from co-located FEM and FRM instruments, as well as against PM data from the intensive field campaign. The comparison procedures are illustrated in Figures 1 and 2.

Processed data will be shared with CARB staff using a secure cloud-based folder as soon as it becomes available, or at least quarterly. At the conclusion of this project, the final ACSM datasets, as well as any raw and intermediate data files needed to reproduce the final dataset, will be provided to CARB.

Task 2: Conduct an Intensive Field Campaign using Cutting-edge Instruments and Perform Comprehensive Data Analysis

The air pollution problem in the SJV is difficult to model and control mainly because of the limited understanding of the complex emission sources and the intertwining atmospheric formation and transformation processes in the region. Performing ambient measurement studies using advanced instruments and innovative techniques is an effective way to fill the knowledge gap. In this project, UCD will conduct the first comprehensive characterization of gas-phase and particle-phase pollutants using two state-of-the-science real-time mass spectrometers in Fresno, aiming to significantly improve the understanding and increase confidence in model simulations and emissions control programs for primary and secondary $PM_{2.5}$ in the SJV.

A month-long intensive measurement campaign will be performed in Fresno during the fall/winter of 2023 using two real-time mass spectrometers: SP-AMS (Onasch et al., 2012)) and LTOF-CIMS with a VOCUS proton transfer reactor (PTR), an acetone AIM reactor, and a FIGAERO aerosol sampling inlet. UCD will perform thorough analyses of the LTOF-CIMS data to determine chemically detailed organic carbon composition, including VOCs (using PTR), highly functionalized semi-volatile and intermediate VOCs (using acetone AIM), and individual OA constituents with a wide range of volatility and oxidation state (using FIGAERO).

The SP-AMS will be employed to characterize the concentration and size distributions of sub-micrometer particles (PM_1) components, including black carbon, during this study. As shown in Figure 3, the SP-AMS uses an aerodynamic lens to sample PM_1 into the vacuum, where they are aerodynamically sized, vaporized, and chemically analyzed via 70 eV electron impact ionization time-of-flight mass spectrometry. UCD will operate the SP-AMS with both an intracavity (1064 nm) infrared laser vaporizer and a resistively heated tungsten vaporizer (~600 ^{o}C), alternating between laser on and off. With the laser vaporizer off, the instrument operates as a standard high-resolution aerosol mass spectrometer (HR-AMS) (Decarlo et al., 2006) and measures the size-resolve concentrations of non-refractory (NR) particle components, including nitrate, sulfate, chloride, ammonium, and organics. With the laser vaporizer on, the SP-AMS can determine the refractory black carbon (rBC) content, in addition to the NR components.

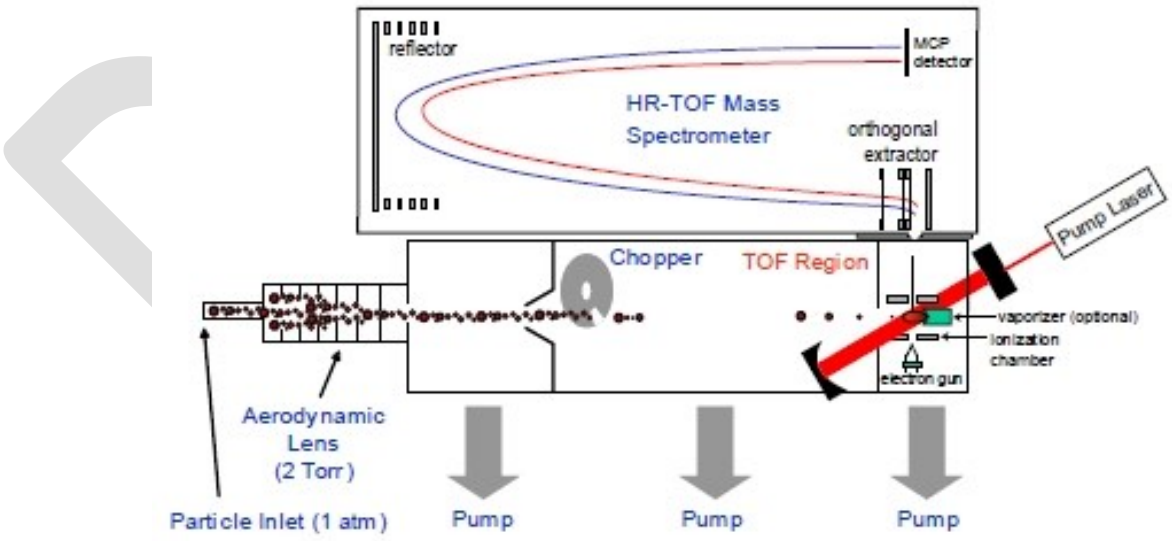

Figure 3. Schematic of a Soot Particle Aerosol Mass Spectrometer (SP-AMS)

Due to the usage of a high mass resolution mass spectrometer ($m/\Delta m$ ~ 5000), the SP-AMS can determine the elemental composition of major ions and the organic mass-to-carbon ratio (OM/OC), and atomic ratios of oxygen-to-carbon (O/C), hydrogen-to-carbon (H/C), and nitrogen-to-carbon (N/C) of OA (Aiken et al., 2008). Information about the elemental compositions of the organic ions can provide valuable insights into PM

chemistry, such as key functional groups, as well as their sources (Mclafferty and Turecek, 1993; Ge et al., 2014). By applying multivariate factor models, such as Positive Matrix Factorization (PMF) (Paatero and Tapper, 1994) and Multilinear Engine (Paatero, 1999), to the SP-AMS mass spectral data, distinct sources of PM can be determined (Zhang et al., 2011a).

Furthermore, UCD will use a thermodenuder (TD) upstream of the SP-AMS to determine aerosol volatilities. The TD consists of a bypass line and a heated line terminating in a section with activated carbon cloth (Fierz et al., 2007). The temperature inside the heated line is digitally controlled and will be programmed to cycle through 12 temperatures (40°C, 66°C, 86°C, 110°C, 150°C, and 200°C upward and 180, 130, 100°C, 70°C, 50°C, and 30°C downward) every 2 hours. The sample flow will be switched between the bypass and TD modes automatically every 5 min to alternate between ambient and heated airflow. By comparing the measurements between these two modes, it is possible to determine the volatility profiles of individual aerosol species and OA factors, such as biomass burning OA (BBOA) (Zhou et al., 2017). The aerosol volatility information will help the apportionment of BBOA and understanding of its aging in the atmosphere.

UCD will perform thorough and advanced analyses of the high-resolution mass spectra of the SP-AMS to obtain detailed chemical information on ambient PM (Canagaratna et al., 2007). Specifically, UCD will determine 1) the concentration time series of inorganic and organic species, 2) the ion-speciated mass spectra, 3) average elemental ratios (e.g., H/C, O/C, and N/C) and oxidation state of OA (Aiken et al., 2008), and 4) the size distributions of individual aerosol species and ions. An effort will be placed on studying tracer ions that can fingerprint aerosol sources and processes, e.g., $C_2H_4O_2^+$ (*m/z* = 60) and $C_3H_5O_2^+$ (*m/z* = 73) for anhydrous sugars such as levoglucosan from biomass burning emissions (Mohr et al., 2009; Alfarra et al., 2007), $C_4H_9^+$ (*m/z* = 57) for fossil fuel combustion (Zhang et al., 2005), HCO_2^+ (*m/z* = 45) for organic acids, and CO_2^+ (*m/z* = 44) for oxygenated organics (Zhang et al., 2005; Aiken et al., 2008).

UCD will also examine the fractional contribution of a tracer ion to the total organic mass signal (expressed as f_x, where x is the *m/z* value or the chemical composition of the ion) to gain insights into distinct aerosol types or chemical properties. For example, f_{60} has been used to differentiate biomass burning influence (Cubison et al., 2011; Schneider et al., 2006; Alfarra et al., 2007), f_{44} was found to correlate well with O/C (Aiken et al., 2008) and has been used as an indicator of the average oxidation degree of the OA, and the relationships between *f*55 and *f*57 or between $fC_3H_3O^+$ and $fC_3H_5O^+$ after subtracting contributions from oxygenated OA factors have been used to distinguish OA from cooking activities (Mohr et al., 2012).

A high sensitivity and high mass resolution LTOF-CIMS that is equipped with a suite of swappable front-end modules will be deployed during the intensive field measurement campaign, alongside the SP-AMS. While the SP-AMS is a powerful instrument that can be used to characterize the bulk composition of aerosol particles, the VOCUS chemical ionization mass spectrometer is exceptionally capable of detecting a larger and more diverse range of compounds in both gas and aerosol phases, and on a molecular level (Brophy and Farmer, 2015; Lee et al., 2014). In this project, UCD will deploy a LTOF-CIMS instrument that includes multiple, swappable “front-ends” to enable sensitive quantification of a broad range of VOC molecules and particulate species, including highly polar, multifunctional molecules that are missed by conventional mass spectrometry techniques yet are highly abundant in air pollutants such as biomass burning smoke, pesticides and herbicides, and cooking emissions. The choice of reagent ion is critical in detecting relevant compounds while avoiding interference from other species. CIMS selectively ionizes a subset of molecular species present in the sampled air, simplifying analysis and reducing interferences. Through these efforts, UCD will acquire a rich gaseous and particulate air pollution chemistry dataset that will help us achieve a process-level, quantitative understanding of the $PM_{2.5}$ NAAQS attainment challenges in the SJV.

UCD will perform advanced and integrated analyses of the SP-AMS and LTOF-CIMS data to obtain unprecedented insights into the sources and characteristics of air pollution in the region. PMF analyses will be performed on the high-resolution mass spectra from both instruments in order to quantitatively determine the contributions of different emission sources and aging processes that contribute to wintertime $PM_{2.5}$ pollution in

the SJV. UCD will thoroughly examine each OA factor according to its mass spectral profile (i.e., chemical information), size distribution, temporal and diurnal patterns, and correlations with tracer compounds to interpret its chemical properties and association with specific sources or atmospheric process (Zhang et al., 2011b). Specifically, UCD will investigate 1) the contribution of various primary emission sources (e.g., mobile, biomass burning, cooking, and agricultural activities) to $PM_{2.5}$ pollution and 2) the influence of secondary formation pathways and nocturnal residual-layer chemistry on the concentration and temporal patterns of critical secondary inorganic and organic PM species in the SJV. The SP-AMS measurement data of bulk aerosol composition (organics, sulfate, nitrate, ammonium, chloride, and black carbon) will be analyzed together with the CIMS data to achieve a comprehensive understanding of the roles that various primary emission sources (e.g., mobile, biomass burning, personal care products, cooking), secondary formation pathways, and nocturnal residual-layer chemistry play on influencing $PM_{2.5}$ pollution in SJV.

Task 3: ACSM Data Analysis and Source Apportionment

UCD will analyze the ACSM datasets from Task 1 and Task 2, and leverage additional measurements collected by CARB to characterize ambient $PM_{2.5}$. The results from this study will be compared to the findings from CARB contract #17RD008, as well as other air monitoring efforts. The goal is to quantify the changing influences of various emission sources, atmospheric chemistry, and meteorological conditions that contribute to high ambient $PM_{2.5}$ events in the Valley. UCD will also examine the influence of $PM_{2.5}$ control strategies implemented in the SJV after 2018. The following data analysis efforts will be performed:

a. rolling-window ME-2 source apportionment analysis of the ACSM mass spectral data;
b. quantitative evaluation of inorganic and organic fractions of measured particulate nitrate, their temporal trends, and the impact of nighttime chemistry on their behavior;
c. examination of the diurnal, seasonal, and annual variations in $PM_{2.5}$ concentration and composition;
d. evaluation of the impact of meteorological conditions on aerosol mass loading and composition, particularly BC;
e. assessment of the effectiveness of $PM_{2.5}$ control measures implemented in the SJV since 2018 that affect ambient $PM_{2.5}$ levels and their chemical components; and
f. comparison of aerosol mass concentration and chemical composition between Fresno and Bakersfield to understand the implications of the differences within the framework of future air quality modeling and emission reduction strategies.

Task 3.1 Source apportionment analysis of the ACSM mass spectral data

The ACSM provides both concentration time series of NR-$PM_{2.5}$ species and a matrix of the mass spectra of OA and inorganic species. This matrix is composed of ensemble mass spectra of NR-$PM_{2.5}$ sampled over specified time intervals. Each column in the matrix indicates the concentration of an ion with a particular mass-to-charge ratio (*m/z*) measured during the time series (Zhang et al., 2005). The ensemble spectra represent linear superpositions of the mass spectra of organic and inorganic species from different sources, weighted by their concentrations. Therefore, the signal measured at each *m/z* is a linear combination of the contributions of the various sources of compounds that generate the *m/z* in the ACSM.

By using this information, it is possible to decompose the ACSM mass spectral matrix into its contributing components as a matrix product, where one matrix provides the mass spectral compositions of different sources (i.e., source profiles), and the other matrix represents their contributions to the particle mass over time (i.e., source strengths) (Zhang et al., 2011a). This decomposition allows for the identification and quantification of the sources of the organic and inorganic aerosol components in the ACSM mass spectral matrix.

The unique characteristics of the ACSM spectral matrix make it ideally suited for source apportionment analysis using bilinear factor analytical modeling techniques such as PMF (Paatero and Tapper, 1994). PMF represents different sources and types of PM by grouping variables into distinct factors based on specific criteria (Zhang et al., 2011a; Ulbrich et al., 2009). By identifying the mass spectral compositions from different sources, it is

possible to determine the sources responsible for generating specific *m/z* in the ACSM, thereby aiding in source identification and quantification. Equation 1 provides the mathematical expression for the bilinear decomposition, which can be solved by PMF using an iterative technique that minimizes the weighted norm (*Q*) using Equation 2:

$$X = GF + E \qquad \text{Eq. 1}$$

$$Q = \left\| (X - GF)./\sigma \right\|_F^2 \qquad \text{Eq. 2}$$

where X is the $m \times n$ matrix of measured ACSM mass spectra of NR-$PM_{2.5}$,
G is the $m \times p$ matrix of strengths (time series) of p sources,
F is the $p \times n$ matrix of the mass spectral profiles of p sources
σ is the matrix of standard deviations of the errors of the elements of X,
E is the $m \times n$ matrix of errors or residuals of each data point not fit by p sources,
./ represents element-by-element division, and
$||B||_F$ represents the Frobenius Norm, $= \sqrt{\sum_i \sum_j B_{ij}^2}$.

PMF incorporates error estimates of the data to solve matrix factorization of the linear model as a constrained, weighted least-squares problem (Paatero and Tapper, 1994). The user chooses the number of factors, *p*, and PMF minimizes the Q value to find the best solution. The program uses error estimates of the data to down-weight observations that are compromised by sampling errors, detection limits, missing data, or outliers. This normalization in PMF establishes the best physical relationship between the data and its measurement technique. The resulting factors are constrained to be nonnegative and represent different sources of air pollution and their contributions to the measured mixture.

The PMF model can be solved using either the PMF-2 (Paatero and Tapper, 1994) or the ME-2 algorithm (Paatero, 1999). Although PMF-2 is the most commonly used source apportionment method for the AMS/ACSM data (Zhang et al., 2011a), it may yield mixed results in scenarios where aerosols from different sources temporally covary, for example, due to rotational ambiguity (Paatero and Hopke, 2009) or systematic meteorological conditions such as boundary layer evolution, or the source spectral profiles are highly similar. In such scenarios, ME-2, which is a more flexible fitting algorithm, may be more capable of apportioning aerosol sources.

ME-2 is a variation of PMF-2 that enables the incorporation of *a priori* information in the form of factor profiles or time series to guide the model. ME-2 can be viewed as a hybrid of the unconstrained PMF and the chemical mass balance (CMB) approach, where all factor profiles are predetermined. One advantage of ME-2 is that it allows for the quantification of additional factors that would otherwise be unresolvable through the unconstrained PMF analysis. This is achieved by using a set of rules to maintain consistent and objective factor analysis results. ME-2 can also utilize nonlinear factors, such as wind information, as independent or free variables, thus can effectively model scenarios where aerosol concentrations sharply increase due to wind blowing directly from a specific source, or variations associated with weekend/weekday activity patterns, time of day, or time of year (Paatero and Tapper, 1993; Paatero et al., 2002).

The ME-2 algorithm can be particularly crucial for source apportionment analysis of the ACSM data. This is due to the design of the capture vaporizer (CV), which is used instead of the standard cone-shaped vaporizer (SV) in the ACSM. The CV is better suited to trap incoming particles and prevent them from bouncing off the vaporizer surface, resulting in a more accurate quantification of particle mass and composition compared to the SV (Hu et al., 2017). However, since particles reside in the CV for a longer time, leading to more thermal decomposition and fragmentation during ionization, mass spectra obtained using the CV tend to suffer from reduced chemical resolution and show enhanced signals at smaller *m/z*'s for both inorganic and organic species and more similar spectral patterns of OA from different sources (Hu et al., 2017; Hu et al., 2018). Despite these challenges, since the CV-ACSM mass spectra of major OA sources, such as vehicular emissions, biomass burning, and secondary formation, still maintain unique source-identifiable features, albeit weaker, meaningful

source apportionment results may still be achievable through PMF modeling. However, source apportionment using unconstrained PMF-2 may produce results that are more mixed and rotationally ambiguous. By constraining the fitting of known source profiles of one or more POA factors, such as BBOA and hydrocarbon-like OA (HOA), the ME-2 solver can better resolve different OA sources. For example, in the analysis of nine months of ACSM data acquired from London, UK, Reyes-Villegas et al. (2016) used ME-2 to successfully resolve five OA factors, including BBOA, HOA, COA, semivolatile oxygenated OA (SV-OOA), and low-volatility oxygenated OA (LV-OOA). Similarly, Sun et al. (2022) demonstrated that constraining BBOA and HOA mass spectra through ME-2 analysis was essential for successfully resolving vehicle emissions from local and regional biomass burning in the Fresno ACSM data collected under CARB contract #17RD008.

In this project, UCD will use the ME-2 algorithm to perform a rolling-window source apportionment analysis of the long-term NR-$PM_{2.5}$ mass spectral data from Fresno and Bakersfield. The goal is to identify the sources of OA and determine their contributions to $PM_{2.5}$ in the SJV during different seasons over a span of three years. The rolling window approach is useful for capturing the dynamic variations in the chemical properties of the OA factors over time, while the incorporation of *a priori* information in ME-2 will significantly reduce rotational uncertainties (Parworth et al., 2015; Chazeau et al., 2022). A rolling window approach is essential for the analysis of long-term datasets (on the order of years) since the source profiles of OA will likely change due to a variety of reasons, including seasonality of biogenic emissions, differences in solar insolation driving photochemistry, ambient temperature, RH and changes within the sources themselves. Rolling window PMF source apportionment analysis is known to be more efficient and outperforms the seasonal approach, exhibits better correlations with external tracers, and minimizes the scaled residuals (i.e., the Q value) of the model fit (Via et al., 2022).

Specifically, UCD will apply ME-2 on the ACSM mass spectral matrices for every two weeks of data, incrementing by 6-24 hours, until the end of the datasets is reached. For every ME-2 analysis, an OA ensemble mass spectral matrix and a measurement error matrix will be calculated. The 2-week interval was chosen based on the fact that this length spans the typical variations of aerosols observed at Fresno and is representative of the average lifecycle of aerosols in the atmosphere. Both matrices will then be pretreated following the procedures outlined in Zhang et al. (2011). Specifically, m/z's with low signal-to-noise ratio will be down-weighted; a minimum error determined from the ACSM spectral data will be applied to the error matrix; and *m/z*'s that are scaled according to the organic signal at m/z 44 will be down-weighted. A main benefit of the proposed rolling-window ME-2 analysis is the ability to determine not just the mass concentration time series and the mass spectra of distinct OA factors, but also the uncertainties in them. In addition, this approach allows factor profiles to vary over time, leading to a more realistic representation of ambient OA sources.

To access the physical meaning of each resulting OA factor, we will examine its temporal, diurnal, and seasonal variations, mass spectral profile, potential source regions, and correlations with tracer species such as oxides of nitrogen (NO_x) and carbon monoxide (CO), both of which are trace gases emitted from combustion sources, as well as meteorological conditions. Since BBOA from different biomass burning activities tends to have similar mass spectral profiles, UCD will investigate whether the ME-2-derived BBOA factors are associated with specific fuel burning activities, such as residential wood burning, agricultural residual burning, prescribed burns, and fossil fuel combustion.

Task 3.2 Analysis of particulate nitrate and evaluate the nighttime chemistry

Previous measurements have demonstrated that ammonium nitrate is a major component of $PM_{2.5}$ in the SJV during the winter. Typically, ammonium nitrate is formed from the reaction of nitric acid with ammonia and nitric acid, and the production of nitric acid during winter is mainly driven by nighttime reactions of NO_2 and nitrate radical (NO_3). Nitric acid production can also occur at night from reactions of NO_3 with VOCs, which can also result in the formation of organonitrates. Both inorganic nitrate species and organonitrates contribute to the nitrate signals reported by the ACSM/AMS. Differentiating between these two types of species is possible by examining the signal ratio of NO^+ (m/z = 30) and NO_2^+ (m/z = 46). Previous studies report that the NO^+/NO_2^+ ratios for organonitrates (R_{ON}) are ~2.25 - 3.7 times higher than that of ammonium nitrate (R_{AN}) (Farmer et al.,

2010; Fry et al., 2013; Fry et al., 2009). Based on this information, UCD can estimate the contribution of organonitrates and quantify the inorganic and organic fractions of measured particulate nitrate. In addition, UCD will determine the temporal trends of oxidant levels and evaluate the nighttime chemistry in the context of future NO_x reductions on PM formation. Examination of the relationships between $PM_{2.5}$ and its constituents, and other air pollutants, such as ozone and NO_x can also help identify the major emission sources contributing to $PM_{2.5}$ and its constituents, including their primary and secondary sources.

Task 3.3 Assess the dependence of $PM_{2.5}$ constituents on the meteorological conditions at varying time scales

Meteorological conditions (e.g., temperature, humidity, wind speed and direction, and atmospheric vertical structure) can significantly affect the formation, transport, and dispersion of $PM_{2.5}$ and its constituents in the atmosphere. The dependence of $PM_{2.5}$ constituents on meteorological conditions can vary depending on the time scale of interest. On a short time scale, from hours to days, temperature inversions can lead to the buildup of $PM_{2.5}$, whereas high wind speeds can disperse $PM_{2.5}$ and its constituents over a wider area. Changes in wind direction, such as the arrival of wind from a clean upstream location, and precipitation can cause an abrupt decrease in $PM_{2.5}$ concentration and changes in $PM_{2.5}$ composition. On a longer time scale, variations in $PM_{2.5}$ composition may be substantial due to seasonal variations in meteorological conditions that can significantly influence emission sources and atmospheric chemistry. Understanding the different impacts of meteorological conditions on varying time scales is important for developing effective strategies to mitigate ambient $PM_{2.5}$ pollution in the SJV.

UCD will conduct a comprehensive analysis of the temporal variations in $PM_{2.5}$ concentration and composition, focusing on the dependence of aerosol mass loading and composition (particularly black carbon) on the meteorological conditions across varying time scales (e.g., diurnally, weekly, seasonally, and annually). This study will investigate the pattern and influence of various meteorological parameters, such as temperature, humidity, wind speed and direction, and boundary layer height, on the temporal and spatial variations of $PM_{2.5}$ and its constituents. Additionally, UCD will analyze the differences in temporal trends and their associated meteorological factors. Co-located measurements of VOC species by CARB (via PTR-MS) and various trace gas phase pollutants will also be analyzed to augment the understanding of how meteorological conditions affect ambient $PM_{2.5}$ pollution in the SJV.

Task 3.4 Examining the differences in $PM_{2.5}$ characteristics between Fresno and Bakersfield and evaluating their implications for future air quality modeling and emission reduction strategies

UCD will compare the differences in aerosol mass loading and composition between Fresno and Bakersfield measurements. Furthermore, UCD will evaluate the implications of the differences in the context of future air quality modeling and emission reduction strategies. Specifically, UCD will analyze the temporal trends in $PM_{2.5}$ and its constituents in Fresno and Bakersfield and compare their differences to better understand the contributions of different aerosol sources and their variations in different seasons, years, and locations in the SJV. The results from these efforts will provide insights into the effectiveness of $PM_{2.5}$ control strategies and inform future air quality management efforts in the SJV.

Task 4: Conduct Meetings and Disseminate Scientific Findings

UCD will present scientific findings from ongoing work during science team meetings, scientific conferences, and quarterly update meetings with CARB throughout the course of the project. In addition, UCD will provide formal presentations at two data meetings: the first meeting will center on final data quality, data archive, and a presentation of preliminary findings; the second meeting will be a presentation of finalized results that addresses the objectives of this contract.

UCD will provide the finalized measurement datasets and detailed analyses to improve the understanding of current and future $PM_{2.5}$ sources in the SJV. This information will be summarized that include a description of the progress of ongoing air pollution mitigation strategies that reduce ambient $PM_{2.5}$ levels in the SJV and bring

the region into compliance with $PM_{2.5}$ NAAQS. A simple easy-to-understand project summary will be provided to CARB.

IV. Reporting and Deliverables

This project will generate the following deliverables:

At the Beginning of the Contract

- All researchers must undergo cultural competency training (examples include implicit bias training, racial equity training, etc.). Training should be completed or scheduled within 30 days of contract execution.
- Participate in a kick-off meeting to give an overview of the project.
- Work with CARB to formulate deployment strategies, finalize data collection timelines, and instrument maintenance plans for both Fresno and Bakersfield air monitoring sites.
- Work with CARB to formulate additional data collection strategies using CARB resources.

During the Contract

- Submit quarterly progress update reports to CARB. These reports will include plain-language summaries that can be posted publicly. A progress report template will be provided by CARB.
- Hold frequent consultation calls with CARB and key stakeholders to coordinate field measurements that support the objectives of this project.
- Hold conference calls with CARB to discuss the progress on a need basis.

Prior to Contract Close

- Work with CARB to create plain-language outreach deliverables for the public summarizing results and impacts of the project (available in multiple languages).
- Package and submit the finalized datasets to CARB. The package will include all data, analyses, and analytical tools generated through the course of this project. The package will be handed over to CARB before the end of the contract.
- Submit the draft final report 6 months before the end of the contract, which will include
    - a plain language executive summary in the draft final report.
    - a plain-language equity implications section in the draft final report.
- Final Report and virtual or in-person seminar.
- Peer-reviewed publications that are accessible to the public. Publications ready for submission will be subjected to CARB review before being submitted

V. Project Timeline and Management Plan

The project duration is three years. Some tasks will be completed sequentially, while others will be performed simultaneously to ensure that the project goals and tasks' products are met in a timely manner. A timeline of the project and products is provided below.

PROJECT PLAN	YEAR 1												YEAR 2												YEAR 3											
Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1																																				
2																																				
3																																				
4																																				
C																																				
W																																				

C = Collaborate with CARB staff *W = Writing report and journal articles*

Project Management Plan

Project Leadership
Zhang, PI: Dr. Zhang will devote 1 person-month (8.333% based on annual FTE) in each of the project years. Dr. Zhang will serve as PI for this project and will be closely involved in all aspects of the work including but not limited to supervising the To-Be-Named Postdoctoral Scholar and Graduate Student Researchers.

Role of Participants
Postdoc: The Postdoctoral Scholar will be employed for 12 person-months (equivalent to 87.7% effort based on annual FTE) per year on the project. The Postdoctoral Scholar will have primary responsibility for conducting the intensive field campaign and analyzing the resulting data.

GSRs (2 positions): Two graduate students will be employed for the project, with each dedicating 12 person-months per year (equivalent to 50% effort based on annual FTE). The graduate students will primarily be responsible for operating and maintaining the ACSM systems in Fresno and Bakersfield. Additionally, they will be responsible for analyzing the ACMS data.

Meetings

A. Initial meeting. Before work on the contract begins, the Principal Investigator and key personnel will meet with the CARB Contract Project Manager and other staff to discuss the overall plan, details of performing the tasks, the project schedule, items related to personnel or changes in personnel, and any issues that may need to be resolved before work can begin.

B. Progress review meetings. The Principal Investigator and appropriate members of his or her staff will meet with CARB's Contract Project Manager at quarterly intervals to discuss the progress of the project. This meeting may be conducted by phone.

C. Technical Seminar. The Contractor will present the results of the project to CARB staff and a possible webcast at a seminar at CARB facilities in Sacramento or Riverside.

Health and Safety

Contractors are required to, at their own expense, comply with all applicable health and safety laws and regulations. Upon notice, Contractors are also required to comply with the state agency's specific health and safety requirements and policies. Contractors agree to include in any subcontract related to the performance

of this Agreement, a requirement that the subcontractor complies with all applicable health and safety laws and regulations, and upon notice, the state agency's specific health and safety requirements and policies.

VI. References

Aiken, A. C., DeCarlo, P. F., Kroll, J. H., Worsnop, D. R., Huffman, J. A., Docherty, K., Ulbrich, I. M., Mohr, C., Kimmel, J. R., Sueper, D., Sun, Y., Zhang, Q., Trimborn, A., Northway, M., Ziemann, P. J., Canagaratna, M. R., Onasch, T. B., Alfarra, M. R., Prevot, A. S. H., Dommen, J., Duplissy, J., Metzger, A., Baltensperger, U., and Jimenez, J. L.: O/C and OM/OC Ratios of Primary, Secondary, and Ambient Organic Aerosols with a High Resolution Time-of-Flight Aerosol Mass Spectrometer, Environ. Sci. and Technol., 42, 4478-4485, 10.1021/es703009q, 2008.

Alfarra, M. R., Prevot, A. S. H., Szidat, S., Sandradewi, J., Weimer, S., Lanz, V. A., Schreiber, D., Mohr, M., and Baltensperger, U.: Identification of the mass spectral signature of organic aerosols from wood burning emissions Environ. Sci. and Technol., 41, 5770-5777, 10.1021/es062289b, 2007.

Altshuler, S. L., Zhang, Q., Kleinman, M. T., Garcia-Menendez, F., Moore, C. T., Hough, M. L., Stevenson, E. D., Chow, J. C., Jaffe, D. A., and Watson, J. G.: Wildfire and prescribed burning impacts on air quality in the United States, Journal of the Air & Waste Management Association, 70, 961-970, 10.1080/10962247.2020.1813217, 2020.

Betha, R., Russell, L. M., Chen, C.-L., Liu, J., Price, D. J., Sanchez, K. J., Chen, S., Lee, A. K. Y., Collier, S. C., Zhang, Q., Zhang, X., and Cappa, C. D.: Larger submicron particles for emissions with residential burning in wintertime San Joaquin Valley (Fresno) than for vehicle combustion in summertime South Coast Air Basin (Fontana), Journal of Geophysical Research: Atmospheres, doi:10.1029/2017JD026730, 2018.

Bond, T. C., Habib, G., and Bergstrom, R. W.: Limitations in the enhancement of visible light absorption due to mixing state, Journal of Geophysical Research: Atmospheres, 111, n/a-n/a, 10.1029/2006JD007315, 2006.

Brophy, P. and Farmer, D. K.: A switchable reagent ion high resolution time-of-flight chemical ionization mass spectrometer for real-time measurement of gas phase oxidized species: characterization from the 2013 southern oxidant and aerosol study, Atmos. Meas. Tech., 8, 2945-2959, 10.5194/amt-8-2945-2015, 2015.

Brown, S. G., Roberts, P. T., McCarthy, M. C., Lurmann, F. W., and Hyslop, N. P.: Wintertime vertical variations in particulate matter (PM) and precursor concentrations in the San Joaquin Valley during the California Regional coarse PM/fine PM Air Quality Study, Journal of the Air & Waste Management Association, 56, 1267-1277, 2006.

Canagaratna, M., Jayne, J., Jimenez, J. L., Allan, J. A., Alfarra, R., Zhang, Q., Onasch, T., Drewnick, F., Coe, H., Middlebrook, A., Delia, A., Williams, L., Trimborn, A., Northway, M., DeCarlo, P., Kolb, C., Davidovits, P., and Worsnop, D.: Chemical and Microphysical Characterization of Ambient Aerosols with the Aerodyne Aerosol Mass Spectrometer, Mass Spectrometry Reviews, 26, 185-222, DOI:110.1002/mas.20115, 2007.

Cappa, C. D., Zhang, X., Russell, L. M., Collier, S., Lee, A. K. Y., Chen, C.-L., Betha, R., Chen, S., Liu, J., Price, D. J., Sanchez, K. J., McMeeking, G. R., Williams, L. R., Onasch, T. B., Worsnop, D. R., Abbatt, J., and Zhang, Q.: Light Absorption by Ambient Black and Brown Carbon and its Dependence on Black Carbon Coating State for Two California, USA, Cities in Winter and Summer, Journal of Geophysical Research: Atmospheres, 124, 1550-1577, doi:10.1029/2018JD029501, 2019.

Chazeau, B., El Haddad, I., Canonaco, F., Temime-Roussel, B., D'Anna, B., Gille, G., Mesbah, B., Prévôt, A. S. H., Wortham, H., and Marchand, N.: Organic aerosol source apportionment by using rolling positive matrix factorization: Application to a Mediterranean coastal city, Atmospheric Environment: X, 14, 100176, https://doi.org/10.1016/j.aeaoa.2022.100176, 2022.

Chen, C.-L., Chen, S., Russell, L. M., Liu, J., Price, D. J., Betha, R., Sanchez, K. J., Lee, A. K. Y., Williams, L., Collier, S. C., Zhang, Q., Kumar, A., Kleeman, M., Zhang, X., and Cappa, C. D.: Organic aerosol particle chemical properties associated with residential burning and fog in wintertime San Joaquin Valley (Fresno) and with vehicle and firework emissions in summertime South Coast Air Basin (Fontana), Journal of Geophysical Research: Atmospheres, 123, 10707-10731, https://doi.org/10.1029/2018JD028374, 2018.

Chen, J., Yin, D., Zhao, Z., Kaduwela, A. P., Avise, J. C., DaMassa, J. A., Beyersdorf, A., Burton, S., Ferrare, R., Herman, J. R., Kim, H., Neuman, A., Nowak, J. B., Parworth, C., Scarino, A. J., Wisthaler, A., Young,

D. E., and Zhang, Q.: Modeling air quality in the San Joaquin valley of California during the 2013 Discover-AQ field campaign, Atmospheric Environment: X, 5, 100067, https://doi.org/10.1016/j.aeaoa.2020.100067, 2020.
Chen, J. J., Ying, Q., and Kleeman, M. J.: Source apportionment of wintertime secondary organic aerosol during the California regional PM(10)/PM(2.5) air quality study, Atmospheric Environment, 44, 1331-1340, 10.1016/j.atmosenv.2009.07.010, 2010.
Chow, J. C., Chen, L.-W. A., Watson, J. G., Lowenthal, D. H., Magliano, K. A., Turkiewicz, K., and Lehrman, D. E.: PM2.5 chemical composition and spatiotemporal variability during the California Regional PM10/PM2.5 Air Quality Study (CRPAQS), Journal of Geophysical Research: Atmospheres, 111, https://doi.org/10.1029/2005JD006457, 2006.
Chow, J. C., Watson, J. G., Lowenthal, D. H., Chen, L. W. A., Zielinska, B., Mazzoleni, L. R., and Magliano, K. L.: Evaluation of organic markers for chemical mass balance source apportionment at the Fresno Supersite, Atmospheric Chemistry and Physics, 7, 1741-1754, 2007.
Collier, S., Williams, L. R., Onasch, T. B., Cappa, C. D., Zhang, X., Russell, L. M., Chen, C.-L., Sanchez, K. J., Worsnop, D. R., and Zhang, Q.: Influence of emissions and aqueous processing on particles containing black carbon in a polluted urban environment: Insights from a soot particle – aerosol mass spectrometer, Journal of Geophysical Research: Atmospheres, 123, 6648-6666, 10.1002/2017JD027851, 2018.
Cubison, M. J., Ortega, A. M., Hayes, P. L., Farmer, D. K., Day, D., Lechner, M. J., Brune, W. H., Apel, E., Diskin, G. S., Fisher, J. A., Fuelberg, H. E., Hecobian, A., Knapp, D. J., Mikoviny, T., Riemer, D., Sachse, G. W., Sessions, W., Weber, R. J., Weinheimer, A. J., Wisthaler, A., and Jimenez, J. L.: Effects of aging on organic aerosol from open biomass burning smoke in aircraft and laboratory studies, Atmos. Chem. Phys., 11, 12049-12064, 10.5194/acp-11-12049-2011, 2011.
DeCarlo, P. F., Kimmel, J. R., Trimborn, A., Jayne, J., Aiken, A. C., Gonin, M., Fuhrer, K., Horvath, T., Worsnop, D. R., and Jimenez, J. L.: A Field-Deployable High-Resolution Time-of-Flight Aerosol Mass Spectrometer, Analytical chemistry, 10.1021/ac061249n, 2006.
Ding, A. J., Huang, X., Nie, W., Sun, J. N., Kerminen, V.-M., Petäjä, T., Su, H., Cheng, Y. F., Yang, X.-Q., Wang, M. H., Chi, X. G., Wang, J. P., Virkkula, A., Guo, W. D., Yuan, J., Wang, S. Y., Zhang, R. J., Wu, Y. F., Song, Y., Zhu, T., Zilitinkevich, S., Kulmala, M., and Fu, C. B.: Enhanced haze pollution by black carbon in megacities in China, Geophysical Research Letters, 43, 2873-2879, https://doi.org/10.1002/2016GL067745, 2016.
Farmer, D. K., Matsunaga, A., Docherty, K. S., Surratt, J. D., Seinfeld, J. H., Ziemann, P. J., and Jimenez, J. L.: Response of an aerosol mass spectrometer to organonitrates and organosulfates and implications for atmospheric chemistry, Proc Natl Acad Sci U S A, 107, 6670-6675, 10.1073/pnas.0912340107, 2010.
Fierz, M., Vernooij, M. G. C., and Burtscher, H.: An improved low-flow thermodenuder, Journal of Aerosol Science, 38, 1163-1168, http://dx.doi.org/10.1016/j.jaerosci.2007.08.006, 2007.
Frohlich, R., Cubison, M. J., Slowik, J. G., Bukowiecki, N., Prevot, A. S. H., Baltensperger, U., Schneider, J., Kimmel, J. R., Gonin, M., Rohner, U., Worsnop, D. R., and Jayne, J. T.: The ToF-ACSM: a portable aerosol chemical speciation monitor with TOFMS detection, Atmospheric Measurement Techniques, 6, 3225-3241, 10.5194/amt-6-3225-2013, 2013.
Fry, J. L., Kiendler-Scharr, A., Rollins, A. W., Wooldridge, P. J., Brown, S. S., Fuchs, H., Dubé, W., Mensah, A., dal Maso, M., Tillmann, R., Dorn, H. P., Brauers, T., and Cohen, R. C.: Organic nitrate and secondary organic aerosol yield from NO_3 oxidation of β-pinene evaluated using a gas-phase kinetics/aerosol partitioning model, Atmos. Chem. Phys., 9, 1431-1449, 10.5194/acp-9-1431-2009, 2009.
Fry, J. L., Draper, D. C., Zarzana, K. J., Campuzano-Jost, P., Day, D. A., Jimenez, J. L., Brown, S. S., Cohen, R. C., Kaser, L., Hansel, A., Cappellin, L., Karl, T., Hodzic Roux, A., Turnipseed, A., Cantrell, C., Lefer, B. L., and Grossberg, N.: Observations of gas- and aerosol-phase organic nitrates at BEACHON-RoMBAS 2011, Atmos. Chem. Phys., 13, 8585-8605, 10.5194/acp-13-8585-2013, 2013.
Ge, X., Shaw, S., and Zhang, Q.: Toward understanding amines and their degradation products from post-combustion CO_2 capture processes with aerosol mass spectrometry, Environ. Sci. and Technol., 48, 5066-5075, 10.1021/es4056966, 2014.

Ge, X., Setyan, A., Sun, Y., and Zhang, Q.: Primary and secondary organic aerosols in Fresno, California during wintertime: Results from high resolution aerosol mass spectrometry, Journal of Geophysical Research-Atmospheres, 117, 10.1029/2012JD018026, 2012a.
Ge, X., Zhang, Q., Sun, Y., Ruehl, C. R., and Setyan, A.: Effect of Aqueous-Phase Processing on Aerosol Chemistry and Size Distribution in Fresno, California, during Wintertime, Environmental Chemistry, 9, 221-235, 10.1071/EN11168, 2012b.
Hu, W., Campuzano-Jost, P., Day, D. A., Croteau, P., Canagaratna, M. R., Jayne, J. T., Worsnop, D. R., and Jimenez, J. L.: Evaluation of the new capture vaporizer for aerosol mass spectrometers (AMS) through field studies of inorganic species, Aerosol Science and Technology, 51, 735-754, 10.1080/02786826.2017.1296104, 2017.
Hu, W., Day, D. A., Campuzano-Jost, P., Nault, B. A., Park, T., Lee, T., Croteau, P., Canagaratna, M. R., Jayne, J. T., Worsnop, D. R., and Jimenez, J. L.: Evaluation of the new capture vaporizer for aerosol mass spectrometers: Characterization of organic aerosol mass spectra, Aerosol Science and Technology, 52, 725-739, 10.1080/02786826.2018.1454584, 2018.
IPCC: IPCC - Climate Change 2013: The Physical Science Basis, 2013.
Jaffe, D. A., O'Neill, S. M., Larkin, N. K., Holder, A. L., Peterson, D. L., Halofsky, J. E., and Rappold, A. G.: Wildfire and prescribed burning impacts on air quality in the United States, Journal of the Air & Waste Management Association, null-null, 10.1080/10962247.2020.1749731, 2020.
Koch, D. and Del Genio, A. D.: Black carbon semi-direct effects on cloud cover: review and synthesis, Atmos. Chem. Phys., 10, 7685-7696, 10.5194/acp-10-7685-2010, 2010.
Lee, B. H., Lopez-Hilfiker, F. D., Mohr, C., Kurtén, T., Worsnop, D. R., and Thornton, J. A.: An Iodide-Adduct High-Resolution Time-of-Flight Chemical-Ionization Mass Spectrometer: Application to Atmospheric Inorganic and Organic Compounds, Environmental Science & Technology, 48, 6309-6317, 10.1021/es500362a, 2014.
Lurmann, F. W., Brown, S. G., McCarthy, M. C., and Roberts, P. T.: Processes influencing secondary aerosol formation in the San Joaquin Valley during winter, Journal of the Air & Waste Management Association, 56, 1679-1693, 2006.
McLafferty, F. W. and Turecek, F.: Interpretation of Mass Spectra, University Science Books, Mill Valley, California1993.
Mohr, C., Huffman, J. A., Cubison, M. J., Aiken, A. C., Docherty, K. S., Kimmel, J. R., Ulbrich, I. M., Hannigan, M., and Jimenez, J. L.: Characterization of Primary Organic Aerosol Emissions from Meat Cooking, Trash Burning, and Motor Vehicles with High-Resolution Aerosol Mass Spectrometry and Comparison with Ambient and Chamber Observations, Environ. Sci. Technol., 43, 2443-2449, 10.1021/es8011518, 2009.
Mohr, C., DeCarlo, P. F., Heringa, M. F., Chirico, R., Slowik, J. G., Richter, R., Reche, C., Alastuey, A., Querol, X., Seco, R., Peñuelas, J., Jiménez, J. L., Crippa, M., Zimmermann, R., Baltensperger, U., and Prévôt, A. S. H.: Identification and quantification of organic aerosol from cooking and other sources in Barcelona using aerosol mass spectrometer data, Atmos. Chem. Phys., 12, 1649-1665, 10.5194/acp-12-1649-2012, 2012.
Ng, N. L., Herndon, S. C., Trimborn, A., Canagaratna, M., Croteau, P., Onasch, T. B., Sueper, D., Worsnop, D. R., Zhang, Q., Sun, Y. L., and Jayne, J. T.: An Aerosol Chemical Speciation Monitor (ACSM) for routine monitoring of the composition and mass concentrations of ambient aerosol, Aerosol Science and Technology, 45, 770-784, 10.1080/02786826.2011.560211, 2011.
Onasch, T. B., Trimborn, A., Fortner, E. C., Jayne, J. T., Kok, G. L., Williams, L. R., Davidovits, P., and Worsnop, D. R.: Soot Particle Aerosol Mass Spectrometer: Development, Validation, and Initial Application, Aerosol Science and Technology, 46, 804-817, 10.1080/02786826.2012.663948, 2012.
Paatero, P.: The multilinear engine - A table-driven, least squares program for solving multilinear problems, including the n-way parallel factor analysis model, Journal of Computational and Graphical Statistics, 8, 854-888, 10.2307/1390831, 1999.
Paatero, P. and Hopke, P. K.: Rotational tools for factor analytic models, J. Chemometrics, 23, 91-100, 2009.
Paatero, P. and Tapper, U.: Analysis of Different Modes of Factor-Analysis as Least-Squares Fit Problems, Chemometrics and Intelligent Laboratory Systems, 18, 183-194, 1993.

Paatero, P. and Tapper, U.: Positive matrix factorization: A non-negative factor model with optimal utilization of error estimates of data values, Environmetrics, 5, 111-126, 10.1002/env.3170050203, 1994.
Paatero, P., Hopke, P. K., Song, X. H., and Ramadan, Z.: Understanding and controlling rotations in factor analytic models, Chemometrics and Intelligent Laboratory Systems, 60, 253-264, 10.1016/S0169-7439(01)00200-3, 2002.
Parworth, C., Fast, J., Mei, F., Shippert, T., Sivaraman, C., Tilp, A., Watson, T., and Zhang, Q.: Long-term Measurements of Submicrometer Aerosol Chemistry at the Southern Great Plains (SGP) Using an Aerosol Chemical Speciation Monitor (ACSM), Atmospheric Environment, 106, 43-55, doi:10.1016/j.atmosenv.2015.01.060, 2015.
Parworth, C. L., Young, D. E., Kim, H., Zhang, X., Cappa, C. D., Collier, S., and Zhang, Q.: Wintertime water-soluble aerosol composition and particle water content in Fresno, California, Journal of Geophysical Research: Atmospheres, 122, 3155-3170, 10.1002/2016JD026173, 2017.
Peck, J., Gonzalez, L. A., Williams, L. R., Xu, W., Croteau, P. L., Timko, M. T., Jayne, J. T., Worsnop, D. R., Miake-Lye, R. C., and Smith, K. A.: Development of an aerosol mass spectrometer lens system for PM2.5, Aerosol Science and Technology, 50, 781-789, 10.1080/02786826.2016.1190444, 2016.
Prabhakar, G., Parworth, C. L., Zhang, X., Kim, H., Young, D. E., Beyersdorf, A. J., Ziemba, L. D., Nowak, J. B., Bertram, T. H., Faloona, I. C., Zhang, Q., and Cappa, C. D.: Observational assessment of the role of nocturnal residual-layer chemistry in determining daytime surface particulate nitrate concentrations, Atmos. Chem. Phys., 17, 14747-14770, 10.5194/acp-17-14747-2017, 2017.
Pusede, S. E., Duffey, K. C., Shusterman, A. A., Saleh, A., Laughner, J. L., Wooldridge, P. J., Zhang, Q., Parworth, C. L., Kim, H., Capps, S. L., Valin, L. C., Cappa, C. D., Fried, A., Walega, J., Nowak, J. B., Weinheimer, A. J., Hoff, R. M., Berkoff, T. A., Beyersdorf, A. J., Olson, J., Crawford, J. H., and Cohen, R. C.: On the effectiveness of nitrogen oxide reductions as a control over ammonium nitrate aerosol, Atmos. Chem. Phys., 16, 2575-2596, 10.5194/acp-16-2575-2016, 2016.
Ramanathan, V. and G., C.: Global and regional climate changes due to black carbon, Nature Geoscience, 1, 221-227, 2008.
Reyes-Villegas, E., Green, D. C., Priestman, M., Canonaco, F., Coe, H., Prévôt, A. S. H., and Allan, J. D.: Organic aerosol source apportionment in London 2013 with ME-2: exploring the solution space with annual and seasonal analysis, Atmos. Chem. Phys., 16, 15545-15559, 10.5194/acp-16-15545-2016, 2016.
Schneider, J., Weimer, S., Drewnick, F., Borrmann, S., Helas, G., Gwaze, P., Schmid, O., Andreae, M. O., and Kirchner, U.: Mass spectrometric analysis and aerodynamic properties of various types of combustion-related aerosol particles, International Journal of Mass Spectrometry, 258, 37-49, 10.1016/j.ijms.2006.07.008, 2006.
Setyan, A., Zhang, Q., Merkel, M., Knighton, W. B., Sun, Y., Song, C., Shilling, J. E., Onasch, T. B., Herndon, S. C., Worsnop, D. R., Fast, J. D., Zaveri, R. A., Berg, L. K., Wiedensohler, A., Flowers, B. A., Dubey, M. K., and Subramanian, R.: Characterization of submicron particles influenced by mixed biogenic and anthropogenic emissions using high-resolution aerosol mass spectrometry: results from CARES, Atmospheric Chemistry & Physics, 12, 8131-8156, 10.5194/acp-12-8131-2012, 2012.
Sun, P., Farley, R. N., Li, L., Srivastava, D., Niedek, C. R., Li, J., Wang, N., Cappa, C. D., Pusede, S. E., Yu, Z., Croteau, P., and Zhang, Q.: PM2.5 composition and sources in the San Joaquin Valley of California: A long-term study using ToF-ACSM with the capture vaporizer, Environmental Pollution, 292, 118254, https://doi.org/10.1016/j.envpol.2021.118254, 2022.
Ulbrich, I., Canagratna, M., Zhang, Q., Worsnop, D., and Jimenez, J. L.: Interpretation of Organic Components from Positive Matrix Factorization of Aerosol Mass Spectrometric Data, Atmos. Chem. Phys., 9, 2891-2918, doi:10.5194/acp-9-2891-2009, 2009.
Via, M., Chen, G., Canonaco, F., Daellenbach, K. R., Chazeau, B., Chebaicheb, H., Jiang, J., Keernik, H., Lin, C., Marchand, N., Marin, C., O'Dowd, C., Ovadnevaite, J., Petit, J. E., Pikridas, M., Riffault, V., Sciare, J., Slowik, J. G., Simon, L., Vasilescu, J., Zhang, Y., Favez, O., Prévôt, A. S. H., Alastuey, A., and Cruz Minguillón, M.: Rolling vs. seasonal PMF: real-world multi-site and synthetic dataset comparison, Atmos. Meas. Tech., 15, 5479-5495, 10.5194/amt-15-5479-2022, 2022.

Xu, W., Croteau, P., Williams, L., Canagaratna, M., Onasch, T., Cross, E., Zhang, X., Robinson, W., Worsnop, D., and Jayne, J.: Laboratory characterization of an aerosol chemical speciation monitor with PM2.5 measurement capability, Aerosol Science and Technology, 51, 69-83, 10.1080/02786826.2016.1241859, 2017.

Young, D. E., Kim, H., Parworth, C., Zhou, S., Zhang, X., Cappa, C. D., Seco, R., Kim, S., and Zhang, Q.: Influences of emission sources and meteorology on aerosol chemistry in a polluted urban environment: results from DISCOVER-AQ California, Atmos. Chem. Phys., 16, 5427-5451, 10.5194/acp-16-5427-2016, 2016.

Zhang, Q., Alfarra, M. R., Worsnop, D. R., Allan, J. D., Coe, H., Canagaratna, M. R., and Jimenez, J. L.: Deconvolution and quantification of hydrocarbon-like and oxygenated organic aerosols based on aerosol mass spectrometry, Environmental Science & Technology, 39, 4938-4952, 10.1021/es048568l, 2005.

Zhang, Q., Jimenez, J. L., Canagaratna, M., Ng, N. L., Ulbrich, I., Worsnop, D., and Sun, Y. L.: Understanding Organic Aerosols via Factor Analysis of Aerosol Mass Spectrometry: a Review, Analytical and Bioanalytical Chemistry, 401, 3045-3067, 10.1007/s00216-011-5355-y, 2011a.

Zhang, Q., Jimenez, J. L., Canagaratna, M. R., Ulbrich, I. M., Ng, N. L., Worsnop, D. R., and Sun, Y.: Understanding atmospheric organic aerosols via factor analysis of aerosol mass spectrometry: a review, Anal. Bioanal Chem, 401, 3045-3067, 10.1007/s00216-011-5355-y, 2011b.

Zhang, Q., Zhou, S., Collier, S., Jaffe, D., Onasch, T., Shilling, J., Kleinman, L., and Sedlacek, A.: Understanding Composition, Formation, and Aging of Organic Aerosols in Wildfire Emissions via Combined Mountain Top and Airborne Measurements, in: Multiphase Environmental Chemistry in the Atmosphere, ACS Symposium Series, 1299, American Chemical Society, 363-385, doi:10.1021/bk-2018-1299.ch018

10.1021/bk-2018-1299.ch018, 2018.

Zhang, Y., Tang, L., Croteau, P. L., Favez, O., Sun, Y., Canagaratna, M. R., Wang, Z., Couvidat, F., Albinet, A., Zhang, H., Sciare, J., Prévôt, A. S. H., Jayne, J. T., and Worsnop, D. R.: Field characterization of the PM2.5 Aerosol Chemical Speciation Monitor: insights into the composition, sources, and processes of fine particles in eastern China, Atmos. Chem. Phys., 17, 14501-14517, 10.5194/acp-17-14501-2017, 2017.

Zheng, Y., Cheng, X., Liao, K., Li, Y., Li, Y. J., Huang, R. J., Hu, W., Liu, Y., Zhu, T., Chen, S., Zeng, L., Worsnop, D. R., and Chen, Q.: Characterization of anthropogenic organic aerosols by TOF-ACSM with the new capture vaporizer, Atmos. Meas. Tech., 13, 2457-2472, 10.5194/amt-13-2457-2020, 2020.

Zhou, S., Collier, S., Jaffe, D. A., Briggs, N. L., Hee, J., Sedlacek Iii, A. J., Kleinman, L., Onasch, T. B., and Zhang, Q.: Regional Influence of Wildfires on Aerosol Chemistry in the Western US and Insights into Atmospheric Aging of Biomass Burning Organic Aerosol, Atmos. Chem. Phys., 17, 2477-2493, 10.5194/acp-17-2477-2017, 2017.

RÉSUMÉ / BIOSKETCH

Curriculum Vitae – Qi Zhang

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date	FIELD OF STUDY
Nanjing University, China	BS	06/1994	Chemical Engineering
University of California, Davis	Ph.D.	07/2002	Atmospheric Chemistry
University of Colorado, Boulder	Postdoctoral	09/2004	Aerosol mass spectrometry

Positions, Scientific Appointments, and Honors

Positions and Employment

2016- Professor, Dept. of Environmental Toxicology, University of California at Davis, CA
2012-2016 Associate professor, Dept. of Environmental Toxicology, University of California at Davis, CA
2009-2012 Assistant professor, Dept. of Environmental Toxicology, University of California at Davis, CA
2005-2009 Assistant Professor / Research Associate, Atmospheric Sciences Research Center and Dept. of Environmental Health, State University of New York at Albany, NY
2004-2005 Research Associated Step II, CIRES, University of Colorado, Boulder.

Other Experience and Professional Activities

1. Chair, Agricultural and Environmental Chemistry Graduate Group, University of California, Davis (since 2022)
2. Chair, Telluride Science Research Center (TSRC) Workshop on Organic Aerosol (2018 – 2022)
3. Editor, Aerosol and Air Quality Research (AAQR) (since 2015)
4. Editorial Advisory Board, Atmospheric Environment (since 2013)
5. Board of Directors, American Association of Aerosol Research (AAAR) (since 2020)

Honor

2020 Leadership for the 21st century (LEAD21, Class 15)
2014 - 20 Highly Cited Researchers
2015 Chancellor's Fellow, University of California, Davis
2014 *Zhang et al. 2007* "Ubiquity and dominance of oxygenated species in organic aerosols in anthropogenically-influenced Northern Hemisphere midlatitudes" article was selected in the Geophysical Research Letter (GRL) 40th Anniversary Special Collection. The only publication selected in the Atmospheric Science field.

Contributions to Science

Selected Peer-reviewed Publications (Selected from 200 peer-reviewed publications, trainees from Zhang's lab are underscored, * denotes corresponding author)

Most relevant to the current application

1. Sun, P., Farley, R. N., Li, L. J., Srivastava, D., Niedek, C. R., Li, J. J., Wang, N. X., Cappa, C. D., Pusede, S. E., Yu, Z., Croteau, P., and **Zhang, Q.*** (2022) $PM_{2.5}$ composition and sources in the San Joaquin Valley of California: A long-term study using ToF-ACSM with the capture vaporizer, *Environmental Pollution*, 292, 118254, https://doi.org/10.1016/j.envpol.2021.118254.

2. Farley, R., N. Bernays, D. A. Jaffe, D. Ketcherside, L. Hu, S. Zhou, S. Collier and **Zhang, Q.*** (2022) Persistent Influence of Wildfire Emissions in the Western United States and Characteristics of Aged Biomass Burning Organic Aerosols under Clean Air Conditions. *Environmental Science & Technology* **56**(6): 3645-3657
3. Pande, P., Shrivastava, M., Shilling, J. E., Zelenyuk, A., **Zhang**, **Q.**, Chen, Q., Ng, N. L., Zhang, Y., Takeuchi, M., Nah, T., Rasool, Q. Z., Zhang, Y., Zhao, B., and Liu, Y. (2022) Novel Application of Machine Learning Techniques for Rapid Source Apportionment of Aerosol Mass Spectrometer Datasets. *ACS Earth and Space Chemistry, 6(4): 932-942.*
4. Wang, J., Ye, J., **Zhang, Q.**, Zhao, J., Wu, Y., Li, J., Liu, D., Li, W., Zhang, Y., Wu, C., Xie, C., Qin, Y., Lei, Y., Huang, X., Guo, J., Liu, P., Fu, P., Li, Y., Lee, H. C., Hwang, S., Zhang, J., Chen, H. L. M., Sun, Y., Ge, X., Martin, S. T., and Jacob, D. J. (2021) Aqueous production of secondary organic aerosol from fossil fuel emissions in winter Beijing haze, *Proceedings of the National Academy of Sciences (PNAS),* 118, e2022179118, 10.1073/pnas.2022179118
5. Huang, D. D., Zhu, S., An, J., Wang, Q., Qiao, L., Zhou, M., He, X., Ma, Y.-g., Sun, Y., Huang, C., Yu, J. Z., and **Zhang, Q.*** (2021) Comparative assessment of cooking emission contributions to urban organic aerosol using online molecular tracers and aerosol mass spectrometer measurements, *Environmental Science & Technology*, 55, 14526-14535, 10.1021/acs.est.1c03280, 2021. https://pubs.acs.org/doi/pdf/10.1021/acs.est.1c03280
6. Li, H., **Zhang, Q.***, Jiang, W., Collier, S., Sun, Y., Zhang, Q., and He, K. (2021) Characteristics and sources of water-soluble organic aerosol in a heavily polluted environment in Northern China, *Science of The Total Environment*, 758, 143970
7. Zhao, Q. B., Huo, J. T., Yang, X., Fu, Q. Y., Duan, Y. S., Liu, Y. X., Lin, Y. F., **Zhang, Q.*** (2020) Chemical characterization and source identification of submicron aerosols from a year-long real-time observation at a rural site of Shanghai using an Aerosol Chemical Speciation Monitor, *Atmospheric Research*, 256, 105154, https://doi.org/10.1016/j.atmosres.2020.105154.
8. Parworth, C. L., Young, D. E., Kim, H., Zhang, X., Cappa, C. D., Collier, S., and **Zhang, Q*** (2017) Wintertime water-soluble aerosol composition and particle water content in Fresno, California: Results from DISCOVER-AQ 2013, *Journal of Geophysical Research - Atmospheres*, 122(5), 3155-3170, 10.1002/2016JD026173
9. Young, D., Kim, H. J., Parworth, C., Zhou, S., Zhang, X. L., Cappa, C., Seco, R., Kim, S., and **Zhang, Q.*** (2016) Influences of emission sources and meteorology on aerosol chemistry in a polluted urban environment: Results from DISCOVER-AQ California, *Atmospheric Chemistry & Physics,* 16, 5427-5451, 10.5194/acp-16-5427-2016.
10. **Zhang, Q.***, J. L. Jimenez, M. Canagaratna, I. Ulbrich, N. L. Ng, D. Worsnop, and Y. L. Sun (2011) Understanding atmospheric organic aerosols via factor analysis of aerosol mass spectrometry: a review, *Analytical and Bioanalytical Chemistry*, 401, 3045-3067, doi 10.1007/s00216-011-5355-y

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

11. Zheng, Y., Miao, R., **Zhang, Q.**, Li, Y., Cheng, X., Liao, K., Koenig, T. K., Ge, Y., Tang, L., Shang, D., Hu, M., Chen, S., and Chen, Q. (2023) Secondary Formation of Submicron and Supermicron Organic and Inorganic Aerosols in a Highly Polluted Urban Area, *Journal of Geophysical Research: Atmospheres*, 128, e2022JD037865, https://doi.org/10.1029/2022JD037865.
12. Collier, S., Zhou, S., Onasch, T. B., Jaffe, D., Kleinman, L., Sedlacek, A. J., Briggs, N., Hee, J., Fortner, E., Shilling, J. E., Worsnop, D. R., Yokelson, R. J., Parworth, C. L., Ge, X. L., Xu, J. Z., Butterfield, Z., Chand, D., Dubey, M.K., Pekour, M., Springston, S., and **Zhang, Q*.** (2016) Regional Influence of Aerosol Emissions from Wildfires Driven by Combustion Efficiency: Insights from the BBOP Campaign. *Environ. Sci. and Technol.* 50, 8613–8622, 10.1021/acs.est.6b01617, 2016.

13. Zhou, S., Collier, S., Jaffe, D. A., Briggs, N. L., Hee, J., Sedlacek III, A. J., Kleinman, L., Onasch, T. B., and **Zhang, Q***. (2017) Regional influence of wildfires on aerosol chemistry in the Western US and insights into atmospheric aging of biomass burning organic aerosol, *Atmos. Chem. Phys.*, 2017, 2477-2493, 10.5194/acp-17-2477-2017.
14. Kim, H., **Zhang, Q**. *, Bae, G. N., Kim, J. Y., and Lee, S. B. (2017) Sources and atmospheric processing of wintertime aerosols in Seoul, Korea: Insights from real-time measurements using a high-resolution aerosol mass spectrometer, *Atmos. Chem. Phys.*, 17, 2009-2033, 10.5194/acp-17-2009-2017.
15. Li, H., **Zhang, Q.** *, Zhang, Q., Chen, C., Wang, L., Wei, Z., Zhou, S., Parworth, C., Zheng, B., Canonaco, F., Prévôt, A. S. H., Chen, P., Zhang, H., and He, K. (2017) Wintertime aerosol chemistry and haze evolution in an extremely polluted city of north China plain: Significant contribution from coal and biomass combustions, *Atmos. Chem. Phys.* 17, 4751-4768, 10.5194/acp-17-4751-2017
16. Collier, S., Williams, L. R., Onasch, T. B., Cappa, C. D., Zhang, X., Russell, L. M., Chen, C.-L., Sanchez, K. J., Worsnop, D. R., and **Zhang, Q.*** (2018) Influence of emissions and aqueous processing on particles containing black carbon in a polluted urban environment: Insights from a Soot Particle – Aerosol Mass Spectrometer, *Journal of Geophysical Research: Atmospheres*, 123, 6648-6666, 10.1002/2017JD027851.
17. Kim, H.; Collier, S.; Ge, X.; Xu, J.; Sun, Y.; Jiang, W.; Wang, Y.; Herckes, P.; **Zhang, Q.*** (2019) Chemical Processing of Water-Soluble Species and Formation of Secondary Aerosol in Fogs. *Atmospheric Environment*, 200, 158-166
18. Zhou, S., S. Collier, D. A. Jaffe, and **Zhang, Q.*** (2019) Free Tropospheric Aerosols at the Mt. Bachelor Observatory: More Oxidized and Higher Sulfate Content Compared to Boundary Layer Aerosols, *Atmospheric Chemistry and Physics*. **19**, 1571–1585, 10.5194/acp-19-1571-2019
19. Ge, X. L., **Zhang, Q.***, Y. L. Sun, C. R. Ruehl, A. Setyan (2012) Effect of Aqueous Phase Processing on Aerosol Chemistry and Size Distributions in Fresno, California, during Wintertime, *Environmental Chemistry*, 9(3), 221-235, 10.1071/EN11168
20. Ge, X. L., A. Setyan, Y. L. Sun, **Zhang, Q.*** (2012) Primary and Secondary Organic Aerosols in Fresno California during Wintertime: Results from High Resolution Aerosol Mass Spectrometry, *Journal of Geophysical Research – Atmospheres*, 117, D19, doi:10.1029/2012JD018026

Complete List of Published Work Available at:
https://sites.google.com/site/qizhanggroup/publications?authuser=0

Published Work and Citation Metrics in Publons:
https://publons.com/researcher/2824772/qi-zhang/

CURRENT & PENDING SUPPORT

PI: Qi Zhang					
Status	**Award #**	**Source**	**Project Title**	**Start Date**	**End Date**
Active	22RD038	CARB	Long-term Chemical Characterization and Source Apportionment of $PM_{2.5}$ in the San Joaquin Valley	6/15/2023	6/14/2026
Active	DE-SC0022140	DOE	Investigating the Impacts of Aqueous-Phase Processing on Organic Aerosol Chemical Climatology Using ARM and ASR Observations	8/15/2021	8/14/2024
Active	DE-SC0021242	DOE	Characterization of carbonaceous aerosols during TRACER-CAT	8/15/2020	8/14/2023
Active	DE-SC0020182	DOE	Characterizing the impact of water uptake on light absorption by aerosol particles	8/15/2019	8/14/2023
Active	AGS-2220307	NSF	Formation of photo-oxidants and processing of organic species in aerosol liquid water	7/15/2022	6/30/2025
Pending		NSF	Aqueous aerosol chemistry: elucidating the mechanisms causing mismatch between field and laboratory chemical composition of biomass burning organic aerosol	7/1/2023	6/30/2026