EXHIBIT A

SCOPE OF WORK

☒ Contract ☐ Grant

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

PI Name: Jun Wu

Project Title: Examining the Health Impacts of Short-Term Repeated Exposure to Wildfire Smoke

PROJECT SUMMARY

The University of Irvine (UCI) has assembled a multi-disciplinary team with expertise in community air quality modeling, remote sensing and air pollution exposure assessment, air pollution epidemiology, biostatistics, and risk communication. This study will expand the understanding of wildfire-induced health impacts by identifying gaps in previous studies and filling those gaps by linking detailed health and covariates data with high spatiotemporal resolution wildfire smoke exposure obtained from sophisticated air quality modeling, and addressing specific concerns for disadvantaged communities (DAC) through inclusive and informative outreaches with designated community members in California. The results of the project will provide insight into how health risks can be mitigated during wildfire events, including those in DAC.

UCI will: 1) conduct a literature review on the health impacts of short-term exposure to wildfire air pollution; 2) model statewide wildfire air pollution at a high spatiotemporal resolution across multiple years to determine time-series exposure data for smoke wave events; 3) obtain and process health and covariate data; 4) conduct an epidemiological analysis on the health effects of short-term exposure to wildfire air pollution; 5) address specific concerns for DAC through inclusive and informative outreach with designated community members; and 6) deliver a detailed and comprehensive final research report and data to California Air Resources Board (CARB).

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.

STATEMENT OF SIGNIFICANCE

The occurrence and severity of wildfires in California has sharply increased in recent decades, and this trend is expected to continue in response to climate change and other factors[1.] This raises serious human health concerns as exposure to fine particulate matter (PM) less than 2.5 micrometer (μm) ($PM_{2.5}$) and particulate matter less than ten μm (PM_{10}) from wildfires may even be more toxic than from other sources[2]. In addition, toxic air pollutants, such as polycyclic aromatic hydrocarbons (PAH) are a key contributor to smoke-induced health effects[3]. However, the health consequences of exposure to wildfire-generated smoke are not as well understood as those for conventional sources of air pollution due to differences including the chemical composition of wildfire air pollution and the exposure patterns, including the duration and frequency of events. Most notably, exposure to wildfire air pollution occurs as smoke waves, which are characterized as extreme pollution events that may occur sporadically, while most research on $PM_{2.5}$ is associated with chronic exposure to ambient (i.e., non-wildfire) $PM_{2.5}$. Specifically, this project will seek to quantify and spatially resolve the health effects in California resulting from recurrent, short-term exposure to very high levels of wildfire air pollution.

Furthermore, individuals with lower socioeconomic status (SES), including minorities are disproportionately burdened by, and vulnerable to, air pollution generated by wildfires for numerous reasons, including lack of healthcare, occupational aspects, substandard housing, and others[3,4]. For example, the recommendation by health agencies to stay indoors during smoke wave episodes may not be followed by lower SES individuals who are more likely to work essential jobs requiring them to be outdoors. Similarly, a lack of resources may preclude lower SES individuals from purchasing air purifiers or air conditioning units. Socioeconomic factors have been shown to be modifying risk factors for cardio-respiratory consequences associated with exposure to wildfire smoke[5]. Therefore, there is a critical need to 1) develop a detailed understanding of how DAC are impacted by wildfire smoke waves and 2) provide tangible insights into how those risks can be communicated and mitigated within those communities.

The goal of this project is to advance the state-of-science regarding the short-term health effects of repeated exposure to wildfire-specific air pollution and to communicate the results to socially vulnerable populations. The results of this work will provide insight into how health risks can be mitigated during wildfire events, including in DAC. To meet this goal, the UCI will conduct the following tasks:

1. Conduct a literature review on the health impacts of short-term exposure to wildfire air pollution;
2. Model statewide wildfire air pollution at a high spatiotemporal resolution across multiple years to determine time-series exposure data for smoke wave events;
3. Obtain and process health and covariate data;
4. Conduct an epidemiological analysis on the health effects of short-term exposure to wildfire air pollution;
5. Address specific concerns for DAC through inclusive and informative outreach with designated community members; and
6. Deliver a detailed and comprehensive final research report and data to CARB.

TECHNICAL PLAN

Task 1: Conduct a literature review on the health impacts of short-term exposure to wildfire air pollution

First, UCI will conduct a thorough review of peer-reviewed literature and published reports regarding 1) quantifying and characterizing short-term exposure to wildfire smoke and 2) the health effects associated with exposure to identify gaps between current understanding of the short-term health effects in California, particularly within socially DAC who experience increased vulnerability to wildfire impacts. An emphasis will be placed on short-term health effects (e.g., hospitalization and emergency room visits due to respiratory and cardiovascular outcomes, preterm birth, depression incidences) occurring within DAC (i.e., low SES and minority population) and/or vulnerable populations (e.g., children, elderly, and people with existing diseases or preconditions that may put them at higher risk from wildfire-generated smoke exposure) to specifically identify gaps within that framework. The research will be designed to best address those gaps. There could be long-term health effects due to exposures to wildfire smoke. But the current research on long-term health effect is very limited, likely due to the complexity of potential confounding factors and challenges in tracking people over time. Thus, UCI will mainly focus on the short-term health effects in this project.

In addition to air pollution exposure and health impact from wildfires, UCI will also review existing literature on risk perception, risk communication, and public health responses to reduce exposure to wildfire smoke during extreme events, including recommendations from public health agencies and other sources. The public may have different perceptions to wildfire risk due to differences in socio-demographic factors, prior experience, and pre-existing conditions, etc. Further, risk communication messages from the government and research communities may or may not be effective given that these messages might not be tailored to specific sub-populations or population with the highest risk. In addition, due to the increasing frequency of wildfire incidences in California, residents and organizations (e.g. schools) have critical needs for clear recommendations from the government or public health agency on whether or not to perform routine activities (e.g. outdoor physical education class, and running) and what to do for exposure mitigation during wildfire events. Several bills were passed in California to address the emerging wildfire problem, including Assembly Bill (AB) 661 that requires the Sacramento Metropolitan Air Quality Management District to prepare a wildfire smoke air pollution emergency plan as an informational source for local agencies and the public and AB 836 that established the Wildfire Smoke Clean Air Centers for Vulnerable Populations Incentive Pilot Program. The content and activities of these established programs will be incorporated as part of the literature review. The results of the project will provide a basis for such recommendations; but, a literature review on public health practices, especially what have worked or failed, would be helpful for communications with community partners and for the development of future recommendations by the CARB.

Task 2: Model statewide wildfire air pollution at a high spatiotemporal resolution across multiple years to determine time-series exposure data for smoke wave events

To define smoke wave events associated with wildfires in the period of study at fine spatial resolution (i.e., zip code or smaller), UCI will apply state-of-the-art techniques combining machine learning models with rich spatiotemporal covariates. Daily mean wildfire-specified $PM_{2.5}$ concentrations for 2017, 2018, and 2020 at a one kilometer (km) spatial resolution over California will be estimated using deep learning models that incorporate information from multiple sources, including ground measurements, satellite remote sensing, chemical transport model simulations, meteorological fields, land-use variables, etc. UCI has first-hand experience with these and other techniques used to evaluate the health effects of exposure to wildfire smoke, including contributing to a recent study quantifying the public health and economic damages caused by the 2018 California wildfires using similar methods to those proposed here[1]. It should be noted that, for this study, improvements will be added to provide more detailed and accurate fire exposure estimates. Table 1 lists inputs and potential inputs to the methodology.

TABLE 1. LIST OF INPUTS VARIABLES FOR EXPOSURE MODELING

Inputs	Type	Source	Resolution
Wildfire Emissions			
Fire Inventory from National Center for Atmospheric Research (FINN)v2.2	Data	Moderate Resolution Imaging Spectroradiometer (MODIS) (2020) + Visible Infrared Imaging Radiometer Suite (VIIRS) (2019)	1 x 1 km
FINNv1.5	Data	MODIS (2020)	1 x 1 km
GBBEP (Global Biomass Burning Emissions Product)	Data	MODIS + VIIRS (2021)	0.1 x 0.1 degree
Quick Fire Emissions Dataset (QFED) fire inventory	Data	MODIS (2020)	0.1 x 0.1 degree
BlueSky Daily Runs	Model	https://tools.airfire.org/websky/v1/#status	1.3 km / 4 km
AirFire Tools	Data + Model	https://portal.airfire.org/	N/A
SMOKE EMISSIONS REFERENCE APPLICATION (SERA)	Model	https://depts.washington.edu/nwfire/sera/index.php	N/A
FINN2CMAQ (Community Multiscale Air Quality Modeling System Processor)	Model	https://github.com/barronh/finn2cmaq	N/A
Anthropogenic Emissions			
CARB inventory	Data	CARB	4 x 4 km
ESTA (Emissions Spatial and Temporal Allocator model)	Data + Model	CARB	4 x 4 km
SMOKE 4.7	Model	U.S. EPA	4 x 4 km
California Emissions Projection Analysis Model (CEPAM) 2019	Data + Model	CARB	EIC-County
Biogenic Emissions			
Model of Emissions of Gases and Aerosols from Nature (MEGAN)v2.1	Data + Model	https://bai.ess.uci.edu/megan/data-and-code	4 x 4 km
MEGANv3.1	Data + Model	https://bai.ess.uci.edu/megan/data-and-code	4 x 4 km
Meteorology			
NARR (North American Regional Reanalysis)	Data	https://rda.ucar.edu/datasets/ds608.0/index.html#sfol-wl-/data/ds608.0?g=3	32 km
Boundary			
Community Atmosphere Model with Chemistry (CESM) 2.1/CAM-chem	Data	https://rda.ucar.edu/datasets/ds313.7/index.html#!description	0.9°*1.25°
Machine Learning			
Multiangle Implementation of Atmospheric Correction (MAIAC) Aerosol Optical Depth (AOD) (PM_{10}, $PM_{2.5}$)	Data + Model	https://modis-land.gsfc.nasa.gov/MAIAC.html	1 km
Hazard Mapping System (HMS)	Data	https://www.ospo.noaa.gov/Products/land/hms.html	4 km
gridMET	Data	http://www.climatologylab.org/gridmet.html	4 km
National Land Cover Database (NLCD)	Data	https://www.mrlc.gov	30 m
Population density: 2020 Census	Data	https://www.census.gov/programs-surveys/decennial-census/data/datasets.html	N/A
Road Length	Data	https://catalog.data.gov/dataset/tiger-line-shapefile-2019-state-california-primary-and-secondary-roads-state-based-shapefile	1 km
Elevation	Data	https://lpdaac.usgs.gov/products/astgtmv003/).	30 m
CARB and U.S. EPA Air Quality System (AQS) (PM_{10}, $PM_{2.5}$)	Data	https://www.epa.gov/aqs	N/A
PurpleAir	Data	https://www.purpleair.com/sensorlist	N/A

Sub-task 2.1: Estimate direct wildfire emissions for the years of study

To estimate direct fire emissions, UCI will potentially use several databases, including the latest versions of Quick Fire Emissions Dataset (QFED), and Fire Inventory from National Center for Atmospheric Research (FINNv2.2)[7]. FINN uses satellite observations of active fires and land cover, together with emission factors and estimated fuel loadings to provide daily, highly resolved one km open burning emissions estimates for use in regional and global chemical transport models. The latest version of FINNv2.2 is generated based on both the Moderate Resolution Imaging Spectroradiometer (MODIS) fire product[8] and the Visible Infrared Imaging Radiometer Suite (VIIRS) fire product[9]. More specifically, current available fire emissions for 2017 and 2018 is based on both MODIS and VIIRS, and fire emission for 2020 will be obtained as soon as they are released. UCI will review the various fire emissions databases and determine which will support the best Community Multiscale Air Quality Modeling System (CMAQ) model performance including spatio-temporal granularity.

The raw emission inventory needs to be properly grided and temporally allocated for air quality simulations. For this process, several tools will be used to treat different emission sources. For anthropogenic emissions, the Sparse Matrix Operator Kernel Emissions[10] modeling system will be used, to convert and project the CARB California Emissions Projection Analysis Model (CEPAM) 2016 emission inventory[11] to 2017, 2018, and 2020 accordingly. UCI has extensive experience translating CEPAM into gridded and speciated emissions suitable for input into CMAQ. The projection ratio for each year will be calculated at the state level for different emission sectors using the CEPAM[12] standard emission tool. The biogenic emissions will be generated using the Model of Emissions of Gases and Aerosols from Nature version 2.1 (MEGANv2.1)[13] model, which accounts for land coverage, vegetation type, and meteorology. Finally, a new conversion tool will be developed to prepare the FINN emission raw data for CMAQ air quality simulation for specific chemical species and modeling grids. The heat flux from fire smoke, including: PM_{10}, $PM_{2.5}$ and PAH will be scaled using a constant emission factor for all fires (0.14 kg fuel per gram of $PM_{2.5}$ emission)[14]. The ArcGIS™ (Redlands, CA) tool will be used to spatially allocate the burned areas into the simulation grids. The daily to hourly temporal scale will be based on the Western Regional Air Partnership - Fire Emissions Tracking System[15].

Sub-task 2.2: Quantify and spatially resolve wildfire pollution using the CMAQ chemical transport model

<u>CMAQ description:</u> The CMAQ was developed by the United State Environmental Protection Agency (U.S. EPA) and is widely used for air quality assessment needs including regulatory compliance and atmospheric research associated with tropospheric ozone (O_3), PM, acid deposition, and visibility[16,17]. CMAQ simulates pollutant concentrations from both primary emissions (i.e., direct fire emissions) and secondarily formed pollutants through atmospheric photochemical reactions (i.e., O_3, secondary $PM_{2.5}$). The research team has extensive experience utilizing the CMAQ modeling platform for various research needs including assessing the air quality impacts of emission inventories[18], energy sectors[19,20], integrating alternative technologies in energy systems[21], atmospheric chemical mechanisms[22], and climate[23].

<u>CMAQ modeling:</u> To develop fully resolved distributions of important air pollutants (e.g. $PM_{2.5}$, PM_{10}, and $PM_{2.5}$ particle-bound PAHs) that are key contributors to smoke-induced health effects[3], UCI will use the CMAQ v5.3.2[24] to simulate pollutant concentrations at four km by four km horizontal resolution covering the entire state of California for 2017, 2018, and 2020 at a hourly resolution. UCI has CEPAM emission inputs and meteorological fields ready for 2017 and 2018 and will develop

a 2020 inventory using expected 2020 data adjusted for the impacts of COVID-19 pandemic. It should be noted that the CMAQ modeling will serve to develop a ratio of fire-contributed pollution only, and the CMAQ output will not serve as the final concentrations utilized in exposure estimates. Due to the high computational cost of CMAQ simulations, 2019 is not included as the occurrence of wildfires was relatively low[1]. The Statewide Air Pollution Research Center-07 chemical mechanism[25] will be selected for gas-phase chemistry, and AEROsol model version 6 (AERO6) module[26] will be used to calculate aerosol dynamics. The Advanced Research Weather Research

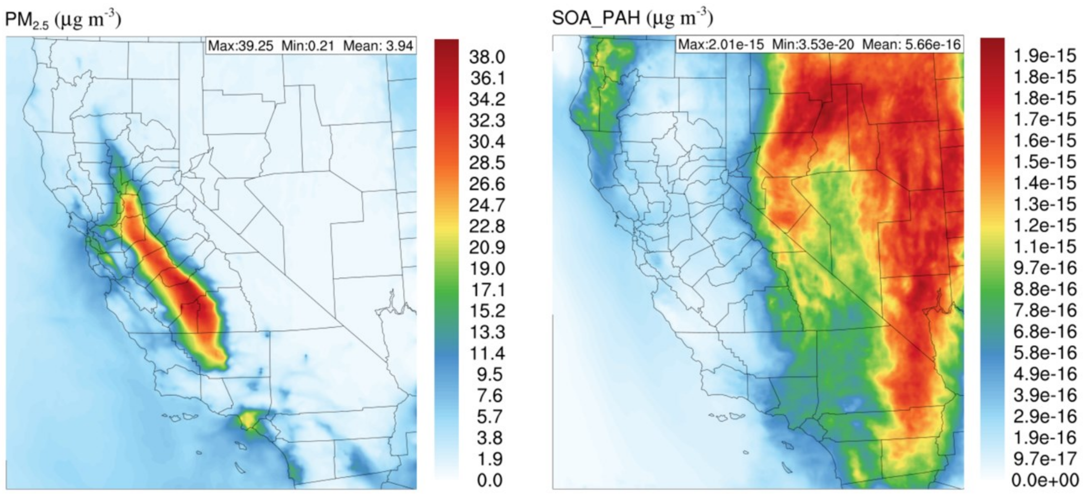
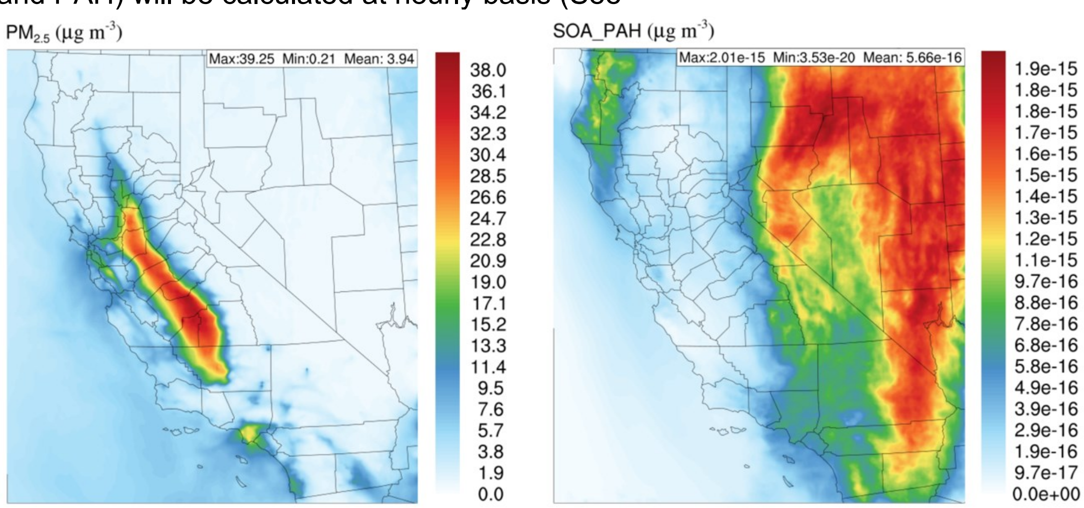


Figure 1. Spatial distribution of $PM_{2.5}$ and PAH particles calculated using CMAQ

and Forecasting Model (WRF-ARWv3.9.1) will be used to downscale meteorological conditions from the (Final) Operational Global Analysis data[27]. The boundary conditions will be obtained via the Community Earth System Model 2.1/ The Community Atmosphere Model with Chemistry` (CESM2.1/CAM-chem)[28]. Model performance for the years of study will be validated using observational data from the CARB and the U.S. EPA's Air Quality System (AQS)[29].

For each selected year, two annual simulations will be conducted, one with fire emissions included and another without. From CMAQ, fully resolved distributions of key pollutant species ($PM_{2.5}$, PM_{10}, and PAH) will be calculated at hourly basis (See



[1] https://www.fire.ca.gov/stats-events/

Figure 1). The AERO6 module[26] will be selected for this study instead of AERO7[30], as the PAH specified information is no longer available in AERO7. The AERO6 can calculate secondary organic aerosols and combine resulting PAH species into three $PM_{2.5}$ aggregates. The model simulations will be validated using observational data from the U.S. EPA's AQS[29] for PM_{10} and $PM_{2.5}$ based on model performance criteria recommended by Emery et al.[31]

The evaluation for PAH estimates will also be conducted; but, will be limited to sparse measurements available from the U.S. EPA's air toxics database (https://www3.epa.gov/ttnamti1/toxdat.html#data) in California and the 2018 Multiple Air Toxics Exposure Study V measurements at ten sites collected by the South Coast Air Quality Management District (http://www.aqmd.gov/home/air-quality/air-quality-studies/health-studies/mates-v).

Hourly concentrations of fire-generated pollutants will be determined by subtracting simulated concentrations between the two scenarios with and without fire emissions, in particular the fraction of total pollutant concentration attributed to wildfires during the smoke wave events.

($R_{fire} = {(C_{with\ fire} - C_{without\ fire})}/{C_{with\ fire}}$) on a daily basis.

Besides estimated pollutant concentrations, intermediate products, such as planetary boundary layer height (PBL) and meteorological parameters (e.g. vertical layer wind speeds) that reflect atmospheric stability and mixing will be stored from the WRF-CMAQ system outputs for pollutant modeling in the next stage. Data from the ceilometer network of CARB will be used to evaluate PBL heights from the CMAQ outputs.

Sub-task 2.3: Obtain detailed spatiotemporal covariates for daily total $PM_{2.5}$ and PM_{10} concentration estimation

In addition to the chemical transport model outputs from the CMAQ, UCI will obtain rich spatiotemporal covariates for $PM_{2.5}$ and PM_{10} modeling, including aerosol optical depth (AOD) from satellite measures, smoke plume data, meteorological parameters, land-cover data, population density, and elevation.

Satellite data: Given the limitations of relatively sparse surface monitoring networks, such as state and national PM monitoring networks, or the AErosol RObotic NETwork for $PM_{2.5}$ measurements, AOD from satellite observations have been used to characterize aerosols, particularly over large geographic areas. Since 2000, the MODIS instruments on the polar orbiting Terra and Aqua satellites have provided daily AOD retrievals with global coverage. As a high spatiotemporal-resolution product, the Multiangle Implementation of Atmospheric Correction (MAIAC) algorithm[32,33] was developed to simultaneously retrieve surface bi-directional reflection function and AOD over bright and dark surfaces from MODIS at one km resolution on a daily basis. However, due to cloud cover and conditions of high surface reflectance, the MAIAC AOD can miss as much as 50 percent of the data if accounting for both spatial and temporal completeness in the data[34]. UCI will leverage deep learning (i.e. autoencoder-based full residual deep network) with Modern-Era Retrospective analysis for Research and Applications Version 2 (MERRA-2) Global Modeling Initiative Replay Simulation (M2GMI) data to fill the gaps of missing MAIAC AOD (MCD19A2 products) in space and time. The MERRA-2 M2GMI (https://acd-ext.gsfc.nasa.gov/Projects/GEOSCCM/MERRA2GMI) is a global reanalysis data product[35], which assimilates multiple aerosol remote sensing, emissions, and meteorological data using the Goddard Earth Observing System Model; but, further incorporates aerosols, chemistry, atmosphere, land, ice, and ocean biogeochemistry. MERRA-2 M2GMI provides estimates of 0.5° × 0.625° (grids >50 km in both latitude and longitude directions) total column AOD and certain chemical species across the study region at a daily temporal resolution. Additional variables will be used to fill in the missing MAIAC AOD data, including gridMET meteorological parameters[36], elevation, and geo-coordinates to account for spatial effects. The same approach has been used to impute weekly MAIAC AOD values in 2000-2016 across California and achieved excellent model performance with a mean evaluation R^2 of 0.94 and a root-mean-square-error of 0.007 in an independent test[34]. Similar evaluations will be conducted in this project for MAIAC AOD imputation.

Smoke plume data: Smoke plume will be extracted from the Hazard Mapping System (HMS) of the National Oceanic and Atmospheric Administration[37] to identify residences within the smoke plume. The HMS generates a four km grid smoke product from 2002 to present by combining satellite imagery from multiple NOAA and National Aeronautics and Space Administration (NASA) instruments[38]. However, the HMS data do not differentiate whether the smoke plume is at the ground or at a higher elevation. This is one of the main reasons for UCI to use the CMAQ model outputs with and without wildfire emissions. The HMS variable may be helpful for fire smoke prediction; but, its importance and contribution need to be evaluated in this project.

Meteorological data: Meteorological factors play very important roles in the formation, dispersal, and transport of PM at regional and local scales. Daily meteorological parameters will be extracted from four km gridMET surface meteorological outputs that cover the contiguous United States (U.S.) (http://www.climatologylab.org/gridmet.html)[36]. These parameters include daily minimum and maximum air temperature, wind speed, specific humidity, daily mean downward shortwave radiation, and accumulated precipitation.

Land cover variables: Land use parameters can capture non-wildfire pollutant emission sources and sinks. The National Land Cover Database (NLCD) (https://www.mrlc.gov) provides nationwide data on land cover at a 30 m resolution on a yearly basis. Percent cover of each of the 16 land cover classes (e.g., open water, developed with low intensity, developed with high intensity, barren land, grassland and cultivated crops etc.) will be calculated for each one-km modeling grid. The latest year of available data is in 2016; newer data will be used if they become available by the end of 2022. Surface imperviousness layer will also be extracted from the NLCD products. Further, normalized difference vegetation index (NDVI) based on 16-day MODIS NDVI average values from NASA's Aqua and Terra satellites (MOD13A2 V6 andMCD13A2 V6) will be obtained at a one km resolution.

Additional variables: Population density, representing small area source emissions based on 2020 Census will be extracted. Total roadway length will also be calculated for each one-km grids. Elevation data at a 30-meter resolution will be obtained from the U.S. Geological Survey (https://lpdaac.usgs.gov/products/astgtmv003/).

Sub-task 2.4: Utilize an encoder-decoder full residual deep network model to predict daily total $PM_{2.5}$ and PM_{10} concentrations at one-km resolution

Deep learning model description: A deep learning model, namely encoder-decoder full residual deep network, will be used to model daily pollutant concentrations. The full residual deep network consists of the encoding layers (including the input layer and hidden layers with a decreasing number of nodes), the latent (coding) representation layer, the decoding layers, and the output layer (Figure 2)[39]. In the autoencoder, the coding/latent layer is used to extract the representation from the input. Each decoding layer has the same number of nodes corresponding to its symmetrical encoding layer. The latent layer has a compressed dimension to have a powerful representation for the input layer and help with efficient model training. Full residual connections are established: each of the encoding layers has a shortcut of identity mapping (residual connection) to its corresponding decoding layer to improve training and error backpropagation. Residual learning has been demonstrated to be an efficient method to appropriately increase the depth of the hidden layers without reduction in the performance[39].

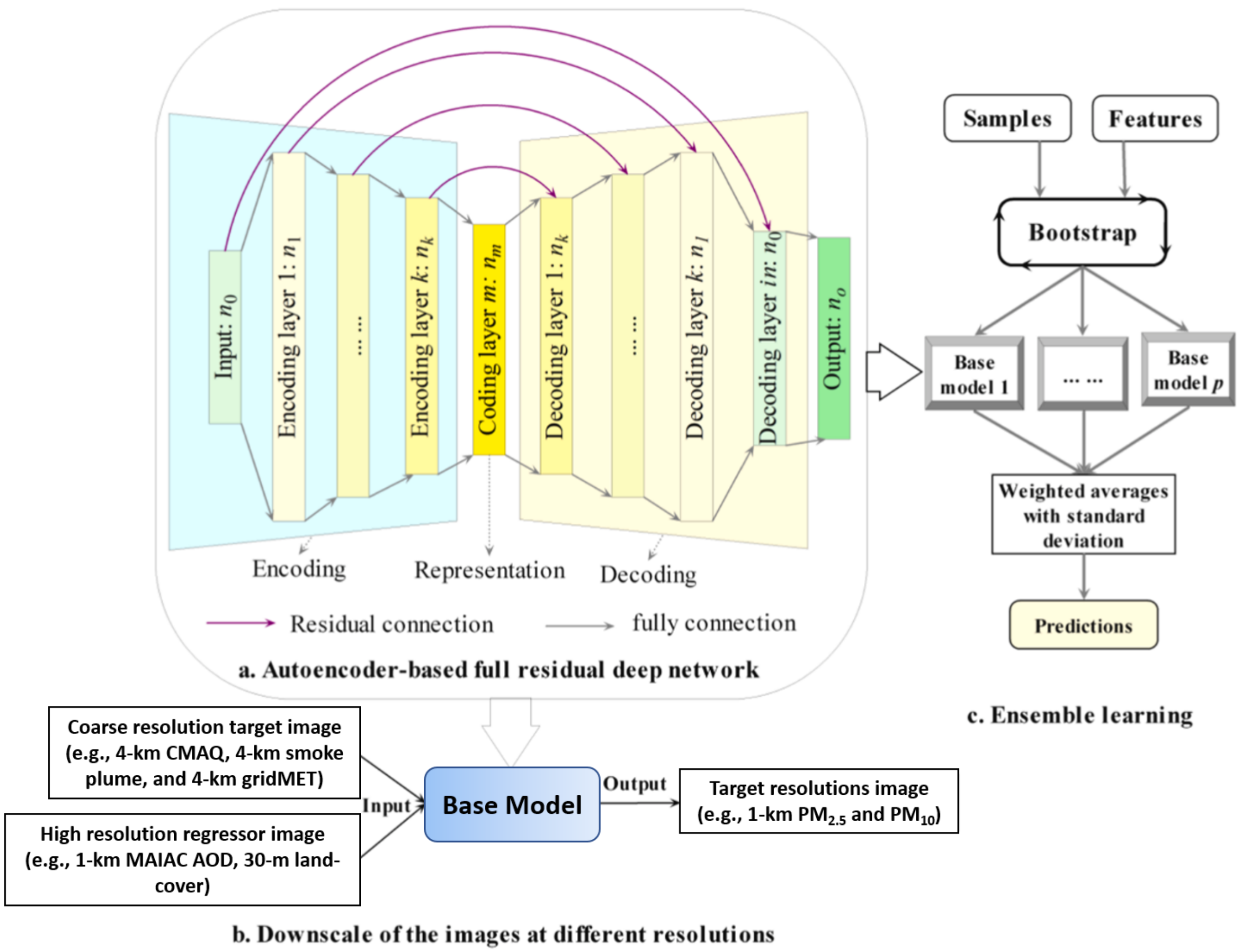


Figure 2. Autoencoder-based full residual deep network modeling

Training data: Measured daily ambient concentrations of $PM_{2.5}$ and PM_{10} will be obtained from the U.S. EPA's AQS for the study region and period. For $PM_{2.5}$, additional data from the low-cost PurpleAir sensors will be obtained and processed. The PurpleAir sensor uses light scattering properties to estimate particle mass. The latest model (PA- II-SD) contains two PMS5003 sensors

(Plantower, Beijing, China) and showed good accuracy for $PM_{2.5}$ mass measurements, compared to U.S. EPA’s reference instrumentation[40,41]. PurpleAir sensors can also capture pollution during special episodes, such as wildfire burning days, although over-prediction of $PM_{2.5}$ concentrations for wildfire-related PM needs to be systematically corrected before use[42–44]. Continued expansion of the PurpleAir network in California has resulted in an increase in the number of operating sensors from roughly 150 in 2017 to 2,100 in July 2020, which allows for high spatiotemporal resolution exposure estimates. In this study, ten-minute $PM_{2.5}$ concentration data in the study period will be retrieved from the PurpleAir network using the ThingSpeak’s Application Programming Interface (https://www2.purpleair.com/community/faq#hc-thingspeak-api). UCI has developed a two-step post-process algorithm with systematic quality control (QC) and calibration with U.S. EPA's reference monitors to minimize potential sensor malfunction, intra-sensor bias, and environmental and operational parameters impact. The quality-controlled data (>two million hourly data points) had a robust agreement with U.S. EPA's monitoring data (R^2: 0.95; slope: 0.98)[45]. UCI will use the same approach to correct/calibrate the PurpleAir sensor data and conduct QC measures before combining these data with CARB and the U.S. EPA's routine monitoring data to form a rich training and validation dataset.

Deep learning modeling: UCI will train and validate the deep learning model (i.e., encoder-decoder full residual deep network)[34,46] using spatiotemporal variables to estimate daily one-km total $PM_{2.5}$ and PM_{10} mass concentrations. A similar model that UCI developed for $PM_{2.5}$ prediction in 2008-2017 in California showed robust model performance (>0.8 correlation and <three μg/m^3 root mean square error)[39]. First, preprocessing of training data and covariates will be conducted including data cleaning, outlier filtering, AOD missing data filling, and conversion of AOD from satellite column measures to surface aerosol extinction coefficient[39]. Correlation analysis will be conducted between measured pollutant concentrations and various covariates. The covariates with a low, non-statistically significant correlation (i.e. absolute correlation coefficient <0.02) with measured concentrations will be removed from the list of potential predictors. Physical interpretability and redundancy (e.g. meteorological parameters generated from gridMET and WRF-CMAQ system) will then be considered to filter out remaining features.

Second, full residual deep network will be developed as the base model (Figure 2b). The model will be trained using multiple sources: four-km resolution $PM_{2.5}$ and PM_{10} concentrations estimated by CMAQ, four-km HMS smoke plume data[47], four-km gridMET meteorological parameters[36],one-km grid MAIAC AOD[33,48] with missing data (due to cloud and high surface reflectance) imputed and filled[34], land-cover, population density, elevation, and roadway density. Further, ensemble learning based on boot-strap sampling will be used so that pollutant concentration estimates can be more reliable, and uncertainty of the exposure estimates can be obtained. In order to reduce the dependence between samples in each bootstrap, the training samples will first be divided into different groups based on the spatiotemporal factor of county identification and month index; random shuffling and bootstrap will then be conducted between different strata, and within each selected stratum[39]. By merging all of the selected samples, the training samples for each bootstrap will be obtained while the rest of the samples will be used as the validation and test samples. The stratified bootstrap sampling reduces spatiotemporal dependence between strata. UCI will generate 100 models as previous work has shown that increasing the number of models beyond 100 only improved model performance very slightly; but, added training time substantially[39]. For each model, two-thirds of the data will be used for training (80 percent of the data) and cross validation (20 percent of the data), while one-third of the data will be used for independent test. Ten-fold cross-validation will be used for the two-thirds of training data.

Third, one x one km^2 surfaces of daily total $PM_{2.5}$ and PM_{10} concentrations from ensemble predictions and their uncertainty (coefficient of variation) during the study period will be generated based on bagging of the 100 trained models. The uncertainty estimates provide a quantitative estimate of variability or confidence in predicted concentrations.

Fourth, by comparing the estimates of total $PM_{2.5}$ obtained from the deep learning model with the CMAQ outputs (Sub-task 2.2), UCI will calculate daily adjusting factors for $PM_{2.5}$ that will be used to calibrate or scale the PAH estimates from the CMAQ simulations, assuming that CMAQ has similar model bias for the PAH estimates as for $PM_{2.5}$. To be more specific, for each one x one km grid cell, assuming the $PM_{2.5}$ concentration after the downscaling by machine learning model is C_1, and the four x four km grid cell which contains this one x one km cell has a $PM_{2.5}$ value of C_0 from CMAQ simulation, then UCI can obtain a correction factor $R_c=C_1/C_0$. Then, this correction factor R_c will be applied for other aerosol species such as PAHs to downscaling them from four x four km grid to one x one km grid. Given that PAHs are primarily directly emitted and the lack of black carbon data, the results should be interpreted with caution. Model outputs of daily concentrations pollutant at one-km resolution will be assigned to individual residences and zip code level estimates will also be aggregated based on population density.

Sub-task 2.5: Quantify wildfire specific pollutant concentrations and smoke wave events

The fire-induced $PM_{2.5}$, PM_{10} and PAH will be calculated by applying the daily fire ratio (R_{fire}) that UCI will get from the four-km CMAQ simulations for each of the pollutants to the total concentration estimated by the machine learning model.

Smoke wave events occurring during the study period will be defined for smoke exposure over certain defined levels for consecutive days. As a starting point, UCI will follow the methods of Liu et al. (2017)[49], which concluded that only smoke wave days with wildfire-specific $PM_{2.5}$ (> 37 μg/m^3) increased risk of respiratory admissions. However, UCI will also examine additional thresholds using $PM_{2.5}$ levels based on the extremes of long-term $PM_{2.5}$ concentrations as UCI did in the previous heatwave study[50] with additional health data for multiple adverse health endpoints. More specifically, smoke waves will be defined as extreme total $PM_{2.5}$ concentrations (e.g. 95th, 98th, and 99th percentiles) and durations (e.g. ≥ two, three, and or more consecutive days); the percentile distributions will be calculated based on measured $PM_{2.5}$ concentrations in the past 20 years across California. This definition will encompass a broad set of classifications that capture periods of smoke exposures of varying intensity and duration. Further, UCI will estimate smoke waves based on the wildfire-specific $PM_{2.5}$ concentrations estimated by the CMAQ-estimated R_{fire} and based on total $PM_{2.5}$ concentration. This has not been examined in the literature; but, similar to the total $PM_{2.5}$ concentrations, UCI will define specific thresholds for fire specific $PM_{2.5}$ to identify smoke waves. UCI will also examine smoke wave events defined by other air pollutants including PM_{10} and PAH using a similar approach.

The final product from this task will be time-series exposure data for 1) daily concentrations of $PM_{2.5}$, PM_{10} and PAH for both total concentration and wildfire-contributed concentration; and 2) indicators of whether a day is a smoke wave day (0/1) based on different thresholds of concentration distribution of total $PM_{2.5}$, fire-specific $PM_{2.5}$, PM_{10} and PAH, respectively. The exposure estimates will be conducted for each zip code and for individual residences depending on the health outcome data UCI will analyze.

Task 3: Obtain and process health and covariate data

UCI will obtain health outcome data from three sources:

1) Zip-code level hospital admission and emergency department visit data from the California State Office of Statewide Health Planning and Development (OSHPD);

2) Individual-level birth certificate data from the California Department of Public Health (CDPH) Vital Records; and

3) Individual-level electronic health record data from University of California (UC) Health.

Sub-task 3.1: Obtain Institutional Review Board (IRB) approval to work with various health data

UCI will submit IRB applications to UCI Office of Research Administration and to the CDPH to use various health outcome data with covariates. UCI will use Research Electronic Data Capture (REDCap) Health Insurance Portability and Accountability Act (HIPAA) compliant databases in which data from all sites and sources can be collated and remain HIPAA compliant. UCI is part of University of California Biomedical, Research, Acceleration, Integration, and Development that facilitates the University of California (UC) system data collaboration. The study will comply with the IRB requirements from UCI and the CDPH to ensure human subject protections and HIPAA compliance. All research team members will complete their Collaborative Institutional Training Initiative Human Subject protections training before the study starts.

Task 3.2: Obtain daily hospital admission and emergency room visit data at the zip code level

OSHPD data: Daily hospital admission and emergency department visit data across the state will be obtained from the California State OSHPD patient discharge data emergency department data at the zip code level[51]. UCI will focus on respiratory outcomes and cardiovascular disease-related hospital and emergency department visits using International Classification of Diseases (ICD) codes (both ICD-9 and ICD-10 codes). Respiratory outcomes include asthma, acute bronchitis and bronchiolitis, chronic obstructive pulmonary disease (COPD), pneumonia, upper respiratory infections, and interstitial lung disease. Flu diagnosis will also be explored. Cardiovascular diseases include ischemic heart disease, dysrhythmia, heart failure, pulmonary embolism, and stroke. Other variables from OSHPD include age, sex, race, ethnicity, five-digit zip code, and admission date. All data will be aggregated at the daily level by zip code and converted into both daily number of admissions and rates of admission by dividing the admission counts by the population.

Sub-task 3.3: Obtain individual-level birth and death certificate data with residential address from the CDPH Vital Records

Birth certificate data: UCI has previously used birth certificate data for air pollution and pregnancy outcome studies from 2001 to 2008 in a study funded by the Health Effect Institute (#4787-RFA09-4/10-3), and birth and death certificate data (for identification of still birth) from 2008 to 2018 in a study funded by the National Institute of Health (R01ES030353). Individual-level birth and death certificate data will be obtained from the CDPH Vital Records for years 2017, 2018, and 2020 in the study. Preterm birth (PTB) will be the main outcome variable that UCI will consider because the focus is this study is the short-term effect of wildfire smoke. A latest review paper[56] showed that only four epidemiological studies have examined wildfire smoke on duration of gestation including two studies from U.S. and two from Australia. The only U.S. study that estimated air-pollution (in comparison to distance to wildfire-affected areas) and adjusted for potential confounders, such as maternal factors[57] showed that PTB was positively associated with exposure to wildfire smoke $PM_{2.5}$ over the full gestation (odds ratio: 1.076 per 1 µg/m3; 95% confidence interval: 1.016-1.139; p: 0.013) and during the second trimester (odds ratio: 1.132 per 1 µg/m3; 95 percent confidence interval: 1.088- 1.178; $p < 0.0001$), respectively. In this study, gestational age, residential address, and potential confounding factors (e.g. maternal age, education, parity, and pregnancy complications) will be extracted for subsequent data analysis.

Sub-task 3.4: Obtain individual-level electronic health record (EHR) data from UC Health

UC Health data: By combining the data resources and informatics expertise at the Universities of California Davis (UCD), San Francisco, Los Angeles, Irvine, and San Diego, UC Health is uniquely positioned to provide high-quality clinical data of diverse patient populations across the State of California. UC Health is a $13 billion enterprise providing comprehensive care to over six million Californians[52]. UC Health is proud of caring for underserved communities in the state: despite representing less than six percent of the acute care hospital beds in California, more than 35 percent of UC Health's inpatient days are associated with Medi-Cal. At UCD Health and UCI Health, 41 percent and 45 percent respectively, of total inpatient days are for Medi-Cal patients. The race distribution of UC Health patients is approximately 50 percent White, ten percent Asian Americans and Pacific Islanders, five percent Black, nine percent other, and 26 percent unknown (mostly Latinos based on clinical observations at UCI Health). Hispanic or Latino account for approximately 34 percent of the patient population. In total, about 14 percent, 20 percent, 19 percent, 20 percent, and 26 percent of the patients are <17, 18-35, 36-50, 51-64, and ≥65 years of age, respectively. Fifty-five percent of patients are females.

All five UC Health campuses have agreed to participate in this study and cover a wide catchment area from northern to southern California spanning 26 counties, including Alameda, Colusa, Contra Costa, El Dorado, Kern, Los Angeles, Marin, Napa, Orange, Placer, Riverside, Sacramento, San Bernardino, San Diego, San Francisco, San Joaquin, San Luis Obispo, San Mateo, Santa Barbara, Santa Clara, Solano, Sonoma, Sutter, Ventura, Yolo, and Yuba. A unique medical record number is available for each patient within each UC health system along with the patient's current residential address. Diagnoses, lab test results, medication prescriptions, and procedures for individual patients are available from the standardized UC Health Data Warehouse, from which respiratory, cardiovascular, and depression outcomes will be retrieved. Table 2 shows summary statistics of UC Health data. Medication prescriptions will be used together with diagnoses to identify adverse outcomes, such as control and rescue medication for asthma and antidepressant prescription for depression.

Table 2. Number of unique UC Health patients with specific diseases* by year

OUTCOMES	2017	2018	2020
OVERALL RESPIRATORY OUTCOMES	334,278	339,143	129,608
ASTHMA	78,949	80,730	35,447
CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD)	39,540	39,687	16,354
INFLUENZA, PNEUMONIA, AND ACUTE BRONCHITIS	40,456	41,092	10,119
OVERALL CIRCULATORY / CARDIOVASCULAR SYSTEM OUTCOMES	398,740	412,648	203,273
DEPRESSION	94,790	97,681	42,983
PATIENT ON ANTIDEPRESSANT PRESCRIPTION**	327,512	372,236	188,082

* All the numbers are based on ICD10 codes and the cross-reference table with ICD9 codes. Overall Respiratory outcomes: ICD10 codes J00-J99; Asthma: ICD10 codes J45 and J46; COPD: ICD-10 codes J40-J44 and J47; Influenza, Pneumonia, and Acute Bronchitis: ICD-10 codes J09-J18 and J20; Overall circulatory / cardiovascular system outcomes: ICD10 codes I00-I99; depression: ICD-10 code F32, F33, F34.1, and F41.2. ** Antidepressant medications include Selective serotonin reuptake inhibitors (citalopram: 797617; escitalopram: 715939; fluvoxamine: 751412; paroxetine: 722031; fluoxetine: 755695; sertraline: 739138; olanzapine: 785788; aripiprazole: 757688; quetiapine: 766814; brexpiprazole: 46275300; vilazodone: 40234834; vortioxetine: 44507700), SNRIs (duloxetine: 715259; venlafaxine: 743670; desvenlafaxine: 717607; levomilnacipran: 43560354), and Norepinephrine-dopamine reuptake inhibitors (bupropion: 7509820).

Sub-task 3.5: Geocoding and exposure assessment of the addresses

For zip-code level data, the coordinates of zip-code centroid will be used to represent the entire zip-code. The residential addresses from UC Health EHR and birth certificate data will be geocoded to latitude and longitude coordinates using ArcGIS Pro (version 2.2.0) Online World Geocoding Service. Exposure of each zip code centroid and residential location to wildfire smoke will be estimated based on the procedures, as described in Task 2.

Task 4: Conduct an epidemiological analysis on the health effects of short-term exposure to wildfire air pollution

UCI envision different types of statistical analyses exploiting the different spatial resolution at which health data is available and the different aspects of air pollution and wildfire exposure. $PM_{2.5}$ is used as an example for all of the data analysis; but, the associations of PM_{10} and particle-bound PAHs with various outcomes will also be explored in the analysis.

Sub-task 4.1: Analyze zip-code level OSHPD data

The zip-code level data have a high temporal resolution (daily); but, moderate spatial resolution. A time-series analytic approach will be used to analyze zip-code level health data. This approach allows to infer upon the health effects of wildfire air pollution through the comparison of the daily number of hospital admissions over time. Besides the equivalence between case-crossover and time series in environmental epidemiology, the time series approach has been used in multiple studies that have investigated the effect of air pollution exposure and, more recently, heat-wave on human health, specifically mortality and morbidity[53]. Following the set-up of these studies, for each zip code, UCI will model the daily number of hospital and emergency room admissions due to respiratory and cardiovascular diseases, respectively, using an over dispersed Poisson log-linear model that allows the accounting for extra variability.

The model will link the number of hospital admissions on day *t* in zip code *j* to: (i) a smooth function that takes into account the size of the population in the zip code, as well as other factors that influence the population as a whole at time *t*, with the function typically represented using a cubic spline function of time to capture seasonal trends; (ii) a smooth function of temperature and dew point modeled using natural splines with a moderate number of degrees of freedom; (iii) additional, appropriate confounders, such as day of the week and/or day of the year; and (iv) air pollution (e.g. $PM_{2.5}$) exposure. The effect of $PM_{2.5}$ exposure can in turn be decomposed into the sum of: (a) the effect of $PM_{2.5}$ concentration on day *t* and in the previous *l* days (e.g. lagged effect of $PM_{2.5}$ exposure), and (b) the effect of being in a smoke-wave. The latter can be represented in the model in different ways: a variable indicator of whether day *t* is in a smoke-wave (thus, introducing a dichotomous variable), or a step function, alternatively, a smooth function, of the length of the smoke-wave at day *t* (e.g., is day *t* the 1st, 2nd, etc. day of the smoke-wave). If day *t* is not a smoke-wave day or it is the first day in the smoke wave, the length of the smoke wave at day *t* is set equal to zero. This model allows the derivation of the relative risk of hospitalization due to $PM_{2.5}$ exposure for the given zip code and also allows the estimation of the change in the relative risk of hospitalization due to smoke waves. The model will be of the following type: let N_{jt} be the number of hospital admission on day t in zip code j. Then the model will be:

(A) log(N_{jt})= m_{jt} + s_{jt} + l_{jt} + r_{jt} where m_{j} is the smooth function described in (i), s_{jt} is the smooth function described in (ii), I_{jt} is the part of the model described in (iii), and r_{jt} is the part of the model described in (iv) and is the component of the log-risk of hospitalization in zip code j on day t that is due to air pollution exposure. The model will include two smooth functions to account for seasonal trends (s_{jt}) and for the effect of meteorological factors (m_{jt}). From fitting the model to the hospitalization data for each zip code separately we can estimate all the different parts of the left hand side in (A) and thus estimate what is r_{jt} or better $\exp(r_{jt})$, the risk of hospitalization in zip code j on day t due to air pollution exposure. The coefficients of the term relative to smoke-wave will tell us how smoke waves affect the risk of hospitalization in zip code j on day t.

UCI will fit the models described above to each zip code separately, thus estimating a zip code specific relative risk of hospitalization. This will allow the comparison of the relative risk for different subpopulations within California. The estimates of the parameters obtained for each zip code can be pooled together by revisiting the proposed Poisson log-linear model and reframing it to be a multi-level, Bayesian hierarchical model in which the regression coefficients vary by zip code. For each zip code, and each regressor, UCI will model the regression coefficients to be drawn from a common distribution with a mean that represents the population-level (e.g. the California-level) effect of the regressors on the risk of hospitalization and/or emergency room admissions. Through this parametrization, the estimated zip-code specific regression coefficients allow to quantify how different the effect of the regressors on the relative risk of hospitalization and/or emergency room admission are for a given zip-code compared to their overall effect for the entire population.

The analyses based on model (A) above will be performed also for different strata of the population. Additionally, the same modeling approach and framework will be used to analyze the all-cause, as well as the respiratory and cardiovascular disease mortality zip-code level data except that the N_{jt} now here refers to the number of people dead of respiratory and cardiovascular disease in zip code j on day t.

Liu et al. (2017)[49] examined the short-term effect of wildfire $PM_{2.5}$ on respiratory and cardio-vascular disease-related hospitalization and emergency room visits in U.S. counties using a matched analysis. The use of a matched case-crossover approach was justified by the fact that the exposure in their case was just the wildfire $PM_{2.5}$, which, absent a wildfire event, is mostly null for the majority of the days in a year. In this study, a similar matched approach will be used as a sensitivity analysis to analyze the zip-code level health OSHPD data. Hospitalization rate in a zip-code on smoke-wave days will be compared to hospitalization rates in the same zip code on non-smoke wave days. The non-smoke wave (control) days will be chosen (1) within the window of seven calendar days before or seven days after the smoke-wave day; but, primarily in a different year and (2) they are chosen so that they are separated from any other smoke-wave day by at least two days. This choice of non-smoke wave days can account for larger seasonal trends such as the greater propensity for wildfires to occur during the hotter and drier months. Having defined the case and controls, the zip-code respiratory – respectively, cardiovascular – disease- related hospitalization and emergency room visits data will be analyzed using a Poisson log-linear mixed model with adjustments for seasonal factors such as year, daily temperature, daily dew point, and non-fire $PM_{2.5}$ exposure.

Due to the intense wildfire activities in recent years, it may be challenging to find a good number of control days in the study period for the zip codes that frequently experience wildfires. Thus, the focus of the analysis will be put on the time-series approach, although a comparison will be conducted for the results using the matched analysis.

Sub-task 4.2: Analyze individual-level birth certificate data on PTB

To assess the effect of wildfire $PM_{2.5}$ on PTB, UCI will use the geocoded birth record data for years 2017, 2018, and 2020. Each birth record in the dataset will be attached a binary label to indicate whether the birth was preterm (i.e. delivery with gestational age <37 weeks) or not. The binary outcome of PTB will be analyzed using a multiple logistic regression where the exposure to wildfire $PM_{2.5}$ will enter the model in different forms: (i) as the average wildfire $PM_{2.5}$ experienced by the mother throughout her pregnancy; (ii) the average wildfire $PM_{2.5}$ experienced by the mother during different pregnancy periods (first trimester, second trimester, and third trimester); (iii) the total number of smoke-wave days during the mother's pregnancy; (iv) the total number of smoke-wave days during the different trimester of the mother's pregnancy; (v) the maximum length of a smoke-wave that occurred during the course of a mother's pregnancy. The same metrics of air pollution exposure for non-wildfire $PM_{2.5}$ will also be considered and included in the model. For both wildfire and non-wildfire $PM_{2.5}$, exposure for each mother is assigned based on the concentration of wildfire and non-wildfire $PM_{2.5}$ in the one-km grid-cell where the mother's residential address lies.

Considering different forms of exposure metrics in the multiple logistic regression model allows the determination of which aspect of exposure to wildfire $PM_{2.5}$ is associated with the risk of PTB, and in which period of the pregnancy a woman is more vulnerable to the deleterious effects of wildfire $PM_{2.5}$. Each multiple logistic regression analysis will adjust for various maternal confounders, based on prior, established evidence. These confounders include maternal age, parity, race and ethnicity, maternal SES, and season of conception. Analyses will be conducted using data on all women for which UCI has geocoded birth records, and stratified by race, ethnicity, and SES. The sensitivity analyses will evaluate how results change based on whether the exposure is introduced as a continuous variable vs. as a categorical variable with exposure classified based on quartiles.

Sub-task 4.3: Analyze individual-level UC Health EHR data

Respiratory outcomes are used to describe the statistical analysis method below; but the same approach will be used to assess the effect of wildfire exposure on cardiovascular and depression outcomes. A time-stratified case-crossover design will be used to model the respiratory outcomes, with the day of a subject's medical encounter being treated as the day of the event. This design is appropriate as the main interest is to assess the short-term effect of an exposure with the risk of an acute event which has a low probability of occurring for each individual.

UCI will implement the case-crossover design within a conditional logistic regression framework, in two fashions, depending on how the exposure is introduced. In the first implementation, using exposure to $PM_{2.5}$ as a continuous exposure, for each subject who experience an "event", that is, for each subject that has a medical visit due to a respiratory outcome – respectively, due to a cardiovascular or a depression outcome – the $PM_{2.5}$ exposure will be compared on the day of the event vs. a control day. The control day is selected to be a day of same type (e.g. weekend vs weekday) and within a four-week period from the day of the event. The $PM_{2.5}$ exposure here is the daily concentration of $PM_{2.5}$ at the one-km grid cell of the subject residential address on the day of the event and on the control day, with $PM_{2.5}$ exposure being subdivided into wildfire and non-wildfire $PM_{2.5}$. As confounding by individual-level characteristics and characteristics that vary over durations longer than a month are automatically controlled for in this matched design, the model will not adjust for any of these confounders, and will only examine the association between a respiratory outcome and the $PM_{2.5}$ exposure the day of the event – respectively, the matched control day, as well as the lagged $PM_{2.5}$ exposure up to three days since the day of the subject's medical visit, respectively, up to three days since the matched control day. As dew point and temperature might be different between the day of the event and the matched day, the model will adjust for these two meteorological confounders. The analyses for this conditional logistic regression model will be performed stratified by age, race/ethnicity, and SES.

In a second implementation of the case-cross over design, exposure will enter the model as a binary variable. Specifically, days will be categorized as smoke-wave days or not, based on one of the different definitions of smoke-wave identified in Sub-task 2.5. Using the smoke-wave classification, the case-crossover conditional logistic regression analysis will be limited only to the discordant case-control sets, or instances where the cases had a different type of daily $PM_{2.5}$ exposure (smoke-wave or non-smoke wave) than the corresponding controls, since only the discordant cases

contribute information in a matched design with a binary exposure. Again, the model will not adjust for any individual-level characteristics nor will it adjust for confounders that are not-time varying or that do vary over duration of times longer than one month, as those are already accounted for via the matching. However, the model will include a covariate that provides information on the length of the smoke-wave up to three-days before the event and before the matched day. Again, analyses will be performed stratified by age, race/ethnicity, and SES.

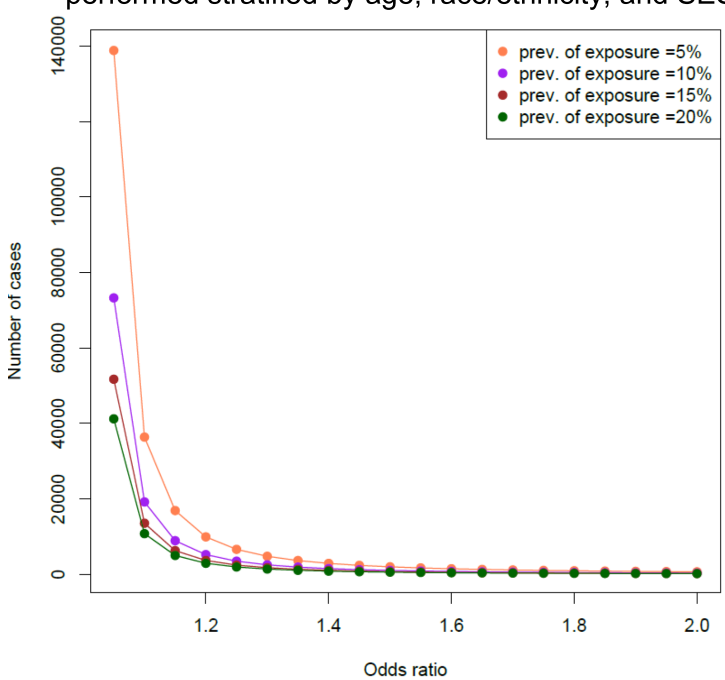


Figure 3. Sample Size for an 80% Power

<u>Power analysis:</u> The large number of visits due to the outcomes of interest in the analysis, displayed in Table 2, guarantees that there will be enough events in the UC Health data to identify and estimate the effect, if significant, of $PM_{2.5}$ and wildfire $PM_{2.5}$ on respiratory, cardiovascular and depression outcomes. To assess whether there will be enough cases to identify a significant effect of smoke-wave on respiratory outcomes for the strata in the population that is less represented in the UC Health data (e.g., Black population), UCI has carried out a power analysis (Figure 3). Specifically, UCI has performed calculations of the sample size needed to detect an odds ratio for hospitalization and emergency room admissions for respiratory outcomes ranging from 1.1 to 2.0 due to a smoke-wave versus a non-smoke wave with a power of 80 percent at 0.05 significance level. The sample size has been obtained under the assumption of the model, that is a matched case-crossover conditional logistic regression with each case relative to the day of the medical visit matched to one control day.

To consider different scenarios, UCI has also varied the prevalence of the exposure from five percent to 20 percent. Given the number of cases per year reported in Table 2 for overall respiratory outcomes, UCI sees that even for small odds ratio, there is a sample size large enough to detect the effect of a smoke-wave in the entire population. For specific demographic groups (e.g. five percent Black population), UCI would be able to detect the effect of a smoke-wave with a power of 80 percent if the odds ratio is greater than 1.2.

Task 5: Address specific concerns for DAC through inclusive and informative outreach with designated community members

Sub-task 5.1: Obtain IRB for community engagement focus group and survey

The PI will submit IRB applications to UCI to conduct community focus group and survey studies. For virtual focus group discussions, consent will be reviewed with participants during phone screening conversations explaining the purpose of the listening sessions and that virtual discussions will be audio-recorded for accuracy purposes. Personal identifiers will be removed and replaced with pseudonyms in transcript data. Surveys will be anonymous to satisfy exempt status.

Sub-task 5.2: Develop focus group discussion guides and survey instruments

CARB established the Community Air Protection Program to implement AB 617 and recognize communities disproportionately burdened by wildfire and smoke risk in California. Critical efforts to mitigate the exacerbation of communities of color, Hispanic, and tribal communities being adversely impacted by wildfires involves their engagement early in planning phases to mitigate risk. Both public health researchers Drs. Wu and Hopfer are working closely with communities impacted by repeated wildfire and smoke risk across California including AB 617 communities of the Eastern Coachella Valley (ECV) – Communities for a New California Education Fund (CNC EF) in southern California and SB 535 and AB1550 communities impacted throughout the San Joaquin Valley (SJV) in central California through the Central California Asthma Collaborative (CCAC), including South Modesto (Stanislaus County), La Vine (Madera County), and Lindsay (Tulare County).

For the SJV communities, UCI will work closely with CCAC's co-directors and co-founders Kevin Hamilton and Tim Tyner. CCAC meets monthly with a community steering committee (CSC) on air quality issues impacting communities. A health equity framework and the wildfire community vulnerability framework will guide the focus of questions developed for surveying community members and for designing questions listening sessions for the focus group discussion guide (Figure 4). CCAC will conduct six in person and/or virtual CSC meetings with each of three SJV communities for a total of 18 focus groups/meetings. The three Senate Bill (SB) 535 and AB 1550 SJV communities include South Modesto (Stanislaus County), La Vine (Madera County), and Lindsay (Tulare County). Thus, a total of 18 CSC meeting will be convened across the ~~three~~ **four** years. Surveys for participants will be co-developed between CCAC and UCI. The surveys will be developed to be culturally and linguistically appropriate in Spanish and Hmong and will be guided both by the prior experiences of CCAC working with communities, and by an environmental justice and wildfire community vulnerability framework. Surveys and CSC community discussions will be guided by eliciting the experiences and in particular, the health impacts of air quality, and repeated exposure to wildfire and smoke risk. Discussion questions will elicit from CSC members experienced with wildfire and smoke exposure, in many cases repeatedly, and will explore with impacted communities about how they have been impacted, including their health; but, also explore structural determinants of health impacts for example, including questions/probes about housing, languages spoken/literacy, occupational policies to assess family/household vulnerability, and adaptive capacity to wildfire risk. The CCAC will administer surveys and logistics of organizing and implementing virtual or in-person focus groups. UCI will regularly communicate with CCAC on survey development and qualitative content analyses of focus group discussions, as described in Phase I below, as well as planning for sharing and disseminating any findings with communities and community members mid-way through the project from air pollution exposure modeling being done. To this end, a CSC-based community outreach plan related to project findings will be shared.

In Southern California, UCI will work with CNC EF from the ECV region serving low-income, underserved, immigrant communities of color, Native American tribes, and indigenous communities. Approximately 91 percent of adults and 94 percent of children living in the ECV, identify as Hispanic/Latino in this region. CNC EF serving ECV includes the unincorporated communities of Thermal, Oasis, Mecca, and North Shore. These communities include tribal lands of the Torres Martinez Desert Cahuilla Indians. It is a predominantly agricultural area, which has been increasingly experiencing poor air quality from agricultural burning, illegal dumping/burning, electrical fires from unstable housing structures, shrinking of the Salton Sea, and increasing number of extreme heat days. CNC EF is an active member of the AB 617 ECV Community Steering Committee. These activities will include: 1) Conducting door-to-door outreach and hosting community engagement events including focus group discussions; 2) Assisting in developing and administering a survey to help better understand wildfire and "smoke wave" incidences, exposure, health concerns, and any other community input related to smoke impact; and 3) conducting a second round of community engagement activities to promote an in-person workshop to disseminate UCI findings from epidemiological modeling of smoke exposure and address smoke related aspects.

UCI's community interactions will occur in three phases. Phase 1, at the beginning of the ~~three~~**four**-year project, will involve listening sessions to enlist the voices and concerns of these communities. Phase 1 will involve a). enlisting views, questions, feedback from the communities about how they have been impacted by wildfires and smoke risk, b.) what community member concerns are, c). how wildfire(s) have impacted their community with questions possibly being integrated into planned data analyses and exposure modeling, and d.) what policies/actions would best help communities mitigate wildfire risk, to have policy relevance about risk mitigation strategies (e.g., obtaining air purifiers, being able to stay inside, and adaptation strategies for communities given their existing situation). Phase 2 activities will involve civic engagement and dissemination of preliminary findings with communities mid-way through, if possible and Phase 3, includes dissemination of findings with all communities at ~~the end of the three-year~~ **Year 3 or Year 4 of the** study (see details in Sub-task 5.3). CNC EF and CCAC will work the communities to conduct virtual focus groups i.e., listening sessions. CNC EF will work with four communities of ECV and CCAC will work with three communities in the SJV).

CNC EF will conduct outreach in teams of two on weekends with a total of five teams. Canvassers will go to specific neighborhoods, chosen in advance by UCI and CNC EF, in joint collaboration, that will provide diverse perspectives to truly represent the residents. All canvassers will be bilingual in English and Spanish. Each of the four communities will have a dedicated team of canvassers who will canvass the specified neighborhoods each weekend for a month. Feedback from the residents will be collected by the CNC EF canvassers via electronic tablets. CNC EF will be able to analyze the data quickly and easily, and segment it, if desired by the community. The data will assist CNC EF staff to organize three focus group discussions for each of the four identified communities in the ECV (a total of 12 focus groups). The Lead Community Organizer will schedule and facilitate twelve focus group discussions. Each focus group will be two hours in duration. An agenda along with a survey will be developed in joint collaboration with UCI and guided by the community vulnerability framework (Figure 4). Reminder calls and text messages will be sent to all confirmed participants a few days prior to the focus group. Focus group attendees will be compensated with a stipend in the amount of $50 for their time and participation.

For CCAC, Kevin Hamilton who has been working with SJV communities for many years, and who participates in monthly CSC meetings, will engage the South Modesto, La Vina, and Lindsay communities via the CSC to conduct six virtual and or in-person community focus groups and distribute surveys ~~across the three years~~. Surveys will be developed together with UCI public health Hopfer and will be translated into Spanish and Hmong by CCAC for administration to community members. These are SB 535 and AB 1550 DAC. UCI will work diligently to generate informative modeling data by mid-way of the project to share any relevant data with communities as results emerge. An effort will be made to share relevant findings sooner than the end of the **four**~~three-~~year project if possible.

To ensure productive workshops, prior organization, advertisement, and networks will be activated. Additionally, the SHOWeD method[54], will be used, asking workshop participants to take pictures of areas in their towns where wildfires have already occurred, or locations at high risk for future wildfire and smoke risk, to generate questions on behalf of communities to present and interact with UCI. These community-based workshops will be guided by a health equity perspective to listen to communities and elicit their questions and concerns, including those for wildfire and smoke risk to inform the scientific process of inquiry. Workshop participants will be asked to complete ~~an~~ ~~**electronic**~~ survey **in either the electronic or paper format. Paper surveys will be used as back up given the lack of WIFI in most of the public spaces in this disadvantaged community and that some community members are not comfortable using tablet or phone to put their answers.** Survey questions will be informed by the wildfire community vulnerability framework[55] (Figure 4) e.g., how to handle animals and pets during wildfire risk (horses, cattle, and pets) and how this may drive evacuation behaviors – eliciting questions and concerns regarding acute response and chronic repeat exposures, having questions about language/literacy, housing, transportation impacts response to wildfire risk, managing acute and chronic repeated risk over time, as well as health domains covering cardiovascular, respiratory, and mental health aspects. Qualitative and quantitative information from these workshops and surveys will be summarized to inform future community-based wildfire mitigation and action plans.

UCI plan to recruit at least 100 participants for both the surveys and the focus group. These data will be translated from Spanish to English, quality-checked, and then analyzed in SAS for the questionnaire data and in NVivo for the focus group data.

Figure 4. Unequal Wildfire Vulnerability[55]

Sub-task 5.3:
Disseminate findings from UCI to the SJV and ECV communities

Phase 2 will occur mid-way of the ~~three~~**four**-year project depending on when findings become available and will involve disseminating UCI findings with communities organized through CCAC and CNC EF who are connected with communities. The CCAC and CNC EF have an excellent track record of community engagement and reaching difficult to sample populations and are trusted members of the communities they serve. For Phase 3, workshops will be organized with CNC EF with AB 617 Communities in the ECV (four communities), and CCAC with three SB 535 and AB 1550 communities in the SJV to share study findings. This phase ~~at the end of the three years~~ will involve communities in civic engagement to learn about the wildfire risk and air quality relevant in their communities. Findings may be disseminated using a variety of approaches and platforms to share UCI findings from epidemiological modeling of smoke exposure, and smoke related aspects. Working jointly with communities with a civic engagement focus findings will be disseminated in creative and efficient ways through social media, and possibly art, depending on the community. Dissemination platforms will be decided by the relevant communities and will provide an opportunity for meaningful dialogue with community residents that will develop evidence to a) inform policy, b) generate evidence of health exposures in localized contexts, the possible need for more funding for local communities to mitigate health risks, and c) develop strategies to prevent or minimize exposure.

Each workshop will be widely publicized in both English, Spanish, and Hmong depending on the community. A link to RSVP for the workshop will be made available to ensure participation and reminders will be sent to participants prior to each workshop. To increase participation, the workshop will be held in easily accessible places (e.g., high schools, libraries, and churches), and will include translation services (English, Spanish, and Hmong). Stipends will be provided to participants as acknowledgement of their time/participation in the workshops. Understanding that not all interested community members may be able to participate in the workshops, CNC EF and CCAC will create a link to UCI's reporting research website where findings can be reviewed by families and community members at their own leisure. This will contribute to the further dissemination of the findings and to continue generating interest. The link will be housed on CCAC's http://cencalasthma.org and on CNC EF's www.cncedfund.org websites. CNC EF and CCAC will also create social media posts and blogs to inform the public about the overall findings through the use of relevant data, infographics, digital strategies to prevent or minimize exposure, and any updates pertaining to the overall project goals.

Task 6: Deliver a detailed and comprehensive final research report and data to CARB

UCI will meet with CARB staff quarterly and will submit quarterly progress reports, using the CARB designated template, and an invoice for the same period will accompany each progress report.

Six months prior to the end of the study, UCI will submit a draft final report (dfr) which will include the results of the study and incorporate the equity components in the deliverables, and a detailed assessment of how the results demonstrate a commitment to improving environmental quality within DAC and other populations with adverse risk to wildfire health effects. The dfr shall be submitted in accordance with the Final Report Format and reviewed by CARB staff. CARB's comments will be sent to UCI and after receiving the reviewer's comments, UCI shall modify and resubmit the modified dfr to the CARB contract manager. The modified dfr will be subject to formal review by the Research Screening Committee (RSC). Once accepted by the RSC, UCI will revise the modified draft final report addressing the RSC comments and any remaining concerns from CARB staff and will submit the revised final report to CARB. If CARB has additional comments on the report, the UCI will be notified so appropriate changes can be made; otherwise, CARB will accept the revised final report as the final. The UCI will submit the final report in an Americans with Disabilities compliant format.

UCI will work with CARB to provide raw data, modeled data, and all the data analyses results generated through the course of the project in an electronic format. These data are listed in Exhibit A1 and will include:

- Literature review results (Task 1),
- Time-series exposure data at one-km resolution for 1) daily concentrations of $PM_{2.5}$, PM_{10}, and PAH for both total concentration and wildfire-contributed concentration; and 2) indicators of whether a day is a smoke wave day (0/1) based on different thresholds of concentration distribution of total $PM_{2.5}$, fire-specific $PM_{2.5}$, PM_{10}, and PAH (Task 2),
- Summary of health outcome and covariate data (Task 3). To protect the confidentiality of study subjects, UCI will only deliver summary statistics at relatively large spatial units (e.g., catchment area, county, sub-region),
- Results of epidemiological analysis (Task 4), and
- Findings from the community-engagement activities (e.g., community feedbacks, surveys, and workshops) (Task 5). Any participant identifier information will be removed from the report.

In addition, UCI will provide a summary of the project in lay-friendly language, including an overview of the research for Phase 1 activities, and a project summary, results, and interpretation of the findings for Phase 2 and 3 activities for submission to CARB and distribution to the community.

UCI will present study findings at a CARB research seminar and write peer-reviewed journal publications.

Data Management Plan

UCI has many years of experience managing large complex datasets and quality assurance (QA) and QC of data. Data QC measures will be conducted regularly for each type of data, including data related to environmental exposures (e.g., measured air pollutant concentrations, meteorological data, remote sensing data, outputs of CMAQ model, and final products of wildfire-related exposure estimates), health outcome and covariate data (e.g., gestational age from birth certificate, hospitalization and emergency room visit, diagnosis, and medication from the UC Health EHR data), and questionnaire survey data. The PI and key research personnel will develop procedures to QA/QC different types of data and maintain and update documentation for datasets and data dictionaries, as well as procedures for data quality checking, data cleaning, and data inclusion/exclusion criteria. Descriptive analyses, such as shape of distribution, extreme values, spatial trends, and correlations will be used to examine the quality of data.

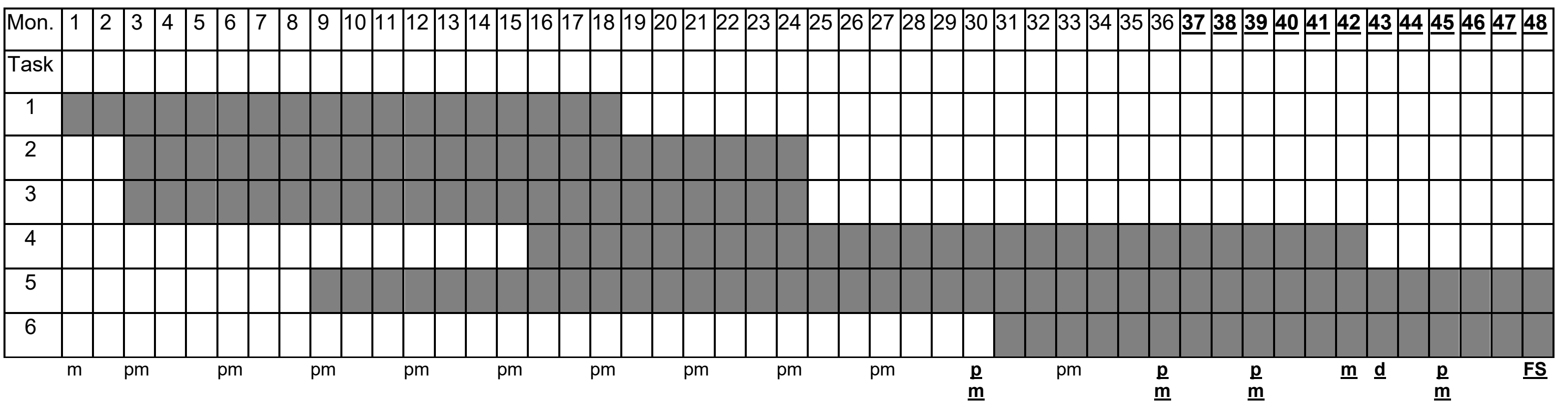
Before any data collection, the PI will obtain institutional IRB approval at UCI. Data Safety Monitoring will be conducted under the direction of an existing Data Safety and Monitoring Plan carried out by the UCI Clinical and Translational Science. The PI will review any issues related to study procedures, adverse events, and data analysis regularly. If any adverse event is discovered, all mandatory-reporting guidelines will be followed. Adverse events will be reported to the UCI IRB within 24 hours of occurrence.

Database security will meet HIPAA requirements. All the confidential electronic data records will be uploaded into the REDCap electronic data repository system. The REDCap is a secure web application for building and managing online databases and UCI is already a member of the REDCap consortium. REDCap allows for password protection, systematic deidentification of participant information from data for analyses, and for shared access to members on the study's approved IRB. REDCap also assists in creation of customized questionnaires and databases for this study. Only the PI and essential research key personnel (e.g., Co-I who collect questionnaire data or conduct health outcome analysis) will be authorized access to any datasets with confidential information (e.g. residential address and patient information). Once geocoding of addresses is completed, a unique identifier will be created for each record and the residential addresses will be removed from subsequent datasets. Further, once air pollution exposures are assigned to each residential location, the latitude and longitude coordinates will be removed from future analysis.

Project Schedule

The project duration is project duration is ~~three~~ **<u>four</u>** years. Tasks will be completed sequentially, and some will be performed simultaneously to ensure that the project goals and tasks' products are met in a timely manner.
The project timeline is below.

Task 1: Conduct a literature review on the health impacts of short-term exposure to wildfire air pollution.
Task 2: Model statewide wildfire air pollution at a high spatiotemporal resolution across multiple years to determine time-series exposure data for smoke wave events.
Task 3: Obtain and process health and covariate data.
Task 4: Conduct an epidemiological analysis on the health effects of short-term exposure to wildfire air pollution.
Task 5: Address specific concerns for DAC through inclusive and informative outreach with designated community members.
Task 6: Deliver a detailed and comprehensive final research report and data to CARB.



p = Quarterly progress report
d = Deliver draft final report (to be submitted 6 months prior to contract expiration)
F = Deliver final report
S = Research seminar in Sacramento
m = Meeting with CARB staff

Meetings:

A. <u>Initial meeting.</u> 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. <u>Progress review meetings.</u> 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. Substantial progress will be presented at informative meetings to the public.

C. <u>Technical Seminar.</u> 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 El Monte.

Project Management Plan

Project Leadership:

The project will be led by PI Professor Jun Wu of UCI Public Health. As PI, Professor Wu will manage the project and interactions between the UCI team and the CARB. The PI has overall responsibility for project management, including timing and meeting milestones, appropriating resources and their distribution, outreach, and coordination with the complementary UCI research programs. Dr. Jun Wu is Professor and Director of the Environmental Health Sciences Graduate Program at the Department of Environmental and Occupational Health, Program in Public Health, University of California, Irvine. Dr. Wu's research aims to provide a strong scientific basis to protect public health from exposure to air pollution and built environmental factors through exposure assessment and environmental epidemiological studies. For environmental exposure assessment, Dr. Wu focuses on developing advanced exposure assessment methods using geographical information system (GIS) techniques, spatial modeling, air quality modeling, and sophisticated statistical methods. Dr. Wu has conducted more than ten projects as PI, subcontract PI or Co-investigator and have published 40 papers related to environmental exposure assessment. Previous research has included characterization ambient and personal exposure to environment agents including air pollutants, meteorology, soil lead, and built environment using measurement data, GIS, and rich spatial data; development of advanced statistical methods for spatiotemporal modeling of air pollutant mixtures; and characterization of time-activity patterns using questionnaire and Global Positioning System tracking. For environmental epidemiology, Dr. Wu focuses on the impact of air pollution (gases and particles; mass, source, composition) and the built environment on reproductive outcomes, children's health, and cancer outcomes. Dr. Wu as published more than 45 papers in environmental epidemiology. In addition, Dr. Wu's recent work has expanded to environmental injustice related to disparities in environmental exposure and related adverse health outcomes, as well as using community participatory research methods to work with DAC to improve their environmental health. Dr. Wu was the recipient of the prestigious Walter A. Rosenblith New Investigator Award from the Health Effects Institute in 2010. Dr. Wu was also recognized with the 2005 Young Investigator Award and the 2014 Joan M. Daisey Outstanding Young Scientist Award, respectively, from the International Society of Exposure Sciences.

Project Key Personnel:

Dr. Veronica Berrocal (UCI Statistics) is Associate Professor at Department of Statistics, UCI. Dr. Berrocal has expertise in statistical methods and will be the Co-I for statistics including exposure modeling and exposure-outcome analysis. Dr. Berrocal's research focus is in the development and application of statistical models for the analysis of data that is collected in space and time, with a particular emphasis on the development and application of spatial statistical models to characterize environmental exposure (e.g. air pollution, weather, built environment) and its effect on health. Dr. Berrocal has a strong record on modeling and investigating the effect of air pollution exposure on health. Particularly, Dr. Berrocal has developed hierarchical Bayesian statistical models that have been adopted by the U.S. EPA to estimate O_3 and $PM_{2.5}$ concentrations at census tracts across the U.S., leveraging multiple data sources, particularly the output of the air quality model CMAQ. Dr. Berrocal has studied the effect of personal and ambient exposure to fine PM on pregnancy outcomes; and, investigated multi-level spatio-temporal statistical methods to obtain improved estimates of traffic-related air pollutants concentrations in urban environment leveraging the output of a Gaussian plume dispersion model. Dr. Berrocal 's expertise in environmental exposure assessment and environmental epidemiology has been recognized nationally and internationally. Dr. Berrocal has been the chair of the Section of Statistics and the Environment for the American Statistical Association (ASA; year: 2017), an elected officer for the Section of Statistics in Epidemiology of ASA (2017-2019), an Associate Editor (AE) for the Journal of the American Statistical Association, the premier journal for statistical science, and the official journal of ASA, and an AE for the Journal of Agricultural, Biological and Environmental

Statistics, one of four journals sponsored by the ASA, an AE for Bayesian Analysis, the journal of the International Society for Bayesian Analysis, and a statistical reviewer for JAMA Network Open. Further, Dr. Berrocal has been invited to serve on various advisory committees for the U.S. EPA and has been awarded the Early Investigator Award by the Section of Statistics and the Environment of ASA.

Dr. Suellen Hopfer (UCI Public Health) is Assistant Professor at Department of Health, Society & Behavior, Program in Public Health, UCI. Dr. Hopfer has expertise in risk communication for public health and community-participatory research and will serve as Co-I for community engagement, workshops, surveys, and curriculum development and implementation. Dr. Hopfer has conducted public health communication focused research (advancing communication theory) applied in the domains of effective messaging approaches around vaccine hesitancy and climate-sensitive health risks. Dr. Hopfer's research includes modeling communication networks, eliciting community narratives, family approaches to health behavior change, and designing prevention interventions for changing health behaviors and building policy support. An additional research area involves the use of real-time social media data to characterize how climate and vaccine risk are discussed among the public, to understand what kinds of engagement strategies can be used strategically to build policy support. Dr. Hopfer is uniquely qualified in eliciting, designing, and implementing culturally targeted communications given her training in health communication in community settings and having developed, adapted, and taken to scale an NCI research tested intervention program HPV Stories that doubled HPV vaccination rates in a randomized controlled trial.

Dr. Kai Zheng (UCI Informatics) is Professor of Informatics and Emergency Medicine and Chief Research Information Officer of UCI Health. Dr. Zheng has expertise in health informatics and will serve as Co-I for UC Health electronic health record data retrieval and quality assurance and QC The core mission of Dr. Zheng's office is to provide and innovate informatics solutions to facilitate clinical research, accelerate results translation, and engender the transformation of hospitals and clinics into a learning health system. Dr. Zheng has been working in the field of biomedical informatics for over 20 years. Dr. Zheng has led several large federally funded research projects to study topics, such as assessing the impact of health information technology (IT) implementation on clinical workflow and developing information retrieval systems for electronic health records. Dr. Zheng has also conducted many research studies focusing on the usability of clinical IT systems and translational research informatics applications. These studies aim to achieve a wide variety of objectives, from understanding user needs to developing computerized clinical decision-support applications and patient-facing health apps. Dr. Zheng was elected Fellow of the American College of Medical Informatics (FACMI) in 2018. From 2019 to 2020, Dr. Zheng served as Chair of American Medical Informatics Association's Clinical Information Systems Working Group. Dr. Zheng's extensive experience in biomedical informatics research, in addition to his leadership position in overseeing the translational informatics efforts at UCI, make Dr. Zheng ideally suited for serving as a Co-Investigator on the project. Prior to joining UCI, Dr. Zheng was Associate Professor of Health Management and Policy in the School of Public Health and Associate Professor of Information in the School of Information at the University of Michigan. Dr. Zheng was Director of University of Michigan's Health Informatics Program preparing students for careers that will harness the power of information to enhance health and transform individual health and healthcare. In this project, Dr. Zheng will lead the UC Health data extraction for main outcomes and covariates in Task 3. He will also support the team on data cleaning and analysis related to the UC Health data.

Dr. Michael MacKinnon (APEP), a Senior Research Scientist at APEP, has considerable experience in advanced transportation technologies, energy systems, emissions characterization, and air pollution. Dr. MacKinnon will manage the Advanced Power and Energy Program (APEP) research staff who will develop and apply the exposure model for wildfire smoke and pollutant estimates (Task 2). Dr. Mac MacKinnon will closely monitor the progress and help the research staff to receive proper help in solving problems arising from the project.

Dr. MacKinnon will be responsible for the management of budget and personnel for APEP and addressing problems as they occur in the research project. Dr. MacKinnon has an MS in Environmental Toxicology and Environmental Engineering and a PhD in Environmental Engineering from UC Irvine. Dr. MacKinnon‘s research activities involve the design and integration of advanced energy technologies and systems that can improve efficiencies, reduce harmful impacts on society and the environment, and enhance sustainability from current strategies. A specific focus of his research includes assessing air quality and greenhouse gas (GHG) impacts of emissions arising from regional energy systems via advanced atmospheric models. Dr. MacKinnon‘s primary expertise lies in technological mitigation strategies applicable to key sources that can most effectively improve atmospheric pollutant concentrations in tandem with GHG reductions.

Dr. Shupeng Zhu (APEP), a Senior Research Scientist at APEP, has considerable experience with all aspects of air quality modeling including air quality impact analysis of advanced energy technologies, air quality related health and economic cost/benefits analysis, air quality modeling, aerosol dynamics, atmospheric chemistry, pollution mitigation strategy, emission inventory, energy policy and climate change. Dr. Shupeng Zhu will be the main technical lead on supporting the smoke wave exposure modeling. He received his MS in Urban and Environmental Planning from the École centrale de Nantes and his PhD from the University of Paris-Est in Environmental Sciences.

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EXHIBIT A1

SCHEDULE OF DELIVERABLES

If use of any Deliverable is restricted or is anticipated to contain preexisting Intellectual Property with any restricted use, it will be clearly identified in Exhibit A4, Use of Preexisting Intellectual Property & Data.

Unless otherwise directed by the State, the University Principal Investigator shall submit all deliverables to State Contract Project Manager, identified in Exhibit A3, Authorized Representatives.

Deliverable	Description	Due Date
Initial Meeting	Principal Investigator and key personnel will meet with CARB Contract Project Manager and other staff to discuss the overall plan, details of performing the tasks, project schedule, items related to personnel or changes in personnel, and any issues that may need to be resolved before work can begin.	Month 1
Progress Reports & Meetings	Quarterly progress reports and meetings throughout the agreement term, to coincide with work completed in quarterly invoices.	Quarterly
Draft Final Report	Draft version of the Final Report detailing the purpose and scope of the work undertaken, the work performed, and the results obtained and conclusions.	Six (6) months prior to agreement end date.
Data	Data compilations first produced in the performance of this Agreement by the Principal investigator or the University's project personnel. Data will include the following: Summary of literature review (Task 1) Time-series exposure data for 1) daily concentrations of $PM_{2.5}$, PM_{10} and PAH for both total concentration and wildfire-contributed concentration; and 2) indicators of whether a day is a smoke wave day (0/1) based on different thresholds of concentration distribution of total $PM_{2.5}$, fire-specific $PM_{2.5}$, PM_{10} and PAH (Task 2) Summary of health outcome and covariate data (Task 3) Results of epidemiological analysis (Task 4) Findings from the community-engagement activities (e.g., community feedbacks, survey, and workshop) (Task 5)	Two (2) weeks prior to agreement end date.
Summary of the project in lay-friendly language	Lay-friendly summary of the project, including an overview of the research for Phase 1 activities, and a project summary, results, and interpretation of the findings for Phase 2 and 3 activities for submission to CARB and distribution to the community.	Month ~~32~~**44**

Technical Seminar	Presentation of the results of the project to CARB staff and a possible webcast at a seminar at CARB facilities in Sacramento or El Monte.	On or before agreement end date.
The following Deliverables are subject to paragraph 19. Copyrights, paragraph B of Exhibit C		
Final Report	Written record of the project and its results.	Two (2) weeks prior to agreement end date.

1. Reports and Data Compilations

A. With respect to each invoice period University shall submit, to the CARB Contract Project Manager, one (1) electronic copy of the progress report. When emailing the progress report, the “subject line” should state the contract number and the billing period. Each progress report will begin with the following disclaimer:

The statements and conclusions in this report are those of the University and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

B. Each progress report will also include:

1. A brief narrative account of project tasks completed or partially completed since the last progress report;
2. A brief discussion of problems encountered during the reporting period and how they were or are proposed to be resolved;
3. A brief discussion of work planned, by project task, before the next progress report; and
4. A graph or table showing allocation of the budget and amount used to date.
5. A graph or table showing percent of work completion for each task.

C. If the project is behind schedule, the progress report must contain an explanation of reasons and how the University plans to resume the schedule.

D. Six (6) months prior to Agreement expiration date, University will deliver to CARB five (5) bound copies of a draft final report. The reports may be stapled or spiral bound, depending on size. The draft final report will conform to Exhibit A1, Section 2 – Research Final Report Format.

E. Within forty-five (45) days of receipt of CARB’s comments, University will deliver to CARB’s Contract Project Manager two (2) copies of the final report incorporating all reasonable alterations and additions. Within two (2) weeks of receipt of the revised report, CARB will verify that all CARB comments have been addressed. Upon acceptance of the amended final report approved by CARB in accordance to Exhibit A1, Section 2 – Research Final Report Format, University will within two (2) weeks, deliver to CARB two (2) camera ready UNBOUND originals of a final report incorporating all final alterations and additions.

F. Together with the final report, University will deliver a copy of the report on CD, using any common word processing software (please specify the software used) and a set of all data compilations as specified in Exhibit A1 – Schedule of Deliverables.

G. University’s obligation under this Agreement shall be deemed discharged only upon submittal to CARB of an acceptable final report in accordance to Exhibit A1, Section 2 – Research Final Report Format, report CD, all required data compilations, and any other project deliverables.

2. Research Final Report Format

The research contract Final Report (Report) is as important to the contract as the research itself. The Report is a record of the project and its results, and is used in several ways. Therefore, the Report must be well organized and contain certain specific information. The CARB’s Research Screening Committee (RSC) reviews all draft final reports, paying special attention to the Abstract and Executive Summary. If the RSC finds that the Report does not fulfill the requirements stated in this Exhibit, the document will not be approved for release, and final payment for the work completed may be withheld. This Exhibit outlines the requirements that must be met when producing the Report.

Note: In partial fulfillment of the Final Report requirements, the Contractor shall submit a copy of the Report on a CD in PDF format <u>and</u> in a word-processing format, preferably in Word – Version 6.0 or later. This is in addition to the submission of any paper copies required. The CD shall be clearly labeled with the contract title, CARB contract number, the words "Final Report", and the date the report was submitted.

Legibility. Each page of the approved Final Report must be legible and camera-ready.

Accessibility. In order to maintain compliance with California Government Code Sections 7405 and 11135, and Web Content Accessibility Guidelines, Assembly Bill No. 434, the final Report must be submitted in an Americans with Disabilities Act compliant format. The final Report will be posted on the CARB website and therefore must but be in an accessible format so that all members of the public can access it.

Binding. The draft Report, including its appendices, must be either spiral bound or stapled, depending on size. The revised Report and its appendices should be spiral bound, except for two unbound, camera-ready originals.

Cover. Do not supply a cover for the Report. The CARB will provide its standard cover.

One-sided vs. two-sided. To conserve paper, the draft Report, the revised Report, and the unbound camera-ready copies should be printed on both sides of the page.

Watermark. Each page of the draft Report must include a watermark stating “DRAFT.” The revised report should not include any watermarks.

Title. The title of the Report should exactly duplicate the title of the contract unless a change is approved in writing by the contract manager.

Spacing. In order to conserve paper, copying costs, and postage, please use single or one-line (1) spacing.

Page size. All pages should be of standard size (8 ½" x 11") to allow for photo-reproduction.

Large tables or figures. Foldout or photo-reduced tables or figures are not acceptable because they cannot be readily reproduced. Large tables and figures should be presented on consecutive 8 ½" x 11" pages, each page containing one portion of the larger chart.

Color. Printing shall be black on white. However, color images are acceptable where necessary.

Corporate identification. Do not include corporate identification on any page of the Final Report, except the title page.

Unit notation. Measurements in the Reports should be expressed in metric units. However, for the convenience of engineers and other scientists accustomed to using the British system, values may be given in British units as well in parentheses after the value in metric units. The expression of measurements in both systems is especially encouraged for engineering reports.

Section order. The Report should contain the following sections, in the order listed below:

Title page
Disclaimer
Acknowledgment (1)
Acknowledgment (2)
Table of Contents
List of Figures
List of Tables
Abstract
Executive Summary
Body of Report
References
List of inventions reported and copyrighted materials produced
Glossary of Terms, Abbreviations, and Symbols
Appendices

Page numbering. Beginning with the body of the Report, pages shall be numbered consecutively beginning with "1", including all appendices and attachments. Pages preceding the body of the Report shall be numbered consecutively, in ascending order, with small Roman numerals.

Title page. The title page should include, at a minimum, the contract number, contract title, name of the principal investigator, contractor organization, date, and this statement: "Prepared for the California Air Resources Board and the California Environmental Protection Agency"

Disclaimer. A page dedicated to this statement must follow the Title Page:

The statements and conclusions in this Report are those of the contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

Acknowledgment (1). Only this section should contain acknowledgments of key personnel and organizations who were associated with the project. The last paragraph of the acknowledgments must read as follows:

> This Report was submitted in fulfillment of [CARB contract number and project title] by [contractor organization] under the [partial] sponsorship of the California Air Resources Board. Work was completed as of [date].

Acknowledgment (2). Health reports should include an acknowledgment to the late Dr. Friedman. Reports should include the following paragraph:

This project is funded under the CARB's Dr. William F. Friedman Health Research Program. During Dr. Friedman's tenure on the Board, he played a major role in guiding CARB's health research program. His commitment to the citizens of California was evident through his personal and professional interest in the Board's health research, especially in studies related to children's health. The Board is sincerely grateful for all of Dr. Friedman's personal and professional contributions to the State of California.

Table of Contents. This should list all the sections, chapters, and appendices, together with their page numbers. Check for completeness and correct reference to pages in the Report.

List of Figures. This list is optional if there are fewer than five illustrations.

List of Tables. This list is optional if there are fewer than five tables.

Abstract. The abstract should tell the reader, in nontechnical terms, the purpose and scope of the work undertaken, describe the work performed, and present the results obtained and conclusions. The purpose of the abstract is to provide the reader with useful information and a means of determining whether the complete document should be obtained for study. The length of the abstract should be no more than about 200 words. Only those concepts that are addressed in the executive summary should be included in the abstract.

Example of an abstract:

A recently developed ground-based instrument, employing light detecting and ranging (lidar) technology, was evaluated and found to accurately measure ozone concentrations at altitudes of up to 3,000 meters. The novel approach used in this study provides true vertical distributions of ozone concentrations aloft and better temporal coverage of these distributions than other, more common methods, such as those using aircraft and ozonesonde (balloon) techniques. The ozone and aerosol measurements from this study, in conjunction with temperature and wind measurements, will provide a better characterization of atmospheric conditions aloft and the processes involved in the formation of unhealthful ozone concentrations than can be achieved with traditional ground-based monitors.

Executive Summary. The function of the executive summary is to inform the reader about the important aspects of the work that was done, permitting the reader to understand the research without reading the entire Report. It should state the objectives of the research and briefly describe the experimental methodology[ies] used, results, conclusions, and recommendations for further study. All of the concepts brought out in the abstract should be expanded upon in the Executive Summary. Conversely, the Executive Summary should not contain concepts that are not expanded upon in the body of the Report.

The Executive Summary will be used in several applications as written; therefore, please observe the style considerations discussed below.

Limit the Executive Summary to two pages, single spaced.

Use narrative form. Use a style and vocabulary level comparable to that in Scientific American or the New York Times.

Do not list contract tasks in lieu of discussing the methodology. Discuss the results rather than listing them.

Avoid jargon.

Define technical terms.

Use passive voice if active voice is awkward.

Avoid the temptation to lump separate topics together in one sentence to cut down on length.

The Executive Summary should contain four sections: Background, Objectives and Methods, Results, and Conclusions, described below.

THE BACKGROUND SECTION. For the Background, provide a one-paragraph discussion of the reasons the research was needed. Relate the research to the Board's regulatory functions, such as establishing ambient air quality standards for the protection of human health, crops, and ecosystems; the improvement and updating of emissions inventories; and the development of air pollution control strategies.

THE OBJECTIVES AND METHODS SECTION. At the beginning of the Objectives and Methods section, state the research objectives as described in the contract. Include a short, one or two sentence, overview of what was done in general for this research.

The methodology should be described in general, nontechnical terms, unless the purpose of the research was to develop a new methodology or demonstrate a new apparatus or technique. Even in those cases, technical aspects of the methodology should be kept to the minimum necessary for understanding the project. Use terminology with which the reader is likely to be familiar. If it is necessary to use technical terms, define them. Details, such as names of manufacturers and statistical analysis techniques, should be omitted.

Specify when and where the study was performed, if it is important in interpreting the results. The findings should not be mentioned in the Objectives and Methods section.

THE RESULTS SECTION. The Results section should be a single paragraph in which the main findings are cited and their significance briefly discussed. The results should be presented as a narrative, not a list. This section must include a discussion of the implications of the work for the Board's relevant regulatory programs.

THE CONCLUSIONS SECTION. The Conclusions section should be a single short paragraph in which the results are related to the background, objectives, and methods. Again, this should be presented as a narrative rather than a list. Include a short discussion of recommendations for further study, adhering to the guidelines for the Recommendations section in the body of the Report.

Body of Report. The body of the Report should contain the details of the research, divided into the following sections:[1]

[1] Note that if the research employs multiple distinct methods, analyses, etc., the final report can include separate materials/methods, results, and discussion sections to allow for coherent discussion of each set of analyses and findings. However, the executive summary and conclusions sections should synthesize the collective findings of the entire study.

INTRODUCTION. Clearly identify the scope and purpose of the project. Provide a general background of the project. Explicitly state the assumptions of the study.

Clearly describe the hypothesis or problem the research was designed to address. Discuss previous related work and provide a brief review of the relevant literature on the topic.

MATERIALS AND METHODS. Describe the various phases of the project, the theoretical approach to the solution of the problem being addressed, and limitations to the work. Describe the design and construction phases of the project, materials, equipment, instrumentation, and methodology. Describe quality assurance and quality control procedures used. Describe the experimental or evaluation phase of the project

RESULTS. Present the results in an orderly and coherent sequence. Describe statistical procedures used and their assumptions. Discuss information presented in tables, figures and graphs. The titles and heading of tables, graphs, and figures, should be understandable without reference to the text. Include all necessary explanatory footnotes. Clearly indicate the measurement units used.

DISCUSSION. Interpret the data in the context of the original hypothesis or problem. Does the data support the hypothesis or provide solutions to the research problem? If appropriate, discuss how the results compare to data from similar or related studies. What are the implications of the findings? Identify innovations or development of new techniques or processes. If appropriate, discuss cost projections and economic analyses.

SUMMARY AND CONCLUSIONS. This is the most important part of the Report because it is the section that will probably be read most frequently. This section should begin with a clear, concise statement of what, why, and how the project was done. Major results and conclusions of the study should then be presented, using clear, concise statements. Make sure the conclusions reached are fully supported by the results of the study. Do not overstate or overinterpret the results. It may be useful to itemize primary results and conclusions. A simple table or graph may be used to illustrate.

RECOMMENDATIONS. Use clear, concise statements to recommend (if appropriate) future research that is a reasonable progression of the study and can be supported by the results and discussion.

References. Use a consistent style to fully cite work referenced throughout the Report and references to closely related work, background material, and publications that offer additional information on aspects of the work. Please list these together in a separate section, following the body of the Report. If the Report is lengthy, you may list the references at the end of each chapter.

List of inventions reported and publications produced. If any inventions have been reported, or publications or pending publications have been produced as a result of the project, the titles, authors, journals or magazines, and identifying numbers that will assist in locating such information should be included in this section.

Glossary of terms, abbreviations, and symbols. When more than five of these items are used in the text of the Report, prepare a complete listing with explanations and definitions. It is expected that every abbreviation and symbol will be written out at its first appearance in the Report, with the abbreviation or symbol following in parentheses [i.e., carbon dioxide (CO2)]. Symbols listed in table and figure legends need not be listed in the Glossary.

Appendices. Related or additional material that is too bulky or detailed to include within the discussion portion of the Report shall be placed in appendices. If a Report has only one appendix, it should be entitled "APPENDIX". If a Report has more than one appendix, each should be designated with a capital letter (APPENDIX A, APPENDIX B). If the appendices are too large for inclusion in the Report, they should be collated, following the binding requirements for the Report, as a separate document. The contract manager will determine whether appendices are to be included in the Report or treated separately. Page numbers of appendices included in the Report should continue the page numbering of the Report body. Pages of separated appendices should be numbered consecutively, beginning at "1".

3. Other Deliverables

A. Any other deliverables shall be provided in a mutually agreed upon format unless the deliverable format is already specified in Exhibit A.

EXHIBIT A2

KEY PERSONNEL

Last Name, First Name	Institutional Affiliation	Role on Project
Principal Investigator (PI):		
Wu, Jun	University of California, Irvine	Professor Wu will be the Principal Investigator and act as project manager, overseeing interactions, timelines, and milestones
Other Key Personnel:		
MacKinnon, Michael	University of California, Irvine	Dr. MacKinnon will be responsible for the conduct of the research and the coordination and management of reporting for Task 2
Zhu, Shupeng	University of California, Irvine	Dr. Zhu will serve as the technical lead for the exposure modeling in Task 2.
Zheng, Kai	University of California, Irvine	Professor Zheng will be Co-I and lead the UC Health data collection in Task 3.
Berrocal, Veronica	University of California, Irvine	Professor Berrocal will be Co-I and guide the graduate student in Task 4 exposure-outcome statistical analysis.
Hopfer, Suellen	University of California, Irvine	Professor Hopfer will be Co-I and lead Task 5 for community engagement activities.

EXHIBIT A3

AUTHORIZED REPRESENTATIVES & NOTICES

The following individuals are the authorized representatives for the State and the University under this Agreement. Any official Notices issued under the terms of this Agreement shall be addressed to the Authorized Official identified below, unless otherwise identified in the Agreement.

State Agency Contacts Agency Name: CARB	**University Contacts** University Name: UCI
Contract Project Manager (Technical) Name: Feng-Chiao Su Address: Research Division 1001 I Street, 5th Floor Sacramento, CA 95814 Telephone: (916) 440-8245 Fax: (916) 322-4357 Email: feng-chiao.su@arb.ca.gov	***Principal Investigator (PI)*** Name: Jun Wu Address: 100 Theory, Suite 100 ZOT 1830 Irvine, CA 92617 Telephone: (949) 824-054 Email: junwu@hs.uci.edu
Authorized Official (contract officer) Name: Brandy Hunt, Branch Chief Address: Non-IT Acquisitions 1001 I Street, 19th Floor Sacramento, CA 95814 ***Send notices to (if different):*** Name: Renee Carnes Address: Research Division 1001 I Street, 5th Floor Sacramento, CA 95814 Telephone: (916) 445-3366 Fax: (916) 322-4357 Email: renee.carnes@arb.ca.gov	***Authorized Official*** Name: Maria Andrade-Stern Address: Office of Research 160 Aldrich Hall Irvine, CA 92697-7600 Telephone: (949) 824-3428 Fax: (949) 824-2094 Email: mcandrad@uci.edu

Administrative Contact Name: Renee Carnes Address: Research Division 1001 I Street, 5th Floor Sacramento, CA 95814 Telephone: (916) 324-4816 Fax: (916) 323-1045 Email: renee.carnes@arb.ca.gov	***Administrative Contact*** Name: Warda Bzeih Address: 653 El Peltason Drive AIRB 2070-A Irvine, CA 92697-3957 Telephone: (949) 824-0238 Fax: (949) 824-2039 Email: bzeihw@hs.uci.edu
Financial Contact/Accounting Name: Accounts Payable Address: P.O. Box 1436 Sacramento, CA 95814 Email: AccountsPayable@arb.ca.gov **Send courtesy copy to Sarah Szepesi:** Fax: (916) 322-4357 Telephone: (916) 327-1256 Email: sarah.szepesi@arb.ca.gov	***Authorized Financial Contact/Invoicing*** Name: Trini Lee Address: Accounting and Fiscal Services 120 Theory, suite 200 Irvine, CA 92697-1050 Telephone: (949) 824-3308 Fax: (949) 824-3895 Email: trinil@uci.edu

EXHIBIT A4

USE OF PREEXISTING INTELLECTUAL PROPERTY & DATA

A. State: Preexisting Intellectual Property (IP)/Data to be provided to the University from the State or a third party for use in the performance in the Scope of Work.

☐ None or ☒ List:

Owner (State Agency or 3rd Party)	Description	Nature of restriction:
OSHPD	Daily hospital admission and emergency department visit data.	Must follow recommended practices for safeguarding access to confidential data: https://oshpd.ca.gov/data-and-reports/request-data/data-documentation/security-guidelines/.
CDPH	Birth certificate data with residential address	Residential address data are confidential; cannot share the data with anyone.

B. University: Restrictions in Preexisting IP/Data included in Deliverables identified in Exhibit A1, Deliverables.

☐ None or ☒ List:

Owner (University or 3rd Party)	Description	Nature of restriction:
University of California Office of the President (UCOP)	Electronic health record (EHR) data from UC Health	Residential address, name and contact information of the EHR data are confidential and must follow the requirement of UC Health.

C. Anticipated restrictions on use of Project Data.

If the University PI anticipates that any of the Project Data generated during the performance of the Scope of Work will have a restriction on use (such as subject identifying information in a data set), then list all such anticipated restrictions below. If there are no restrictions anticipated in the Project Data, then check "none" in this section.

☐ None or ☒ List:

Owner (State Agency or 3rd Party)	Description	Nature of restriction:
OSHPD	Daily hospital admission and emergency department visit data.	Subject identifying information cannot be shared with other parties.
CDPH	Birth certificate data with residential address	Subject identifying information cannot be shared with other parties.
UCOP	Electronic health record (EHR) data from UC Health	Subject identifying information cannot be shared with other parties.

EXHIBIT A5

RÉSUMÉ / BIOSKETCH

Jun Wu, Ph.D.

Professor, Department of Environmental and Occupational Health
Director, Environmental Heath Graduate Program
University of California, Irvine, CA 92697

Education and Training

University of California, Los Angeles	Environmental Health	Ph.D.	2004
Penn State University	Environmental Engineering	M.S.	2000
Tsinghua University, China	Environmental Engineering	B.E.	1997

Research Focus

Environmental health in general with five focused areas: 1) environmental exposure assessment; 2) health impact of environmental exposures; 3) application of "big data", machine learning, and spatial analysis in environmental health; 4) climate change impact on the environment and health; 5) environmental justice issues focusing on community-driven problems.

Professional Experience:

Jul. 2020 – present	Professor and Graduate Director UCI Department of Environmental and Occupational Health
Jul. 2013 – Jun. 2020	Associate Professor UCI Program in Public Health
Jul. 2006 – Jun. 2013	Assistant Professor UCI Program in Public Health
Jul. 2005 – Jun. 2006	Assistant Researcher UCLA School of Public Health

HONORS AND AWARDS

Internal Society of Exposure Science (ISES) Joan M. Daisey Outstanding Young Scientist Award	2014
Celebration of Teaching School Honoree Award for Excellence in Undergraduate Teaching	2012
Health Effects Institute Walter A. Rosenblith New Investigator Award	2010
Committee on Research Award, UC-Irvine School of Medicine	2007
Internal Society of Exposure Analysis (ISEA) Young Investigator Award	2005

Publications (Recent and Relevant Examples out of 95 peer-reviewed papers)

1. Masri S, Scaduto E, Jin Y, Wu J. 2021. Disproportionate impacts of wildfires among elderly and low-income communities in California from 2000–2020. *International Journal of Environmental Research and Public Health*. 18, 3921.

2. Sun Y, Wang X, Zhu J, Chen L, Jia Y, Lawrence JM, Jiang L, Xie X, Wu J. 2021. Using machine learning to examine street green space and their associations with socioeconomic factors in Los Angeles County. Science of the Total Environment: 787. https://doi.org/10.1016/j.scitotenv.2021.147653.
3. Mousavi A, Wu J. 2021. Indoor-generated PM2.5 during COVID-19 Shutdowns across California: Application of Purple Air indoor-outdoor low-cost sensor network. Environmental Science & Technology. doi: 10.1021/acs.est.0c06937.
4. Masri S, LeBrón AMW, Logue MD, Valencia E, Ruiz A, Reyes A, Lawrence J, Wu J. 2020. Social and spatial distribution of soil lead concentrations in the City of Santa Ana, California: Implications for health inequities. Science of the Total Environment: 743:140764. doi: 10.1016/j.scitotenv.2020.140764. PubMed PMID: 32663692.
5. Li L, Girguis M, Lurmann F, Pavlovic N, Franklin M, Wu J, Oman L, Breton C, Gilliland F, Habre R. 2020. Ensemble-Based Deep Learning for Estimating PM2.5 over California with Multisource Big Data Including Wildfire Smoke. Environmental International 145: 106143.
6. Sun Y, Sheridan P, Laurent O, Li J, Sacks D, Fischer H, Qiu Y, Jiang Y, Yim I, Jiang L, Molitor J, Chen JC, Benmarhnia T, Lawrence J, Wu J. 2020. Associations between green space and preterm birth: Windows of susceptibility and interaction with air pollution. *Environmental International*. 142: 105804.
7. Li L, Lurmann F, Habre R, Urman R, Ritz B, Gilliland FD, Wu J. 2017. Constrained mixed-effect models with ensemble learning for prediction of nitrogen oxides concentrations at high spatiotemporal resolution. *Environ Sci Technol 51: 9920-9929*
8. Kunzli N, Avol E, Wu J, Gauderman WJ, Rappaport E, Millstein J, Bennion J, McConnell R, Gilliland FD, Berhane K, Lurmann F, Winer A, Peters JM. 2006. Health effects of the 2003 Southern California wildfires on children. American Journal of Respiratory and Critical Care Medicine 174(11): 1221-1228.
9. Delfino RJ, Brummell S, Wu J, Gillen D, Ostro B, Lipsett M, Winer A, Street DH, Zhang L, Tjoa T, Stern H. 2009. The relationship of respiratory and cardiovascular hospital admissions to the southern California wildfires of 2003. *Occupational and Environmental Medicine* 66:189-197.
10. Wu J, Ren C, Delfino R, Chung J, Wilhelm M, Ritz B. 2009. Association between local traffic-generated air pollution and preeclampsia and preterm delivery in the South Coast Air Basin of California. *Environmental Health Perspectives* 117(11): 1773-1779.
11. Wu J, Winer AM, Delfino RJ. 2006. Exposure assessment of particulate matter air pollution before, during, and after the 2003 Southern California wildfires. *Atmospheric Environment* 40(18): 3333-3348.

A list of PubMed available papers can be found here:
https://www.ncbi.nlm.nih.gov/myncbi/1B7znR_Soua5e/bibliography/public/

Synergistic Activities

1. I have published one of the first studies that estimated daily PM_{10} and $PM_{2.5}$ mass concentrations at a zip-code level for southern CA before, during, and after the 2003 wildfires using MODIS satellite data and ground $PM_{2.5}$ measurements. Wildfire smoke exposure was then associated with increased respiratory symptoms, medication use, physician visits in children, and increased respiratory hospital admissions among children and the elderly.
2. For air pollution exposure assessment, I focused on developing advanced exposure assessment methods using geographical information system (GIS) techniques, spatial modeling, air quality modeling, and sophisticated statistical methods. I have conducted more than 10 projects as PI, subcontract PI or co-investigator and have published more than 35 papers in environmental exposure assessment, particularly on air pollution. I have extensive experience using measurement data, GIS, remote sensing, and rich spatial data to develop advanced statistical methods for spatiotemporal modeling of air pollutants.

3. For environmental epidemiology, I focused on the impact of air pollution (gases and particles; mass, source, composition), meteorology, and the built environment on reproductive outcomes and children's health and have published more than 45 papers in environmental epidemiology.
4. I am PI of an NIH R01 study (ES030353) that examines exposure to air pollution mixtures and pregnancy complications prospectively-recorded individual-level high quality clinical data and residential addresses from the electronic health record of Kaiser Permanente Southern California.
5. I am MPI of a pending NIH R01 grant proposal (submitted in March 2021) that will examine extreme weather and wildfire impacts on adult life expectancies in a diverse multi-ethnic cohort in California that have been tracked since 1993 till present and will identify vulnerable subgroups and mediating factors.

Michael MacKinnon, Ph.D.
Senior Research Engineer
Advanced Power and Energy Program (APEP)
University of California, Irvine, CA 92697-3550

Education and Training:

University of California, Irvine	Environmental Engineering	Ph.D.	2015
University of California, Irvine	Environmental Engineering	M.S.	2013
University of California, Irvine	Environmental Toxicology	M.S.	2010
University of Arizona	Ecological and Evolutionary Biology	B.A.	2007

Research Focus:
Use of atmospheric modeling to study spatial and temporal impacts on primary and secondary pollutant species to elucidate sustainable energy technologies and strategies with potential for air quality and greenhouse gas co-benefits. Assessment of the use of fuel cell technologies in microgrid design and deployment at major shipping ports. Assessment of natural gas infrastructure for methane emissions and improved leakage assessment methodology development. Identification and assessment of the climate change, air quality, and water co-benefits associated with the deployment of renewable energy technologies and fuels. Assessing the air quality impacts of meeting renewable resource policy targets in California including emissions from existing fossil generators arising from altered grid dynamics as a consequence of integration of intermittent resources.

Professional Experience:

11/15 – present	Senior Research Engineer, APEP
6/15 – 10/15	Senior Air Quality Associate Intern, Ramboll Environ Corp.
8/07 – 6/10	Laboratory Assistant, UCI Air Pollution Health Effects Laboratory

Publications (Examples):

1. Wang, D., Guan, D., Zhu, S., Mac Kinnon, M., Geng, G., Zhang, Q., ... & Davis, S. J. (2021). Economic footprint of California wildfires in 2018. *Nature Sustainability*, *4*(3), 252-260.
2. Samuelsen, S., Zhu, S., Mac Kinnon, M., Yang, O. K., Dabdub, D., & Brouwer, J. (2020). An Episodic Assessment of Vehicle Emission Regulations on Saving Lives in California. *Environmental Science & Technology*.
3. Zhu, S., Horne, J. R., Mac Kinnon, M., Samuelsen, G. S., & Dabdub, D. (2019). Comprehensively assessing the drivers of future air quality in California. *Environment international*, *125*, 386-398.
4. Zhu, S., Mac Kinnon, M., Shaffer, B. P., Samuelsen, G. S., Brouwer, J., & Dabdub, D. (2019). An uncertainty for clean air: Air quality modeling implications of underestimating VOC emissions in urban inventories. *Atmospheric Environment*, *211*, 256-267.
5. Mac Kinnon, M., Zhu, S., Carreras-Sospedra, M., Soukup, J. V., Dabdub, D., Samuelsen, G. S., & Brouwer, J. (2019). Considering future regional air quality impacts of the transportation sector. *Energy policy*, *124*, 63-80.
6. Mac Kinnon, Michael A., Jacob Brouwer, and Scott Samuelsen. "The role of natural gas and its infrastructure in mitigating greenhouse gas emissions, improving regional air quality, and renewable resource integration." *Progress in Energy and Combustion science,* 64 (2018): 62-92.

7. Mac Kinnon, M., Heydarzadeh, Z., Doan, Q., Ngo, C., Reed, J., & Brouwer, J. (2018). Need for a marginal methodology in assessing natural gas system methane emissions in response to incremental consumption. *Journal of the Air & Waste Management Association*, *68*(11), 1139-1147.
8. Saeedmanesh, Alireza, Michael A. Mac Kinnon, and Jack Brouwer. "Hydrogen is essential for sustainability." *Current Opinion in Electrochemistry* 12 (2018): 166-181.
9. Benosa, Guillem, Shupeng Zhu, Michael Mac Kinnon, and Donald Dabdub. "Air quality impacts of implementing emission reduction strategies at southern California airports." *Atmospheric Environment* 185 (2018): 121-127. http://www3.epa.gov/ttn/chief/conference/ei21/session1/mackinnon_fuelcell.pdf
10. Mac Kinnon, M., Shaffer, B., Carreras-Sospedra, M., Dabdub, D., Samuelsen, G. S., & Brouwer, J. (2016). Air quality impacts of fuel cell electric hydrogen vehicles with high levels of renewable power generation. *International Journal of Hydrogen Energy*, *41*(38), 16592-16603.

Synergistic Activities:

1. Active participant of AirUCI, an organized research unit at UCI representing collaboration and integration of a multidisciplinary team of researchers, engineers, and health scientists whose focus is the elucidate the fundamental science and impacts of pollution, energy, and climate change.
2. Facilitation of communication and planning of collaboration of multiple research groups at UCI in air quality assessment of energy technologies including Earth Systems Science, Mechanical and Environmental Engineering, and Atmospheric Chemistry.

Shupeng Zhu, Ph.D.

Senior Research Scientist
Advanced Power and Energy Program
University of California, Irvine, CA 92697-3550

Education and Training:

University of Paris-Est	Environmental Sciences	Ph.D.	2016
École centrale de Nantes	Urban and Environmental Planning	M.S.	2012
École centrale de Nantes	Urban Studies and Planning	B.S.	2012
Ocean University of China	Marine Sciences	B.S.	2006

Research Focus:

Air quality impact analysis of advanced energy technologies, air quality related health and economic cost/benefits analysis, air quality modeling, aerosol dynamics, atmospheric chemistry, pollution mitigation strategy, emission inventory, energy policy and climate change.

Professional Experience:

Oct 19-Present	Senior Research Scientist, APEP. UCI.
Oct 16-Oct 19	Postdoctoral researcher, MAE, UCI.
Jan 16-Jul 16	Postdoctoral researcher, CEREA, ENPC-EDF R&D, France.
Nov 12-Dec16	Research Assistant, CEREA, ENPC-EDF R&D, France.
Mar 12-Sep16	Research Assistant, IETR, INSA Rennes, France.

Publications (Examples):

1. Zhu, S.; Horne, J.R.; Mac Kinnon, M.; Samuelsen, G.S.; Dabdub, D. Comprehensive assessing the drivers of future air quality in California. Environment International 2019, 125, 386-398
2. Zhu, S; Mac Kinnon, M.; Shaffer, B.P.; Samuelsen, G.S.; Brouwer, J.; Dabdub, D. An uncertainty for clean air: Air quality modeling implications of underestimating VOC emissions in urban inventories. Atmospheric Environment 2019, 211, 256-267
3. Zhu, S.; Horne, J.R.; Montoya-Aguilera, J.; Hinks, M.L.; Nizkorodov, S.; Dabdud, D. Modeling reactive ammonia uptake by secondary organic aerosol in CMAQ: application to the continental US, Atmospheric Chemistry and Physics 2018, 18, 3641-3657
4. Zhu, S.; Sartelet, K.N.; Zhang, Y.; Nenes A. Three-dimensional modelling of the mixing state of particles over Greater Paris, Journal of Geophysical Research: Atmospheres 2016, 121, 5930-5947
5. Zhu, S.; Sartelet, K.N.; Healy R.; Wenger J. Simulation of particle diversity and mixing state over Greater Paris: A model-measurement inter-comparison, Faraday Discussion: Chemistry in the Urban Atmosphere 2016, 189, 547-566
6. Zhu, S.; Sartelet, K.N.; Seigneur, C. A size-composition resolved aerosol model for simulating the dynamics of externally-mixed particles: SCRAM (v 1.0). Geoscientific Model Development 2015, 8 (6), 1595-1612

Synergistic Activities:

1. Member: Royal Society of Chemistry (UK)

Kai Zheng, Ph.D.
Professor
5228 Donald Bren Hall
Irvine, CA 92697-3440

(a) Professional Preparation

Shanghai Jiaotong University	Shanghai, China	Electrical Engineering	BE, 1999
Carnegie Mellon University	Pittsburgh	Information Systems	PhD, 2006

(b) Appointments

2021–Pres	Chief Research Information Officer, UC Irvine Health, University of California, Irvine, Irvine, CA
2021–Pres	Adjunct Professor, Department of Psychiatry, Michigan Medicine, University of Michigan, Ann Arbor, MI
2020–Pres	Professor, Department of Informatics, Donald Bren School of Information and Computer Sciences, University of California, Irvine, Irvine, CA
2020–Pres	Professor, Department of Emergency Medicine, School of Medicine, University of California, Irvine, Irvine, CA
2016–Pres	Director, Center for Biomedical Informatics, Institute for Clinical and Translational Science, University of California, Irvine, Irvine, CA
2016–2020	Associate Professor, Department of Informatics, Donald Bren School of Information and Computer Sciences, University of California, Irvine, Irvine, CA
2016–2020	Associate Professor, Department of Emergency Medicine, School of Medicine, University of California, Irvine, Irvine, CA
2015	Director, University of Michigan Health Informatics Program (Interim Director, 2014–15), University of Michigan, Ann Arbor, MI
2006–2015	Associate Professor of Health Management and Policy (Assistant Professor, 2006–12), School of Public Health Department of Health Management and Policy, University of Michigan, Ann Arbor, MI
2006–2015	Associate Professor of Information (Assistant Professor, 2006–12), School of Information, University of Michigan, Ann Arbor, MI

(c) Products

(i) Most closely related to the proposed project

1. Kim J, Neumann L, Paul P, Day ME, Aratow M, Bell DS, Doctor JN, Hinske LC, Jiang X, Kim KK, Matheny ME, Meeker D, Pletcher MJ, Schilling LM, SooHoo S, Xu H, **Zheng K**, Ohno-Machado L; R2D2 Consortium. Privacy-protecting, reliable response data discovery using COVID-19 patient observations. J Am Med Inform Assoc. 2021. PMCID: PMC8194878
2. Park JI, Kim D, Lee JA, **Zheng K**, Amin A. Personalized risk prediction of 30-day readmissions with venous thromboembolism using machine learning. J Nurs Scholarsh. 2021;53(3):278– 87. PMID: 33617689
3. Saran R, Pearson A, Tilea A, Shahinian V, Bragg-Gresham J, Heung M, Hutton DW, Steffick D, **Zheng K**, Morgenstern H, Gillespie BW, Leichtman A, Young E, O'Hare AM, Fischer M, Hotchkiss J, Siew E, Hynes D, Fried L, Balkovetz D, Sovern K, Liu CF, Crowley S; VA-REINS Steering Committee; VA Advisory Board. Burden and cost of caring for US veterans with CKD: initial findings from the VA Renal Information System (VA-REINS). Am J Kidney Dis. 2021;77(3):397–405. PMID: 32890592

4. Hanauer DA, Barnholtz-Sloan J, Beno M, Fiol GD, Durbin E, Gologorskaya O, Harnett B, Kawamoto K, May B, Meeks E, Pfaff E, Weiss J, **Zheng K**. EMERSE: an information retrieval tool for supporting cancer research. JCO Clin Cancer Inform. 2020;4:454–63. PMCID: PMC7265780
5. Hanauer DA, Mei Q, Law J, Khanna R, **Zheng K**. Supporting information retrieval from electronic health records: a report of University of Michigan's eight-year experience in developing and using the Electronic Medical Record Search Engine (EMERSE). J Biomed Inform. 2015;55(6):290–300. PMCID: PMC4527540

(ii) Other significant products
1. He L, Yin T, Hu Z, Chen Y, Hanauer DA, **Zheng K**. Developing a standardized protocol for computational sentiment analysis research using health-related social media data. J Am Med Inform Assoc. 2021;28(6):1125–34. PMID: 33355353
2. Tran BD, Rosenbaum K, **Zheng K**. An interview study with medical scribes on how their work may alleviate clinician burnout through delegated health IT tasks. J Am Med Inform Assoc. 2021;28(5):907–14. PMID: 33576391
3. **Zheng K**, Ratwani RM, Adler-Milstein J. Studying workflow and workarounds in Electronic Health Record–supported work to improve health system performance. Ann Intern Med. 2020;172(11 Supplement):S116–22. PMID: 32479181
4. Tran BD, Chen Y, Liu SZ, **Zheng K**. How does medical scribes' work inform the development of speech-based clinical documentation technologies? A systematic review. J Am Med Inform Assoc. 2020;27(5):808–17. PMID: 32181812
5. Hussain MI, Nelson AM, Yeung BG, Sukumar L, **Zheng K**. How the presentation of patient information and decision-support advisories influences opioid prescribing behavior: a simulation study. J Am Med Inform Assoc. 2020;27(4):613–20. PMID: 32016407

(d) Synergistic Activities

I have been working in the field of biomedical informatics for over 20 years. I have led several large federally funded research projects to study topics such as assessing the impact of health IT implementation on clinical workflow and developing information retrieval systems for electronic health records. I have also conducted many research studies focusing on the usability of clinical IT systems and translational research informatics applications. These studies aim to achieve a wide variety of objectives, from understanding user needs to developing computerized clinical decision-support applications and patient-facing health apps. I was elected Fellow of the American College of Medical Informatics (FACMI) in 2018. From 2019 to 2020, I served as Chair of American Medical Informatics Association's Clinical Information Systems Working Group.

At UC Irvine, I serve as Chief Research Information Officer of UC Irvine Health. The core mission of my office is to provide and innovate informatics solutions to facilitate clinical research, accelerate results translation, and engender the transformation of hospitals and clinics into a learning health system. My extensive experience in biomedical informatics research, in addition to my leadership position in overseeing the translational informatics efforts at UC Irvine, make me ideally suited for serving as a co-investigator on the proposed project. Prior to joining UC Irvine, I was Associate Professor of Health Management and Policy in the School of Public Health and Associate Professor of Information in the School of Information at the University of Michigan. I was Director of University of Michigan's Health Informatics Program preparing students for careers that will harness the power of information to enhance health and transform individual health and healthcare.

Veronica Berrocal, Ph.D.
Associate Professor, Department of Statistics
School of Information and Computer Science
University of California, Irvine, CA 92697

Education and Training:

University of Washington, Seattle, WA			
Michigan State University, East Lansing, MI	Statistics	Ph.D.	2007
University "Joseph Fourier" Grenoble, France	Statistics	M.Sc.	2002
now renamed Universite Grenoble Alpes		Diplôme	
	Mathematics	d'études	1998
		approfondies	
University of Rome "La Sapienza", Roma, Italy		(D.E.A.)	
	Mathematics	Laurea	
1996			

Research Focus:
Spatial and spatio-temporal statistics with focus on: 1) environmental exposure assessment; 2) health impact of environmental exposures; 3) environmental risk assessment; 4) data assimilation/data integration; 5) spatial epidemiology.

Professional Experience:

Sept. 2007 – Aug. 2008 NRC Postdoctoral Research Associate, U.S. Environmental Protection Agency, Research Triangle Park, NC

Sept. 2008 – Aug. 2009 Postdoctoral Associate, Department of Statistical Science, Duke University, Durham, NC

Sept. 2009 – Aug. 2010 Postdoctoral Associate, Statistical and Applied Mathematical Sciences Institute (SAMSI), Research Triangle Park, NC

Sept. 2010 – Aug. 2016 Assistant Professor, Department of Biostatistics, University of Michigan, Ann Arbor, MI

Sept. 2016 – Aug. 2019 Associate Professor, Department of Biostatistics, University of Michigan, Ann Arbor, MI

Sept. 2019 – present Associate Professor, Department of Statistics, University of California, Irvine, CA

Honors and awards:

2008 American Statistical Association, Section on Statistics and the Environment (ENVR), Award for Best Poster Presentation at the ENVR workshop.

2012 The International Biometrics Society, Award for best paper published in the Journal of Agricultural, Biological and Environmental Statistics during years 2010-2012.

2015 University of Michigan/NSF Advance Elizabeth Crosby Research Award.

2015 American Statistical Association, Section on Statistics for the Environment (ENVR), Early Investigator Award.

2015-2016 John G. Searle, Assistant Professorship, School of Public Health, University of Michigan

Publications (out of 55 peer-reviewed publications):

1. V. J. Berrocal, Y. Guan, A. Muyskens, H. Wang, B. J. Reich, A. J. Mulholland, and H. H. Chang (2020). A comparison of statistical and machine learning methods for creating national daily maps of ambient PM2.5 concentration. *Atmospheric Environment* **222**, 117-130.
2. O. Gilani, **V. J. Berrocal**, and S. Batterman (2019). Nonstationary spatio-temporal Bayesian data fusion for pollutants in the near-road environment. *Environmetrics*. DOI:10.1002/env.2581.
3. Chen, Y.-H., Mukherjee, B., and **Berrocal, V.J.** (2018). Distributed lag interaction models with two pollutants. Journal of the Royal Statistical Society Series C. In press.
4. O. Gilani, **V. J. Berrocal**, and S. Batterman (2016). Non-stationary spatio-temporal modeling of traffic-related pollutants in the near-road environment. *Spatial and spatio-temporal epidemiology* **18**, 24-37.
5. Gilani, O., **Berrocal, V.J**., and Batterman, S. (2016). Predicting traffic-related pollutant concentrations in near-road urban environments using a Bayesian spatio-temporal model. Spatial and spatio-temporal epidemiology 18, 24-36.
6. Gronlund, C.J., **Berrocal, V.J**, White-Newsome, J.L., Conlon, K., O'Neill, M.S. (2015). Vulnerability to extreme heat by individual-level and neighborhood level land cover and socioeconomic characteristics among the elderly in Michigan, 1990-2007. Environmental Research 136, 449-461.
7. Berrocal, V.J, Gelfand, A.E., and Holland, D.M. (2014). Assessing exceedance of ozone standards: a space-time downscaler of fourth highest ozone concentrations. Environmetrics 25, 279-291.
8. Berrocal, V.J., Gelfand, A.E., and Holland, D.M. (2012). Space-time data fusion under error in computer model output: an application to modeling air quality. Biometrics 68, 837-848.
9. Berrocal, V.J., Gelfand, A.E., and Holland, D.M. (2010). A spatio-temporal downscaler for output from numerical models. Journal of Agricultural, Biological and Environmental Statistics 15, 176-197.
10. Berrocal, V.J., Gelfand, A.E., and Holland, D.M. (2010). A bivariate space-time downscaler under space and time misalignment. Annals of Applied Statistics 4, 1942-1975.

Synergistic Activities:

2011-2018	Associate Editor, Journal of Agricultural, Biological and Environmental Statistics
2014-2015	Ad-hoc member of the Federal Insecticide, Fungicide, Pesticide Act (FIFRA) Scientific Advisory Panel to the US Environmental Protection Agency
2016	Member of the external review panel for the US Environmental Protection Agency on "Significant Impact Levels (SILS) for ozone and fine particle pollution".
2016	Member of the external review panel for the US Environmental Protection Agency on "Environmental Relative Moldiness Index (ERMI)"
2016-2018	Associate Editor, Journal of the American Statistical Association
2017	Ad-hoc member of Biostatistical Methods and Research Design (BMRD) study section of the National Institute of Health
2018-present	Statistical Reviewer, *Journal of the American Medical Association (JAMA) Network-Open*
2018-present	Associate Editor, *Bayesian Analysis*
2019-2020	Ad-hoc member of scientific advisory panels for the Federal Insecticide, Fungicide, Pesticide Act (FIFRA) and the Toxix Substance Control Act (TSCA) of the US Environmental Protection Agency

Suellen Hopfer, Ph.D.

Assistant Professor, Program in Public Health
Department of Health, Society & Behavior
Department of Pediatrics
Department of Asian American Studies
Susan & Henry Samueli College of Health Sciences
University of California, Irvine 92697

Education and Training:

The Pennsylvania State University	Post Doctorate		2011
The Pennsylvania State University	Health Communication	PhD	2009
University of Arizona, Tucson	Human Genetics	MS	1998
Earlham College, Richmond, IN	Economics/German	BS	1992

Research Focus:

Health Communication; Messaging, Designing Prevention Interventions, Health Behavior Change, Health Disparities; Working with schools and safety net community clinics (worked with safety net Planned Parenthood health centers to reach low socioeconomic populations and scale up interventions); Designing family and youth based social media prevention interventions; Culturally grounded community narratives for designing prevention interventions

Professional Experience:

July 2015-present Assistant Professor, University of California, Irvine

Publications

1. Duong, H. & **Hopfer, S**. (2021). Let's Chat: Development of a family group chat cancer prevention intervention for Vietnamese families. *Health Education & Behavior*. 48(2), 208-219. https://doi.org/10.1177/1090198121990389.
2. Masri, S., Simolaris, A**., Hopfer, S**., Wu, J. (2020). Assessment of climate change sentiment, engagement, and adaptation through a community based outreach campaign and questionnaire across the United States. *Earth*, 1(1), 75-96. https://doi.org/10.3390/earth1010006
3. Matlock, M., **Hopfer, S**., Ogunseitan, O. A. (2019). Communicating risk for a climate sensitive disease: A case study of Valley Fever in central California, *International Journal of Environmental Research and Public Health*, 16(18), 3254. https://doi.org/10.3390/ijerph16183254.
4. **Hopfer, S**., Garcia, S., Duong, H., Russo, J. A., Tanjasiri, S. P. (2017). A narrative engagement framework to understand HPV vaccination among Latina and Vietnamese

women in a Planned Parenthood setting. *Health Education & Behavior*, 1-10, DOI: 10.1177/1090198117728761
5. **Hopfer, S**. (2012). Effects of a narrative HPV vaccine intervention aimed at reaching college women: A randomized controlled trial. *Prevention Science*, 13(2),173-182.
6. **Hopfer, S**. & Clippard, J. (2011) College women's HPV vaccine decision narratives, 21(2): 262-77, *Qualitative Health Research*. Doi:10.1177/1049732310383868.
7. Kreager, D., Haynie, D., **Hopfer, S**. (2013). Dating and substance use in adolescent peer networks: A replication and extension. *Addiction*, 108, 638-647. Doi: 10.1111/j.1360-0443.2012.04095
8. **Hopfer, S.,** MacEachren, A. M. (2007). Leveraging the potential of geospatial annotations for group decisions: A communication theory perspective*. International Journal of Geographic Information Systems*, *8*(21), 921-934.
9. Parrott, R. L., **Hopfer, S.,** Ghetian, C. B., Lengerich, E. J. (2007). Mapping as visual health communication tool: Promises and dilemmas. *Health Communication, 22*(1), 13-24.
10. Parrott, R. L., Volkman, J. E., Lengerich, E. J., Ghetian, C., Chadwick, A. E., **Hopfer, S.** (2010). Community involvement: Use of geographic information systems for comprehensive cancer control. *Health Communication*, *25*(3), 276-285.

Synergistic Activities

Since July 2015 I have been faculty at UCI's Program in Public Health in the Department of Health, Society & Behavior where I conduct public health communication focused research (advancing communication theory) applied in the domains of effective messaging approaches around vaccine hesitancy and climate-sensitive health risks. My research includes modeling communication networks, eliciting community narratives, family approaches to health behavior change, and designing prevention interventions for changing health behaviors and building policy support. An additional research area involves the use of real-time social media data to characterize how climate and vaccine risk are discussed among the public, to understand what kinds of engagement strategies can be used strategically to build policy support.

Member of UCI's Solutions that Scale – a climate collaborative https://sites.ps.uci.edu/solutions/

EXHIBIT A6

CURRENT & PENDING SUPPORT

University will provide current & pending support information for Key Personnel identified in Exhibit A2 at time of proposal and upon request from State agency. The "Proposed Project" is this application that is submitted to the State. Add pages as needed.

PI: Jun Wu

Status (currently active or pending approval)	**Award #** (if available)	**Source** (name of the sponsor)	**Project Title**	**Start Date**	**End Date**
CURRENTLY ACTIVE	21RD003	CARB	Examining the Health Impacts of Short-Term Repeated Exposure to Wildfire Smoke	**2**/15/2022	**2**/**28**/202**6**
CURRENTLY ACTIVE	21RD006	CARB	High Spatiotemporal Resolution $PM_{2.5}$ Speciation Exposure Modeling	**3**/**1**/2022	**2**/**28**/2025
CURRENTLY ACTIVE		NIEHS	Research to Action: Inequities in Childhood Life-Course Lead Exposure and Academic and Neurobehavioral Outcomes (I-CLEAN)	7/01/21	6/30/26
PENDING APPROVAL		NIEHS	Impact of Climate Change on Life Expectancy in a Multiethnic Population	12/01/21	11/30/26
PENDING APPROVAL		NIEHS	Air Pollution and Age-Related Eye Diseases	04/01/22	3/31/24
CURRENTLY ACTIVE	HEAPF014	SCAQMD	Impact of Ambient Air Pollution on the Risk and Survival of Breast Cancer in Los Angeles County: The Multiethnic Cohort Study	7/01/20	6/30/22
CURRENTLY ACTIVE	R01 ES030353	NIEHS	Air Pollution and Pregnancy Complications in Complex Urban Environments: Risks, Heterogeneity, and Mechanisms	8/01/19	6/30/23
CURRENTLY ACTIVE	R01 ES026171	NIEHS	A Cohort Study of Air Pollution, Lung Cancer, and COPD in Los Angeles County	2/01/17	8/31/21

Michael MacKinnon					
Status (currently active or pending approval)	**Award #** (if available)	**Source** (name of the sponsor)	**Project Title**	**Start Date**	**End Date**
CURRENTLY ACTIVE	21RD003	CARB	Examining the Health Impacts of Short-Term Repeated Exposure to Wildfire Smoke	**2/15/2022**	**2/28/2026**
CURRENTLY ACTIVE	A20-3584-S003	California Environmental Protection Agency	Carbon Neutrality Studies: Reducing Transportation Fossil Fuel Demand and Emissions, and Managing the Decline in Transportation Fossil Fuel Supply: Study 1	3/19/20	03/18/21
CURRENTLY ACTIVE	19RD026	CARB	Low-Carbon Transportation Incentive Strategies Using Performance Evaluation Tools for Heavy-Duty Trucks and Off-Road Equipment	6/01/20	11/30/2022
CURRENTLY ACTIVE	16RD011	CARB	The Optimal Route for a Clean Heavy Duty Sector in California	6/15/2017	12/14/2020

Shupeng Zhu					
Status (currently active or pending approval)	**Award #** (if available)	**Source** (name of the sponsor)	**Project Title**	**Start Date**	**End Date**
CURRENTLY ACTIVE	21RD003	CARB	Examining the Health Impacts of Short-Term Repeated Exposure to Wildfire Smoke	**2**/15/2022	**2**/**28**/202**6**
CURRENTLY ACTIVE	A20-3584-S003	California Environmental Protection Agency	Carbon Neutrality Studies: Reducing Transportation Fossil Fuel Demand and Emissions, and Managing the Decline in Transportation Fossil Fuel Supply: Study 1	3/19/20	3/18/21
CURRENTLY ACTIVE	19RD026	CARB	Low-Carbon Transportation Incentive Strategies Using Performance Evaluation Tools for Heavy-Duty Trucks and Off-Road Equipment	6/01/20	11/30/2022

Veronica Berrocal					
Status (currently active or pending approval)	**Award #** (if available)	**Source** (name of the sponsor)	**Project Title**	**Start Date**	**End Date**
CURRENTLY ACTIVE	21RD003	CARB	Examining the Health Impacts of Short-Term Repeated Exposure to Wildfire Smoke	**2**/15/2022	**2**/**28**/202**6**
CURRENTLY ACTIVE	21RD006	CARB	High Spatiotemporal Resolution $PM_{2.5}$ Speciation Exposure Modeling	1/15/2022	1/14/2025
PENDING APPROVAL		NIAID	UC Irvine Outbreak Data Science Institute: Preparing a Diverse Workforce for Data Science Intensive Infectious Disease Research	3/01/22	2/28/27
CURRENTLY ACTIVE	IIS 1910281	NSF	CHS Small: Shared Mobility Systems to Address Transportation Barriers of Underserved Urban and Rural Communities	1/01/20	12/31/22
CURRENTLY ACTIVE	R01 HL131610	NHLBI	Characterizing Health Impacts of Built Environment Features using Complex Data	2/15/17	1/31/22
CURRENTLY ACTIVE	R01 HD088638	NICHD	Study of Ovarian Aging and Reserve in Young Women (SOAR)	6/15/17	1/31/22
Suellen Hopfer					
Status (currently active or pending approval)	**Award #** (if available)	**Source** (name of the sponsor)	**Project Title**	**Start Date**	**End Date**
CURRENTLY ACTIVE	21RD003	CARB	Examining the Health Impacts of Short-Term Repeated Exposure to Wildfire Smoke	**2**/15/2022	**2**/**28**/202**6**
PENDING APPROVAL		SANOFI	Vaccine Hesitancy Among Young Men in Botswana	8/15/21	8/14/22

Kai Zheng					
Status (currently active or pending approval)	**Award #** (if available)	**Source** (name of the sponsor)	**Project Title**	**Start Date**	**End Date**
CURRENTLY ACTIVE	21RD003	CARB	Examining the Health Impacts of Short-Term Repeated Exposure to Wildfire Smoke	**2**/15/2022	**2**/**28**/202**6**
CURRENTLY ACTIVE		University of Michigan/PCORI	Enhancing the Cardiovascular Safety of Hemodialysis Care: A Cluster-Randomized, Comparative Effectiveness Trial of Multimodal Provider Education and Patient Activation Interventions	11/2016	10/2021
CURRENTLY ACTIVE		University of Michigan/NIH	Advanced Development and Dissemination of EMERSE for Cancer Phenotyping from Medical Records	8/2017	7/2021
CURRENTLY ACTIVE		University of California San Diego/NHLBI	Protecting Privacy and Facilitating Shared Access of Clinical and Genetic Data of Special Populations	4/2018	11/2021
CURRENTLY ACTIVE		California Mental Health Services Authority	Innovation Technology-Based Mental Health Solutions Program Evaluation	12/2018	05/2022
CURRENTLY ACTIVE		University of California San Diego/NIH	California Precision Medicine Research Program Consortium (All of US)	4/2018	3/2021
CURRENTLY ACTIVE		University of California San Diego/NHGRI	iAGREE: A Multi-Center, Networked Patient Consent Simulation Study	5/2020	2/2022
CURRENTLY ACTIVE		Westat/CDC	Virtual Incident and Severe Influenza Outcomes Network (VISION)	2/2020	9/2021
CURRENTLY ACTIVE		Westat/CDC	Virtual Network to Investigate the Trajectory of COVID-19-Related Severe Outcomes in an Electronic Cohort of Elderly Persons and Persons with High Risk Conditions	5/2020	6/2021

EXHIBIT A7

THIRD PARTY CONFIDENTIAL INFORMATION REQUIREMENT

CONFIDENTIAL NONDISCLOSURE AGREEMENT

EXHIBIT B2

BUDGET PERTAINING TO SUBAWARDEE(S)

Exhibit B2 is not applicable for this Agreement.

EXHIBIT B3

INVOICE AND DETAILED TRANSACTION LEDGER ELEMENTS

In accordance with Section 14 of Exhibit C – Payment and Invoicing, the invoice, summary report and/or transaction/payroll ledger shall be certified by the University's Financial Contact and the PI (or their respective designees).

Invoicing frequency

☒ Quarterly ☐ Monthly

Invoicing signature format

☐ Ink ☒ Facsimile/Electronic Approval

Summary Invoice – includes either on the invoice or in a separate summary document – by approved budget category (Exhibit B) – expenditures for the invoice period, approved budget, cumulative expenditures and budget balance available[1]

- Personnel
- Equipment
- Travel
- Subawardee – Consultants
- Subawardee – Subcontract/Subrecipients
- Materials & Supplies
- Other Direct Costs
    - TOTAL DIRECT COSTS (if available from system)
- Indirect Costs
    - TOTAL

Detailed transaction ledger and/or payroll ledger for the invoice period [2]

- University Fund OR Agency Award # (to connect to invoice summary)
- Invoice/Report Period (matching invoice summary)
- GL Account/Object Code
- Doc Type (or subledger reference)
- Transaction Reference#
- Transaction Description, Vendor and/or Employee Name
- Transaction Posting Date
- Time Worked
- Transaction Amount

[1] If this information is not on the invoice or summary attachment, it may be included in a detailed transaction ledger.

[2] For salaries and wages, these elements are anticipated to be included in the detailed transaction ledger. If all elements are not contained in the transaction ledger, then a separate payroll ledger may be provided with the required elements.

EXHIBIT D

ADDITIONAL REQUIREMENTS ASSOCIATED WITH FUNDING SOURCES

Exhibit D is not applicable for this Agreement.

EXHIBIT E

SPECIAL CONDITIONS FOR SECURITY OF CONFIDENTIAL INFORMATION

Exhibit E is not applicable for this Agreement.

EXHIBIT F

ACCESS TO STATE FACILITIES OR COMPUTING RESOURCES

Exhibit F is not applicable for this Agreement.

EXHIBIT G

NEGOTIATED ALTERNATE UTC TERMS

Exhibit C, Section 14 – Payment & Invoicing is hereby amended to incorporate the following:

Add Item A – Section 6:

6) CARB shall withhold payment equal to 10 percent after the contractor has been compensated for 90 percent of the agreement per Exhibit B1, Budget Justification. The 10 percent shall be withheld until completion of all work and submission to CARB by the University of a final report approved by CARB in accordance with Exhibit A1, Schedule of Deliverables, Section 2. It is the University's responsibility to submit one (1) original and one (1) copy of the final invoice.

Modify Item C – Invoicing, 2 is hereby replaced in its entirety with the following:

2) Invoices shall be submitted in arrears not more frequently ~~than monthly and not less frequently~~ than quarterly to the State Financial Contact, identified in Exhibit A3. Invoices may be submitted electronically by email. If submitted electronically, invoice must include the following certification for State certification to the State Controller's Office, in compliance with SAM 8422.1

   This bill has been checked against our records and found to be the original one presented for payment and has not been paid. We have recorded this payment so as to prevent later duplicate payment.

   Signed: ______________________________

   State Agency Accounting Officer

Add Item E:

E. Advance Payment

1) Nothing herein contained shall preclude advance payments pursuant to Title 2, Division 3, Part 1, Chapter 3, Article 1 of the Government Code of the State of California.

2) Upon termination or completion of this Agreement, Contractor shall refund any excess funds to the CARB. Contractor will reconcile total Agreement costs to total payments received in advance and any remaining advance will be refunded to the CARB's Accounting Office. In the event the Agreement is terminated, total project costs incurred prior to the effective date of termination (including close-out costs) will be reconciled to total project payments received in advance and any remaining advance will be refunded to the CARB. In either event Contractor shall return any balance due to CARB within sixty (60) days, of expiration or earlier termination.