Spatiotemporal high-resolution prediction of wildfire smoke exposure: Leveraging satellite remote sensing and low-cost sensor data

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The primary goal of this study is to build a "proof-of-concept" framework for spatiotemporally high-resolution (daily, 1-km) wildfire $PM_{2.5}$ exposure estimates based on satellite and low-cost sensor data with a novel spatial machine learning algorithm, and to apply the framework to the entire western U.S., including WA, OR, CA, NV, MT, ID, WY, UT, AZ, CO, and NM. The estimated wildfire $PM_{2.5}$ exposure will support future smoke-related epidemiological and environmental justice analyses.

Wildfire activity has significantly increased over the past decades. Recent wildfire events point to the emergence of extreme wildfires at a higher frequency, including in the western U.S. Among wildfire-derived air pollutants, fine particulate matter ($PM_{2.5}$) is most substantially elevated during smoke events, making it the most crucial for public health. In the U.S., approximately 52% of all summertime daily $PM_{2.5}$ observations above 35 μg/m^3 occur when a smoke plume is present. However, a major impediment to comprehensive epidemiological and environmental justice analyses regarding wildfire $PM_{2.5}$ is the lack of geospatially accurate exposure estimates. Existing methods either generate biased wildfire $PM_{2.5}$ estimates (*e.g.*, rely on outputs from chemical transportation models) or use total $PM_{2.5}$ during smoke events as an imprecise surrogate. These exposure estimates are particularly uncertain in rural areas/remote communities near fire sources that are not covered by regulatory air monitoring. The spatial variation and temporal duration of smoke exposures among the residents in those regions are largely unknown.

Recently, the paradigm of wildfire smoke monitoring is shifting with increasingly available satellite remote sensing and low-cost sensor instruments: A novel remote sensing parameter, Ultraviolet Aerosol Index (UVAI), is sensitive to wildfire smoke with global coverage; A commercial low-cost PM sensor, PurpleAir, has been increasingly deployed by the public, largely expanding the scope of $PM_{2.5}$ monitoring in both urban and rural areas. In fact, remote sensing and low-cost sensor data are usually the only available measurements of $PM_{2.5}$ in populated areas near wildfire sources. However, very limited efforts have been made to utilize these promising data to improve spatiotemporal wildfire $PM_{2.5}$ estimation.[1]

Project Goals and Phases

- *Phase 1*: Due in Spring 2023 – To develop a "proof-of-concept" statistical framework for high-resolution wildfire $PM_{2.5}$ prediction at the daily level in Washington, with the incorporation of novel satellite and low-cost sensor data.
- *Phase 2*: Due in Autumn 2023 – To conduct an independent prediction validation with $PM_{2.5}$ observations collected in a rural community, Methow Valley in Northern Washington, and its surrounding areas heavily affected by wildfire smoke in recent years.

Experimentation Requirements: AWS Cloud Computing

Our experiments deal with processing and training multi-level statistical models with large volumes of data, therefore requiring powerful computation resources such as AWS Cloud Computing, which can handle CPU intensive jobs with high demand of memory and disk I/O.

The cloud computing resources we will use include a single EC2 node (m6g.8xlarge, vCPUs = 32, Memory = 128 GB) with 700 GB storage. We expect to use the EC2 node on a demand basis with 20% utilization per month. The total cost estimate for 12 months is approximately USD 2,998. Please see this link regarding the detailed cost estimates.

For this one-year proposal, we aim to apply for AWS research credit of **USD 3,000** to cover the cost associated with the aforementioned AWS computing resources. We will not reapply for the research credit over the one-year project period.

Additional research cost, including data request and processing, device deployment and maintenance, personnel, and any extra cloud computing cost, will be covered by the Population Health Initiative (PHI) Pilot Research Grant at the University of Washington.

Summary

Our large-scale wildfire smoke data will serve as the foundation of extensive community-based applications and population-based health research: 1) Our fine-scale exposure data will allow local agencies to identify particular communities heavily and disproportionally affected by wildfire smoke and facilitate early warning and prevention of heavy smoke episodes; 2) Our exposure data will substantially improve large-scale epidemiological analyses of the harmful effects of wildfire smoke, as existing studies have largely relied upon inaccurate exposures. This pilot study will provide important preliminary data for our future NIH R01-level grant proposals. This pilot study, along with our future research, will address all three pillars foundational to the Population Health Initiative.

References

1. Bi, J.; Wildani, A.; Chang, H. H., et al., Incorporating Low-Cost Sensor Measurements into High-Resolution $PM_{2.5}$ Modeling at a Large Spatial Scale. Environmental Science & Technology 2020, 54, (4), 2152-2162. PMID: 31927908.