COVER SHEET

Proposal To:	California Air Resources Board	Due Date:	7/5/2023
	1001 I Street, Sacramento, CA 95814	Submitted	7/5/2023
State Agency Contact:	Contact Name:	Phone #	
	Contact Title:	Email:	
Project Title:	Unlocking Health Benefits for Californians through Active Land Management Strategies		
University Name:	University of California, Merced		
Award To:	The Regents of University of California, Merced		
Project Period:	12/01/2023 to 11/30/2026	Funding Amount:	$549,316
IT Activity/Component?	No: X Yes:		
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I certify that this proposal is compliant with the State & University Proposal and Administrative Manual and that the Principal Investigator has approved the Scope of Work and Proposad Budget Estimate, which are compliant with University Policy.

Lauren Hogan

Authorized Official Signature:	Lauren Hogan, Contracts and Grants Officer		
		Date:	7/5/2023

Exhibit A – Scope of Work

Project Summary & Scope of Work

☒ Contract ☐ Grant

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

PI Name: John Abatzoglou

Project Title: Unlocking Health Benefits for Californians through Active Land Management Strategies

Project Summary/Abstract

Briefly describe the long-term objectives for achieving the stated goals of the project.

Ensuring the preservation and well-being of California's Natural and Working Lands (NWL) is of utmost importance due to their capacity to store carbon and promote public health advantages. The Contractor will build upon previous research supported by the California Air Resources Board (CARB) to geographically quantify the public health benefits of enacting management approaches in NWL under near-term climate change that foster resilient ecosystems while mitigating the adverse effects of wildfires. The University of California, Merced (UC Merced or Contractor) has experience with existing ecosystem, health, and air quality models central to CARB's work and with expertise working across diverse biogeographic, climatic, and social landscapes of California. The Contractor will develop an efficient and reproducible framework for quantifying the health benefits of statewide management strategies for NWL in the face of climate change scenarios spanning from 2025 to 2045. The Contractor will update health impact functions based on established relationships between wildfire fine particulate matter (PM2.5) and overall mortality, cardiac, and respiratory impacts, as well as incorporating new research linking PM2.5 to perinatal outcomes. The Contractor will develop a compute efficient methodology for translating wildfire emissions to PM2.5 concentrations at sub-weekly and 2-kilometer (km) scales. The Contractor will use open-source software Environmental Benefits Mapping and Analysis Program-Community Edition (BenMAP-CE), the updated health impact functions, and PM2.5 concentrations for climate and NWL scenarios to quantify potential health benefits of active NWL management. The Contractor will explicitly incorporate differences in health functions by race and socioeconomic status, where available, and elucidate avoided health burdens through NWL management strategies among vulnerable communities as well as geographic hotspots of persistent risk. This project will develop a reproducible workflow for incorporating scenarios of wildfire emissions to health impacts across the state of California that can be used by CARB in continuing work. Ultimately, the work will equip natural and working land management with valuable support in reducing wildfire risks by quantifying the health benefits derived from implementing these strategies.

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, Third Party Confidential Information.

Scope of Work

Describe the goals and specific objectives of the proposed project and summarize the expected outcomes. If applicable, describe the overall strategy, methodology, and analyses to be used. Include how the data will be collected, analyzed, and interpreted as well as any resource sharing plans as appropriate. Discuss potential problems, alternative strategies, and benchmarks for success anticipated to achieve the goals and objectives.

Statement of Significance

Recent increases in the occurrence of large wildfires in California have had significant and widespread impacts to air quality, public health, and the state's economy. Federal, state, and local efforts have been taken to limit the potential for large wildfires through a variety of means including technological means tied to fire prevention, detection, and forecasting, as well as planned efforts to reduce vegetation in regions of heightened fire impacts. CARB plays a vital role in formulating policies and strategies to reduce air pollution and protect the public from exposure to harmful air through modeling future management scenarios and their impacts on wildfires. This project aims to provide CARB with a workflow for quantifying the health benefits of potential proactive management strategies in natural working lands of the state for future climate conditions. This project will thus equip CARB with data and tools to inform decisions on NWL management scenarios based on avoided health impacts from potential future wildfire smoke. Such information can be beneficial to CARB mission to attaining and maintaining healthy air quality for the state and prioritize efforts to improve air quality for groups most vulnerable to air quality impacts.

One of the primary objectives of the project is to assess the direct health benefits of future potential limiting of wildfire smoke impacts on the population of California through active NWL management. To achieve these objectives, the project will update the literature of health impact functions from wildfire PM2.5 (e.g., respiratory illnesses, cardiovascular issues) and incorporate new health impact functions of wildfire PM2.5 on perinatal health outcomes. This work will expand efforts to quantify the future potential health impacts of wildfire PM2.5 and improve the ability of CARB to quantify health impacts from wildfire PM2.5. Secondly, the project will develop a computationally efficient approach for modeling wildfire PM2.5 concentrations across the state by fusing together ecological units (ecounit) fire emissions and high-resolution reanalysis data sufficient for use in future projection modeling. Lastly, the BenMAP-CE modeling framework will be used to integrate health impact functions and spatially explicit wildfire PM2.5 data to quantify health impacts from various potential climate and NWL scenarios. These products can help inform the efficacy of different NWL approaches and locations targeted to abate health impacts on vulnerable communities in the state.

The results of this project will provide CARB with robust scientific evidence, tools, and data to make well-informed policy decisions. By understanding the specific health benefits associated with active NWL management, CARB can advocate for measures to strengthen wildfire mitigation strategies that additionally enhance public health outcomes.

Quantitative assessment of various proactive management efforts in natural working lands can allow CARB to highlight approaches that prioritize efforts to protect vulnerable communities from wildfire smoke exposure. Hence, this project is well connected to CARB's mission of protecting California's residents and environment from the adverse impacts of wildfires, fostering a safer and healthier state for future generations.

Introduction

Since 1970, the wildfire area in California has increased over seven-fold, punctuated by the 2020 and 2021 fire seasons that had the highest carbon and particulate matter emissions in recent decades (CARB, 2022; Jerrett et al., 2022). These changes have been linked to an assortment of factors, including accumulation of fuel due to a century of fire suppression in forested lands (North et al., 2015), and drier fuels linked to human-caused climate change (Abatzoglou & Williams, 2016). Increased emissions from these fires have reversed technological progress made in reducing PM2.5 levels across the western United States (McClure and Jaffe, 2018) and in many areas are the key source of chronic air quality events (e.g., Kalashnikov et al. 2022) that pose significant immediate and long-term health burdens to populations through increased excess morbidity and mortality (Johnston et al., 2012; Prunicki et al 2019, Heft-Neal et al 2022). Climate change is projected to increase fire activity in fuel-rich environments and favor the occurrence of large fires that resist fire suppression efforts (Westerling et al., 2018; Goss et al., 2019) and increase PM2.5 exposure and health impacts (Neuman et al., 2021). However, management of NWL can counteract the influence of a warming climate on fire outcomes in some ecosystems (e.g., Maxwell et al., 2022), while fuels may become self-limiting in other systems (Kennedy et al., 2021). These studies illustrate the importance of scaling up proactive management efforts to reduce negative fire impacts on human health and ecosystems while enhancing longer-term carbon stocks. Initial work from CARB has shown notable differences in wildfire, carbon, and emissions for alternative management approaches in NWL under climate change scenarios relative to a business-as-usual approach (CARB 2022).

Traditional air quality modeling on wildfire emissions for present day or retrospective analysis requires the use of air transport models that ingest information on exactly where and when wildfires occurred. Beyond the need for precise information, these models are computationally intensive. Future wildfire projections and their subsequent emissions done by the state of California do not predict where and when fires will occur. Instead, they project changes to regional fire regimes and emissions. These projections consider variability in future climate, emissions, and management scenarios. This variability requires the simulation of hundreds of potential futures to generate how wildfires will change. For this reason, running air transport models on a monthly basis across all these scenarios is not computationally feasible, nor appropriate for the fire emissions information generated. Therefore, the Contractor will develop a computationally efficient methodology to translate scenarios of future wildfire regimes and emissions to local and sub-weekly air quality data and quantify these impacts on public health. The Contractor will work collaboratively with CARB on the development of this methodology.

The Contractor's interdisciplinary team of applied researchers proposes to leverage and extend existing CARB funded work to elucidate the health benefits of active NWL management over the next two (2) decades. The Contractor will synthesize and integrate disparate health, fire, and smoke datasets to quantify avoided detrimental health impacts at sub weekly and 2 km scales through the implementation of escalated proactive management on NWL. The Contractor will advance the state-of-the-knowledge by leveraging ongoing work by Co-Principal Investigator (Co-PI) Ha on environmental impacts to perinatal health outcomes from PM2.5 and Co-PI Kolden on social vulnerability of communities to wildfire and build upon past CARB funded work by Co-PI Brown on smoke dispersion modeling. In addition to addressing the core scientific tasks, the Contractor seeks to specifically resolve the health benefits of avoided wildfire smoke from proactive NWL management efforts for the most vulnerable communities. Likewise, the Contractor seeks to elucidate seasonal hotspots of elevated exposure with NWL management that may require additional adaptation support to mitigate negative health outcomes. This project will provide insights for implementing NWL management efforts that optimize indirect and direct health benefits from wildfire, reduce wildfire risk to communities and carbon stocks, and thereby promote resilience to climate change. Finally, a central deliverable to CARB will be a reproducible workflow for converting wildfire smoke emissions to health impacts across California that leverages advances in health impact functions, statistical transformations for smoke dispersion, and exposure modeling.

Project Tasks

Task 1 – Literature Review

As part of this project, an important task is to update and review the existing health functions established by CARB specifically for health endpoints related to PM2.5 emissions from wildfires. These health endpoints include mortality, emergency room visits for cardiac, respiratory, and asthma-related outcomes, as well as hospitalizations for respiratory, asthma, and chronic lung disease (as outlined in the 2022 CARB Scoping Plan, Appendix G). In this process, careful consideration will be given to whether these health functions need to be revised based on socioeconomic status. It has been observed through studies that there is an elevated risk of respiratory and cardiovascular diseases associated with wildfire exposure (Liu et al., 2015). Vulnerable populations such as children, seniors, and individuals with underlying chronic diseases are particularly susceptible to health impacts (e.g., Hutchingson et al. 2018). Furthermore, socioeconomic factors, outdoor occupation, and other systemic issues contribute to higher exposure levels and reduced access to mitigation resources, thereby impacting social vulnerability (Lambrou et al. 2023). Additionally, given the increasing number of studies on reproductive and perinatal impacts, it is crucial to incorporate new specific impacts on maternal health outcomes (Amjad et al., 2021) that can be extended to explicitly incorporate the influence of PM2.5 from wildfire smoke.

Task 1.1: Update and Identify Health Impact Functions for Wildfire PM2.5

The Contractor will conduct a systematic literature review and meta-analysis of existing studies on health functions explicitly related to wildfire smoke to update and expand upon the health impact functions identified and developed from CARB contracts 19RD015 (completed in 2024) and 21RD003 (to be completed in 2025) that are examining health impacts from NWL and smoke waves, respectively. The systematic review and meta-analysis will follow the latest version of the Transparent Reporting of Systematic Reviews and Meta-analyses (PRISMA) guidelines. The epidemiological literature on risks specific to wildfire PM2.5 is limited, although numerous studies have been published in the past few years highlighting this as an emerging area of interest. D'Evelyn et al. (2022) conducted a review of wildfire smoke-induced health impacts specifically in the context of prescribed fire for forest management. The Contractor will expand upon this effort by conducting a systematic literature review and specifically seek studies that consider 1) longer-duration (> 1 week) PM2.5 events and 2) compound co-exposures of air-quality-heat extremes where possible, as the field has traditionally looked at exposures separately or not explicitly considered chronic air-quality episodes rigorously. Where available in the literature, the Contractor will also examine characteristics of social vulnerability (e.g., age 65+, minority groups, percent below poverty level) from the health impact studies as social vulnerability is likely to drive differential health function given disparities that different groups face in terms of exposure, access to health care, and pre-existing conditions. Social vulnerability metrics such as these are readily available in census level data and could be applied to refine the social vulnerability mapping effort in Task 3.

The Contractor will include peer-reviewed epidemiologic studies pertaining to wildfire exposures and health outcomes including reproductive outcomes, cardiocerebral complications, respiratory diseases, and mortality. Reproductive outcomes will include preterm birth, low birthweight, small for gestational age. Cardiocerebral complications will include myocardial infarction and stroke. Respiratory outcomes will include asthma and chronic obstructive pulmonary disease. Additional outcomes may be included as they come up in the literature search. The Contractor will focus on augmenting the literature reviews from 19RD015 and 21RD003 and studies published in the last few years. The Contractor will exclude qualitative and non-human studies, and those that do not include specific wildfire-related pollutants (i.e., PM2.5). Where supported by studies, the Contractor will articulate differential health impact functions by population subgroups (e.g., age, race). The literature synthesis will employ search engines including but not limited to Pubmed, Web of Knowledge, and Google Scholar. The synthesis will additionally include details of the version and code of the International Classification of Diseases (ICD) used to account for changes in ICD versions over time. The Contractor will also consult reference lists to identify additional studies as appropriate. The search strategy will include the keywords described in Table 1. Keywords for exposures will be used in conjunction (with boolean operator AND) with keywords for the health outcomes separately. Keywords within the same concept will be combined with an OR operator.

	Concepts	Search strategies
Exposure	Wildfire related PM2.5	• wildfire OR • wildland fire OR • forest fire OR • bushfire OR • prescribed fire OR • prescribed burn OR • Biomass burn AND • PM2.5 OR • smoke
Health outcomes	Mortality	• Death OR • mortality OR
	Respiratory	• Respiratory OR • Cardiorespiratory • Breathing OR • Lungs OR • pulmonary OR • Cardiopulmonary

		• Asthma OR • Chronic obstructive pulmonary disease (COPD) OR • Emphysema OR • hospitalization OR • Emergency
	Cardiocerebral	• myocardial infarction OR • Stroke

Health outcomes (cont.)	Cancer	● cancer OR ● neoplasm OR ● hospitalization OR ● Emergency
	Mental health	● Mental health OR ● Psychiatric OR ● Anxiety OR ● Schizophrenia OR ● Bipolar disorder OR ● hospitalization OR ● Emergency
	Reproductive and pregnancy outcomes	● semen OR ● sperm OR ● fecundability OR ● reproduct* OR ● *fertility OR ● conception OR ● pregnancy OR ● pregnancy loss OR ● miscarriage OR ● prenatal OR ● perinatal OR ● fetal OR ● infant OR ● birth OR ● neonatal OR ● newborn OR ● birthweight OR ● preterm birth OR ● premature OR ● early birth OR ● gestation* OR ● restricted growth OR ● birth defect

Table 1. Search strategy for systematic literature review to complement existing studies.

A team of at least two (2) independent reviewers will review all titles, abstract and full texts of eligible studies. The Contractor will extract information related to study design, study participants and settings, exposure assessment methods, health outcome assessment methods, comparison group, effect estimates and 95% confidence interval, statistical approach, and confounders. The Contractor will specifically document any stratified analyses by sociodemographic characteristics such as race/ethnicity and income. Any discrepancies in data extraction will be resolved through discussion.

Bias in published studies will be assessed using the National Toxicology Program's Office of Health Assessment and Translation (NTP OHAT) risk of bias tool (Rooney et al., 2014). This tool has been widely used in environmental health studies, including the most recent systematic review on wildfires and pregnancy outcomes (Amjad et al., 2021). Briefly, NTP OHAT tool uses

11 questions to evaluate the potential sources of bias in six (6) domains, including selection bias, confounding, performance bias, attrition/exclusion bias, detection bias, and selective reporting bias, all assessed at the outcome level. Each domain is related with scores including low, probably low, probability high, and high. The criteria for each score will be pre-specified. Bias assessment will be performed by at least two (2) independent reviewers. Discrepancies will be resolved by discussion. The Contractor will assess the certainty of the evidence using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework adapted to environmental health reviews (Morgan et al., 2016). The GRADE framework uses a four-level scale to describe the strength of evidence for each outcome. These scales include "high", "moderate", "low", or "very low". Study characteristics that impact the certainty of evidence are depicted in Figure 2 below (adapted from Morgan et al. 2016).

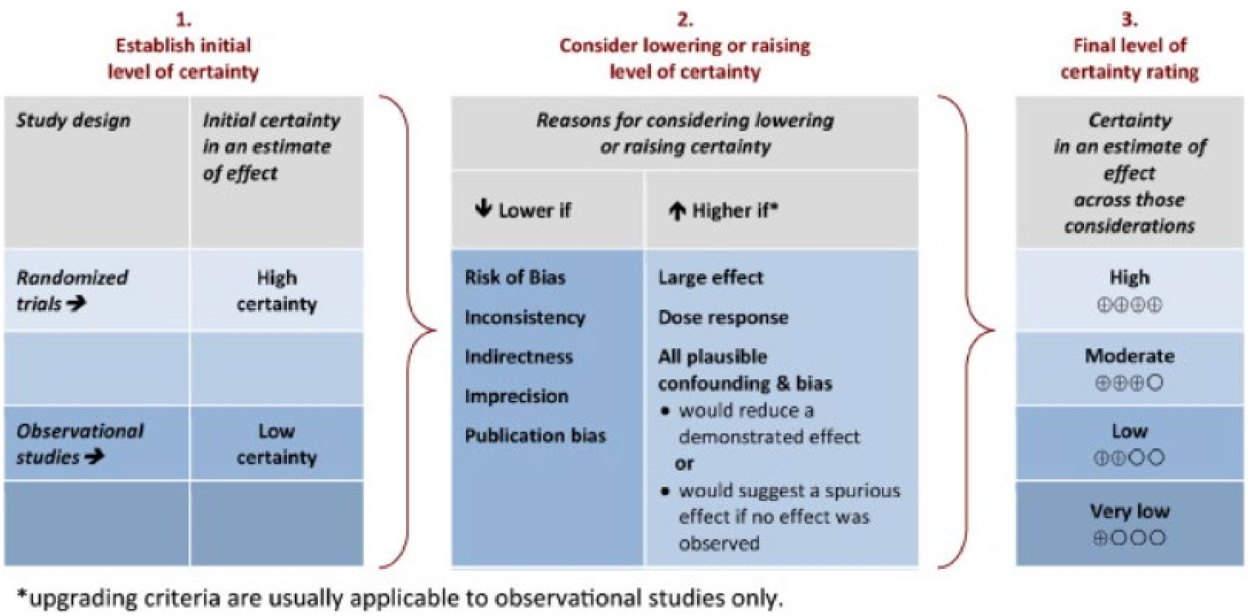


Figure 2. Strength of evidence assessment approach (adapted from Morgan et al., 2016) that will be used in the work.

First, the Contractor will describe study characteristics and risk of bias assessment for each study using tables and figures. Second, the Contractor will also present certainty of evidence for each exposure and outcome combination. Third, the Contractor will standardize all exposure units for all effect estimates to prepare for estimate pooling. For example, the Contractor expects that while some studies report effect estimates for a 5 unit increase in exposure, others may report estimates for other increments. Lastly, if enough studies are available for specific outcome (n>=3), the Contractor will obtain summary estimates across studies. This will be done by using accepted pooling methods or existing meta-analyses that have already conducted systematic reviews of the literature to produced pooled health impact functions. I2 statistics will be calculated to assess the degree of heterogeneity (Higgins et al. 2002). I2 is a quantity that describes the proportion of the variation across studies that is due to heterogeneity rather than chance and has widely been used to assess heterogeneity in systematic reviews. If I2 is <25%, indicating low degree of heterogeneity, the Contractor will use fixed effect models to obtain summary statistics for the overall associations between wildfire PM2.5 and health outcomes of interest. If I2 is >=25%, the Contractor will use mixed models instead. All models will weigh the effect estimates by the inverse of the variance for specific studies. Studies that report estimates for continuous and categorical outcomes will be analyzed separately.

Task 1.2: Develop Health Impact Functions for Wildfire PM2.5 Exposure for Perinatal Outcomes

Co-PI Ha has started examining perinatal health outcomes across the state to climate and air quality extremes, and the Contractor will leverage this ongoing work by explicitly including wildfire smoke data that the Contractor has begun assembling at the zip-code level. This task will examine the influence of short-duration wildfire smoke events (e.g., 1-3 days), compound heat and wildfire PM2.5, and longer-duration (≥ 1 week) wildfire smoke on pregnancy outcomes. The Contractor envisions these new health outcomes functions, including fetal death, infant death, gestational diabetes, and gestational hypertension, being used directly in Task 3 and added to the synthesis. Of note, given the non-acute nature of gestational diabetes and gestational hypertension, these outcomes will only be examined in relation to longer-duration exposures before the event. In other words, because these are not conditions with sudden onset, exposures immediately before the events likely do not have much implications compared to long-term exposure before the event.

Data and participants: The Contractor will obtain perinatal health outcomes including fetal (death before birth), infant death (death within one (1) year of live birth), and gestational complications (diabetes and hypertension) from the California Department of Public Health Office of Vital Statistics. Birth and death certificates (within one (1) year) for all births in California from the years 2009-2019 will be deterministically linked to determine infant mortality outcomes. PI Ha already has Institutional Review Board approval from UC Merced and the Committee for the Protection of Human Subjects.

Exposure assessment: The Contractor will estimate wildfire smoke and heat events using high-resolution validated models. First, daily zip-code level meteorological parameters, including daily maximum temperature, minimum temperature, relative humidity, and dewpoint temperature, were developed by aggregating Gridded Surface Meteorological (gridMET) data to extents of current zip codes. The Contractor will consider multiple metrics of heat including temperature, heat day (defined as a day with temperature exceeding the 98th percentile of zip-code specific annual temperature distribution) and heatwave (defined as at least two (2) consecutive heat days). For each heat day and heat wave definition, the Contractor will use both daily temperature and apparent temperature.

The Contractor will obtain daily wildfire-smoke PM2.5 concentration from Childs et al. 2022, which leverages a machine learning model and a suite of ground-based, satellite, and reanalysis datasets during the study period. Specifically, their approach estimated a measure of the PM2.5 concentration that is attributed to wildfire smoke using measurements at the United States Environmental Protection Agency (US EPA) monitoring stations based on smoke days identified primarily from satellite-based plume classification. To estimate the wildfire-smoke PM2.5 concentration away from the US EPA stations, their approach employed machine learning models trained on the estimated wildfire-smoke PM2.5 concentration at the US EPA stations and other input parameters, including the meteorological variables like the near-surface temperature, moisture information, precipitation, and winds. The resulting spatially varying wildfire-smoke PM2.5 concentration at 10km x10km resolution will be spatially interpolated for each zip code.

Zip-code specific exposures will be spatiotemporally linked with maternal zip code available in birth and death certificates. Short-term exposures will be defined as exposures within 7 days before the mortality event. Long-term exposures will be defined as the whole-pregnancy (up to the point of the event) and average annual exposures within residential zip-codes.

Statistical analyses: The Contractor will assess associations between wildfire/heat exposures and perinatal outcomes using two (2) approaches. For acute/short-term effects, the Contractor will use the case-crossover analyses to allow complete control for time-invariant confounders. Briefly, in this design, each person serves as their own control, and comparisons are made between exposures during a hazard periods (shortly before the event) to control periods during which the event did not happen. Such comparisons allow complete control for individual characteristics that do not change over time. This approach is commonly used in environmental epidemiology with transient exposures and acute health outcomes. Conditional logistic regression models will be used to obtain the associations between mortality outcomes and each 5 units in continuous exposures. The Contractor will also categorize these exposures into categories defined by heat day, heatwave, and smoke day (any day with wildfire smoke PM2.5). For chronic exposures, the Contractor will use logistic regression to estimate associations between exposures and mortality outcomes while adjusting for fetal and maternal characteristics. Of note, given gestational diabetes and hypertension are not considered acute health outcomes with sudden onset, these outcomes will only be assessed in relation to chronic exposures over time (vs. exposures only a few days before onset). We also do not have time of onset for gestational complications.

<u>Task 1 Deliverables</u>: The Contractor will provide an endnote database (or equivalent reference management software) and spreadsheet of the literature review findings which include research articles and health impact functions. Where supported by studies, the Contractor will include differential health impact functions by population subgroups (e.g., age, race). The Contractor will provide a White Paper summarizing the literature review findings including summarized tables of health impact functions in the draft final report. The results from Task 1.2 study of wildfire PM2.5 impacts on perinatal outcomes across the state will be included in the draft final report. The health impact functions from Task 1.2 will be provided in a table/excel spreadsheet.

Task 2 – Develop a Quantitative Approach to Calculate Air Quality Impacts of Wildfire Emissions from Future Statewide Land Management Scenarios for 2025-2045

The Contractor will utilize the wildfire emissions estimates generated by CARB based on outputs from the Regional Hydro-Ecologic Simulation System (RHESSys) model, which is run by Co-PI Bart for a current contract for CARB (20ISD008). This model is designed to consider a range of management scenarios in NWL and climate scenarios spanning the period from 2025 to 2045. The model outputs provide valuable information such as monthly fire extent, carbon fluxes, fire intensity, and other relevant factors that are then translated into fire emissions. Within the land management scenarios, different levels of treatment are taken into account across the state such as 1, 2-2.5, and 5-5.5 million acres/years as well as a business-as-usual (BAU) scenario. These treatments encompass a combination of prescribed fire, thinning, and clearcutting (See 2022 Scoping Plan Appendix I for detail on management scenarios and how management actions are modeled). While the emissions from prescribed fires may be comparatively lower than those from wildfires and result in different health impacts (Williamson et al., 2016), the project involves incorporating any existing prescribed fire emissions into the emissions inventory data for the dispersion modeling task. It is crucial to acknowledge that both fire intensity and dispersion trajectories can significantly differ between wildfires and prescribed fires. These distinctions are not solely rooted in their intensity and plume lofting variations, but more crucially, in their timing and seasonality. This consideration becomes imperative for a thorough health impact analysis. As the fire emissions scenarios include both wildfire and prescribed fire, the health impacts analysis will advance understanding of health trade-offs of NWL scenarios on smoke regimes in California under NWL scenarios.

The Contractor will develop a reproducible framework for integrating the fire emission scenarios utilizing transport and dispersion data from the California and Nevada Smoke and Air Committee (CANSAC) reanalyses products to produce spatially and temporally explicit air quality maps of areas across the state. CANSAC (supported through CARB contract 21AQP013) produces operational forecasts for fire weather and smoke/air quality that have been in service to the state since May 2004 at the Desert Research Institute. CANSAC is an interagency partnership that supports high resolution dispersion modeling for the California/Nevada domain and partners operationally with the United States Forest Service AirFire Team, to model and forecast near-term smoke dispersion from emissions sources. An outgrowth of this activity has been the production of a statewide high-spatial (2-km) and temporal (hourly) historical climatology dataset for use in a wide variety of studies especially focused on air quality and wildfire management. Several agencies have supported the development of this dataset of gridded meteorological outputs at the surface and 32 levels in the upper atmosphere for the period 1980-2022. The outputs are especially useful for calculating smoke related parameters such as mixing height, transport wind, and other air quality indices probabilistically. The 2-km spatial resolution of the CANSAC dataset can readily represent a sub-ecounit and allows for integration at the ecounits described in Appendix I (CARB, 2022). This finer scale spatial resolution better allows for matching up source areas (e.g., emissions) with receptor (community) locations when and where CARB needs to identify such relationships.

For this work to be successful, the reproducible framework will be sufficiently simplified to allow for performance on thousands of future scenarios. Given that future scenario modeling is not designed to provide specific predictions of exact fire location, timing, and behavior, and instead identifies and maps general dispersion patterns over regions and time frames of decades, the methodology will not require the detailed information that traditional air quality and dispersion modeling require. Future projection scenarios can run into the thousands and the methodology will be able translate emissions from each scenario into maps of likely air quality impacts, generated within a reasonable compute time, under one (1) month on CARB's high performance computing cluster.

The following framework as detailed in the below subtasks are necessary to relate CARB's monthly ecounit scale wildfire emissions to the CANSAC 2-km daily spatial scale resolution grid for BAU and NWL scenarios. While the exact steps of the methodology will need to be elucidated during the contract, the Contractor will work iteratively with CARB throughout the duration of the contract to ensure that the processes required to accomplish Task 2 fit CARB's needs.

Task 2.1: Obtain and Work with Future Wildfire Emissions Data from CARB

CARB will provide total monthly PM2.5 for the 12 ecounits outlined in the 2022 Scoping Plan update. These emissions will be accompanied by the proportion of emissions that result from forests, shrublands, or grasslands, and from which ownership within the ecounit. Maps of vegetation types and ownerships can also be provided as needed by contractors. In this way, monthly emissions can be delineated by ecounit, vegetation type, and ownership. Further, monthly emissions will be provided for every year from 2025 to 2045 for five (5) management scenarios, four (4) Global Climate Models (GCM), two (2) Representative Concentration Pathways (RCP), and ten (10) monte carlo scenarios (400 in total). The scenarios provided may be different than the 2022 Scoping Plan scenarios depending on CARB direction. These emissions will only include those coming from wildfires. If feasible and agreed upon between CARB and the Contractor, emissions (and pixel-level emissions profiles distributed across the relevant ecounits) generated by prescribed fire emissions will be developed. However, regardless of ignition source, the method developed by the Contractor should function with the emissions provided.

Task 2.2: Fuel Type and Elevation Integration for Emissions Estimation in CANSAC Grid

The Contractor will acquire fuel type from the Fuel Characteristic Classification System (FCCS) (https://www.fs.usda.gov/research/treesearch/58172), which summarizes and classifies wildland fuel characteristics based on critical factors such as fuel moisture, loadings, and flammability.

The FCCS categorizes fuel properties and fire potentials to elements and landscapes across the United States. These elements include canopy, shrubs, herbaceous fuels, downed wood, litter-lichen-moss, and ground fuels. The FCCS defines a fuelbed as the inherent physical characteristics of fuels that contribute to fire behavior and effects, with each fuelbed representing a fairly uniform scale. For instance, a large area like a 5000 hectare (ha) western sagebrush system might be represented by a single fuelbed, while a smaller area like a 5-ha tropical rainforest may require multiple fuelbeds to account for variations in fuel structure and composition.

The classification system breaks down wildland fuel characteristics into strata and further into categories and subcategories to accommodate the complexity of both natural and managed fuels. By classifying vegetation and fuel components, the FCCS can be used to predict surface fire behavior, crown fire potential and available fuel for estimating consumption, fire effects, and emissions. (https://www.landfire.gov/fccs.php). Fuelbeds provided in the FCCS library (https://www.landfire.gov/viewer/) will be used as starting points for creating fuelbeds. Plant association and forest community guides, photo series, available experimental results and expert opinion might be used to modify the fuelbed descriptions and adjust fuelbed inputs, including loading, depths, percentage cover, and species to represent the fuelbeds identified in the pathways and that fell outside the six (6) important fuelbed types.

The purpose of this task is to determine the potential for flammability and subsequent emissions by ensuring that emissions are only associated with grid cells that have combustible biomass. The Contractor will also acquire an elevation grid and align the FCCS and elevation with the CANSAC grid. This data is essential for understanding how elevation influences fire behavior and potential emissions. This step ensures that the fuel type and elevation information are accurately matched with the spatial resolution of the CANSAC reanalysis products.

Task 2.3: Determine Historical Fire in the CANSAC Grid to Relate to Emissions Sources

For the period 2006-2022, the Contractor will create a dataset of daily fire occurrence within each ecounit. Moderate Resolution Imaging Spectroradiometer (MODIS) satellite derived fire radiative power (FRP) will be used as an indicator of occurrence. The fire detection strategy involves absolute fire detection (based on fire strength) and relative detection (considering temperature variability and reflection). The MODIS product provides fire details like occurrence, location, selection criteria, confidence, FRP, and other attributes. The FRP metric quantifies the radiant heat energy emitted by a fire. MODIS data from Terra and Aqua satellites are acquired twice daily at mid-latitudes. This information will be used in monitoring the spatial and temporal distribution of fires in different ecosystems, detecting changes in fire distribution and identifying new fire frontiers, wildfires, and changes in the frequency of the fires or their relative strength. Additional variables like land cover will be used to isolate burning of agricultural lands and where agency records are available, to identify fire activity attributed with prescribed fire. The MODIS instrument supplies FRP measurements at a native 1-km resolution (https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2013GL059086). An advantage of MODIS is that it is also used in the Fire Inventory from National Center for Atmospheric Research dataset (FINN), which was used to inform the emission calculations shown in Table 30 of Appendix I of the 2022 Scoping Plan (annual modeled California wildfire specific PM2.5 emissions for each future scenario; CARB, 2022).

The Contractor will match the geospatial location of these occurrences to the corresponding CANSAC grid cell. Since MODIS is 1-km in spatial scale, if FRP is detected anywhere within the CANSAC 2-km grid cell that cell will be assigned an occurrence and its associated FRP value. The collected FRP data will be grouped by day and CANSAC grid cell. Each day and grid cell combination will be checked for any FRP occurrence. If so, the grid cell will be marked as having a fire occurrence and aggregate values such as sum of FRP values will be calculated. As a product a dataset with columns for ecounit, date, grid cell coordinates, fire occurrence, and aggregated FRP value will be generated.

Task 2.4: : Create a Regression Predictive Model for Historical and Future Emissions Estimation within CANSAC Grid Cells

The Contractor will develop a statistical regression predictive model that establishes a relationship between FRP within CANSAC grid cells, and CARB's future monthly wildfire emissions by ecounit. This will likely be a simple linear regression model but only through exploration of this analysis and iteration with CARB will it be known if a more robust model will be needed. The purpose of the model is to quantify historical emissions per CANSAC grid cell that historically occurred for the period 2006-2022 and subsequently utilize it for predicting emissions per grid cell based on CARB's monthly wildfire emissions by ecounit from 2025-2045. The objective of the prediction equation is to enable the association of daily emissions with the grid cell by leveraging FRP values, or some statistical/probabilistic derivative thereof. That is, applying appropriate FRP-based empirical data to assigning daily emissions values to the CANSAC grid.

The prediction equation will allow for relating CARB's monthly wildfire emissions back to the grid cell on a daily basis given the measured FRP. That is, daily emission can be estimated using a grid cell's FRP value. Besides utilizing relevant goodness of fit tests, validation of the regression modeling will be to accumulate daily emissions from the grid over each ecounit and divvy those emissions proportionally out from CARB's monthly wildfire emissions. Fire activity from wildfires and prescribed fires will be treated the same in an emission and dispersion context from the perspective that outcomes will be based on underlying fuels consumed, FRP, and fuel moisture and atmospheric conditions. Further validation will include examining autocorrelation in emissions given the expectation of continuity in where fire burns actively in each day.

The creation of this regression predictive model will provide insights into the historical and future emissions patterns associated with FRP grid cells within ecounits. The model's flexibility and robustness will be assessed, ensuring its accuracy in estimating daily emissions based on FRP values. By validating against CARB's original monthly wildfire emissions data and considering autocorrelation effects, the model's reliability will be solidified.

Task 2.5: Convert Emissions to $PM_{2.5}$ Concentration

Once the detailed emissions are available, their dispersion and air quality impacts such as downwind smoke impact based on seasonal weather patterns will be investigated. To do this, Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT), an atmospheric dispersion model developed by the National Oceanic and Atmospheric Administration, will be applied to simulate the transport, dispersion, and deposition of emitted particulates.

The HYSPLIT model calculates the concentration of pollutants in the atmosphere as they disperse from their sources and as needed for assessing and quantifying the health impact of wildfire smoke. The model considers factors such as atmospheric conditions (wind fields, temperature, humidity, precipitation and stability), and emission rates. The model then calculates the trajectories and dispersion patterns of particles over a specified time period. The contractor will do dispersion modeling for California using historic 40-year Weather Research and Forecasting (WRF) climatology to develop maps of probable smoke dispersion that will show where smoke is likely to go if produced in a specific location based on climatology. These maps will allow for informing preferential climatological pathways for transport. HYSPLIT will be initialized for each grid cell containing an emission estimation from prior subtasks. Combining the maps in relation to future monthly emissions will allow for obtaining concentration estimates for each scenario.

Given the propensity for the bulk of wildfire emissions to occur concurrent with extreme fire danger, the Contractor will further refine the sampling to days with high fire danger that have distinct atmospheric stability and circulation patterns. This provides the details necessary to describe the geographic distribution of emissions on the high-spatial resolution grid. It is anticipated that these patterns will change seasonally; the calculation will be done on a monthly basis to capture changes in the annual wind pattern cycle for smoke dispersion.

The Contractor will perform this methodology statewide on no less than 400 wildfire emission scenarios that CARB provides on at least annual time steps from 2025 to 2045. Air quality information will be developed for every year for every scenario at the 2-km spatial scale and be aggregated at the ecounit and statewide scale.

Task 2.6: Analysis of the Simulated Concentrations

Following the generation of the high-spatial resolution emissions and wind patterns, the results will be summarized at a minimum using the US EPA 24-hour PM2.5 threshold of ≥ 35 μg/m3. For any methodology approach and summarization, to the Contractor will consult these potential outputs with CARB subject matter experts.

Task 2 Deliverables: The Contractor will provide a report with diagrams that outlines the proposed method and processing chain that will be used to complete the task. The Contractor will provide all data and maps acquired and developed in task 2. The Contractor will also provide documented code and workflow for calculating air quality impacts of wildfire emissions from future statewide land management scenarios. This will include a description of the analysis steps, any algorithms incorporated in the process, datasets used in the analysis and documentation of data sources, the open-source or commercial software used and in-house developed computer code. The Contractor will detail the methodology and workflow to take fire emissions and convert those into spatially explicit PM2.5 across California using CANSAC reanalyses, summarized suitably and graphically for inclusion in the draft final report. This will also include projected changes in air quality extremes resulting from different NWL scenarios under future climate. The Contractor will work closely with CARB to ensure that the methodology can be executed on their side for continued work that may inform prioritization of areas for NWL management to abate PM2.5 health impacts. The Contractor will copy, compile, and run the methodology on CARB systems to ensure that CARB can perform these routines independently.

Task 3 – Quantify the Health Benefits from Future Statewide Land Management Strategies that Reduce Emissions from Wildfire

Using the deliverables obtained from Tasks 1 and 2, the Contractor aims to assess the health effects resulting from wildfire smoke under various climate and land management scenarios between 2025 and 2045. The primary objective is to quantify the spatial and temporal health benefits across the state achievable through implemented NWL management efforts. To achieve this, the Contractor will employ established and updated health functions that establish a link between PM2.5 and health impacts. Where health functions exist specifically for fire-PM2.5, those will be used. In all other cases, the Contractor will use functions for general PM2.5. These models will assume no changes in population, pre-existing conditions, or medical practices. To facilitate the analysis, the Contractor will utilize the US EPA BenMAP-CE, a widely used open-source health impact model that has been used to assess air quality policies. BenMAP-CE will incorporate user-defined health endpoint functions derived from Task 1, PM2.5 data obtained in Task 2, and relevant demographic datasets from the 2020 census, and health incidence and prevalence rates/data to assess health impacts. Additionally, the BenMAP-CE framework can incorporate updated and new health impact functions as they become available. In cases where there are mature health impact functions specific to demographic or age classes, the Contractor will incorporate specific functions. In all other cases, the Contractor will use a single health impact function for each health outcome and distill resultant health impacts per socioeconomic class. The Contractor will model all-cause mortality, hospitalizations, emergency room visits related to asthma, COPD, respiratory outcomes, cardiac outcomes, and perinatal outcomes building upon previously supported CARB research and updated thereof mentioned in Task 1. Figure 3 provides a general schema of how the results of Tasks 1-2 can inform potential health outcomes through NWL scenarios in Task 3.

The Contractor will use BenMAP-CE to conduct the health impact assessment given the accessibility of the program and transferability of the resultant implementation to CARB. BenMAP-CE has been used to quantify the health impacts of wildfire smoke (Fann et al., 2018) and includes many built in health impact functions that can be used directly or modified to incorporate advances in the science as the Contractor intend to incorporate from the literature review of Task 1. The Contractor will additionally incorporate health impact functions from BenMAP-CE such as those that link PM2.5 to neurological outcomes. Notably, previous studies that have quantified wildfire PM2.5 health impacts have used annual mean concentrations which may not adequately capture the impacts of episodic smoke on health impacts (Fann et al., 2018; Delfino et al., 2009).

BenMAP-CE inputs may offer insights into any interactive point source air quality factors with NWL scenarios. The tool’s ability to utilize air pollution concentrations, population statistics and public health outcomes offers potential to explore relationships between coinciding point source emissions air quality impacts and nonpoint source emissions resulting from both wildfire smoke and management/mitigation measures. Interactive emissions source scenarios may provide insight into the most effective NWL management strategies to reduce health impacts of wildfire for the most vulnerable communities that are compoundly impacted by industrial and environmental externalities. The immediate and increasing risk to these communities poses an additional need for accessible, public, and quantitative public health risk assessment tools. There is a need for researchers, policymakers, and managers to expand understanding of integrated source air pollutant emissions and public health outcomes. This becomes increasingly true as regulators and industries introduce more complexity into NWL management strategies. Such a significant shift in policy essentially develops an engineered environment approach with sweeping and compounding impacts to air quality within the state.

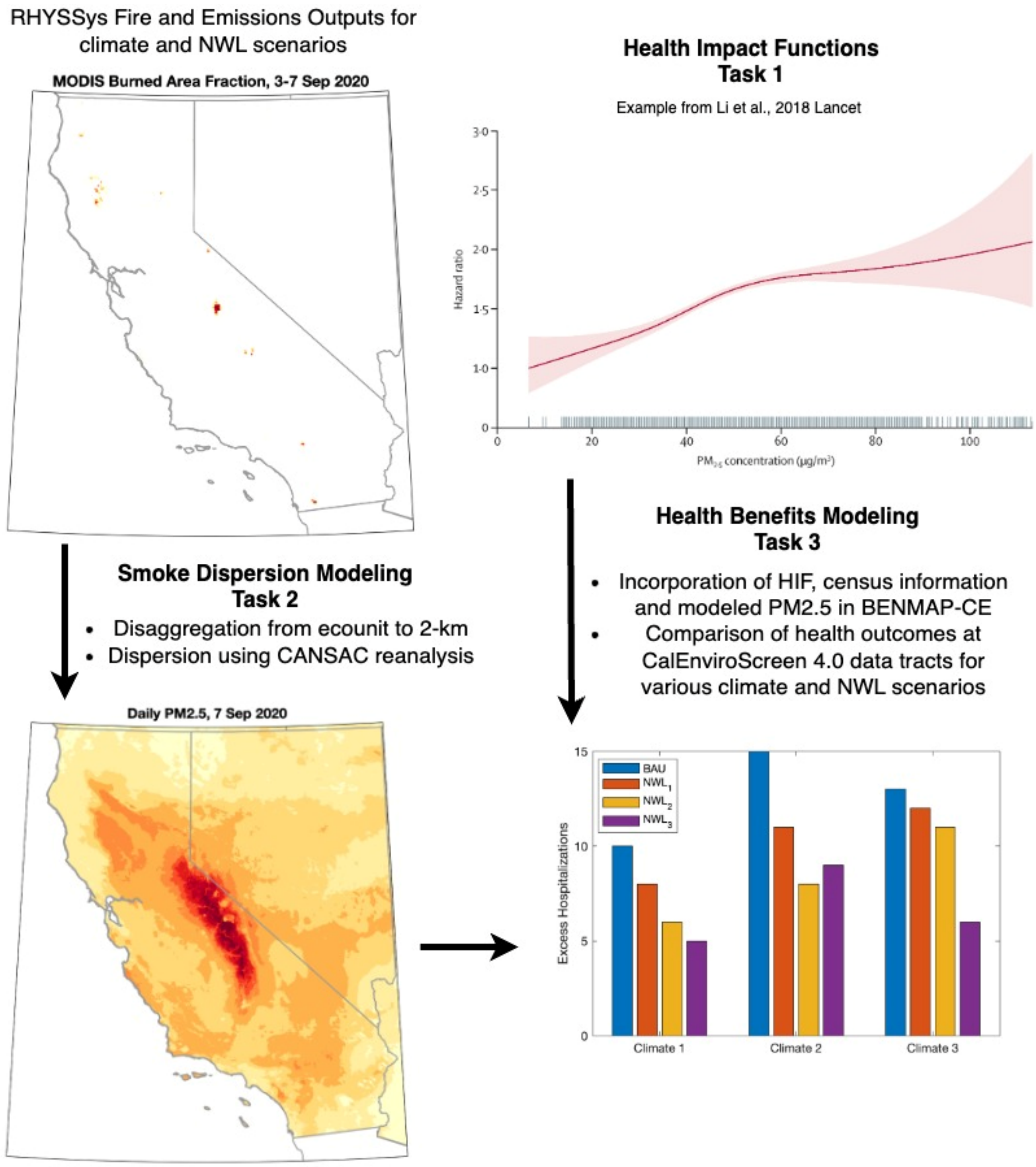


Figure 3: General workflow connecting results from Tasks 1-2 to assess health benefits at zip code scales achieved through NWL scenarios in Task 3. This visualization uses MODIS daily burned area fraction, modeled total PM2.5 during 7 Sep 2020 and an illustrative example of a health impact function from *Li et al., 2018* to show the types of outcomes the Contractor envision producing. The resultant outcomes in the bottom-right show event or annual based health impact for sample zip code according to various NWL and climate scenarios.

The Contractor will perform health impact analyses at least annually for each climate and NWL management scenario throughout the 2025-2045 period. The results obtained will be compared to a business-as-usual land management approach, providing valuable insights for decision-makers. The Contractor will provide valuable insights into the sub-regional health benefit from NWL management scenarios, with a particular focus on vulnerable and overburdened communities, including SB535 Disadvantaged Communities. To do so, the Contractor will build on the approach adopted by the California Office of Environmental Health Hazard Assessment as part of its California Communities Environmental Health Screening Tool (CalEnviroScreen 4.0). The Contractor will utilize data and metrics developed by CalEnviroScreen 4.0, or other metrics identified by CARB. CalEnviroScreen aggregates census data at the census tract scale to 21 total impact indices, including 13 pollution burden metrics and eight (8) population characteristics metrics. For this Task, the Contractor will utilize two (2) Pollution Burden metrics (Ozone and PM2.5) that currently reflect where the highest concentrations of those two (2) pollutants concentrate annually due to non-fire related activity (thus, smoke will exacerbate such concentrations).

Task 3.1: Set up BenMAP-CE for California

The Contractors will set up a working version of BenMAP-CE for California that can operate at the desired spatial scales of interest (i.e., zip code and sub-weekly timescales) and incorporate updated health impact functions not natively present in BenMAP-CE. The health impacts analysis will be conducted for at minimum the following health endpoints: mortality, emergency room visits and hospitalizations for asthma and respiratory outcomes, and perinatal outcomes. Additional health impacts from Task 1 will be added where both health impact functions and requisite baseline datasets exist. Once final health outcomes and their respective health impact functions are chosen for inclusion in the analysis, the Contractor will acquire the corresponding and health incidence and prevalence data. Baseline health data at zip code levels (herein, Zip Code Tabulation Areas) will be acquired from the California Department of Health Care Access and Information for representative historical years (2011-2020) using an existing project for which Co-PI Ha has Institutional Review Board IRB approval for. These baseline data will consist of annual rates of health impacts at the zip code level. The Contractor will explore approaches to refine baseline incidence data at zip code levels to account for gender/age/racial backgrounds. Likewise, where differences in wildfire PM2.5 health impact functions exist in the literature (Task 1.1), the Contractor will apply such differential effects into BENMAP-CE modeling efforts.

Another subtask for 3.1 involves incorporating wildfire PM2.5 data to zip code levels. The standard approach for aggregating environmental data to a unit area (e.g., zip code) is to take a geographic average. This may be acceptable where environmental variables are well mixed or population is well distributed area a unit. To account for the heterogeneous distribution of population density in some larger more rural zip codes, the Contractor will use existing gridded population density to estimate population weighted PM2.5 for each zip code which may materially differ from area-weighted PM2.5. The resultant population-weighted PM2.5 will be used as input into BENMAP-CE.

Health impacts for a given outcome (e.g., Asthma hospitalizations) through BENMAP-CE are modeled as a function of (a) air quality pollutant (i.e., wildfire PM2.5 from Task 2), (b) baseline health data for a given geography (i.e., underlying incidence of Asthma hospitalizations per capita per year), and (c) health impact function that estimate the additional likelihood of adverse health impacts with increased pollutants (i.e., from Task 1.1). These numerically yield an effective estimate that can be scaled across the population within a zip code to approximate modeled health impacts (i.e., number of people with Asthma hospitalizations in the zip code). In addition to quantifying avoided health impacts, BenMAP-CE calculates the economic value of avoided health effects. The Contractor will set up BenMAP-CE to quantify the economic value of the health benefits from NWL scenarios per the difference in modeled economic value compared the BAU scenario. The Contractor will incorporate specific economic valuation for health impacts from California as feasible. This initialization task will occur in parallel with the work for Task 2 to expedite the resultant scenarios into Task 3.2. The Contractor will document the procedures for setting up this workflow to ensure reproducibility by CARB.

Task 3.2: Model Future Health Impacts and Impact Avoidance for NWL Management Scenarios

Building on the working setup from Task 3.1, the Contractor will use BenMAP-CE and wildfire PM2.5 from Task 2 to model future health impacts and impact avoidance through NWL management scenarios, including the economic value of avoided health impacts. Following the overall workflow in Figure 3, the procedure will use wildfire PM2.5 data from Task 2 and health impact functions and baseline incidence data from Task 1.1. Data will be processed through BenMAP-CE to estimate the health effects from future NWL management scenarios compared to the BAU scenario to quantify the health benefits at zip code scales. For example, fire emissions at the ecounit scale will be transformed into spatially explicit wildfire PM2.5 through Task 2 (Fig 3 left panel) and serve as one (1) branch of inputs to BenMAP-CE. Likewise, for all available health impact functions compiled in Task 1, the Contractor will apply such functions by combining zip code PM2.5 data, baseline incidence data, and health impact function data. Across a set of scenarios or ensemble, the Contractor will provide quantitative estimates for various climate and NWL management approaches at zip code scales and at the ecounit and statewide scale to the extent possible. (lower-right of Figure 3).

This will require the Contractor to run a large ensemble of experiments based on available output from Task 2 simulations necessitating an efficient process for processing data per Task 3.1. Using BenMAP-CE runs from many ensembles, the Contractor will identify the health benefits of NWL treatment plans across the state including, where simulations are available, the efficacy of NWL applied to specific ecounits (e.g., isolating the influence of avoided health impacts from NWL treatment of an ecounit in the Tahoe basin). The Contractor will develop a set of map layers that elucidate the overall health benefits geographically across the state. This will identify areas that may benefit the most from NWL management to reduce wildfire.

Task 3.3: Quantify Avoided Impacts to Vulnerable Communities and Hotspots of Continued Risk

Results from Task 3.2 will be used with data from CalEnviorScreen to identify avoided health impacts to vulnerable communities. This will include avoided PM2.5 exposure (e.g., days of PM2.5 exceeding US EPA standards) as well as quantitative health impacts outcomes from BenMAP-CE. The resultant models are also hypothesized to show geographic hotspots of continued risk or even elevated risk to communities under future climate and NWL scenarios. The Contractor will identify these hotspots – identified based on elevated data or clustering of data compared to the expected number given a random distribution of events – and particularly geographic hotspots of vulnerable communities from the model runs.

To understand impacts to the most vulnerable demographics, the Contractor will conduct a spatial overlay-based analysis utilizing outputs from BenMAP-CE and CalEnviroScreen 4.0. CalEnviroScreen 4.0, meets the requirements of Senate Bill (SB) 535 by assigning values to factors of socioeconomic demographic data from the US Census and Pollution Burden data from CalEPA to produce an overall index score for each census tract in the state (https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40). CalEPA then classifies the top 25% of census tracts with the highest total CalEnviroScreen scores as Disadvantaged Communities in accordance with SB 535. In order to translate the results (produced at a zip code level) to those from CalEnviroScreen (at a census tract scale) the Contractor will use a crosswalk (https://www.huduser.gov/portal/datasets/usps_crosswalk.html).

The Contractor will create a four (4)-class Disadvantaged Communities geospatial layer utilizing the CalEnviroScreen 4.0 percentile geospatial dataset, where Class 1 will be the SB 535 Disadvantaged Communities census tracts (top 25% of CalEnviroScreen 4.0 scores) and classes two (2), three (3), and four (4) will be the next three (3) quartiles (with Class four (4) representing the least disadvantaged communities. The Contractor will overlay this four (4)-class dataset on the set of map layers produced in Task 3.2 to identify the total, range, and average overall health benefits and avoided health impacts for each of the four (4) classes/quartiles of Disadvantaged Communities. Further, consistent with the system utilized by and to be compatible with CalEnviroScreen 4.0, the Contractor will rank the average avoided health impacts and health benefits across the NWL scenarios for each census tract and will cross-tabulate and map the avoided health impacts/health benefits against the CalEnviroScreen 4.0 score by decile. This map will spatially highlight which disadvantaged communities will benefit the most from avoided health impacts and benefits of NWL scenarios, and which disadvantaged communities will still be at high risk due to minimal avoided impacts (Figure 4).

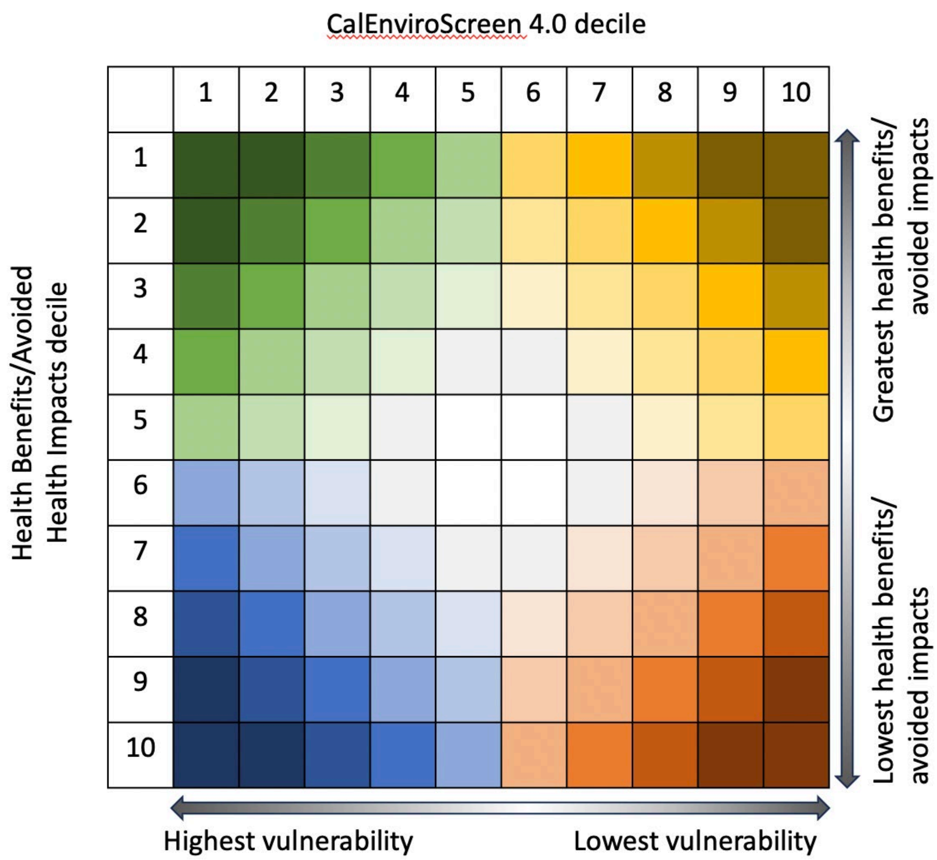


Figure 4: Mock-up of proposed legend for mapped crossed-tabulated Vulnerability – Health Avoidance census tracts by decile. For example, darkest green census tracts would be the most vulnerable communities that would have the greatest avoidance of health impacts under NWL scenarios, while dark blue census tracts would be the most vulnerable communities that would have limited avoided health benefits through NWL scenarios. By contrast, yellow census tracts would be those would see high avoided health impacts but are the least vulnerable communities.

Task 3 Deliverables: The Contractor will provide a report with diagrams that outlines the proposed method and processing chain that will be used to complete the task. The Contractor will provide all data and maps acquired and developed in Task 3. The Contractor will provide a report describing the methodological approaches used in the health impact analysis which will be included in the draft final report. The report will additionally outline health impacts and benefits from different NWL scenarios at zip code scales across the state, consistent with CalEnviroScreen 4.0. Finally, the Contractor will provide all pertinent data, code, and instructions in the implementation of BenMAP-CE to CARB to ensure the results are replicable for future work.

Task 4 – Interim Meetings and Reporting

PI Abatzoglou will be primarily responsible for standing at least monthly meetings with CARB staff on the project throughout its duration. Members of the research team actively working on topics will participate in the meeting to encourage collaboration between our group and CARB throughout. The Contractor will provide quarterly progress reports, and quarterly progress update meetings. The Contractor will provide interim reports for Task 2 and Task 3 by the end of Year 2 that demonstrates that progress is being made toward the final deliverables for Tasks 2 and 3. CARB staff may also contact individual team members funded by this project to ask for updates, clarification, or for collaboration.

Task 5 – Final Report and Sharing of Results

The Contractor will present the work to either an in-person or virtual seminar that provides a high-level overview of the goals, approaches, and conclusions of the project. Many of the PI's have had extensive work in scientific communication and are well versed in communicating with audiences from academic and non-academic backgrounds. The Contractor will work to develop a plain language summary of the key findings that are accessible to a broad audience and available in English and Spanish. The Contractor will generate a draft final report and final report that incorporates all findings from the entire project and includes final results and interpretation from all scenarios assessed. In addition, the Contractor will provide geospatial data layers (e.g., PM2.5 and avoided health impacts through various NWL management strategies). The Contractor will additionally provide workflows (e.g., documented code, functions) to reproduce analyses from Tasks 1-3. The Contractor will work closely with CARB to ensure that the workflows, code, and data are accessible and documented sufficiently, and can run on CARB systems. After CARB review and approval of manuscripts, the Contractor will publish least two articles that will be submitted to peer-review open access journals from Task 1 and Task 3. All code and documentation used to generate data and workflows in this project will be provided to CARB in a form that is readable and understandable.

Conclusion

The project aims to integrate several key components to comprehensively assess the health impacts of wildfire smoke in California. The Contractor plan to enhance existing health functions for wildfire smoke, ensuring a more comprehensive understanding of the health risks faced by vulnerable populations. These results will be combined with smoke dispersion modeling to quantify the health impacts at the community scale across the state across a suite of management scenarios in NWL. The resultant outputs will be used to quantify the health benefits for Californians by escalating proactive management in NWL. Additionally, the research will shed light on specific communities that require additional resources and support to cope with the persistent challenge of wildfire smoke.

2. Project Schedule

The tasks and sub-tasks are broken down into leads and timelines in the Gantt chart below. The Contractor envisions temporal coordination on Tasks 1-3 as Task 3 is dependent on having data from tasks 1-2. However, the Contractor will commence work on all three (3) tasks in Year 1, allowing for more seamless operation of the outputs from Tasks 1-2 to be incorporated into the modeling framework of Task 3. The Contractor will communicate with CARB well ahead if delays in subtasks are encountered.

	Year 1				Year 2				Year 3			
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Task 1: Literature Review												
Task 1.1: Update and Identify Health Impact Functions for Wildfire PM2.5	■	■	■	■	■	■	■	■				
Task 1.2: Develop Health Impact Functions for Wildfire PM2.5 Exposure for Perinatal Outcomes	■	■	■	■	■	■	■	■				
Task 2: Develop a Quantitative Approach to Calculate Air Quality Impacts of Wildfire Emissions from Future Statewide Land Management Scenarios for 2025-2045												
Task 2.1: Obtain and Work with Wildfire Emissions Data from CARB	■											
Task 2.2: Fuel Type and Elevation Integration for Emissions Estimation in CANSAC Grid	■	■										
Task 2.3: Determine Historical Fire in the CANSAC Grid to Relate to Emissions Sources	■	■	■	■								
Task 2.4: Create a Regression Predictive Model for Historical and Future Emissions Estimation within CANSAC Grid Cells					■	■						
Task 2.5: Convert Emissions to PM2.5 Concentration							■	■	■			
Task 2.6: Analysis of the Simulated Concentrations							■	■	■	■		
Task 3: Quantify the Health Benefits from Future Statewide Land Management Strategies that Reduce Emissions from Wildfire												
Task 3.1: Set up BenMAP-CE for California				■	■	■						

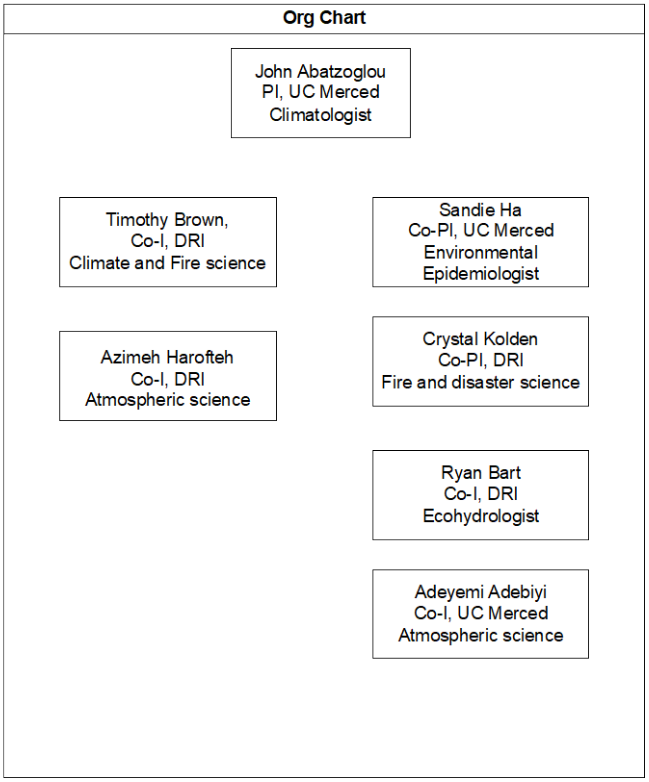
Task 3.2: Model Future Health Impacts and Impact Avoidance for NWL Management Scenarios					■	■	■	■	■	■		
Task 3.3: Quantify Avoided Impacts to Vulnerable Communities and Hotspots of Continued Risk									■	■	■	
Task 4: Interim Meetings and Reporting	■	■	■	■	■	■	■	■	■	■	■	■
Task 5: Final Report and Sharing of Results											■	■

3. Project Management Plan

The Contractor brings together a diverse range of qualifications and experiences across the fields of public health, meteorology, and fire science that make us well-suited for this project. Each member possesses a deep understanding of the subject matter, relevant expertise in their fields, and proven ability to work across disciplines on applied research problems. The Contractor has a track record of successfully collaborating on complex projects including several past and current projects that can be leveraged in the proposed work plan. Kolden and Brown have multiple decades of applied research experience on biophysical and social aspects of wildfire in California and extensive experience working with agencies. Ha has an extensive track record of publications on the impacts of air quality and heat stress on health outcomes in California. Adeyemi leads research on the impacts of dust and smoke aerosols and is an active PI on a project looking at health impacts in California’s central valley. Abatzoglou is an applied climatologist who has extensive work on climate impacts across the western US including those related to wildfire and air quality. Bart is an ecohydrologic modeler who leads research examining the relationship between water, vegetation, and fire in California and is an active PI on a CARB project generating the source of emissions for this proposed project. Drawing on our combined knowledge and past accomplishments, the Contractor are confident in our ability to deliver outstanding results and meet the project's objectives.

As PI, Abatzoglou will be responsible for overseeing the project as a whole and be the primary communication point with CARB on project matters. They will contribute research expertise to all three (3) Tasks, take the lead on Task 3, and devote approximately 10% of his time over the three-year period to this project. Dr. Ha will be the lead for Task 1 with the assistance of a graduate assistant in their lab, help with the integration components of Task 3, and devote 8% of their time to this project. Dr. Bart will provide assistance with fire modeling in Task 2 and devote 2% of their time to the project. Dr. Brown will lead the smoke dispersion modeling in Task 2 and devote 20% of their time to the project. Dr. Kolden will assist with the health integration and synthesis work in Tasks 1 and 3 and will devote 4% of their time to the project. Dr. Harofteh will assist with the smoke dispersion modeling from CANSAC and devote 80% of their time to the project. Dr. Adeyemi will assist with the smoke dispersion modeling in Task 2 and devote 2% of their time to the project. All personnel will contribute to various syntheses and papers resulting from the work.

Organizational Chart



Data Management Plan

The Contractor will use appropriate data and metadata storage standards for storing the spatio-temporal data generated by the project. Data will be spot checked and compared among the Contractor and CARB team to ensure readability and quality assurance of the data. The Contractor will adopt scalable spatial-temporal data formats, such as netCDF and GeoJSON/Shapefiles formats. Metadata will be added to the data to reproduce basic analyses and will be well structured and commented.

In progress datasets will be accessible to all project personnel and CARB via password-protected servers at UC Merced and Desert Research Institute (DRI), during the lifetime of the project and the generation of publications that extend beyond the end of the project. The project has no sensitive data.

The Contractor will deposit all data, software, and metadata to locations highlighted by CARB to ensure accessibility. Where deemed appropriate by CARB, data will be open access and available for use without additional permissions or fees. Any errors noted after publication of the data, by our research team or by others, will be communicated immediately to the archive and will follow their guidance for updating the data and metadata. All project publications will be made publicly available at the time of publication through open access venues.

Facilities

All PIs, collaborators, and graduate student will have access to computers, both desktop and laptops, from the resources supplied by PI. In addition, all PIs and collaborators have in-house instructional and technical sections able to assist in maintaining internet connectivity, software installation and hardware maintenance.

UC Merced

The Climatology Laboratory research group at the University of California, Merced has four (4) high-end Linux servers with over 500 total processors in addition to nearly 180TB of hard drive storage and FTP access for data transfer. Most of the computational burden occurs using MATLAB or R on servers supported through UC Merced for an annual fee. Much of the data services including climate-based web-tools are housed at the Northwest Knowledge Network (NKN), which is a member node of DataONE. Datasets are archived for public access through NKN.

The MERCED Cluster (Multi-Environment Research Computer for Exploration and Discovery Cluster) is available for all faculty projects at no cost. It is a Linux cluster composed of - 100+ nodes with between 20 and 42 cores, from 128G to 256G per machine for a total of 2000+ core and 18T of RAM. - 6 GPU Nodes with 12 NVIDIA Tesla P100- 5 storage nodes for a total of 350TB. All above nodes are interconnected via infiniband w/ RDMA for fast (25Gbits/s) and for low latency (sub ms) data transfer. The network has also been extended over existing infrastructure so that individual labs hosting specialized scientific instrumentation, such as microscopes and imagers, are also connected to provide 10-40Gbps when required. This allows researchers to share their data with centralized computational resources, such as MERCED, or with external collaborators.

Desert Research Institute

Computer: All DRI faculty and staff have the necessary computer hardware, software, and network support to fulfill the requirements of this project. With respect to computer hardware a distributed environment containing personal computer (PC), Apple and other laptop and desktop platforms exists, with Windows, Linux and other operating systems supported. DRI's Atmospheric Science Division also contains several computational clusters. These clusters will be utilized to the extent possible.

Office: All DRI faculty and staff have office and infrastructure support to fulfill the requirements of this project.

Communications: DRI has multiple conference rooms and a PC Lab/Classroom environment in both Reno and Las Vegas campuses. There are 6 HD Video-conference units in Reno and 3 HD Video-conference units in Las Vegas utilizing Polycom video-conferencing hardware. Web-based collaborative software (Microsoft Teams and One-Drive) are available to DRI-Employees in all rooms. The PC Labs in both locations consist of 18 installed computers for class attendees as well as one (1) "teacher" computer. The rooms vary in size and occupancy, ranging from 8 to 90 occupants. The larger rooms offer flexible layout configurations.
Other Resources: DRI is in proximity (2 miles) to the Reno campus of the University of Nevada and participates heavily in UNR's Atmospheric Science graduate and undergraduate degree programs, with B.S., M.S. and Ph.D. degrees offered. The program has strengths with respect to cloud systems and cloud-aerosol interactions, numerical modeling, multiscale dynamics, and regional climate. DRI serves as the host institution for the Western Regional Climate Center, providing products and services to a variety of users within the Intermountain and Pacific West.

4. References

Abatzoglou, J. T., & Williams, A. P. (2016). Impact of anthropogenic climate change on wildfire across western US forests. Proceedings of the National Academy of Sciences of the United States of America, 113(42).

Amjad, S., Chojecki, D., Osornio-Vargas, A., & Ospina, M. B. (2021). Wildfire exposure during pregnancy and the risk of adverse birth outcomes: A systematic review. Environment International, 156, 106644.

D'Evelyn, S. M., Jung, J., Alvarado, E., Baumgartner, J., Caligiuri, P., Hagmann, R. K., et al. (2022). Wildfire, Smoke exposure, human health, and environmental justice need to be integrated into forest restoration and management. *Current Environmental Health Reports*, *9*(3), 366–385.

Depsky, N. J., Cushing, L., & Morello-Frosch, R. (2022). High-resolution gridded estimates of population sociodemographics from the 2020 census in California. *PLoS One*, *17*(7), e0270746.

Goss, M., Swain, D., Abatzoglou, J., Sarhadi, A., Kolden, C., Williams, A., & Diffenbaugh, N. (2020). Climate change is increasing the risk of extreme autumn wildfire conditions across California. Environmental Research Letters.

Higgins, J. P. T., & Thompson, S. G. (2002). Quantifying heterogeneity in a meta-analysis. Statistics in Medicine, 21(11), 1539–1558.

Hutchinson, J. A., Vargo, J., Milet, M., French, N. H. F., Billmire, M., Johnson, J., & Hoshiko, S. (2018). The San Diego 2007 wildfires and Medi-Cal emergency department presentations, inpatient hospitalizations, and outpatient visits: An observational study of smoke exposure periods and a bidirectional case-crossover analysis. PLoS Medicine, 15(7), e1002601.

Jerrett, M., Jina, A. S., & Marlier, M. E. (2022). Up in smoke: California's greenhouse gas reductions could be wiped out by 2020 wildfires. Environmental Pollution, 310, 119888.

Kalashnikov, D. A., Schnell, J. L., Abatzoglou, J. T., Swain, D. L., & Singh, D. (2022). Increasing co-occurrence of fine particulate matter and ground-level ozone extremes in the western United States. Science Advances, 8(1). https://doi.org/10.1126/sciadv.abi9386

Kennedy, M. C., Bart, R. R., Tague, C. L., & Choate, J. S. (2021). Does hot and dry equal more wildfire? Contrasting short- and long-term climate effects on fire in the Sierra Nevada, CA. Ecosphere, 12(7), e03657. https://doi.org/https://doi.org/10.1002/ecs2.3657

Lambrou, N., Kolden, C., Loukaitou-Sideris, A., Anjum, E., & Acey, C. (2023). Social drivers of vulnerability to wildfire disasters: A review of the literature. *Landscape and Urban Planning*, *237*, 104797.

Liu, J. C., Pereira, G., Uhl, S. A., Bravo, M. A., & Bell, M. L. (2015). A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke. Environmental Research, 136, 120–132.

Maxwell, C., Scheller, R., Long, J., & Manley, P. (2022). Forest management under uncertainty: the influence of management versus climate change and wildfire in the Lake Tahoe Basin, USA. *Ecology and Society*, *27*(2).

McClure, C. D., & Jaffe, D. A. (2018). US particulate matter air quality improves except in wildfire-prone areas. Proceedings of the National Academy of Sciences.

Neumann, J. E., Amend, M., Anenberg, S., Kinney, P. L., Sarofim, M., Martinich, J., et al. (2021). Estimating PM2. 5-related premature mortality and morbidity associated with future wildfire emissions in the western US. *Environmental Research Letters*, *16*(3), 35019.

North, M. P., Stephens, S. L., Collins, B. M., Agee, J. K., Aplet, G., Franklin, J. F., & Fulé, P. Z. (2015). Reform forest fire management. Science, 349(6254), 1280–1281.

Prunicki, M., Kelsey, R., Lee, J., Zhou, X., Smith, E., Haddad, F., et al. (2019). The impact of prescribed fire versus wildfire on the immune and cardiovascular systems of children. Allergy, 74(10), 1989.

Rooney, A. A., Boyles, A. L., Wolfe, M. S., Bucher, J. R., & Thayer, K. A. (2014). Systematic review and evidence integration for literature-based environmental health science assessments. Environmental Health Perspectives, 122(7), 711–718.

Westerling, A. L. (2018). Wildfire Simulations for California's Fourth Climate Change Assessment: Projecting Changes in Extreme Wildfire Events with a Warming Climate: a Report for California's Fourth Climate Change Assessment. California Energy Commission.

Williamson, G. J., Bowman, D. M. J. S., Price, O. F., Henderson, S. B., & Johnston, F. H. (2016). A transdisciplinary approach to understanding the health effects of wildfire and prescribed fire smoke regimes. *Environmental Research Letters*, *11*(12), 125009.

CONFIDENTIAL HEALTH DATA AND PERSONAL INFORMATION (OPTIONAL)

CARB will not be provided access to and will not receive any confidential health data or other confidential personal information under this contract. Further, CARB will have no ownership of confidential health data or other confidential personal information used in connection with this contract. The entities conducting the research in this contract will follow all applicable rules and regulations regarding access to and the use of confidential health data and personal information, including the Health Insurance Portability and Accountability Act (HIPAA) and requirements related to the Institutional Review Board (IRB) process. CARB will not be a listed entity with authorized access to confidential information pursuant to the IRB process for this contract.

HEALTH AND SAFETY

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

Exhibit A1

Schedule of Deliverables

List all items that will be delivered to the State under the proposed Scope of Work. Include all reports, including draft reports for State review, and any other deliverables, if requested by the State and agreed to by the Parties.

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
Interim Reports	Interim reports for Tasks 2 and 3 that show progress made toward end goals of the project.	Month 18
Results from Literature Review – Task 1.1	Endnote database with literature review findings. Table/excel spreadsheet of health impact functions. Where supported by studies, the Contractor will include differential health impact functions by population subgroups (e.g., age, race).	Month 24
Summary of Literature Review – Task 1.1	A white paper summarizing the findings from the literature review with summarized tables of health impact functions included in the draft final report	Month 24
Health impact functions perinatal health outcomes from wildfire PM2.5 – Task 1.2	Table/excel spreadsheet of health impact functions	Month 24

Wildfire PM2.5 impacts on perinatal health outcomes– Task 1.2	The results from Task 1.2 study of wildfire PM2.5 impacts on perinatal outcomes across the state will be included in the draft final report.	Month 24
Conceptual Methodological Outline – Task 2	The Contractor will provide a report with diagrams that outline the proposed method and processing chain that will be used to complete this task.	Month 3
Fuel Type and Elevation data – Task 2.1	Raster file of vegetation and elevation	Month 6
Historical fire data in the CANSAC grid – Task 2.2	Dataset of FRP and fire danger (2006-2022) associated with each CANSAC grid cell (dataset with columns for ecounit, date, grid cell coordinates, fire occurrence, and aggregated FRP value)	Month 12
Regression model of emissions for CANSAC grid – Task 2.3	netCDF and raster file of historical and future emissions for different years and scenarios	Month 18
$PM_{2.5}$ concentrations – Task 2.4	netCDF and raster file of CANSAC grid $PM_{2.5}$ concentrations for different years and scenarios	Month 26
Final analysis – Task 2	Documentation of results including summary statistics and relevant tables for the state.	Month 28
Final documentation – Task 2	Code and workflow; implementation on CARB system	Month 30
Conceptual Methodological Outline – Task 3	The Contractor will provide a report with diagrams that outline the methods, data, processing chain, and processing needs expected that will be used to complete this task.	Month 6
Health analysis results – Task 3	Health impact maps and layers provided as netcdf format	Month 31
Final report and assessment – Task 3	Report describing the methodology, datasets, reproducible workflow for BenMAP integration, and assessment of the health impact results with summary statistics	Month 33
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.	Two (2) weeks prior to agreement end date.
Code and Documentation	All code, commented and documented, used to produced data and workflows during the course of the contract will be provided to CARB staff	Two (2) weeks prior to agreement end date

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 SECTION 19. COPYRIGHTS, PARAGRAPH B OF EXHIBIT C		
Final Report	Written record of the project and its results. The Final Report shall be submitted in an Americans with Disabilities Act compliant format. The Public Outreach Document, as described in Exhibit A1, Section 2, shall be incorporated into the Final Report.	Two (2) weeks prior to agreement end date.

1. Reports and Data Compilation

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 must accompany a related invoice covering the same 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 summary of the status of the project, including whether the project is on schedule. If the project is behind schedule, the progress report must contain an explanation of reasons and how the University plans to resume the schedule.

2. A brief narrative account of project tasks completed or partially completed since the last progress report.
3. A brief discussion of problems encountered during the reporting period and how they were or are proposed to be resolved.

4. A brief discussion of work planned, by project task, before the next progress report. And

5. A graph or table showing percent of work completion for each task.

C. Six (6) months prior to Agreement expiration date, University will deliver to CARB an electronic copy of the draft final report in both PDF and Microsoft Word formats. The draft final report will conform to Exhibit A1, Section 2 – Research Final Report Format.

D. Within forty-five (45) days of receipt of CARB's comments, University will deliver to CARB's Contract Project Manager an electronic copy 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 an electronic copy of the final report in both PDF and Microsoft Word formats.

E. As specified in Exhibit A1, Section 2, Final Report will be submitted in an Americans with Disabilities Act compliant Format.

F. Together with the final report, University will deliver 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, 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 in PDF format and in a word-processing format, preferably in Word – Version 6.0 or later. The electronic copy file name shall contain the CARB contract number, the words "Final Report", and the date the report was submitted.

Accessibility. 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.

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. However, minor changes to the title may be approved provided the new title does not deviate from the old title. These minor changes must be approved in writing by the contract manager. Significant changes to the title would require a formal amendment.

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

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
Public Outreach Document
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 "Unlocking Health Benefits for Californians through Active Land Management Strategies"] by University of California, Merced under the [full] 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.

Public Outreach Document. The public outreach document is a one-page document that will be widely used to communicate, in clear and direct terms, the key research findings from the study to the public. CARB will be translating the document into other languages. This document must adhere to the following guidelines:

- Single space, limited to one-page or about 500 words.
- Use narrative form and active voice.
- Incorporate a graphic that it is easy to interpret and captures the results' central message.
- Avoid jargon and technical terms. Use a style and vocabulary level comparable to that of sixth grade reading level.
- The document should contain a title and the following five sections: Issue/s, Main Question, Key Research Findings, Conclusion/s, and More Information. Guidance on how to write these sections is described below.

TITLE: Adopt a short, non-technical title to make the topic clear and concise. The title will likely differ from the original title of the contract.

ISSUE/S: In one to two paragraphs, describe why the project was needed. In this section, identify the problem leading to this study and what the study was set to accomplish to help address the problem. Reference any history that is relevant such as a regulation, legislation, program, law, or other. Without going into detail and disclosing the research findings, mention the methods used in the study and how it informed the results.

MAIN QUESTION: Present a concise central research question driving this project.

KEY RESEACH FINDING/S: This section covers the key research findings. List key points and or findings.

CONCLUSION/S: In one to two paragraphs, discuss how the results could be used. Mention its relevance to policies, rules, regulations, legislations, or CARB programs. Include suggestions for next steps, additional research, or other actions.

MORE INFORMATION: In two to three short sentences provide specifics about the study. This section should include the full title of the study, sponsor, authors, and where the full report can be found (the final report will be posted on the CARB website). In addition to a direct contact to gain more information (author and CARB contract manager).

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 accessible to the general audience. Assume the audience is being exposed the subject for the first time. 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 sentences, 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:

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.

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.

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.

EXHIBIT A2

KEY PERSONNEL

KEY PERSONNEL

List Key Personnel as defined in the Agreement starting with the PI, by last name, first name followed by Co-PIs. Then list all other Key Personnel in alphabetical order by last name. For each individual listed include his/her name, institutional affiliation, and role on the proposed project. Use additional consecutively numbered pages as necessary.

Last Name, First Name	Institutional Affiliation	Role on Project
PI:		
Abatzoglou, John	*University of California, Merced*	*Lead Principal Investigator*
Co-PI(s) – if applicable:		
Ha, Sandie	*University of California, Merced*	*Principal Investigator*
Kolden, Crystal	*University of California, Merced*	*Principal Investigator*
Adebeyi, Adeyimi	*University of California, Merced*	*Principal Investigator*
Brown, Tim	*Desert Research Institute*	*Principal Investigator*
Other Key Personnel (if applicable):		
Bart, Ryan	*University of California, Merced*	*Project Scientist*
Zare Harofteh, Azimeh	*Desert Research Institute*	*Investigator*

Exhibit A3 – Authorized Representatives

AUTHORIZED REPRESENTATIVES AND 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.

<table>
<tr><th>State Agency Contacts

Agency Name: CARB</th><th>University Contacts

University Name: The Regents of the University of California</th></tr>
<tr><td>Contract Project Manager (Technical)

Name: Nicole Hernandez

Address: Research Division
1001 I Street, 5th Floor
Sacramento, CA 95814
Telephone: (916) 842-9670-
Fax: (916) 322-4357
Email: nicole.hernandez@arb.ca.gov</td><td>Principal Investigator

Name: John Abatzoglou
Professor
Address: Management of Complex Systems
5200 N Lake Rd.
Merced, CA 95343
Telephone: 208-596-3144
Fax: NA
Email: jabatzoglou@ucmerced.edu

Designees to certify invoices under Section 14 of Exhibit C on behalf of PI:
1. Kelli Maxey, Assistant Controller, ppfm@ucmerced.edu
2. Denise Cardenas, Supervisor, ppfm@ucmerced.edu
3. Devan Hinojosa, Director, ppfm@ucmerced.edu</td></tr>
<tr><td>Authorized Official (contract officer)

Name: Alice Kindarara, Chief

Address: Acquisition Branch
1001 I Street, 5th Floor
Sacramento, CA 95814
Telephone: (916) XXX XXXX
Fax: NA
Email: @arb.ca.gov</td><td>Authorized Official

Name: Jue Sun
Director
Address: Sponsored Projects Office
5200 N Lake Rd.
Merced, CA 95343
Telephone: 209.201.2039
Fax: NA
Email: spo@ucmerced.edu</td></tr>
</table>

Send notices to (if different): Name: Renee Carnes Address: Research Division 1001 I Street, 5th Floor Sacramento, CA 95814 Telephone: (279) 208-7754 Email: renee.carnes@arb.ca.gov	***Send notices to (if different):*** Name: <Name> <Title> Address: <Department> <Address> <City,State,Zip> Telephone: <Telephone#> Email: <EmailAddress>
Administrative Contact Name: Renee Carnes Address: Research Division 1001 I Street, 5th Floor Sacramento, CA 95814 Telephone: (279) 208-7754 Fax: NA Email: renee.carnes @arb.ca.gov	***Administrative Contact*** Name: Anna Boyanovsky Research Administrator Address: Sierra Nevada Research Institute 5200 N Lake Rd. Merced, CA 95343 Telephone: 209-413-9882 Fax: NA Email: aboyanovsky@ucmerced.edu
Financial Contact/Accounting Name: Accounts Payables Address: P.O.Box 1436 Sacramento, CA 95814 Telephone: (916) XXX XXXX Email: @arb.ca.gov Send courtesy copy to: rd.invoices@arb.ca.gov	***Authorized Financial Contact/Invoicing/Remittance*** Name: Kelli Maxey Assistant Controller Address: Project Portfolio Financial Management 5200 N Lake Rd. Merced, CA 95343 Telephone: 209-285-9447 Fax: NA Email: ppfm@ucmerced.edu Designees for invoice certification in accordance with Section 14 of Exhibit C on behalf of the Financial Contact: 1. Kelli Maxey, Assistant Controller, ppfm@ucmerced.edu 2. Denise Cardenas, Supervisor, ppfm@ucmerced.edu 3. Devan Hinojosa, Director, ppfm@ucmerced.edu

Exhibit A4 – Use of Intellectual Property & Data

USE OF INTELLECTUAL PROPERTY & DATA

If either Party will be using any third-party or pre-existing intellectual property (including, but not limited to copyrighted works, known patents, trademarks, service marks and trade secrets) "IP" and/or Data with restrictions on use, then list all such IP/Data and the nature of the restriction below. If no third-party or pre-existing IP/Data will be used, check "none" in this section.

A. State: Preexisting 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 (Name of State Agency or 3rd Party)	Description	Nature of restriction:

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

☒ None or ☐ List:

Owner (Name of University or 3rd Party)	Description	Nature of restriction:

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 (University or 3rd Party)	Description	Nature of Restriction:

Exhibit A5 - RÉSUMÉ/BIOSKETCH

RÉSUMÉ/BIOSKETCH

Attach 2-3 page Resume/Biosketch for the PI and other Key Personnel listed in Exhibit A2, Key Personnel.

JOHN T. ABATZOGLOU
Professor
Management of Complex Systems
University of California, Merced
jabatzoglou@ucmerced.edu

EDUCATION AND TRAINING
University of California, Davis Atmospheric Science BS, 2000
University of California, Irvine Earth Systems Science PhD, 2006

RESEARCH AND PROFESSIONAL EXPERIENCE
2022-current Professor, University of California, Merced
2020-2022 Associate Professor, University of California, Merced
2014-2020 Associate Professor, University of Idaho
2009 – 2014 Assistant Professor, University of Idaho
2008 – 2009 Assistant Professor, San Jose State University
2006 – 2012 Research Scientist, Desert Research Institute
2008 Lecturer, University of Nevada, Reno

SYNERGISTIC ACTIVITIES
- Co-PI, NOAA RISA Pacific Northwest and California/Nevada – translating climate
- information into actionable science for stakeholders (2010-present);
- Associate Editor International Journal of Climatology (2020-present);
- Idaho Climate-Economy Impact Assessment lead author (2019-2022);
- Production of operational climate datasets, forecasts, climate projections, and visualization
- tools at climatetoolbox.org (2014-present);
- National Integrated Drought Information System contributor (2017-present);
- Science advisor for Climate Central (2017-present).

RELEVENT PUBLICATIONS
Anderegg, W.R., Chegwidden, O.S., Badgley, G., Trugman, A.T., Cullenward, D., J.T. Abatzoglou, Hicke, J.A., Freeman, J. and Hamman, J.J., 2022. Future climate risks from stress, insects and fire across US forests. Ecology Letters
Jones, M.W., J.T. Abatzoglou, Veraverbeke, S., Andela, N., Lasslop, G., Forkel, M., Smith, A.J., Burton, C., Betts, R.A., van der Werf, G.R. and Sitch, S., 2022. Global and regional trends and drivers of fire under climate change. Reviews of Geophysics, p.e2020RG000726.
Hawkins, L. R. , J.T. Abatzoglou, S. Li, D. E. Rupp, 2022, Anthropogenic Influence on Recent Severe Autumn Fire Weather in the West Coast of the United States, Geophysical Research Letters, 49(4). doi: 10.1029/2021GL095496
Balch, J. K., J.T. Abatzoglou, M.B. Joseph, Koontz, M.J., Mahood, A.L., McGlinchy, J., Cattau,

M.E., Williams, A.P., 2022, Warming weakens the night-time barrier to global fire, Nature, 602(7897)
Abatzoglou, J.T., Battisti, D.S., Williams, A.P., W.D. Hansen, B.J. Harvey, C.A. Kolden, 2021, Projected increases in western US forest fire despite growing fuel constraints. Commun Earth Environ 2, 227
McEvoy, D.J., Pierce, D.W., Kalansky, J.F., Cayan, D.R. and J.T. Abatzoglou, 2020. Projected Changes in Reference Evapotranspiration in California and Nevada: Implications for Drought and Wildland Fire Danger. Earth's Future, p.e2020EF001736.
Lynn, E., Cuthbertson, A., He, M., Vasquez, J.P., Anderson, M.L., Coombe, P., J.T. Abatzoglou. and Hatchett, B.J., 2020. Precipitation-phase partitioning at landscape scales to regional scales. Hydrology and Earth System Sciences, 24(11), pp.5317-5328.
Goss, M., Swain, D.L., J.T. Abatzoglou, Sarhadi, A., Kolden, C.A., Williams, A.P. and Diffenbaugh, N.S., 2020. Climate change is increasing the likelihood of extreme autumn wildfire conditions across California. Environmental Research Letters, 15(9), p.094016.
Abatzoglou, J.T., C.M. Smith, D.L. Swain, T. Ptak, C.A. Kolden, 2020, Population exposure to pre-emptive de-energization aimed at averting wildfires in Northern California, Environmental Research Letters, 15 (9), 094046
Williams A P, E.R. Cook, J.E. Smerdon, B.I. Cook, J.T. Abatzoglou, K. Bolles, S.H. Baek, A.M. Badger, B. Livneh, 2020, Large contribution from anthropogenic warming to an emerging North American megadrought Science 368 (6488), 314-318
Qin Y, J.T. Abatzoglou, S. Siebert, L.S. Huning, A. AghaKouchak, J.S. Mankin, C. Hong, D. Tong, S.J. Davis, N.D. Mueller, 2020, Agricultural risks from changing snowmelt Nat. Clim. Chang. 10 (5), 459-465
Albano, C.M., J.T. Abatzoglou, D.J. McEvoy, J.L. Huntington, C.G. Morton, M.D. Dettnger, T.J. Ott, 2022, A Multidataset Assessment of Climatic Drivers and Uncertainties of Recent Trends in Evaporative Demand across the Continental United States, J. Hydrology, 23,4, 505-519
Abatzoglou, J.T., A.P. Williams, R. Barbero, 2019, Global emergence of anthropogenic climate change in fire weather indices, Geophysical Research Letters, 46, 326–336
Abatzoglou, J.T., and A.P. Williams, 2016, The impact of anthropogenic climate change on wildfire across western US forests. Proceedings of the National Academy of Sciences USA 113:11770-11775
Abatzoglou, J.T., 2016: Contribution of cut-off lows to precipitation across the United States, Journal of Applied Meteorology and Climatology, 55, 893-899
Williams, A. P., R. Seager, J.T. Abatzoglou, B.I. Cook, J.E. Smerdon, E.R. Cook, 2015, Contribution of anthropogenic warming to California drought during 2012–2014. *Geophys. Res. Lett.* **42**, 6819–6828
Abatzoglou, J. T. 2013, Development of gridded surface meteorological data for ecological applications and modelling. *Int. J. Climatol.* **33**, 121–131
Barbero, R., J.T. Abatzoglou, H.J. Fowler, 2018, Contribution of large-scale midlatitude disturbances to hourly precipitation extremes in the United States. Climate Dynamics. https://doi.org/10.1007/018-4123-5
Abatzoglou, J.T., 2016: Contribution of cut-off lows to precipitation across the United States, Journal of Applied Meteorology and Climatology, 55, 893-899

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors. Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: SANDIE HA

POSITION TITLE: Assistant Professor

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

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
University of Washington, Seattle, WA	BS	06/2008	Biology – Physiology
University of Florida, Gainesville, FL	MPH	05/2011	Public Health
University of Florida, Gainesville, FL	PhD	08/2015	Epidemiology
Eunice Kennedy Shriver National Institute of Child Health and Human Development	Postdoctor al Fellowship	06/2017	Environmental and perinatal epidemiology

A. Personal Statement

As an environmental/perinatal epidemiologist, I have an important, innovative, and collaborative body of work focusing on understanding environmental determinants of adverse pregnancy outcomes in diverse populations, both in the community and clinical settings. I have been involved in multiple international and national projects. I have also been involved in interventional studies aiming to improve health in both clinical and community settings. My collaborative and direct experience with research focusing on health effects of climate change (e.g., air pollution, wildfires, extreme temperatures) ensures I can make meaningful contributions to the current proposal. I am very excited to be part of this proposal and look forward to make the findings useful for clinical and policy decisions to improve maternal and child health especially in vulnerable and underserved regions.

<u>Selected current projects</u>

Role: Co-PI **Adebiyi (lead PI)** **07/01/2023 – 06/30/2026**

Adaptation pathways for agricultural land repurposing in the San Joaquin Valley and their impacts on heat and air quality extremes on vulnerable communities. This project evaluates land-use and repurposing adaptation strategies in terms of their short- and long-term impacts on air pollution, heat events, and pregnancy outcomes in California. Funder: UC Climate Action Research Seed Fund Competition

Role: PI **Ha (PI)** **01/01/2023 –12/31/2023**

A Health Impact Assessment in Fresno AB617 Communities: Concerns in the Changing Climate This project assesses the health needs and concerns of an underserved Fresno community in the changing climate. Funder: UC Community and Labor Center

Role: PI **Ha (PI)** **05/01/2021 – 12/312033**

Fresno Air Pollution Health Impact Assessment

This project aims to assess environmental health impacts in the City of Fresno. The project will directly inform the City of Fresno in their truck reroute efforts. Funder: Fresno City

Role: Co-PI **Bradman (lead PI)** **09/2021 – 08/2023**

Joaquin Valley Center for Community Air Assessment and Injustice Reduction (SJV CC-AIR) This project aims to increase air monitoring capacity in the San Joaquin Valley of California, an underserved population, and assess health impacts of air pollution in the area. The project also establishes a mobile van that will allow health and air pollution assessment in hard-to-reach populations and enhance health and environmental research and education capacity at the University. Funder: California Department of Justice.

B. Selected positions and Honors

Positions

2017 – Pres Assistant Professor, Department of Public Health, University of California, Merced, CA
2015 – 2017 Postdoctoral Fellow, *Eunice Kennedy Shriver* National Institute of Child Health and Human Development, Bethesda, MD.
2011 – 2015 Graduate School Fellowship Award Fellow, University of Florida, Gainesville, FL
2010 – 2011 Public Health Intern, University of Florida Family Data Center, Gainesville, FL

Honors

2020 Inaugural Faculty Success Initiative Fellow, UC Merced
2019 UC Merced Senate Distinguished Early Career Research Award Nomination
2015 – 2017 National Institute of Health Intramural Research Training Award

C. Contributions to Science

A more complete list of my publications can be found here (some publications were not indexed in Pubmed) https://www.ncbi.nlm.nih.gov/myncbi/sandie.ha.1/bibliography/public/

1.The ambient environment and reproductive, perinatal, and pediatric health
Air pollution and climate change are top public health threats of the 21st century. Studies investigating health effects of air pollution and extreme temperatures primarily focus on cardiorespiratory health, leaving other health effects understudied. To fill this gap, I led an innovative body of work showing that even in areas with temperate climate and moderate air pollution (i.e., below the federal standards), higher exposures increase the risk of a range of adverse reproductive and pediatric outcomes. These include impaired fertility, stillbirth, fetal growth restriction, preterm birth, low birthweight, as well as various gestational complications. My studies also show that prenatal and early life exposures also affect subsequent neurodevelopment for newborns. *My research significantly contributed to our understanding of how air pollution and climate change affect health by demonstrating that have impact beyond cardiopulmonary outcomes as previously known.* It pushes an emerging paradigm suggesting that early exposures have lifelong effects such as neurodevelopment. *My research has contributed to recent policies and clinical guidelines that recognize pregnant people as a vulnerable group in the changing climate.*

a. **Ha S** et al. The effects of air pollution on adverse birth outcomes. *Environmental Research* 2014; 134C:198-204. PMID: 25173052
b. **Ha S**, et al. Ambient air pollution and the risk of pregnancy loss: a prospective cohort study. *Fertility and Sterility* 2018; 109(1):148-153. PMID: 29153729
c. **Ha S**, et al. Ambient temperature and early delivery of singleton pregnancies. *Environmental Health Perspectives* 2017; 25(3):453-459. PMID: 27580125
d. **Ha S**. et al. Prenatal and early-life exposures to air pollution and neurodevelopment. *Environmental Research* 2019; 174:170-175. PMID: 30979514.
e. **Ha S**. The changing climate and pregnancy health. Current Environmental Health Reports 2022; 9: 263-275. PMID: 35194749.
f. **Ha S**, Martinez V, Chan-Golston, MA. Air pollution and preterm birth: a time-stratified case-crossover analysis in the San Joaquin Valley of California. Perinatal and Pediatric Epidemiology 2021; 36(1): 80-89. PMID: 34872160.

2. The ambient environment and adult health
Cardiopulmonary diseases are among the top causes of death worldwide. In my earlier work, I have successfully applied well-developed methods such as time series and case-crossover studies to assess the impact air pollution and ambient temperature on cardiopulmonary mortality and morbidity in US and Chinese populations. *These studies have added to the existing data on the cardiorespiratory impacts of air pollution and extreme temperatures* by addressing major limitations related to confounding.

a. **Ha S**, et al. Effects of heat stress and its effect modifiers on stroke hospitalizations in Allegheny County, Pennsylvania. *Int Archives of Env Epid* 2014; 87(5):557-65. PMID: 23897226
b. Xu X, **Ha S**, et al. Health Effects of Air Pollution on Length of Respiratory Cancer Survival. *BMC Public Health* 2013; 13: 800. PMID: 2400448
c. Xu X, Sun Y, **Ha S**, et al. Association between Ozone Exposure and Onset of Stroke in Allegheny County, Pennsylvania 1994-2004. *Neuroepidemiology* 2013;41(1):2-6.
d. Entwistle MR, et al., **Ha S**. Air pollution and asthma emergency department visits in Fresno, California, USA, during the warm season 2005-2015: a time-stratified case crossover analysis. *Air Quality, Atmosphere and Health* 2019; 12(6): 661–672.
e. Gharibi H, Entwistle MR, **Ha S**, et al. Ozone pollution and asthma emergency department visits in the Central Valley, California, USA, during June to September of 2015: a time-stratified case-crossover analysis. *J of Asthma* 2018; 9:1-12. PMID: 30299181

3.The biologic mechanisms linking air pollution and extreme temperature to health
I also studied short-term physiologic effects of air pollution and extreme temperatures. In collaboration with an international team of researcher, my studies showed that exposures to high levels of particulate matter increased cardiopulmonary burden among healthy volunteers and markers of inflammation, vasoconstriction, and coagulation were increased among type 2 diabetic patients. Our findings also provide evidence that temperature changes increase circulating biomarkers of inflammation, coagulation and vasoconstriction. *These works provided evidence suggesting that the biologic mechanisms linking air pollution and health risk may involve inflammatory, endothelial, and rheological pathways*. These will help in form the design of our proposed intervention.

a. Cai J, Meng X, Wang C, Chen R, Zhou J, Xu X, **Ha S**, Zhao Z, Kan H. The cold effects on circulatory inflammation, thrombosis and vasoconstriction in type 2 diabetic patients. *Science of the Total Environment* 2016; 568:271-277, PMID: 27295598
b. Wang C, Chen R, Zhao Z, Cai J, Lu J, **Ha S**, Xu X, Chen X, Kan H. Particulate air pollution and circulating biomarkers among type 2 diabetic mellitus patients: the roles of particle size and time windows of exposure. *Environmental Research* 2015; 140:112-118. PMID: 25863184

4. Intervention studies
I have also been involved in interventional studies. In collaboration with colleagues from China, I studied the effectiveness of an in-home air purifier intervention. Our randomized, double-blind crossover trial found that the air purifier (vs. sham air purifier) significantly reduced fine particles of outdoor origin while reducing circulating markers of inflammation and coagulation. ***The findings highlight potential benefits of indoor air purifiers***.

1. Chen R, Zhao A, Chen H, Zhao Z, Cai J, Wang C, Yang C, Li H, Xu X, **Ha S**, et al. Cardiopulmonary benefits of reducing indoor particles of outdoor origin: a randomized double-blind crossover trial of air purifiers. *Journal of the American College of Cardiology* 2015; 65(21):2279-87. PMID: 26022815

Crystal Kolden
Associate Professor of Fire Science
Management of Complex Systems
University of California, Merced
ckolden@ucmerced.edu

EDUCATION AND TRAINING

1999 AB History, Minor in American Indian Studies Cornell University
2005 MS Geography, University of Nevada,Reno
2010 PhD Geography, Clark University

RESEARCH AND PROFESSIONAL EXPERIENCE

2020 - present	Associate Professor, University of California, Merced
2017 - 2020	Associate Professor, University of Idaho
2011 - 2017	Assistant Professor, University of Idaho, Moscow, ID
2007 - 2010	Landscape Ecologist, US Geological Survey, Anchorage, AK
2004 - 2012	Affiliate Research Scientist, Desert Research Institute, Reno, NV
2003 - 2006	Fire Ecologist, USDA Forest Service, Nevada City, CA

SYNERGISTIC ACTIVITIES

- Developed and teach annually experiential learning courses with a combined 54 mostly minority students at UC Merced: 'Living with Wildfire' for freshman non-science majors, and Spatial Analysis and Modeling for upper-level engineering students.
- Serve as a founding editorial board member (2017-present) for the scientific journal 'Fire', which was founded by my close collaborator Alistair Smith (the current EIC) as an outcome of my NSF HazardSEES award in 2017.
- Starred as a science expert in a documentary about climate change and fire for the Howard Hughes Medical Institute in 2021.
- Appeared on Sunday PBS Newshour in summer 2019 to discuss my paper on the deficiency of prescribed fire in the western US in the context of current wildfires and its implications for future wildfire disasters.
- Part of the consulting team completing four Community Wildfire Protection Plans and post-fire reviews for communities in Santa Barbara and Ventura counties, California.

RELEVENT PUBLICATIONS

Bowman D, Kolden C, Abatzoglou J, Johnston F, van der Werf G, Flannigan M. Vegetation fires in the Anthropocene. Nature Reviews Earth & Environment. 2020 August 18; 1(10):500- 515.
Goss M, Swain D, Abatzoglou J, Sarhadi A, Kolden C, Williams A, Diffenbaugh N. Climate change is increasing the likelihood of extreme autumn wildfire conditions across California. Environmental Research Letters. 2020 August 20; 15(9):094016-.
Bowman D, Williamson G, Abatzoglou J, Kolden C, Cochrane M, Smith A. Human exposure and sensitivity to globally extreme wildfire events. Nature Ecology & Evolution. 2017 February 06; 1(3):-.
Kolden C, Henson C. A Socio-Ecological Approach to Mitigating Wildfire Vulnerability in the Wildland Urban Interface: A Case Study from the 2017 Thomas Fire. Fire. 2019 February 11; 2(1):9-.
Ray L, Kolden C, Chapin III F. A Case for Developing Place-Based Fire Management, Strategies from Traditional Ecological Knowledge. Ecology and Society. 2012; 17(3):-.

Abatzoglou J, Juang C, Williams A, Kolden C, Westerling A. Increasing Synchronous Fire Danger in Forests of the Western United States. Geophysical Research Letters. 2021 January 25; 48(2):-

Bowman D, Moreira-Muñoz A, Kolden C, Chávez R, Muñoz A, Salinas F, González-Reyes Á, Rocco R, de la Barrera F, Williamson G, Borchers N, Cifuentes L, Abatzoglou J, Johnston F. Human–environmental drivers and impacts of the globally extreme 2017 Chilean fires. Ambio. 2018; 48(4):350-362.

Iglesias V, Stavros N, Balch J, Barrett K, Cobian-Iñiguez J, Hester C, Kolden C, Leyk S, Nagy R, Reid C, Wiedinmyer C, Woolner E, Travis W. Fires that matter: reconceptualizing fire risk to include interactions between humans and the natural environment. Environmental Research Letters. 2022 March 24; 17(4):045014-.

Kolden C. Wildfires: count lives and homes, not hectares burnt. Nature. 2020 September 29; 586(7827):9-9. Available from: https://www.nature.com/articles/d41586-020-02740-4 DOI: 10.1038/d41586-020-02740-4

McWethy D, Schoennagel T, Higuera P, Krawchuk M, Harvey B, Metcalf E, Schultz C, Miller C, Metcalf A, Buma B, Virapongse A, Kulig J, Stedman R, Ratajczak Z, Nelson C, Kolden C. Rethinking resilience to wildfire. Nature Sustainability. 2019 August 19; 2(9):797-804.

Adeyemi Adebiyi
Assistant Professor
Life and Environmental Sciences
University of California, Merced
aaadebiyi@ucmerced.edu

EDUCATION AND TRAINING

University of California – Los Angeles Postdoctoral Fellow 2021
University of Miami Postdoctoral Fellow 2017
University of Miami Meteorology and Physical Oceanography PhD, 2016
Int. Centre for Theoretical Physics, Trieste, Italy Earth System Physics MSc-Eq. Diploma, 2011
Int. Centre for Theoretical Physics, Trieste, Italy Basic Physics MSc-Eq. Diploma, 2011
Federal University of Technology Akure, Nigeria Physics BSc, 2008

RESEARCH AND PROFESSIONAL EXPERIENCE

2021-present Assistant Professor, University of California, Merced
2023 - present Faculty Affiliate, Sierra Nevada Research Institute, University of California, Merced

SYNERGISTIC ACTIVITIES

- Member, Committee on Atmospheric Chemistry, American Meteorological Society - Science and Technology Advisory Commission (STAC) - 2021-Present.
- Program Co-chair, Symposium on Aerosol–Cloud–Climate Interactions, American Meteorological Society Annual Meeting (2022-present).

RELEVENT PUBLICATIONS

Adebiyi A, Zuidema P. Low Cloud Cover Sensitivity to Biomass-Burning Aerosols and Meteorology over the Southeast Atlantic. Journal of Climate. 2018 June 01; 31(11):4329-4346. Available from: http://journals.ametsoc.org/doi/10.1175/JCLI-D-17-0406.1 DOI: 10.1175/JCLI-D-17-0406.1
Adebiyi A, Zuidema P. The role of the southern African easterly jet in modifying the southeast Atlantic aerosol and cloud environments. Quarterly Journal of the Royal Meteorological Society. 2016 April 19; 142(697):1574-1589. Available from: https://onlinelibrary.wiley.com/doi/10.1002/qj.2765 DOI: 10.1002/qj.2765
Adebiyi A, Zuidema P, Abel S. The Convolution of Dynamics and Moisture with the Presence of Shortwave Absorbing Aerosols over the Southeast Atlantic. Journal of Climate. 2015 March 01; 28(5):1997-2024. Available from: http://journals.ametsoc.org/doi/10.1175/JCLI-D-14-00352.1 DOI: 10.1175/JCLI-D-14-00352.1
Adebiyi AA, Kok JF. Climate models miss most of the coarse dust in the atmosphere. Sci Adv. 2020 Apr;6(15):eaaz9507. PubMed Central ID: PMC7141824.
Adebiyi, Adeyemi A., Kok, J. F., Wang, Y., Ito, A., Ridley, D. A., Nabat, P., & Zhao, C. (2020). Dust Constraints from joint Observational-Modelling-experiMental analysis (DustCOMM): comparison with measurements and model simulations. Atmospheric Chemistry and Physics, 20(2), 829–863. https://doi.org/10.5194/acp-20-829-2020

Adebiyi, A. Adeyemi, Kok, J.F., Murray, B.J., Ryder, C.L., Stuut, J.-B.W., Kahn, R.A., Knippertz, P., Formenti, P., Mahowald, N.M., García-Pando, C.P., Klose, M., Ansmann, A., Samset, B.H., Ito, A., Balkanski, Y., Biagio, C.D., Romanias, M.N., Huang, Y., Meng, J., 2023. A review of coarse mineral dust in the Earth system. Aeolian Research 60, 100849. https://doi.org/10.1016/j.aeolia.2022.100849

Timothy J. Brown, Ph.D. Tel: 775-674-7090
Research Professor & Director of Western Regional Climate Center Email: Tim.Brown@dri.edu
Division of Atmospheric Sciences
Desert Research Institute
2215 Raggio Parkway, Reno NV 89512-10905

(a) Professional Background

Univ. of Illinois (Sangamon State Campus), Springfield IL	B.A.	Astronomy 1982
University of Colorado, Boulder, CO	M.A.	Climatology; Geography 1988
University of Colorado, Boulder, CO	Ph.D.	Climatology; Geography 1995

(b) Appointments

2014-2016	Adjunct Senior Research Fellow, School of Geography and Environmental Science, Monash University, Clayton, Victoria, Australia
2010-present	Research Professor, Division of Atmospheric Sciences, Desert Research Institute, Reno, NV
2008-present	Director, Western Regional Climate Center (WRCC); Desert Research Institute, Reno, NV
1998-present	Director, Program for Climate, Ecosystem and Fire Applications; Desert Research Institute, Reno, NV
2003-2010	Associate Research Professor, Division of Atmospheric Sciences
2000-2003	Assistant Research Professor, Division of Atmospheric Sciences; Desert Research Institute, Reno, NV
1996-1999	Research Associate, Division of Atmospheric Sciences; Desert Research Institute, Reno, NV

Ten Relevant Publications

Mills, G., O. Salkin, M. Fearon, S. Harris, T. Brown, and H. Reinbold, 2022: Meteorological drivers of the eastern Victorian Black Summer (2019-2020) fires. Journal of Southern Hemisphere Earth Systems Science 72(2), 139–163. doi:10.1071/ES22011

Boisramé, G.F.S, T.J. Brown, D.M. Bachelet, 2022: Trends in western USA fire fuels using historical data and modeling. Fire Ecology, 18:8, https://doi.org/10.1186/s42408-022-00129-4

Keeley, J.E., J. Guzman-Morales, A. Gershunov, A.D. Syphard, D. Cayan, D.W. Pierce, M. Flannigan, T.J. Brown, 2021: Ignitions explain more than temperature or precipitation in driving Santa Ana wind fires. Science Advances, 7, eabh2262.

Clark, S., G. Mills, T. Brown, S. Harris, and J.T. Abatzoglou, 2021: Downscaled GCM climate projections of fire weather over Victoria, Australia. Part 1: Evaluation of the MACA technique. International Journal of Wildland Fire, https://doi.org/10.1071/WF20174

Clark, S., G. Mills, T. Brown, S. Harris, and J.T. Abatzoglou, 2021: Downscaled GCM climate projections of fire weather over Victoria, Australia. Part 2: A multi-model ensemble of 21st century trends. International Journal of Wildland Fire, https://doi.org/10.1071/WF20175

Mills, G., S. Harris, T. Brown, and A. Chen, 2020: Climatology of wind changes and elevated fire danger over Victoria, Australia. Journal Southern Hemisphere Earth Systems Science. https://doi.org/10.1071/ES19043

Brown, T.J., S. Leach, B. Wachter, and B. Gardunio, 2020: The Northern California 2018 Wildfire Season. Special Supplement to the Bulletin American Meteorological Society, Vol. 101, No. 1, January 2020, S1-S4. DOI:10.1175/BAMS-D-19-0275.1

Kochanski, A. K., Mallia, D. V., Fearon, M. G., Mandel, J., Souri, A. H., and Brown, T., 2019: Modeling wildfire smoke feedback mechanisms using a coupled fire-atmosphere model with a radiatively active aerosol scheme. Journal of Geophysical Research: Atmospheres, 124. https://doi.org/10.1029/2019JD030558

Liu, Y., Kochanski, A., Baker, K. R., Mell, W., Linn, R., Paugam, R., Mandel, J., Fournier, A., Jenkins, M. A., Goodrick, S., Achtemeier, G., Zhao, F., Ottmar, R., French, N. H., Larkin, N., Brown, T. J., Hudak, A., Dickinson, M., Potter, B., Clements, C., Urbanski, S., Prichard, S., Watts, A. C., McNamara, D., 2019: Fire behaviour and smoke modelling: Model improvement and measurement needs for next-generation smoke research and forecasting systems, International Journal of Wildland Fire, 28, 570-588, doi: 10.1071/WF18204

Nauslar, N., Brown, T. J., McEvoy, D. J., Lareau, N., 2019: Record Setting 2018 California Wildfires [in "State of the Climate in 2018", Bulletin of the American Meteorological Society, 100 (9), S195-S196, doi:10.1175/2019BAMSStateoftheClimate.1

(d) Synergistic Activities

- Former Board of Directors, International Association of Wildland Fire
- Co-Symposia Organizer, 4th through 13th American Meteorological Society Symposium on Fire and Forest Meteorology
- Lecturer at USDA Forest Service National Advanced Fire and Resource Institute
- Associate Editor International Journal of Wildland Fire

Ryan R. Bart, Ph.D.

Assistant Project Scientist
Sierra Nevada Research Institute
University of California, Merced | Merced, CA
rbart3@ucmerced.edu

Education and Training

2014	Ph.D.	Geography, University of California, Santa Barbara & San Diego State University
2008	M.S.	Geography, San Diego State University
2001	B.S.	Genetics, University of California, Davis

Research and Professional Experience

2019-	Assistant Project Scientist, University of California, Merced
2018-2019	Postdoctoral Scholar, University of California, Merced
2015-2017	Postdoctoral Scholar, University of California, Santa Barbara
2014-2015	Postdoctoral Scholar, University of California, Berkeley

Synergistic Activities

- Principal developer of RHESSysIOinR, a package to operate RHESSys from R: https://github.com/RHESSys/RHESSysIOinR.
- Active contributor to the Regional Hydro-Ecologic Simulation System Model (RHESSys): https://github.com/RHESSys/RHESSys.

Relevant Publications

Bart RR, Kennedy MC, Tague CL, McKenzie D. 2020. Integrating fire effects on vegetation carbon cycling within an ecohydrologic model. *Ecological Modelling*, 416, 108880.

Kennedy MC, Bart RR, Tague CL, Choate JS. 2021. Does hot and dry equal more wildfire? Contrasting short- and long-term climate effects on fire in the Sierra Nevada, CA. Ecosphere, 12(7), e03657.

Hanan EJ, Ren J, Tague CL, Kolden CA, Abatzoglou JT, Bart RR, Kennedy MC, Liu M, Adam JC. 2021. How climate change and fire exclusion drive wildfire regimes at actionable scales. Environmental Research Letters, 16(2), 024051.

Ren J, Hanan EJ, Hicke JA, Kolden CA, Abatzoglou JT, Tague CL, Bart RR, Kennedy MC, Liu M, Adam JC. 2023. Bark beetle effects on fire regimes depend on underlying fuel modifications in semiarid systems. Journal of Advances in Modeling Earth Systems, 15(1), e2022MS003073.

Bart RR, Ray RL, Conklin MH, Safeeq M, Saksa PC, Tague CL, Bales RC. 2021. Assessing the effects of forest biomass reductions on forest health and streamflow. Hydrological Processes, 35(3), e14114.

Bart RR, Safeeq M, Wagenbrenner JW, Hunsaker CT. 2021. Do fuel treatments decrease forest mortality or increase streamflow? A case study from the Sierra Nevada (USA). Ecohydrology, 14, e2254.

Bart RR, Tague CL, Moritz MA. 2016. Effect of tree-to-shrub type conversion in lower montane forests of the Sierra Nevada (USA) on streamflow. *PLOS ONE*, 11(8):e0161805.

Bart RR, Tague CL, Dennison PE. 2017. Modeling annual grassland phenology along the central coast of California. *Ecosphere*, 8(7):e01875.

Anderson SE, Bart RR, Kennedy MC, MacDonald AJ, Moritz MA, Plantinga AJ, Tague CL, Wibbenmeyer M. 2018. The dangers of disaster-driven responses to climate change. *Nature Climate Change*, 8(8), 651-653.

Azimeh Zare Harofteh, Ph.D.
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Work Experiences

Assistant Research Professor, Air Quality, Desert Research Institute, NV	2022-Present
Visiting Researcher, Yazd University, Yazd	2020
Extended Postdoctoral Fellow, University of California, Berkeley, CA	2015-2019
Postdoctoral Researcher, U.S. Environmental Protection Agency, NC	2016
Guest Scientist, Aarhus University, Department of Chemistry, Aarhus, Denmark	2013-2014
Visiting Researcher, Aarhus University, Department of Environmental Science, Roskilde, Denmark	2010-2013
Lecturer, University of Agricultural Sciences and Natural Resources, Sari	2008-2009
Teaching Assistant and Research Assistant, Yazd University & University of Tehran	2007-2008

Education

Ph.D.	Atmospheric Science	University of Tehran In collaboration with Aarhus University, Denmark	2013
M.S.	Meteorology	University of Tehran In collaboration with University of Canterbury, New Zealand	2008
B.S.	Physics	Yazd University	2004

Research Interests

- Wildfire Smoke Transport and Plume Composition Evolution
- Fire Process Modeling
- Gas-Phase Chemical Mechanism Development and Evaluation
- Applying Machine Learning Techniques in fire process and Air Quality Prediction
- Climate Change and Air Quality Interaction
- Biogenic Emissions and Urban Air Quality

Collaboration on the Funded International Scientific Proposals and/or Projects

- Developing air quality forecast during smoke events available on a phone app, *Funded by the Pennington Family Foundation,* (2023-2024).
- Coastal Dunes Dust Control*, Funded by California State Parks* (2023-2026).
- Development of smoke transport probability and risk Interactive map from trajectories and climatological data analysis to improve management strategies to reduce fire risk on public health, *Funded by California Department of Forestry and Fire Protection (CALFIRE),* (2022-2024).
- Harnessing the data revolution for fire science - using laboratory data and atmospheric chemical transport models, determining wildland fire emissions, and studying wildfire plume chemical evolution, *Funded by National Science Foundation (NSF),* (2022-2026).
- Review and keep track of latest peer-reviewed literature on air quality modeling, measurements, and assessments, *Funded by Electric Power Research Institute (EPRI),* (2022).
- Modeling and Source Attribution of ozone in southeastern New Mexico, *New Mexico Environment Department,* (2022).

- Modeling of Possible Precipitation Enhancement by Glaciogenic Cloud Seeding, *Funded by Faculty of Science, Yazd University, Iran,* (2019-2020).
- Measurements and modeling of organic nitrate gases and aerosol: Influences on the lifetimes of NO_x, ozone and aerosol, *Funded by National Oceanic Atmospheric Administration (NOAA),* (2017-2019).
- The changing role of organic nitrates in the removal and transport of NO_x, *Funded by the NOAA Climate Program Office,* (2016-2017).
-
- Effects of daily meteorology on the interpretation of space-based remote sensing of NO_2, *Funded by NASA Earth and Space Science Fellowship* (2015-2016).
- Anthropogenic influence on biogenic secondary organic aerosol formation in Denmark, *Funded by VILLUM FOUNDATION, Denmark* (2013-2014).
- Sources, composition, and occurrence of secondary organic aerosols in the Arctic, *Funded by Nordic Council of Ministers, the Swedish Environmental Protection Agency, and the Danish Environmental Protection Agency,* (2013-2014).
- The intercontinental transport of air pollution between North America and Europe with objective to contribute to the AQMEII project; Air Quality Modeling Evaluation International Initiative, *Funded by Department of Environmental Science, Aarhus University, Denmark,* (2011-2012).
- Effects of changed climate conditions on tropospheric ozone, *Funded by National Environmental Research Institute, Denmark,* (2010-2011).
- Estimation of surface cooling & heating rate in Yazd, *Funded by Faculty of Science, Yazd University,* (2007-2008).

<u>Technical Skills</u>

- Atmospheric Chemical Transport Models (CMAQ, DEHM, EMEP, WRF-Chem), Air Quality Dispersion Models (HYSPLIT, AERMOD), Biogenic Emission Models (MEGAN, GEIA), Radiation Transport Models (SBDART)
- Generate Emissions Tools (SMOKE, Prep_chem_sources)
- Model Output Post Processing Software (EPA AMET, UNIRAS, Tecplot, VERDI)
- In the Process of Learning Atmosphere-Wildfire Models (WFDS, WRF-SFIRE, HRRR-SMOKE, SMARTFIRE, BlueSky, FIRETEC), and A Stochastic Dust Particle Dispersion Model
- Programming Languages: Fortran, MATLAB, R, Python, Shell scripting, and NCAR Command Language
- Operating Systems: Linux, Windows, and Apple macOS

<u>Awards and Fellowships</u>

- The ORISE Fellowship (U.S. Department of Energy, USA, 2016)
- Marianne Dieckmann Fellowship (CCIS Stanford University, 2014)
- Three Scientific Grants (National Environmental Research Institute, Denmark | Aarhus University Research Foundation Award, Denmark | Department of Environmental sciences, Aarhus University, Denmark (2010-2013))
- AGSoS Visiting Grant (Aarhus Graduate School of Science and Technology, Denmark, 2012)
- Superior student of Meteorology (University of Tehran, 2008)
- Outstanding student of the year 2008 (University of Tehran)
- Travel Grants (American Geophysical Union, 2013
- Gothenburg Atmospheric Science Centre, Sweden, 2013
- European Air Pollution Association, EURASAP, 2012)

Selected Service Activities

- Participate in the Research Immersion Internship program for fall 2023 to train and mentor 4 students from Nevada's state and community colleges (Fall 2023).
- Selection committee of students for Research Immersion Internship program (May 2023)
- Reviewed Manuscripts for Journals: Atmospheric Chemistry and Physics, Atmospheric Pollution Research, Sustainability, Atmosphere, Remote sensing, Energies, Toxics, and Environmental Research and Public Health (2016-). Invited Guest Editor for Journals of Sustainability, Remote Sensing, and Atmosphere (2022- , declined invitation).
- Served as a judge for the Outstanding Student Paper Award, American Geophysical Union Fall Meetings (2016).
- Supervised a master student (Yazd University, 2019), Conducted workshops to train students in running air pollution models (UC Berkeley, 2016-2019 and Aarhus University, Denmark, 2012-2013).
- Editorial Board for the 'Kahroba', Student Scientific Magazine, Department of Physics, Yazd University (2003-2004)
- President of Physics Student Scientific Society, Yazd University (2003)
- Secretariat member for 6th Condensed Matter Conference of Iranian Physical Society (2002)

Selected Scientific Workshop, Training & Summer School Certifications

Practical Strategies for Inclusive Mentoring in Undergraduate Research (Nevada System Sponsored Programs and EPSCoR, April 2023)
Early Career Faculty Mentorship and Writing Program (DRI, 2023)
SMOKE Online Training (EPA, 2022)
Air Dispersion Modeling for Environmental Management (Udemy, 2021)
Current Atmospheric Chemical Mechanisms Training (UC Davis Air Quality Research Center, 2020)
Environmental Protection and Regulatory Compliance (Berkeley Extension, CA, 2014)
Organic Aerosols (University of Gothenburg, Sweden 2013)
Atmospheric Environment (Aarhus University, Denmark, 2012)
Tropospheric Chemical Transport Modeling (Barcelona Supercomputing Center, Spain, 2012)
BVOC Emissions Modeling and Applications (Lancaster University, UK, 2011)
Tropospheric Chemical Transport Modeling (National Environmental Research Institute, Denmark, 2011).

Publications and Presentations

Published 19 peer-reviewed journal articles, and scientific project reports (h-index 10, 645 citations by June 2023 on Google scholar), and Presented at 40+ peer-reviewed conference and as invited talks.

Teaching Experience

Dynamic Meteorology, Synoptic Meteorology and Advanced Dynamic Meteorology (University of Agricultural Sciences and Natural Resources, Sari, Yazd University, Yazd and University of Tehran, Tehran, (2007-2009))

Exhibit A6 – Current & Pending Support

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: John Abatzoglou

Status (currently active or pending approval)	**Award # (if available)**	**Source (name of the sponsor)**	**Project Title**	**Date**	**Date**
Proposed Project		CARB	Unlocking Health Benefits for Californians through Active Land Management Strategies	12/2023	1/2026
CURRENT	Grant	AON	Future Fire Weather Scenarios	09/2022	9/2024
CURRENT	GR16402	NOAA	Climate Adaptation Pathways-building capacity for near- and long-term resiliency in California and Nevada	09/2022	8/2027
CURRENT	NA20OAR4310478	NOAA	Improving Drought Indicators to Support Drought Impact Mitigation for Natural Resource Management	09/2020	8/2026
CURRENT		NSF	Adopt, Adapt, Amplify: Next-Generation AI Systems and Workforce for the Digital Revolution in Agriculture	09/21	8/2026
CURRENT	1562816	USGS	On-Demand Quantitative Climate Scenario Summaries Tool to Support U.S. Fish and Wildlife Service	10/2022	8/2024
CURRENT		NOAA	Joint California-Nevada and Pacific Northwest Drought Early Warning System	09/2022	8/2023
CURRENT		USDA	Technology for trade: new tools and new rules for water use efficiency in agriculture and beyond	11/2018	6/2024
CURRENT		NSF	Managing Future Risk of Increasing Simultaneous Megafires	09/2020	8/2026
CURRENT		DOI	Testing hypotheses of patterns and drivers of human-caused fires	09/2021	8/2024
CURRENT	21-0557-000-SO	CDFA	A Drought Impact Assessment Web-Based Platform for California's Agricultural Systems and Communities	09/2021	8/2024
CURRENT	2021-69012-35916	USDA-NIFA	Securing a climate resilient water future for agriculture and ecosystems through innovation in measurement, management, and markets	09/2021	8/2026
CURRENT	GR16402	NOAA	Climate Adaptation Pathways-building capacity for near- and long-term resiliency in California and Nevada	09/2022	8/2027
PENDING		USGS	Seasonal forecasting for rangeland applications	06/2023	5/2025

PENDING		NOAA	Translating Coastal Research into Application	10/2022	8/2024
PENDING		UCOP	UC Disaster Resilience Network capacity building and adaptation.	09/2023	8/2025

Sandie Ha

Status	Award #	Source	Project Title	Start Date	End Date
Proposed Project		UC Merced CARB	Unlocking Health Benefits for Californians through Active Land Management Strategies	12/2023	11/2026
CURRENT		City of Fresno	Health Impacts of air pollution in Fresno, CA	04/2022	12/2023
CURRENT		State of CA Attorney General	San Joaquin Valley Center for Community Air Assessment and Injustice Reduction (SJV CC-Air)	09/2021	08/2025
CURRENT		UC Merced	Adaptation pathways for agricultural land repurposing in the San Joaquin Valley and their impacts on heat and air quality extremes on vulnerable communities	06/2023	06/2025
PENDING		UC Merced Community and Labor Center	A Health Impact Assessment in Fresno AB617 Communities: Concerns in the Changing Climate	01/2023	12/2023

Krystal Kolden

Status	Award #	Source	Project Title	Start Date	End Date
Proposed Project		CARB	Unlocking Health Benefits for Californians through Active Land Management Strategies	12/2023	11/2026
CURRENT	H-21738CA	HUD	Understanding inclusive community recovery and resilience following complex wildfire disasters	09/2022	09/2015
CURRENT	2022-67019-36435	NIFA	Can Indigenous knowledge systems save western forests and rangelands? Co-producing a framework for collaborative partnerships with tribal fire stewards	02/2022	01/2026
CURRENT	M21PR3385	UCOP	Addressing California communities doubly vulnerable to catastrophic wildfires	01/2021	12/2023
PENDING		NSF	Build and Broaden: Testing an alternative wildfire evacuation framework using local knowledge to reduce fatalities	08/2023	07/2026

Adeyemi Adebiyi

Status	Award #	Source	Project Title	Start Date	End Date
Proposed Project		CARB	Unlocking Health Benefits for Californians through Active Land Management Strategies	12/2023	11/2026

CURRENT	M23PL5960	UCOP	UC-Dust: Addressing Future Changes in California Dust Storms	01/2023	12/2024
CURRENT	DE-SC0023033	UC Merced	Adaptation pathways for agricultural land repurposing in the San Joaquin Valley and their impacts on heat and air quality extremes on vulnerable communities	06/2023	06/2025
CURRENT	DE-SC0023033	DOE	Building collaboration to advance our understanding of regional climate impacts of dust in California's San Joaquin Valley	08/2022	05/2024
PENDING		NOAA	Process-level understanding of projected changes in synoptic to decadal variability of precipitation over North and Central America	06/2023	05/2026
PENDING		NOAA	Radiative Impacts of Wildland Fire Smoke in the Western United States	06/2023	05/2026
PENDING		DOE	Investigating the radiative impacts of coarse-sized dust absorption on precipitation	08/2022	07/2025
PENDING		NASA	Multi-Scale Investigation of Dynamical and Thermodynamical Characteristics of the Southern African Easterly Jet	06/2023	06/2026

Timothy Brown

Status	Award #	Source	Project Title	Start Date	End Date
Proposed Project		UC Merced CARB	Unlocking Health Benefits for Californians through Active Land Management Strategies	12/2023	11/2026
CURRENT	2014.188	Bay Area Air Quality Control Management District	CANSAC Support	07/01/2014	06/30/2023
CURRENT	19-CS-11052012-153	USDA Forest Service	Development and Delivery of CEFA-CANSAC Products R5	08/02/2019	08/01/2024
CURRENT	20078	South Coast Air Quality Management District	CANSAC Support	11/08/2019	11/07/2023
CURRENT	704010	University of California, San Diego	Development and Evaluation of a High Resolution Historical Climate Dataset Over California	09/18/2020	03/31/2024
CURRENT	21AQP013	California Air Resources Board	CANSAC Support FY22-FY24	04/16/2022	04/15/2024
CURRENT	22-JV-11261927-082	USDA Forest Service	Fire & Smoke Model Evaluation Experiment (FASMEE) Phase II Fire Science Coordination	08/27/2022	07/30/2024
CURRENT	8GG21816	CalFire	Development of Smoke Transport Probability and Risk Interactive Map from Trajectories and Climatology Analysis of 2-km CANSAC-Reanalysis Database	06/17/2022	03/31/2025

Ryan Bart

Status	Award #	Source	Project Title		

				Start Date	End Date
Proposed Project		CARB	Unlocking Health Benefits for Californians through Active Land Management Strategies	12/2023	11/2026
CURRENT	20ISD008	CARB	Projecting climate change effects on carbon, water, and wildfire in California's natural and working lands	05/2021	10/2025

Azimeh Zare

Proposed Project		UC Merced CARB	Unlocking Health Benefits for Californians through Active Land Management Strategies	12/2023	11/2026
CURRENT	10015031	Electric Power Research Institute	Estimating Background Ozone Using Data Fusion	03/2022	09/2023
CURRENT	8GG21816	CalFire	Development of Smoke Transport Probability and Risk Interactive Map from Trajectories and Climatology Analysis of 2-km CANSAC-Reanalysis Database	06/2022	03/2025
CURRENT	N/A	William N. Pennington Foundation	Developing Air Quality Forecast During Smoke Events Available on a Phone App	01/2023	01/2024
PENDING		Coordinating Research Council	Pre-proposal: Detailed Organic Nitrate Chemistry in a Photochemical Model, Modeling Changes in NOx Chemistry and Ozone Production in Response to Emission Reduction in the South Coast Air Basin	10/2022	05/2023

Exhibit A7

Third Party Confidential Information

Confidential Nondisclosure Agreement

(Identified in Exhibit A, Scope of Work – will be incorporated, if applicable)

If the Scope of Work requires the provision of third party confidential information to either the State or the Universities, then any requirement of the third party in the use and disposition of the confidential information will be listed below. The third party may require a separate Confidential Nondisclosure Agreement (CNDA) as a requirement to use the confidential information. Any CNDA will be identified in this Exhibit A7.

Exhibit B3 – Invoice Elements

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

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[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 C

UNIVERSITY TERMS AND CONDITIONS

The University Terms and Conditions (UTC) can be found: https://www.ucop.edu/research-policy-analysis-coordination/research-sponsors-agreements/state-of-california/cma-templates.html.

EXHIBIT D

ADDITIONAL REQUIREMENTS ASSOCIATED WITH FUNDING SOURCES

If the Agreement is subject to any additional requirements imposed on the funding State agency by applicable law (including, but not limited to, bond, proposition and federal funding), then these additional requirements will be set forth in Exhibit D. If the University is a subrecipient, as defined in 2 CFR 200 (Uniform Guidance on Administrative Requirements, Audit Requirements and Cost Principles for Federal Financial Assistance), and the external funding entity is the federal government, the below table must be completed by the State agency. (Please see sections 10.A and 10.B of the Exhibit C.)

State Agency to Complete (Required for Federal Funding Source):

Federal Agency	
Federal Award Identification Number	
Federal Award Date	
Catalog of Federal Domestic Assistance (CFDA) Number and Name	
Amount Awarded to State Agency	
Effective Dates for State Agency	
Federal Award to State Agency is Research & Development (Yes/No)	

University to Complete:

Research and Development (R&D) means all research activities, both basic and applied, and all development activities that are performed by non-Federal entities. The term research also includes activities involving the training of individuals in research techniques where such activities utilize the same facilities as other R&D activities and where such activities are not included in the instruction function.

This award ☑ does ☐ does not support Research & Development.

EXHIBIT E

SPECIAL CONDITIONS FOR SECURITY OF CONFIDENTIAL INFORMATION

If the Scope of Work or project results in additional legal and regulatory requirements regarding security of Confidential Information, those requirements regarding the use and disposition of the information, will be provided by the funding State agency in Exhibit E. (Please see section 8.E of Exhibit C.)

OR

Exhibit E is not applicable for this Agreement.

Exhibit F

Access to State Facilities or Computing Resources

If the Scope of Work or project requires that the Universities have access to State agency facilities or computing systems and a separate agreement between the individual accessing the facility or system and the State agency is necessary, then the requirement for the agreement and the agreement itself will be listed in Exhibit F. (Please see section 21 of Exhibit C.)

OR

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. The Contractor 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.