The Contribution of Wildland-Fire Smoke to US $PM_{2.5}$ and its Influence on Recent Trends

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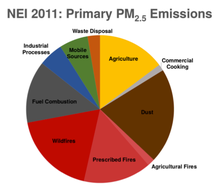
Background and Motivation

Fires are a major source of primary $PM_{2.5}$ emissions across the US.



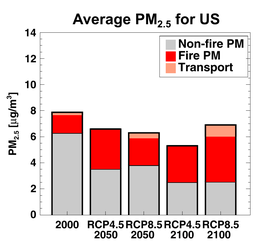
- Wildland fires (wildfires + prescribed burns) account for 25% of primary $PM_{2.5}$ emissions [NEI 2011].
- In the western US, large interannual variability in wildfires drives interannual variability in summer $PM_{2.5}$ [Jaffe et al., 2008].
- Wildfire-specific $PM_{2.5}$ negatively impacts respiratory health [Reid et al., 2016].

Unlike many anthropogenic sources of $PM_{2.5}$, wildfires have not been decreasing in the US.

- Due to emission regulations and controls, anthropogenic sources of $PM_{2.5}$ in the US have been decreasing in recent decades [Hand et al., 2011; Murphy et al., 2011].
- Wildfire frequency and intensity have been increasing in the western US since the 1980s due to changes in climate [Westerling, 2016].
- Extreme $PM_{2.5}$ events associated with wildfires have been increasing in the western US [McClure and Jaffe, 2018]

Over the next century, we expect increases in fire-specific $PM_{2.5}$ in the US.

- Wildfires are expected to increase in frequency and burn area in the western US [e.g. Spracklen et al., 2009].
- $PM_{2.5}$ concentrations emitted from fires are also projected to increase, while anthropogenic $PM_{2.5}$ continues to decline [Ford et al., 2018].

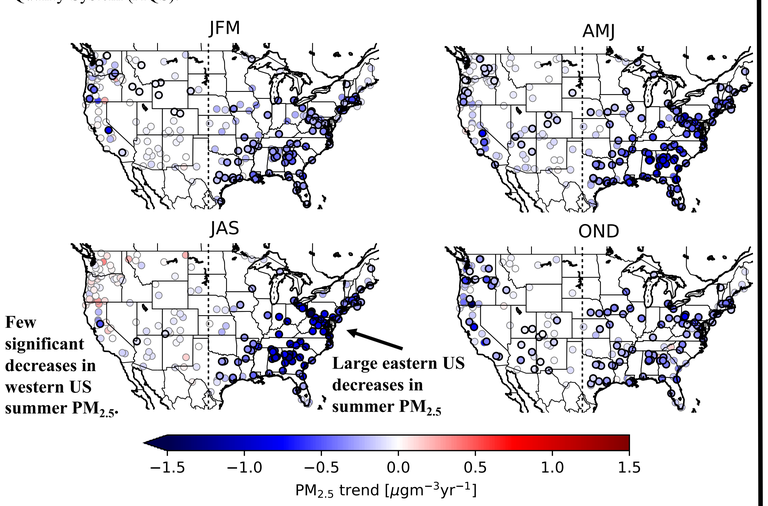


In this work we address the following question:

How have wildfire emissions of $PM_{2.5}$ already impacted US trends in summer $PM_{2.5}$?

Summer trends in $PM_{2.5}$ are vastly different in the eastern and western United States.

We calculate linear trends for monitors in the US Environmental Protection Agency's (EPA) Air Quality System (AQS).



Wildland fire specific $PM_{2.5}$ is not decreasing, unlike anthropogenic $PM_{2.5}$.

We use two methods to distinguish wildland fire specific $PM_{2.5}$.

1. **Observation-based approach**
   We krige EPA AQS surface $PM_{2.5}$ monitors to a 15 x 15 km grid and combine with smoke plumes from the Hazard Mapping System smoke product.

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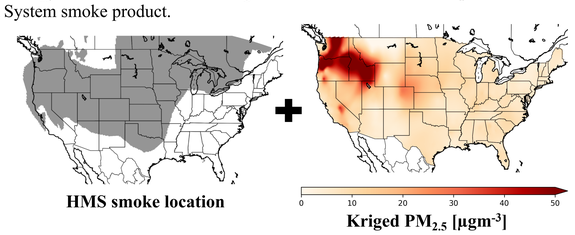


Non-smoke $PM_{2.5}$ = median $PM_{2.5}$ on days with no smoke plume overhead

Smoke-$PM_{2.5}$ = Total $PM_{2.5}$ – non-smoke $PM_{2.5}$ on days with smoke plume overhead

2. **Model-based approach**
   - Pair of global GEOS Chem v11-01 tropchem simulations at 2º x 2.5º resolution for 2006 – 2016
   - MERRA2 meteorology
   - Biomass burning emissions from GFED4s; US anthropogenic emissions from scaled NEI 2011

$PM_{2.5}$ calculation:

$$PM_{2.5} = 1.33 \times (NH4 + NIT + SO4) + BCPI + BCPO + 2.1 \times (OCPO + 1.16 \times OCPI) + DST1 + 0.38 \times DST2 + 1.86 \times SALA$$

Non-smoke $PM_{2.5}$ = mean $PM_{2.5}$ calculated by model with biomass burning emissions turned off

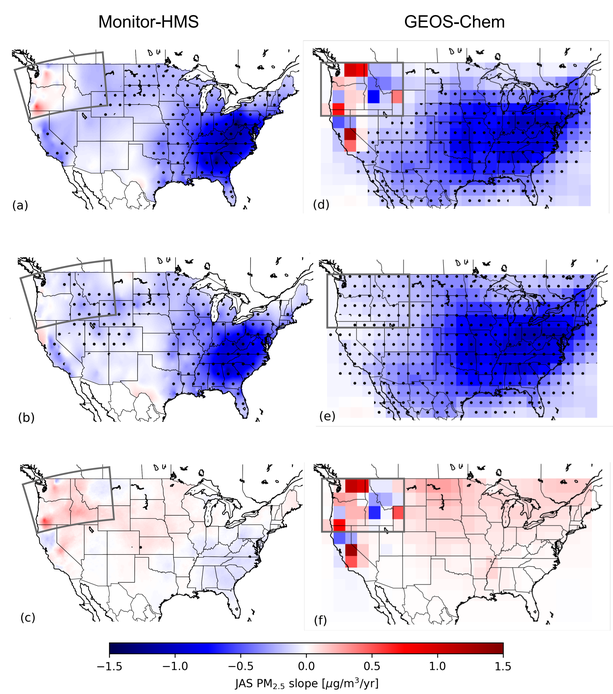
Smoke-$PM_{2.5}$ = Mean $PM_{2.5}$ with biomass burning emissions on – non-smoke $PM_{2.5}$

Both methods agree that the absence of significant decreasing trends in summer $PM_{2.5}$ in the western US can be attributed to wildfire smoke.

Total $PM_{2.5}$
- Large decreases in eastern US, few significant decreases in western US
- GEOS-Chem largely matches the observations, except in California.

Nonsmoke $PM_{2.5}$
- Spatial extent of decreasing $PM_{2.5}$ extends for both methods.
- In the absence of smoke, GEOS-Chem estimates significant $PM_{2.5}$ decreases across the entire US.

Smoke $PM_{2.5}$
- Increases in smoke $PM_{2.5}$ in the Pacific Northwest (boxed region) for both methods.
- GEOS-Chem estimates increases in smoke $PM_{2.5}$ across most of the US (differing from obs.).
- Trends are not statistically significant due to high interannual variability of smoke.



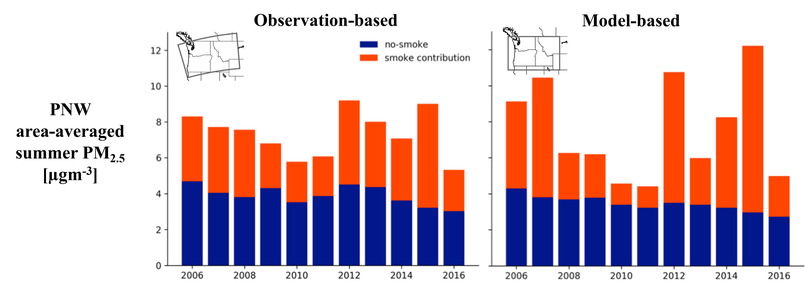
In heavily fire-impacted regions, we estimate improvements in non-smoke summer $PM_{2.5}$.

We calculate a regional area-averaged summer $PM_{2.5}$ for the Pacific Northwest (PNW), a region heavily impacted by fires.

In some years, **smoke $PM_{2.5}$ contributes > 50% of summer $PM_{2.5}$.**

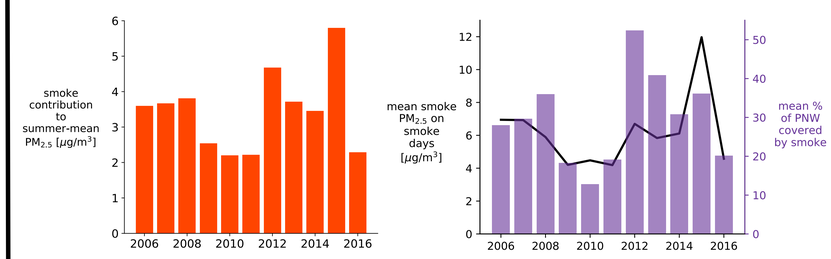
This high interannual variability of smoke makes detecting smoke-driven trends challenging.

However, we can distinguish a significant **negative trend in regional-average non-smoke $PM_{2.5}$.**



Can we attribute variability in summer smoke $PM_{2.5}$ in the Pacific Northwest to:

1. The frequency of smoke days?
2. The intensity of smoke days?



Both the frequency and intensity of smoke days show high interannual variability.

Recent active wildfire seasons can be linked to either:
- larger frequency of smoke days with moderate intensity (e.g. 2012)
- more intense smoke days with a moderate frequency (e.g. 2015)

Summary and References

Implications

- The western US, which in general has lower $PM_{2.5}$ concentrations than the eastern US, still experiences improvements in non-smoke particulate air quality like the eastern US. However, in summer in the western US these improvements are obscured by the impacts of wildfires.
- Although we do not observe significant changes in smoke $PM_{2.5}$ over our study period, we expect increases in smoke $PM_{2.5}$ could be observed if we were able to extend our study period back to the 1980s.

Acknowledgements and References

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The work presented here was recently published:
K. O'Dell, B. Ford, E. V. Fischer, and J. R. Pierce. Contribution of wildland-fire smoke to US PM2.5 and its influence on recent trends. *ES&T*. 53, 1797-1804, doi: 10.1021/acs.est.8b05430.

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