NASA's GEOS Composition Model Assessment of $PM_{2.5}$ During Wildfires: Inferring the Impact of $PM_{2.5}$ Exposure on Adverse Respiratory & Cardiovascular Conditions

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Take Home Message

- NASA Goddard's Earth Observing System Composition Forecast (GEOS-CF) model produces global forecasts of atmospheric pollutants such as O_3, NO_2, $PM_{2.5}$ in near real-time. This project demonstrates one of the model applications for inferring estimated health impacts during severe air quality events.
- In this study we evaluated how the change in $PM_{2.5}$ level concentration may impact an individual's respiratory and cardiovascular health as well as their daily activities during these wildfire events.
- Based upon the estimated health impact results from BenMAP, the change in $PM_{2.5}$ concentration levels, calculated from GEOS-CF, affected between 2-3% of the population of individual's from ages 6-18, with respect to asthma exacerbation in Washington and California.
- This work demonstrates that NASA's observations and models are now detailed enough to assess the impact of wildfires on air quality and human health.

Methods

GEOS-CF simulated $PM_{2.5}$ applied to a human health assessment model, BenMAP (The Environmental Benefits Mapping and Analysis Program, version 1.4.8), estimates the impact on adverse respiratory health conditions due to $PM_{2.5}$ exposure from wildfires.

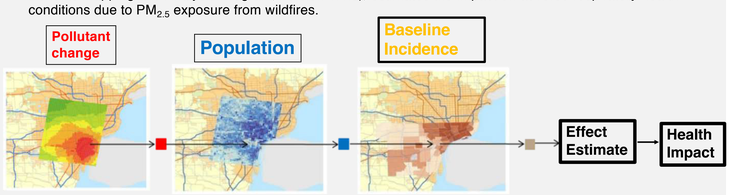


Figure 1: The BenMAP-CE program estimates the human health impacts and economic value of air quality changes. Based upon epidemiologically derived health impact functions. Health impact functions calculate the change in the number of adverse health effects among a certain population, based upon a specific age, race or gender, associated with a change in exposure to air pollution

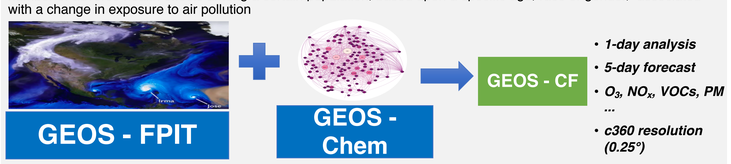


Figure 2: The GEOS -FPIT weather model combined with the detailed chemistry from GEOS-Chem produces the GEOS-CF system, which is able to provide a 5 day forecast for various chemical species across the globe. GEOS-CF includes several chemicals species (i.e. NO_2 and O_3) and the same type of study can be extended to these constituents.

Background Information

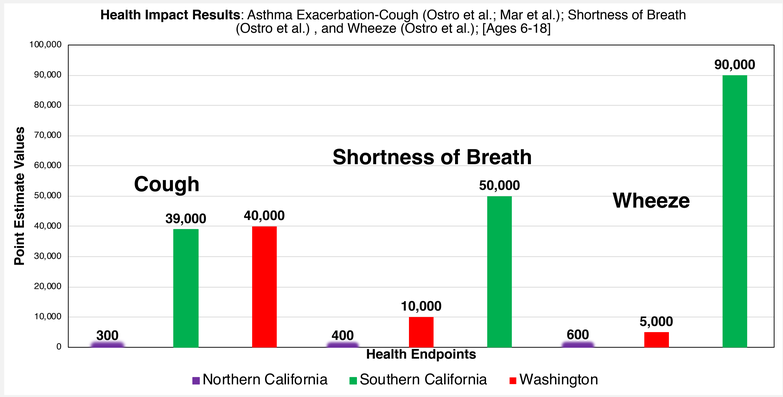
Health Endpoint	Metric	Author	Year	Age Range (years)	Location
Acute Myocardial Infarction Nonfatal	D24 Hour Mean	Pope et al.	2006	0 to 99	Greater Salt Lake city, Utah
Acute Respiratory Symptoms: Minor Restricted Activity Days (MRADs)	D24 Hour Mean	Ostro & Rothfield	1989	18 to 64	Nationwide
Asthma Exacerbation: Cough	D24 Hour Mean	Mar et al.; Ostro et al.	2004; 2001	6 to 18	Spokane, WA; Los Angeles, CA
Asthma Exacerbation: Shortness of Breath	D24 Hour Mean	Mar et al.; Ostro et al.	2004; 2001	6 to 18	Spokane, WA; Los Angeles, CA
Asthma Exacerbation: Wheeze	D24 Hour Mean	Ostro et al.	2001	6 to 18	Los Angeles, CA
Emergency Room Visits: Asthma	D24 Hour Mean	Mar et al.	2010	0 to 99	Greater Takoma, WA
Hospital Admissions: All Cardiovascular (less Myocardial Infarctions)	D24 Hour Mean	Zanobetti et al.	2009	65 to 99	26 U.S. communities
Hospital Admissions: All Respiratory	D24 Hour Mean	Zanobetti et al.	2009	65 to 99	26 U.S. communities
Mortality	Annual	Krewski et al.	2009	30 to 99	116 U.S. cities
Work Loss Days (WLDs)	D24 Hour Mean	Ostro	1987	18 to 64	Nationwide

Table 1: A variety of respiratory-related, cardiovascular-related and morbidity epidemiological studies, as seen in the table above, were applied to BenMAP to estimate the greatest health impact estimate due to the change in $PM_{2.5}$ model concentrations during these severe wildfire events. The results from BenMAP showed the largest impact for the following studies; asthma exacerbation, MRADs, and WLDs.

Location of Wildfire Events	Wildfire event Scenario (Year - 2017)	Background Scenario (Year - 2017)	(Range) Delta of $PM_{2.5}$ Concentration* ($^{\mu g}/_{m^3}$)
Washington State	7/30 - 8/15	8/16 - 8/31	6.0 – 8.0
Northern California	10/01-10/15	10/16 - 10/31	0.06 – 1.33
Southern California	12/04 - 12/24	12/25 -01/12/2018	24.0-30.0

Table 2: The wildfire event scenario dates evaluates the $PM_{2.5}$ levels during the wildfires and the background scenario evaluates the $PM_{2.5}$ levels after the wildfire. The delta is calculated by taking the average of the daily-average PM2.5 for the scenario and the average of the daily-average PM2.5 for the background. The largest delta value was calculated for the Southern California wildfire events.

Health Impact Results



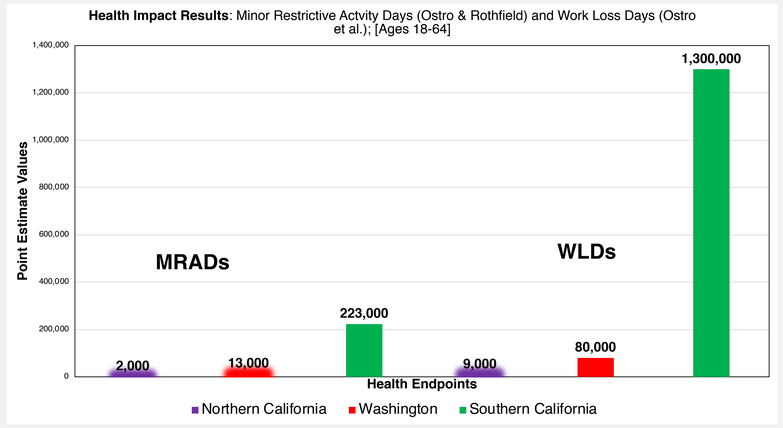


Figure 4: According to the BenMAP estimation for the respiratory related and daily activity health impacts it can assumed that the change in $PM_{2.5}$ concentration levels during the Southern California wildfires had a significant impact on children/young adults health and impacted individual's daily activities.

Location of Wildfire Events	Health Endpoint	Percentage of (Exposed) Population (%)
Washington State	Asthma Exacerbation: Wheeze	0.4%
	Minor Restrictive Activity Days	2.0%
	Work Loss Days	0.3%
Northern California	Asthma Exacerbation: Wheeze	0.03%
	Minor Restrictive Activity Days	0.10%
	Work Loss Days	0.02%
Southern California	Asthma Exacerbation: Wheeze	2.2%
	Minor Restrictive Activity Days	8.3%
	Work Loss Days	1.5%

Table 3: BenMAP estimated that almost 8% of the exposed population daily activities in Southern California were heavily impacted by the change in air quality due to those significant wildfires

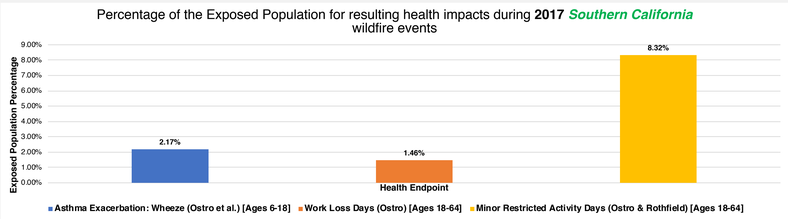


Figure 5: BenMAP's calculated delta $PM_{2.5}$, health impact results for respiratory related and daily activities, and percentage of the exposed population demonstrates how harmful increased amounts of $PM_{2.5}$ concentration levels can be on individual's health during severe air quality events.

GEOS-CF Model concentration vs. Observational studies

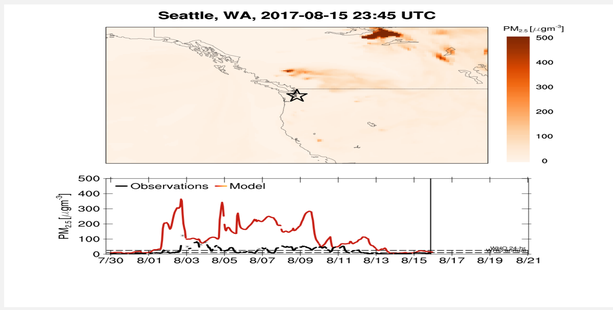


Figure 3: The timeseries above demonstrates how the PM2.5 concentrations levels, simulated by GEOS-CF, are overpredicted during the (October 2017 wildfire event in Seattle, Washington compared to openAQ observational data. GEOS-CF uses satellite observations to constrain fire emissions (i.e. QFED-the Quick fire emissions dataset).

Spatial Maps: Health Impact Results, Exposed Population (County Level)& Delta $PM_{2.5}$

Washington Wildfires (August 2017)

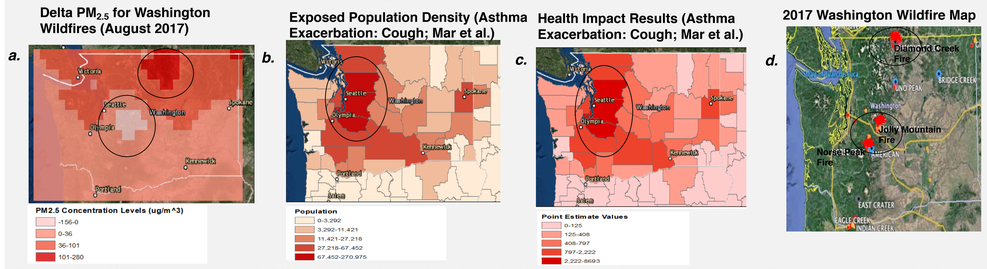


Figure 6: (a. - d.) There were a series of wildfires that burned across Washington in the year of 2017, but there were some wildfires that became very significant. During the month of August in 2017 there were three significant wildfires that causes significant damage to parts of Washington and there are the following; the Diamond Creek, Norse Peak, and Jolly Mountain fires. The prior mentioned fires combined burned thousands of acres of land and lead to multiple school closures, and hazardous air quality for weeks/months to come. The calculated delta $PM_{2.5}$ from GEOS-CF was able to capture two of the major fires (i.e. Diamond Creek and Jolly Mountain fires) during August 2017. Based upon the BenMAP's health impact results and corresponding exposed population density for the asthma exacerbation: cough study showed estimated results in areas where the most significant fires occurred during that time Washington were the highest in areas where the significant wildfires (i.e. Jolly Mountain and Norse Peak fires) occurred.

Northern California Wildfires (October 2017)

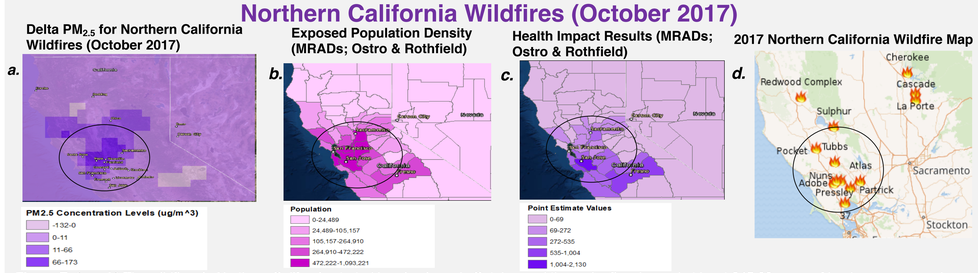


Figure 7: (a. - d.) The wildfires in Northern California started burning in early October and the major fires burned at least 245,00 acres of land across several counties in that area. Some of the significant fires during that time were the Tubbs Fire, the Atlas Fire, Nuns Fire, and several others. These ongoing fires lead to poor air quality due to increase of $PM_{2.5}$ level concentrations in the air and resulted in individuals reducing the amount of activities they participated outdoors due to the smoke from the fires and poor visibility. GEOS-CF was also able to capture the significant fires in this area based upon the delta $PM_{2.5}$ calculation and the BenMAP health impact and population results were the greatest over the wildfires.

Southern California Wildfires (December 2017)

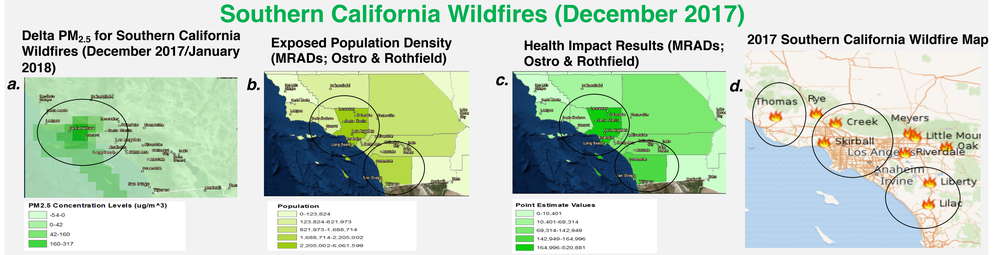


Figure 8: (a. - d.) The significant fires (i.e. Thomas and Creek fires) led to widespread evacuations and property losses. The wildfires burned over 307,900 acres, caused traffic disruptions, school closures, hazardous air conditions, evacuations, and power outages. GEOS-CF captured some of the significant fires in this area and the BenMAP health impact and population results showed areas where the was the most significant impact corresponded to location the significant wildfires.

Conclusions

- GEOS-CF is a multi-species system, which can be used to perform analysis and predictions for $PM_{2.5}$ concentrations during severe air quality events (i.e. wildfires).
- According to the BenMAP results it can be assumed that the 2017 wildfire events in Southern California did impact individual's respiratory health and daily activities, but not so much for individual's cardiovascular health.
- The simulated change in $PM_{2.5}$ from the wildfires was likely not large enough to impact severe-outcome health endpoints such as emergency room visits, hospital admissions, and mortality.

Future Work

- Evaluate severe air quality events across the globe (i.e. India) using the GEOS-CF model.
- Observe the resulting health impact estimates associated with $PM_{2.5}$ due to the 2018 wildfire events in California, Washington and biomass burning events across the globe (i.e. India).
- Apply the same method from this study to other pollutants such as O_3 and NO_2.

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