Modeling Air Quality and Health Impacts of the 2017 California Wildfires

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Introduction

On October 8-9, 2017, a series of wildfires started in the northern San Francisco Bay Area and wildfire smoke spread quickly over a 9-county area. These fires:

- Burned approximately 200,000 acres;
- Destroyed 8,400 buildings;
- Killed 44 people and;
- Caused over 100,000 evacuations.

Because of the smoke and prevailing weather conditions, $PM_{2.5}$ concentrations reached the highest levels recorded to date in the region. Daily $PM_{2.5}$ concentrations exceeded 400 µg/m^3 at monitoring stations near the fires and decreased to 40-50 µg/m^3 in more distant areas. Virtually all the 7.2 million people living in the Bay Area were exposed to unhealthy air during the wildfire period.

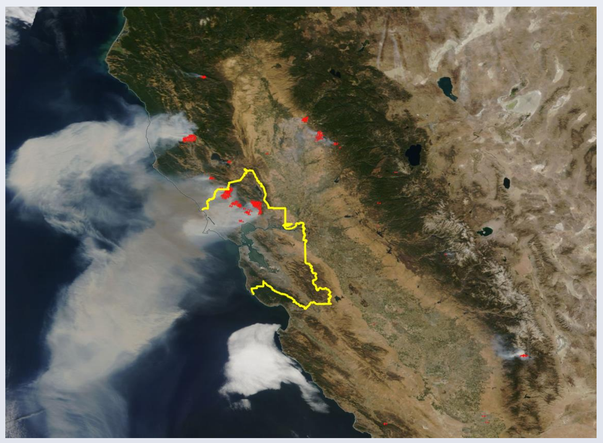

Figure1. NASA satellite image from October 9, 2017 (BAAQMD jurisdiction outlined in yellow).

Members of NASA's Health and Air Quality Applied Sciences Team (HAQAST) and partner agencies are assessing the effects of smoke from the October 2017 California wildfires by:

- Developing a fire emissions inventory;
- Conducting air quality modeling;
- Evaluating and improving model results with satellite observations, and;
- Conducting a health impact analysis using health risk information and hospital incidence rates.

This poster describes air quality modeling conducted by BAAQMD to support this study.

Description of the Modeling System

Three nested WRF domains were used: 36-km, 12-km, and 4-km grid resolution. Outputs from the NCEP North America Mesoscale (NAM) 12-km modeling system were used as the first guess. Key options using to run WRF Version 3.8 include the following:

- Pleim-Xiu Land Surface Model and ACM2 PBL scheme
- Surface-layer Revised MM5 Monin-Obukhov scheme
- Analysis and Observation FDDA

Anthropogenic, biogenic, and wildfire emissions were processed using the Sparse Matrix Operator Kernel Emissions (SMOKE) tool. Anthropogenic emissions inputs were based on inventories developed by BAAQMD and the California Air Resources Board. Biogenic emissions estimates were developed using the Biogenic Emission Inventory System (BEIS) v.3.61. Details about fire emissions processing are provided in the next section.

CMAQ version 5.2 was run at 4-km grid resolution with offline plume rise and biogenic emissions. The simulations featured the SAPRC07 Chemical Mechanism and the AERO6 aerosol module with nonvolatile POA. Default options were used for transport and other processes.

Fire Emission Processing

A baseline fire emissions inventory was prepared by the USDA Forest Service (USFS) and UC Davis using the BlueSky Framework. This work included a newly-developed fire activity algorithm based on satellite-based fire detections (MODIS, VIIRS, GOES-16) merged with ground-based fire perimeters from the GEOMAC system. Plume rise for the base case was calculated using the Pouliot-Godowitch algorithm in SMOKE, which relies on area burned and a pre-computed heat flux.

Figure 2 gives a summary of BlueSky Framework estimates of daily acres burned (left) and $PM_{2.5}$ emissions (right) from the fires that occurred during this episode. For the entire period, BlueSky estimated a total of 198,000 acres burned and 49,000 tons of $PM_{2.5}$ emissions.

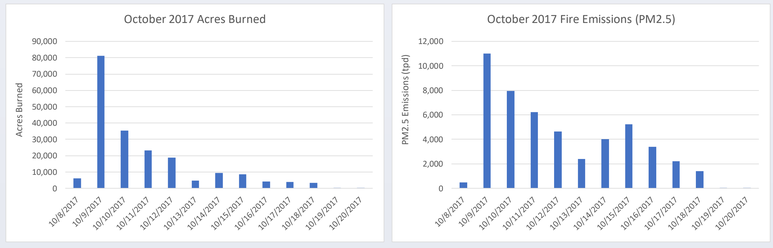

Figure 2. Fire emissions summary from the BlueSky Framework with GOES-16 fire detections

To develop emissions for CMAQ, BAAQMD processed hourly emissions and plume rise data from BlueSky through the SMOKE model and merged the results with previously prepared anthropogenic emissions files.

In addition, USFS and UC Davis prepared data for 2 alternative emissions and plume rise scenarios:

1. Emissions estimated with GOES-16 fire radiative power (FRP) data; plume rise calculated using Briggs algorithm
2. Emissions estimated with FRP data using an approach developed by NASA's Fire Energetics and Emissions Research (FEER) team, along with plume rise estimates prepared using the Sofiev algorithm

BAAQMD performed a total of 4 CMAQ runs: a "no fire" case; the base case fire inventory; and the 2 alternative fire scenarios listed above.

Simulation Results

The CMAQ simulation period was from October 3 - 20, 2017, which allowed for a spin-up period before the fires started. Figure 3 shows daily average $PM_{2.5}$ concentrations averaged across 16 Bay Area monitoring sites, along with CMAQ-predicted daily average values averaged across those same locations. This figure shows that:

- The "no fire" case predicted clean conditions, as expected.
- The baseline fire and sensitivity #1 (s1) cases generally showed good agreement with observations, capturing the daily evolution of smoke impacts (though with a large overprediction on October 17).
- The sensitivity #2 (s2) case estimated much higher $PM_{2.5}$ emissions early in the episode, resulting in a large overprediction on October 9.

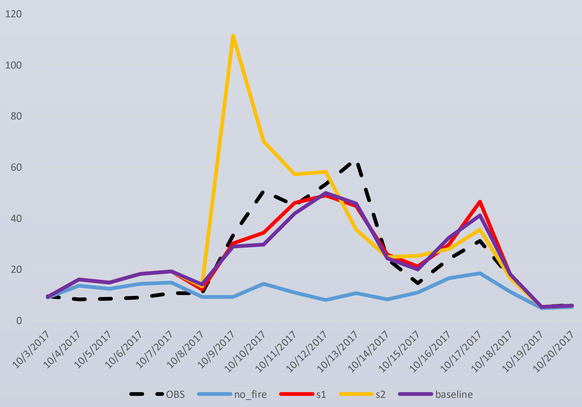

Figure 3. CMAQ vs. observed 24-hour $PM_{2.5}$ concentrations averaged across Bay Area monitoring site locations.

Simulation Results (continued)

More detailed comparisons were also made between modeled and observed $PM_{2.5}$ concentrations at representative monitoring sites across the Bay Area. Figure 4 shows the locations of these sites, along with fire perimeters.

Figure 5 shows that the s1 fire case agrees well with observations at individual sites, though $PM_{2.5}$ is generally over-predicted on October 17. Also, $PM_{2.5}$ is significantly underpredicted on October 13 at the Napa site.

Figure 4. Fire perimeters and Bay Area monitoring site locations.

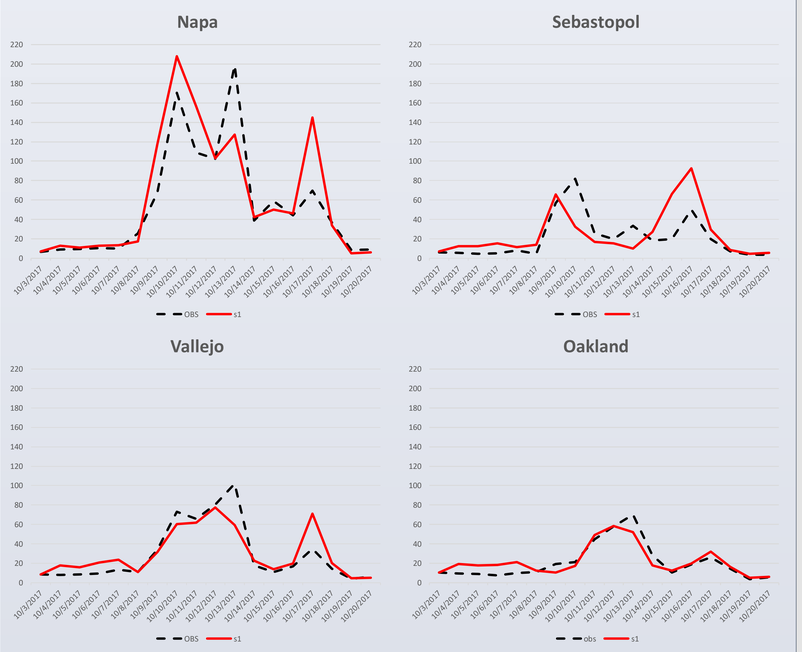

Figure 5. CMAQ and observed 24-hour $PM_{2.5}$ at representative sites.

Modeled $PM_{2.5}$ concentrations were compared to smoke plumes from satellite images. Figure 6 shows a comparison for October 13, when smoke spread from the northeast and "fumigated" the entire Bay Area. On this day, the CMAQ-produced plume (left) was similar to a satellite-based image (right),though modeled $PM_{2.5}$ concentrations were somewhat under-estimated on this day at most area monitors. These results indicate that we can produce a realistic simulation of a large regional wildfire event.

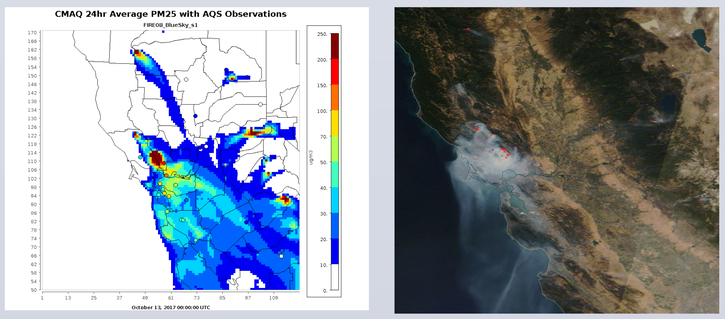

Figure 6. CMAQ 24-hour $PM_{2.5}$ with observations (circles) (left), compared to NASA satellite image from October 13, 2017 (right).

Future Work

Modeled $PM_{2.5}$ concentration fields have been provided to HAQAST project partners for further analyses, including fusion with satellite aerosol optical depth (AOD) data and health impact analyses.

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