Air Quality and Health Burden of 2017 California Wildfires
Tiger Team Workplan

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BACKGROUND

On October 8-9, 2017, a series of wildfires started in the northern San Francisco Bay Area, spread quickly over nine counties and became major fires in the region. During the 9-day wildfire period, more than 160,000 acres were burned, about 8,400 houses and other buildings were destroyed, 43 people died, 185 people were hospitalized, and over 100,000 people were displaced or evacuated. Because of the smoke and prevailing weather conditions, $PM_{2.5}$ concentrations reached the highest levels ever recorded in the region. All 13 air monitoring stations in the Bay Area captured at least one exceedance of the US EPA's 24-hr average $PM_{2.5}$ standard of 35 μg/m^3, and the majority of them captured multiple days of exceedances. Daily (24-hr average) $PM_{2.5}$ concentrations reached 400 μg/m^3 at air monitoring stations near the fires and tapered off to 40-50 μg/m^3 in areas more distant from the fires. Thus, virtually all of the 7.2 million people living in the Bay Area were exposed to unhealthy air during the wildfire period.

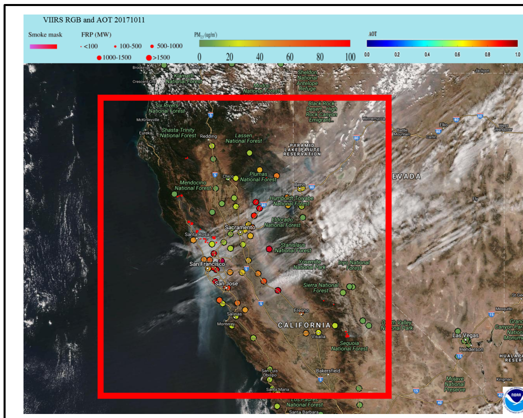

Figure 1. October 11, 2017 VIIRS visible smoke, fire detections (red dots), and measured 24-hr average $PM_{2.5}$ concentrations color-coded by Air Quality Index (AQI). The red square is the BAAQMD 4-km resolution CMAQ domain. AQI: green = good, yellow = moderate, orange = unhealthy for sensitive groups, red = unhealthy, purple = very unhealthy.

PROPOSED WORK

We will assess the effects of wildfire smoke on air quality and human health burden resulting from October 2017 California wildfires using a combination of satellite data, air quality modeling, health risk information and hospital incidence rates. Four components comprise this project: 1) compile a fire emission inventory, 2) conduct air quality modeling, 3) evaluate and improve the model results with satellite observations, and 4) conduct a health impact analysis.

I. Fire Emission Inventory (MODIS, VIIRS, GOES-16)

Prepare a detailed wildfire emissions inventory that includes fire locations, daily/hourly emissions estimates by combustion phase, and representations of smoke plume rise (USFS, NOAA- GOES-16 expertise). This work includes a newly developed integrative fire activity algorithm based on MODIS, VIIRS and the newly available GOES-16 ABI fire detections, merged with ground-based fire perimeters from the GEOMAC system and contributed USFS detailed analysis. This represents a significant improvement over the fire activity system used operationally, which is based solely on fire detections from the NOAA Hazard Mapping System (HMS). Plume rise will be calculated using the heat released from the fires as calculated by the fuel consumption models, and from satellite fire radiative power (FRP). Stakeholders (USFS, BAAQMD, EPA) are also interested in refining fire emissions to account for the large number of structures and cars burned, so we will conduct a literature review for available information.

II. Air Quality Modeling (WRF/CMAQ)

We will apply the WRF/CMAQ air quality modeling system to estimate the air quality impacts of wildfire emissions.

- The BAAQMD is experienced at applying WRF and CMAQ in the Central California region at a 4-km resolution to simulate ozone and $PM_{2.5}$. They have also worked with a 1-km domain[1] over the San Francisco Bay Area which could also be applied but computing resources may limit the areal extent of the domain.
- GMU runs a national-scale air quality modeling system which will provide boundary conditions to the higher-resolution domains.
- We will apply this system to estimate the air quality impacts due to the wildfires for October 2-25, 2017 for two simulations; 1) a base-case wildfire period without fires, and 2) with the detailed fire emissions inventory (from #1) merged with our base-case emission inventory.

With these components, we now have a prototype system that provides information about impacts solely from wildfires (by taking the difference between these two case runs), that can operate on a national scale and be regionally customized for particular state needs[2].

SJSU and Co-Investigators will conduct downscaled dispersion modeling:

- Dr. Freedman will be working with Akula Venkatram on dispersion modeling initialized by coarser 4-km domain PM2.5 fields constructed during the project, aimed at increasing spatial resolution ("downscaling") these coarser fields. He will focus on meteorological aspects, especially acquiring and analyzing all available wind observations, and possibly supplementing this with WRF runs at higher resolution (~ 1 km)[1]. These wind fields would be used to drive Dr. Venkatram's dispersion model.
- Dr. Venkatram will use dispersion models to increase the spatial resolution of the PM2.5 concentration maps based on the proposed CMAQ modeling and MAIAC satellite AOD. Among the physical mechanisms possibly implemented into the dispersion model are: 1) impact of smoldering fires on local air quality, 2) the effect on air quality of the entrainment of elevated smoke plumes into the

[1] This addresses reviewer comment #2, regarding using higher resolution model simulations than 4-km WRF simulations.

[2] This addresses part of reviewer comment #5, which is to make product of greater use to other state agencies.

atmospheric boundary layer, 3) the effects of topography on the dispersion of wildfire smoke in the Bay Area;[3] 4) using dispersion models to connect satellite based PM2.5 concentration estimates to measurements from low-cost sensors deployed during the wildfire event.

- We will aim to develop the dispersion modeling to be computational efficient so that it can be run in fast response mode to meet one of the end-user objectives of the Tiger Team project 3 – to build systems that can be used in future major wildfire events to alert the public and emergency responders of locations of high PM2.5. Use of dispersion models for this purpose has a long precedence (e.g. the ALOHA model and various dispersion model "screening" model designed to assess worst case impacts). Potential implementations of the dispersion model would be to compare its results using two types of initializations: 1) use the satellite-derived surface PM2.5 to initialize downscale model simulations; 2) use the domain emission inventory and ground-monitors to initialize downscale model simulations.

III. Improve Model Prediction with Satellite Observations (MAIAC AOD; CrIS CO, NH3)

We will use satellite and ground-based observations to evaluate model results and iteratively refine wildfire emission estimates to improve the CMAQ model predictions. Several sensitivity case runs will be conducted at the BAAQMD and USFS computing facilities.

We will take advantage of many satellite-based and ground-based measurements, such as:

1) the recently available 2017 MAIAC data and prior Tiger Team (TT) efforts (Kinney 2017). SJSU and Co-I's will derive surface PM2.5 during this wildfire event from the MODIS MAIAC aerosol optical depth product. Potential topics include: 1) test the algorithms in the surfacing model and regression model that provide optimal results for wildfire events. 2) a comparative work with the CMAQ model results. This work is related to Gupta et al. (2018) who recently used MODIS AOD and a low-cost monitoring network of sensors to derive surface PM2.5 concentrations for this wildfire event. Dr. Gupta has agreed to be a collaborator.
2) Furthermore, we will undertake a fusion of CMAQ fields with surface observations and possibly with MAIAC AOD for better estimating the spatial distribution of smoke, capitalizing on experience at Georgia Tech and the Kinney 2017 TT work.
3) Carbon monoxide from the CrIS instrument (NASA JPL).
4) NH3/CO emission ratios from CrIS. Ammonia is an important aerosol precursor, and a little studied pollutant from wildfire. Dr Zondlo will examine how emission ratios change downwind of the fire for aerosol partitioning as the plume ages.
5) The MAIAC dataset also includes an Injection Height parameter. This will be investigated.
6) Several Interagency Monitoring of Protected Visual Environments (IMPROVE) sites surround the study area. It is anticipated that the data should be available Fall 2018. UC Davis (Contributor) will help us access and use the data for model analysis.
7) Near-surface 1-hr average PM2.5 concentrations from permanent monitoring locations (via AirNowTech) and temporary monitoring locations deployed by local agencies for the wildfires (via the USFS PWFSLSmoke R package).
8) Finally, several other smoke modeling datasets are potentially available for model inter-comparison, such as the High Resolution Rapid Refresh (HRRR)-Smoke, BlueSky smoke modeling framework, and VIIRS high-resolution trajectories.

IV. Health Impact Analysis

We will utilize short-term exposure-response relationships already established between $PM_{2.5}$ and public health to assess health impacts of wildfire-induced pollutant exposure. Georgia Tech's collaborator at the CDC

[3] This addresses reviewer comment #2, regarding the influences of topography.

is developing exposure-response functions for wildfires. By conducting model simulations of air quality with and without wildfires we (UNC, Boston University) can estimate short-term health burden specifically caused by wildfires. Potential impacts include increased risk of morbidity and premature mortality from respiratory and cardiovascular diseases. We will cross-validate the results using hospital admission data or other health data as they become available. We are pursuing two leads on hospital information; California Dept. of Public Health, and California EPA. Finally, we believe this analysis can inform a future strategy to apply BenMAP for short-term exposures to wildfire smoke.

Specifically[4]:

1. UNC will lead a graduate student in the following health analysis once the PM2.5 concentrations are modeled:
   - Review the literature for short-term risk functions for PM, ozone, and other pollutants. A starting point would be recent EPA Regulatory Impact Analyses (RIAs), but the project will also look for information specifically for wildfire smoke. This will involve Boston University and EPA (Rappold – Collaborator, as available).
   - Find the baseline health data that is needed for each of the short-term health risks. Any health function that is included in the EPA RIAs should have pre-loaded baseline incidence data already in BenMAP. Other functions specifically for wildfires would need to be added to BenMAP, and we may need to find new baseline health data – either from the CDC or health agencies in CA.
   - Run the health numbers through BenMAP (other methods could be used, but BenMAP may be the most straightforward).
2. Boston University: As a parallel activity, health records from California can be analyzed for time series of health impacts (before-during-after, and perhaps comparing with the same time period in previous years). Link exposure data to health data. Previous collaborations between Boston University and CalEPA (Rupa Basu – Collaborator) will facilitate this work.

DELIVERABLES/PRODUCTS

Wildfire smoke impacts will recur in the future in California and elsewhere, and having a system that can accurately estimate those impacts, not only in terms of $PM_{2.5}$, but in terms of short-term exposure-response relationships is critical to future planning of emergency responders to protect public health.

- Manual/Report: Stakeholders such as the BAAQMD envision using this project information as a basis for an emergency response manual to help inform emergency responders regarding expected levels of ambient PM based on the nature of wildfire and the number of people who may need medical attention, etc. (Deliverable: Case study document of lessons learned to inform this manual. This has synergies with the work of the Fiore TT and elements of this document could also be used to support an Exceptional Event demonstration[5]).

- Fire Activity Information: This work will lead to a significantly refined satellite-based fire activity system (VIIRS, MODIS, GOES-16) used in daily smoke forecasting, supporting personnel deployed on wildfires. Furthermore, this work has great utility for the upcoming 2017 EPA National Emission Inventory (NEI) effort (per EPA Stakeholder Tesh Rao).

- Prototype air quality modeling system specific to wildfire smoke impacts, improved with remotely sensed data: This work will improve the existing air quality modeling system of the BAAQCD (newly

[4] This addresses reviewer comments #1 and #4 regarding strengthening the health-related aspects of the project.
[5] This addresses reviewer comment #5 regarding wanting to see this work tied more specifically to Exceptional Events.

coupled with the fire activity information system) through comparisons (and in some cases, fusion) with MAIAC AOD and CrIS CO and NH3 fields. It will demonstrate a prototype air quality modeling system on a national scale (the GMU system), customizable to a finer grid resolution for a State or regional analysis (e.g. BAAQMD domain), that quantifies impacts from wildland fire smoke.

- Health Impact Analysis: A merging of these fire/AQ system improvements with short-term exposure-response relationships to estimate health burden of $PM_{2.5}$. A health impact assessment of wildfire smoke on the population of northern California for October 2017 based upon satellite supported air quality modeling and evaluated with health data.

- Publication: Results will be published in peer-reviewed publication(s) such as the Journal of Air & Waste Management Association (JA&WMA).

- NASA ARSET Training Module

- Products as detailed in the Communication Plan (Webinars, Presentations, Website)

REFERENCES

Gupta, P., P. Doraiswamy, R. Levy, O. Pikelnaya, J. Maibach, B. Feenstra, A. Polidori, F. Kiros, and K.C. Mills. 2018. Impact of California Fires on Loacl and Regional Air Quality: The Role of a Low-Cost Sensor Network and Satellite Observations. GeoHealth, 2. https://doi.org/10.1029/2018GH000136.

Air Quality and Health Burden of 2017 California Wildfires
Tiger Team Communication Plan

COMMUNICATION PLAN

The Wildfire Tiger Team involves a wide range of communication forms, from highly technical one-on-one interactions, to inter-specialty group coordination, to Stakeholder interaction, to creating public-facing materials. Currently there are 11 HAQAST members, 19 Stakeholders and Contributors, and approximately six more Stakeholders/Contributors identified for outreach (see Table 1). These thirty-plus personnel are working on four somewhat discrete but overlapping project components, as outlined in the Statement of Work (SOW). In this communication plan we lay out how we will communicate; as a team; with existing Stakeholders; with new Stakeholders and Collaborators; and finally, how we are sharing information externally. Note that this Communication Plan is a working document and could see revisions as the TT begins work.

Specifically, there are three tiers of communication for this project:

- Within Team Coordination and Leadership
- Stakeholders Interaction
- Communication Products

We plan on monthly conference calls with the core team and quarterly conference calls with both core team members and Stakeholders. Core team members are those who are actively working on the project tasks (approximately 20 people). Several Stakeholders are also core team members.

WITHIN TEAM COORDINATION AND LEADERSHIP

The USFS will provide overall project coordination. SJSU will co-lead. Then, other HAQAST members will be identified to lead sub-teams (as available and resources warrant). The goal is to ensure necessary expertise is leading particular components and people know who go to for questions (clear line of communication and leadership).

Below are five potential sub-groups. The first conference call of the core team will focus on identifying whether 1) these are the correct/applicable sub-groups, 2) identifying sub-group leads, and 3) ascertaining whether all the necessary participants are included in each sub-group. Monthly conference calls will be held thereafter with the entire team. It is expected that sub-group leads will continue working with their colleagues as needed throughout the month and that the monthly calls will facilitate inter-sub-group questions/discussions. Also, some sub-group work will depend on results from other sub-groups (e.g. CMAQ modeling will depend on the fire emission inventory), therefore, some sub-groups are front-loaded and others are back-end loaded. The monthly conference calls will reflect this.

Potential sub-groups:

- Fire emissions (and other emissions)
- Air Quality Modeling
- Satellite Data Analysis
- Air Quality Model Evaluation & Satellite Data Integration/Comparison
- Health Impact Analysis

The first four steps will be an iterative process. With each iteration we supply data to the health impact analysis step. Start with a base case. We will need to identify how many iterations are possible.

Marlin Martinez, Research Assistant, will organize conference calls, take and disseminate notes from the calls, keep email lists, interact with team members answering questions, and provide webpage content for the project.

STAKEHOLDER INTERACTION

Table 1 identifies nineteen TT Stakeholders and Contributors and there are at least six more identified for outreach. Individual Stakeholder interaction depends on their particular interest and available time to interact with the TT. Some Stakeholders are interested in a portion of the results (such as products supporting a National Emission Inventory), some Stakeholders are Contributors, such as the BAAQMD who will be conducting CMAQ modeling, and some Stakeholders will be providing expertise to a particular sub-group, such as EPA with the health impact analysis. As the TT starts up, input from each Stakeholder will be sought to identify their key interests in the project and desired frequency of interaction. Table 1 will be updated to reflect this. At a minimum all Stakeholders will have the opportunity to participate in quarterly Stakeholder conference calls where they will get a project update and the opportunity to provide input.

Table 1 will also be put into a spreadsheet and expanded to log various stakeholder interactions such as one-on-one conversations, conference calls, in-person meetings etc. Susan O'Neill will do 1-2 trips to California to meet with Stakeholders and other TT members/Contributors. As new Stakeholders are identified, they will be added to the spreadsheet. An initial discussion will occur with the TT Lead(s) and the new Stakeholder to identify their interests and desired level of interaction. Sub-team interactions will also be identified.

Table 1. Stakeholder communication plan

Stakeholder, Contributor contact	***Stakeholder agency***	***Key interests/ Issues***	***Communication vehicle***	***Frequency***	***Comments***
Saffet Tanrikulu	BAAQMD	Satellite data; CMAQ model running and comparisons; health outcomes	Telephone conference; in-person meeting; emails	Monthly	CMAQ Modeling; Model evaluation
Stephen Reid	BAAQMD	Satellite data; CMAQ model running and comparisons; health outcomes	Telephone conference; in-person meeting; emails	Monthly	CMAQ Modeling; Model evaluation
Jeff McQueen	NOAA	Fire emission and smoke modeling improvements	Telephone conference; emails	Quarterly	NOAA Smoke Forecasting System
Pete Lahm	USFS Fire & Aviation Management, Program Lead – Wildland Fire Air Quality Response Program	Smoke forecasting system improvements; satellite information for smoke forecasters on IMT's; smoke impacts	Telephone conference; in-person meeting; emails; online chat	Monthly; Weekly	Deploys ARAs to IMTs
Trent Proctor	USFS Air Program Lead, Region 5 – CA	Smoke forecasting system improvements; satellite information for smoke forecasters on IMT's; smoke impacts	Telephone conference; emails	Quarterly	California state-wide coordinator of smoke and air quality issues

Susan Stone	EPA, Office of Air Quality Planning and Standards (AQI Lead	Health effects and health communication	Telephone conference; emails	Quarterly	EPA AIRNOW
Ana Rappold	EPA, National Health and Environmental Effects Research Lab	Smoke health impacts	Telephone conference; emails	Quarterly, Monthly	Collaborator – Health impacts literature review
Tesh Rao	PA, Office of Air Quality Planning and Standards, National Emission Inventory Lead	Emissions inventories	Telephone conference; emails	Quarterly	EPA National Emission Inventory
Scott Bohning	EPA Region 9 Wildfire Smoke Team	Smoke forecasting, smoke impacts	Telephone conference; emails	Quarterly	
Kathleen Stewart	EPA Region 9 Wildfire Smoke Team	Smoke forecasting, smoke impacts	Telephone conference; emails; online chat	Quarterly	ARA deployed to wildfires
Lauren Maghran	EPA Region 9 Wildfire Smoke Team	Smoke forecasting, smoke impacts	Telephone conference; emails; online chat	Quarterly	ARA deployed to wildfires
ShihMing Huang	Sonoma Technology Inc.	Emissions Inventory, smoke modeling	Telephone conference; emails	Quarterly	EPA NEI developer; Smoke tool developer
Mark Fitch	National Park Service, National Smoke Specialist	Smoke forecasting system improvements; satellite information for smoke forecasters on IMT's; smoke impacts	Telephone conference; in-person meeting; emails; online chat	Monthly; Weekly	WFAQRP core leadership
Lee Tarnay	USFS Region 5 Remote Sensing Lab – CA	Smoke forecasting; fire emissions	Telephone conference; emails; online chat	Monthly	Fuel estimation and consumption
Rupa Basu	California EPA, Office of Environmental Health Hazard Assessment	Health impacts	Telephone conference; emails;	Quarterly; Monthly	Health impact information
Pawan Gupta	NASA, ARSET	Satellite information; Training	Telephone conference; emails;	Quarterly	ARSET training module consultation
Sean Raffuse	University of California, Davis	Satellite information; IMPROVE data	Telephone conference; emails;	Monthly	Satellite fire activity information analysis, IMPROVE data
Yufei Zou	University of Washington	Smoke modeling system development	Telephone conference; emails; online chat; in person	Daily; Weekly	CMAQ Modeling; Model evaluation
Yasmeen Sands	USDA Forest Service, PNW Research Station, Public Affairs Specialist	Communication and outreach of science accomplishments	Telephone conference; emails, online chat; in person	Monthly	Use social media to communicate project accomplishments
Kirk Baker	EPA	Dispersion and photochemical modeling; satellite products	Telephone conference; emails	Monthly	

Joe Wilkins	EPA	Dispersion and photochemical modeling; satellite products	Telephone conference; emails	Monthly
Ravan Ahmadov	NOAA	Smoke forecasting model development; satellite information	Telephone conference; emails	Monthly
Megan Bela	NOAA	Smoke forecasting model development; satellite information	Telephone conference; emails	Monthly
Stu MkKeen	NOAA	Smoke forecasting model development; satellite information	Telephone conference; emails	Monthly

COMMUNICATION PRODUCTS

Communication related products – some are detailed in the Deliverable section and included here for completeness and context.

- Training Modules - ARSET
- Project Webpage
- Publication(s)
- Presentations/Webinars
- Conference Calls – Team members, Stakeholders, External technical groups

TRAINING MODULE(S): Two potential training products are identified coming out of this TT project. 1) ARSET Training Module (in collaboration with Pawan Gupta from NASA ARSET). 2) A recorded training module of satellite information for smoke forecasting and current situational awareness.

WEBBPAGE: A project webpage will be created with project informational sheets and other products of the project. The webpage will also have an interactive map overlaying population data as available from popgrid.com and the BAAQMD with modeled and remotely-sensed products of the project.

PUBLICATION: Results will be published in peer-reviewed publication(s) such as the Journal of Air & Waste Management Association (JA&WMA).

PRESENTATIONS: Presentations will be made at conferences such as the International Smoke Symposium, EPA National Air Quality Conference, and HAQAST meetings. A California-specific conference is the Meteorology and Climate – Modeling for Air Quality (MAC-MAQ) being held at UC Davis, September 2019.

WEBINAR: A webinar will be hosted most likely through the Southern Fire Exchange.

CONFERENCE CALLS: Project progress will be communicated with stakeholders initially via monthly and/or quarterly conference calls depending on their availability and desired level of interaction. Monthly calls will be with project team members (HAQAST members, collaborators, stakeholders depending on level of involvement). See previous sections of the Communication Plan. Externally, project information and progress will be shared with groups such as the JPSS Fire Smoke Initiative monthly calls, NWCG Smoke Committee bi-weekly calls, and monthly US/Canadian fire emission sharing conference calls.