# The Impacts of Prescribed Burning on $PM_{2.5}$ Air Quality and Human Health: Application to Georgia, USA

**Ran Huang, Yongtao Hu, Armistead G. Russell, James A. Mulholland, M. Talat Odman***

School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta GA 30332

## Background and Objective

- Short-term exposure to fire smoke, especially $PM_{2.5}$, is associated with adverse health effects.
- Georgia actively uses prescribed burning for land management with an annual statewide total burned area over one million acres, one of the highest rates in the U.S.
- Epidemiological studies in Atlanta addressing the relationship between source-specific $PM_{2.5}$ exposures and acute health effects such as respiratory disease and cardiovascular disease have found positive associations between same-day $PM_{2.5}$ concentrations attributed to primarily prescribed forest burning and cardiovascular disease-related emergency room (ER) visits.
- Georgia, as well as the entire southeastern U.S. that houses some of the most vulnerable communities in the nation, is more likely to experience high and frequent smoke exposure in comparison to the other parts of the country due to increasing prescribed burning emissions. A better understanding of the contributions of prescribed burning to human health is important, especially to the people who are directly affected by prescribed burning.

## Method

- We use the prescribed burning permit information from the Georgia Forestry Commission and the BlueSky framework to estimate prescribed burning emissions in Georgia during January–April (the most active burning months in Georgia) of 2015–2018.
- We compute the contribution of prescribed burning on $PM_{2.5}$ concentrations simulated by the Community Multiscale Air Quality (CMAQ) model using the Decoupled Direct Method (DDM) for source-specific impact estimation.
- We merge CMAQ-DDM results with observations at monitoring sites (Figure 1) to provide spatiotemporal $PM_{2.5}$ exposure fields for use in health impact estimations using a data fusion method.
- Finally, we employ a log-linear relationship between air pollutant concentration change and health outcome incidence to quantify the health impact from prescribed burning as follows:

$$\Delta Y = Y_0(1 - e^{-\beta \Delta PM}) \times Pop$$

where $Y_0$ is the baseline incidence rate for the health endpoint, $\beta$ is the health effect estimate from the epidemiological study, $\Delta PM$ is the change in air pollutant concentration, and $Pop$ is the population exposed to air pollution.

- Here, we focus on the ER visits for asthma as the health endpoint. We used national asthma-related ER visit in 2013 (626 per 100,000 person) as the annual asthma-related ER visit rate in Georgia and converted to a daily rate by constructing weights based on observed daily ER visits due to asthma during 2013.

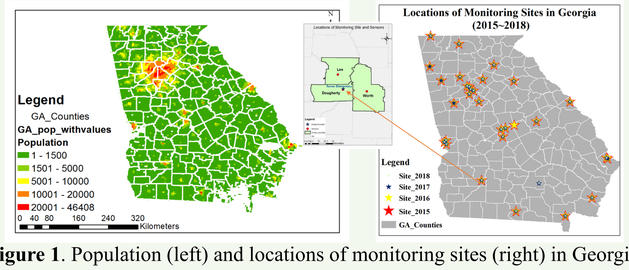


**Figure 1**. Population (left) and locations of monitoring sites (right) in Georgia

## Data Fused Prescribed Fire Impact

- High total $PM_{2.5}$ concentrations in the southwestern and east-central Georgia are mainly due to the active prescribed burning (Figure 2). January, February, and March are more active burn months than April. March is the most active burn month.

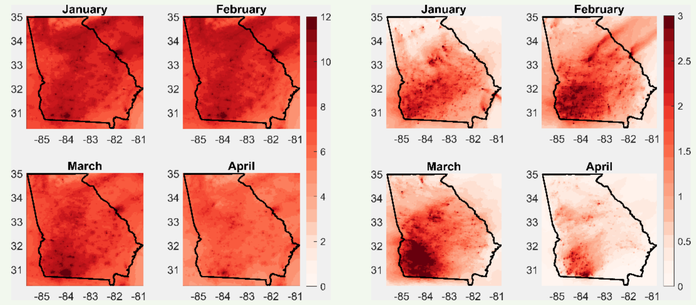


**Figure 2.** January – April monthly averages of total $PM_{2.5}$ (left) and fire impact (right) in 2015

## Fire Impact vs. Observed $PM_{2.5}$

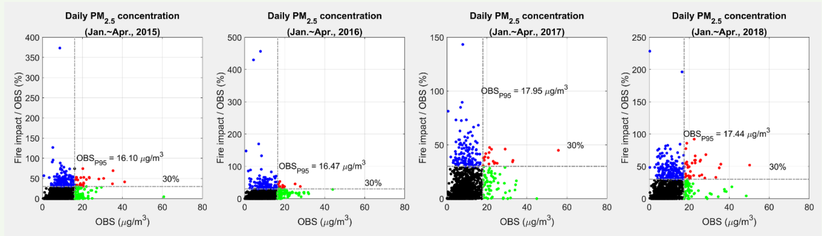


**Figure 3.** Relationship between daily total $PM_{2.5}$ observations (OBS) and ratios of observation-adjusted fire impact to OBS during January–April from 2015 to 2018. The grey dashed lines represent the 95th percentile of observations (vertical) and 30% fire impact to observed $PM_{2.5}$ (horizontal).

- Red dots represent days with high $PM_{2.5}$ observed concentrations due to fire impacts. Future epidemiological studies could focus on these days to find the relationship between short-term high-level $PM_{2.5}$ exposures due to prescribed fire and health impacts over a series of single-day lags.
- Blue dots are days when prescribed fire is still a major source of total $PM_{2.5}$. However, due to the low observed $PM_{2.5}$ concentrations, while concerns cannot be raised about air quality on those days, health impacts from smoke might be non-negligible.
- Green dots are high $PM_{2.5}$ days when other sources are more to blame than prescribed fire.
- Nearly 13% of $PM_{2.5}$ observations in 2018 have burn impact larger than 30%, which is somewhat larger than previous years.

## Application of Low-cost Sensors to Improve Exposure Fields

- The temporal trends at three locations reflect similar trends that show how including observations from low-cost sensors can improve the accuracy of the final exposure fields (Figure 4).
- Using low-cost sensor observations could decrease the underestimation during the night of simulated fire impacts, which is a systematic problem of the meteorological model with overestimation of the nighttime wind speed.
- The missing peaks also have been adjusted to get closer to the observations by including observations from low-cost sensors.

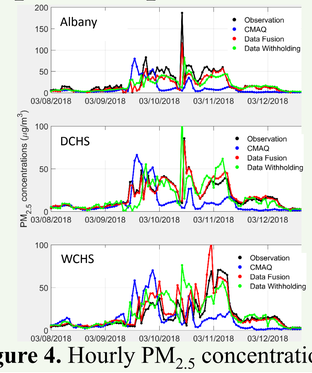


**Figure 4.** Hourly $PM_{2.5}$ concentrations.

## Health Impact from Prescribed Burning

- Estimated daily asthma-related ER visits due to prescribed burning for each year show that February and March have larger health impact than January (Figure 5). February 2017 has a larger estimated daily health impact compared to the other years, probably due to larger emissions related to the drought that year. April 2018 also has a larger estimated daily health impact with more burned areas compared to previous years, likely due to an extended burn season resulting from the need to burn more areas.

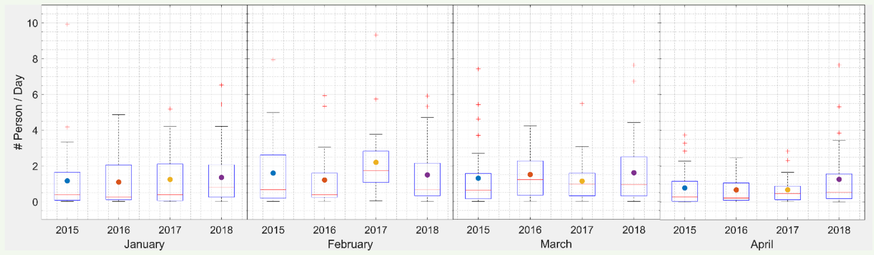


**Figure 5.** Estimated daily asthma-related ER visits in Georgia due to prescribed burning for January–April of each year from 2015 to 2018. The central mark indicates the median, the point indicates the mean, and the bottom and top edges of the box indicate the 25th and 75th percentiles, respectively. The whiskers bound the range of values excluding the outliers.

- February 2017 has the largest estimated health impacts across the reporting years with 62 ER visits due to asthma, a rate of 6.4 per 1,000,000 people (Table 1).

**Table 1.** Estimated monthly total ER visits due to asthma in Georgia. The uncertainties were derived assuming 50% uncertainty in $\beta$ and 40% uncertainty in $\Delta PM$.

| | January | February | March | April | Total |
|---|---|---|---|---|---|
| 2015 | 36±23 | 45±27 | 41±25 | 23±16 | 145±46 |
| 2016 | 34±21 | 35±20 | 47±22 | 20±14 | 136±39 |
| 2017 | 39±21 | 62±30 | 35±19 | 20±11 | 156±43 |
| 2018 | 42±24 | 42±23 | 50±29 | 38±26 | 171±51 |

- There are about 145 ER visits estimated to be due to asthma because of prescribed burning impact, a rate of 15 per 1,000,000 people in 2015 during the first four months. It increases by about 18% in 2018, compared to 2015.
- The estimated asthma-related ER visits due to prescribed burning in Atlanta MSA has an average of about 66 during the reporting years, which is about 0.58% compared to the asthma-related ER visits (11,372) in Atlanta MSA for 2013.

## Conclusions

- Prescribed fire impacts can be estimated by simulations and merged with observations through data fusion to improve exposure fields for health analyses.
- The sparsity of observation sites often leads to fire impacts on air quality being undetected; however, the lack of monitoring sites can be alleviated, in part, by using low-cost sensors.
- While southern Georgia has the highest activity of prescribed burns, the greatest health impacts in terms of absolute number of asthma-related ER visits are found in the Atlanta MSA.

## Acknowledgement and Contact Information

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- For more information contact Talat Odman (*odman@gatech.edu*).