Tradeoffs between Wildfires and Prescribed Fires: A Case Study of 2016 Gatlinburg Fires

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How to compare the air quality impacts of prescribed fire with those of wildfire?

- Prescribed burning reduces wildfire risk.
- However, it can emit large amounts of pollutants.
- These emissions can significantly degrade air quality.
- We want to know the benefits and burdens from prescribed burning versus wildfires.
- Two types of methods are applied:
  - Measurement
  - Simulation

Measurement Methods

- These methods select an area with both wildfires and prescribed burns, and compare increases in ground-level pollutant concentrations at population centers. However,
  - Fuel and atmospheric conditions are different for different fires.
  - Transport of smoke is different at different times.
  - Nearby and distant fires would have different impacts.
  - Existing observational networks may be inadequate.
  - Special measurements tend to be closer to prescribed burns.
  - Satellite-detected smoke may be aloft.

Simulation Methods

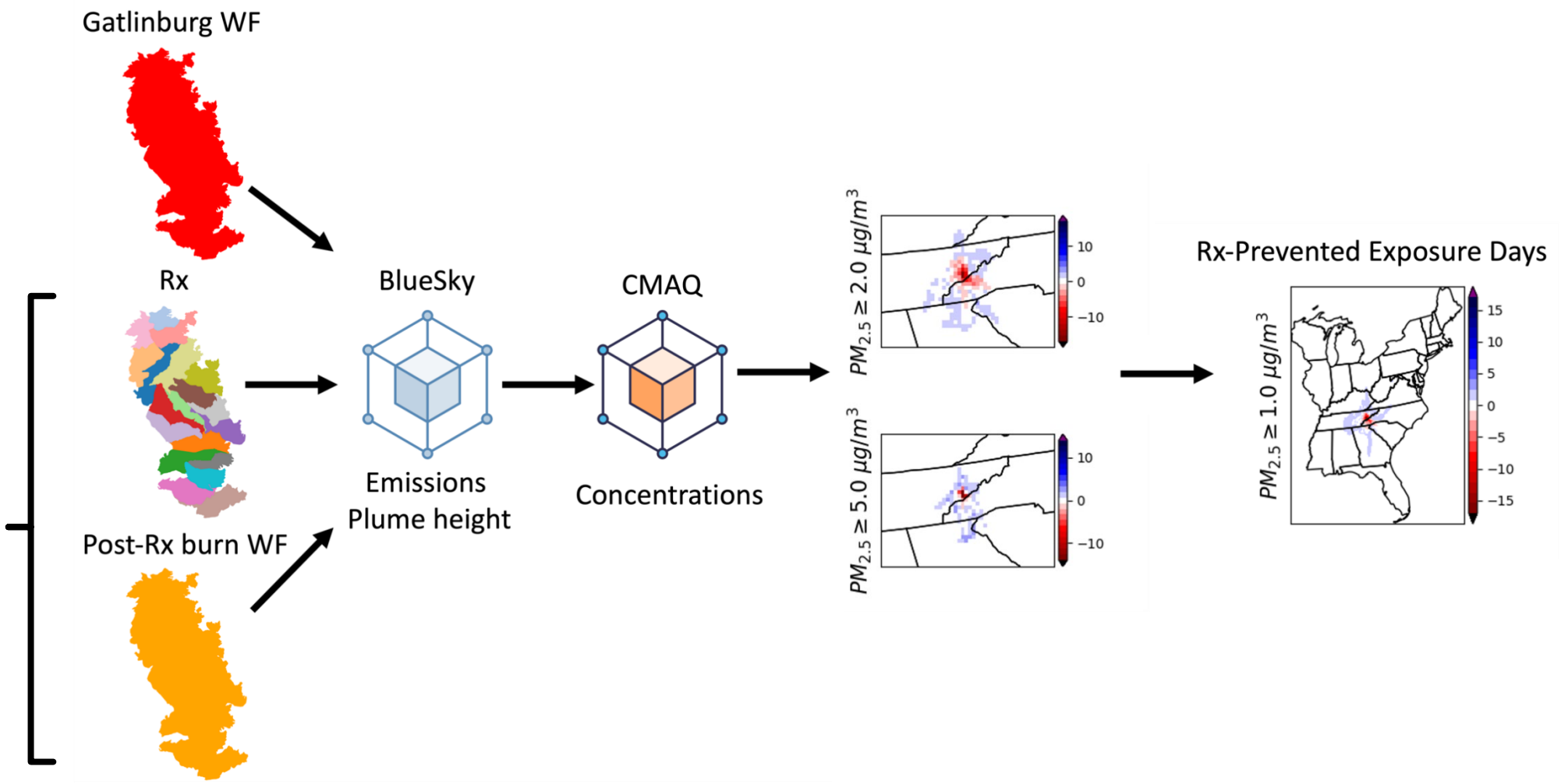
- These methods employ fire emission and air quality models.
- Both factual and counterfactual (or hypothetical) scenarios with wildfires and prescribed burns can be simulated.
- Avoided wildfire emissions must be estimated.
- Many assumptions are necessary:
  - Level of prescribed fire treatment
  - Evolution of fuels between fires
  - Occurrence of post-prescribed burn wildfires
  - Time frame for comparison

This Study

- Focused on the 2016 Gatlinburg Wildfire
  - Late November in Sevier County Tennessee
  - Burned > 15,000 acres, 2000 homes, 14 fatalities, $20 billion damage
- Simulated 3 scenarios:

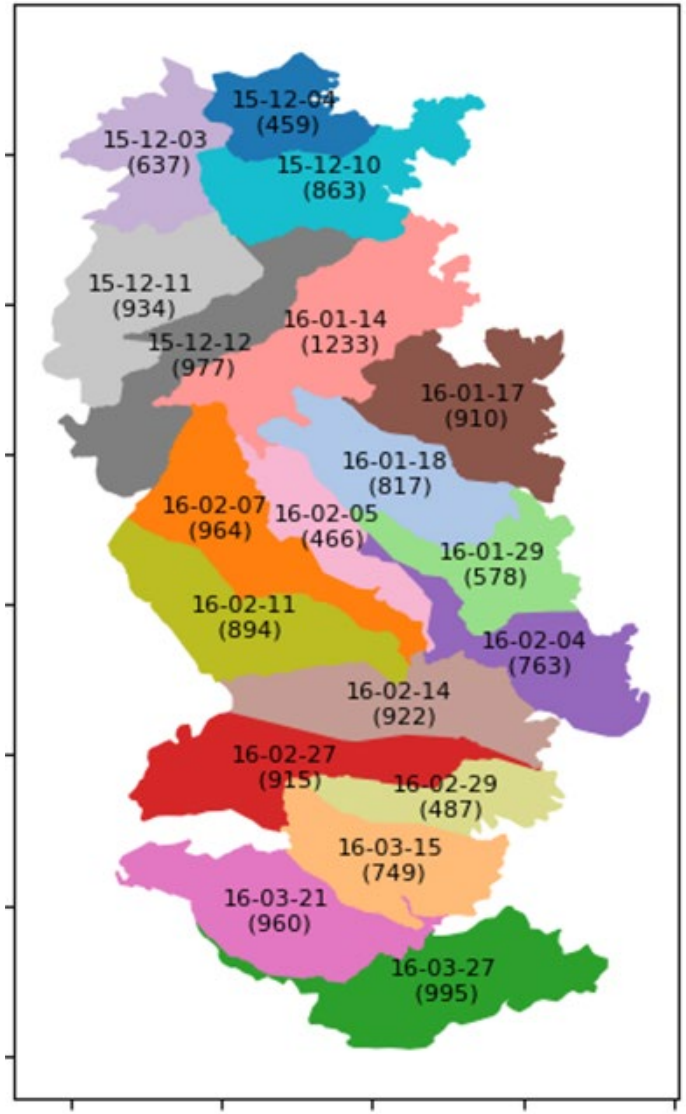
Baseline	No fires
Factual	Gatlinburg Wildfire (WF)
Counterfactual	19 prescribed burns (Rx) before WF + Post-prescribed burn wildfire (Post-Rx WF)

Methodology

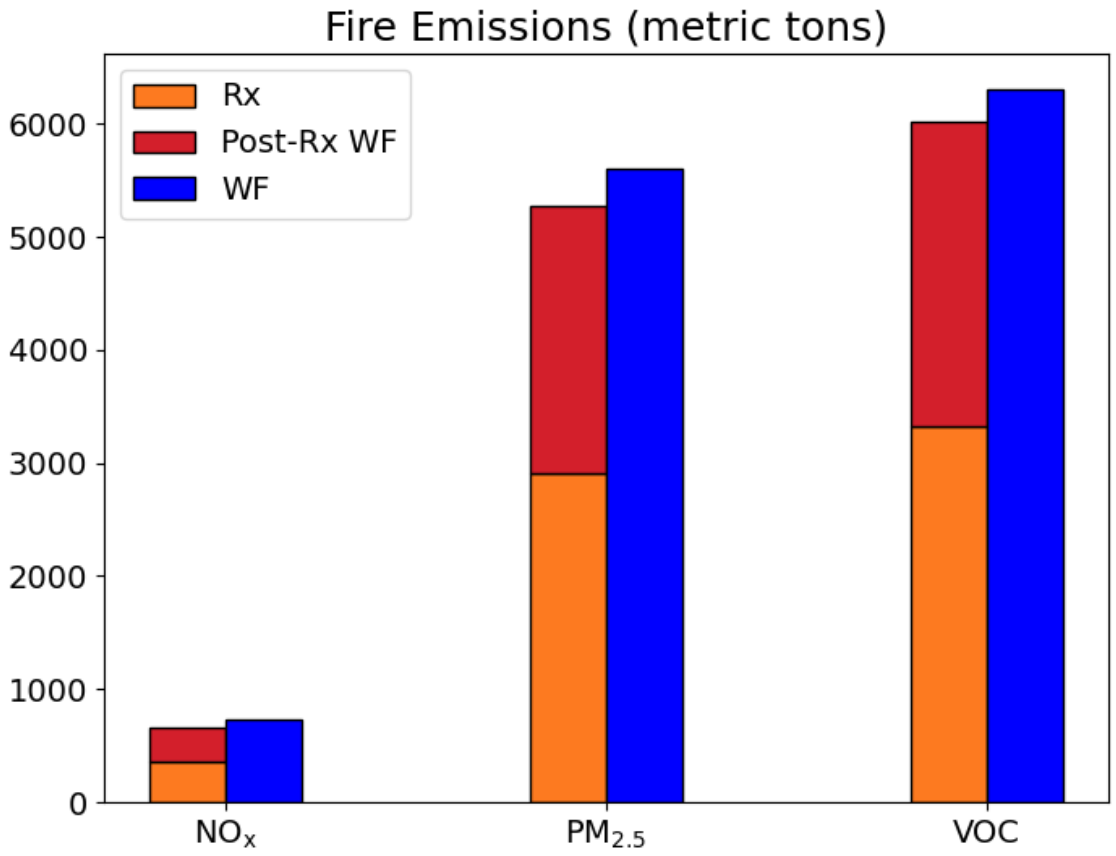


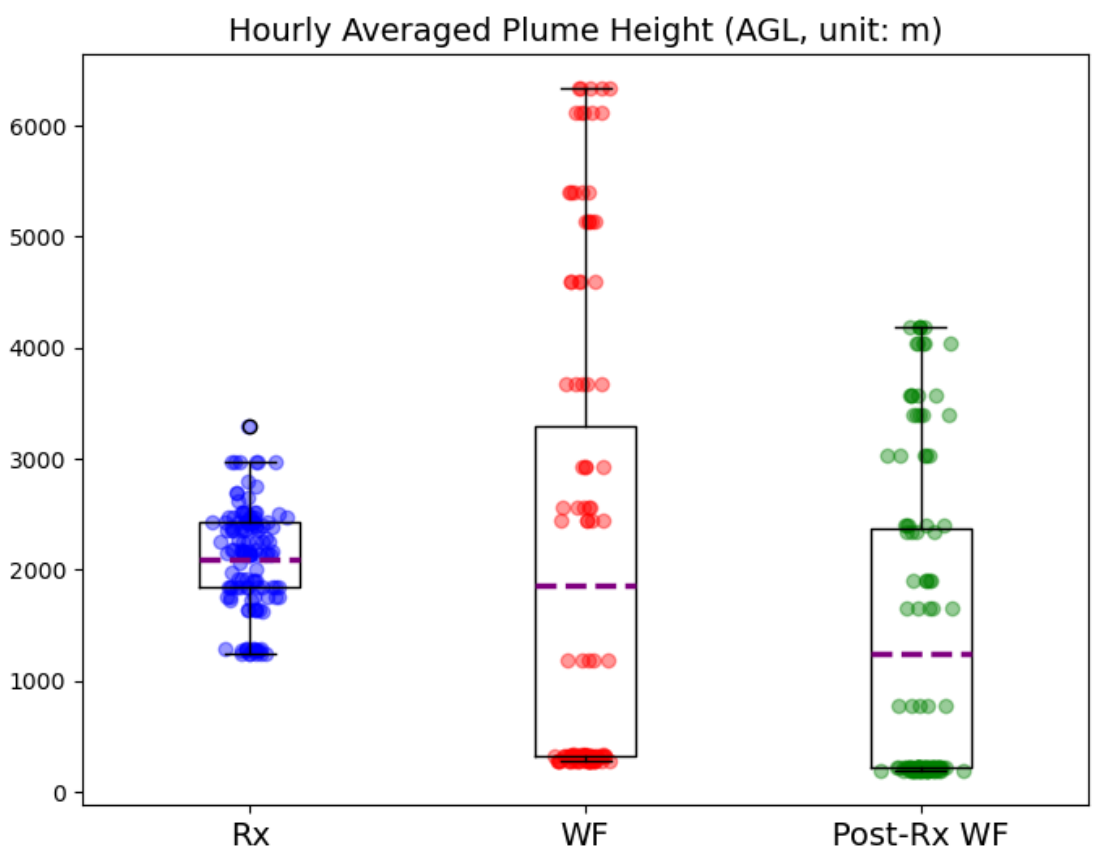
Design of Prescribed Burns (Rx)

- Burned area broken in to 19 parcels < 1000 acres using natural firebreaks and flat terrain
- 19 burn days chosen before WF with
  - Rain < 0.25 inch/day,
  - T < 85 °F, RH > 30%
  - 1650 feet < PBL < 6500 feet
  - 8 mph < WS < 14 mph
  - 9 mph < transport WS < 20 mph



Fire Emissions and Plume Heights



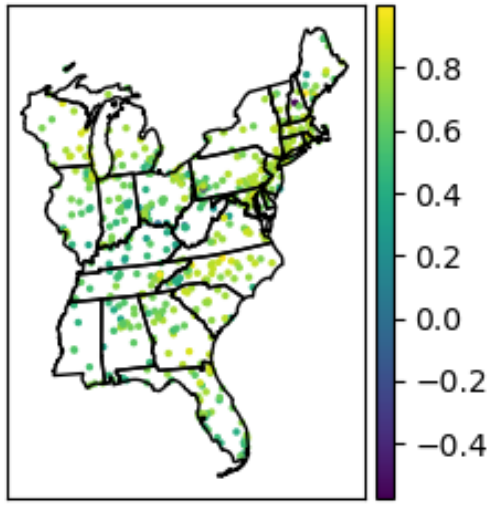


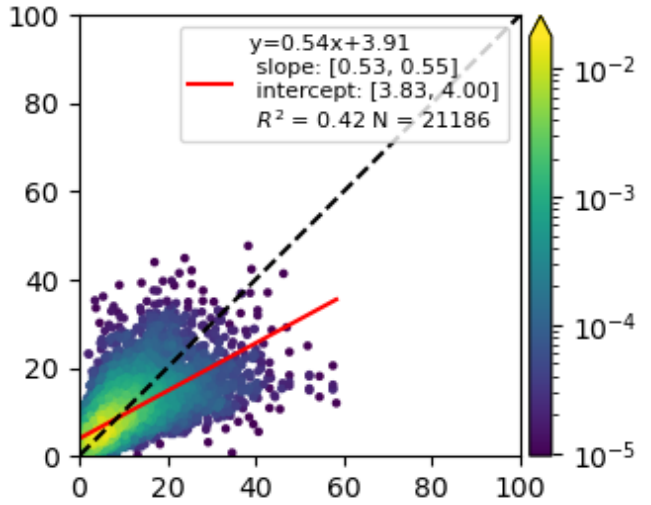
Model Performance Evaluation

Pearson R

Obs. vs Model

Daily $PM_{2.5}$ ($\mu g/m^3$)

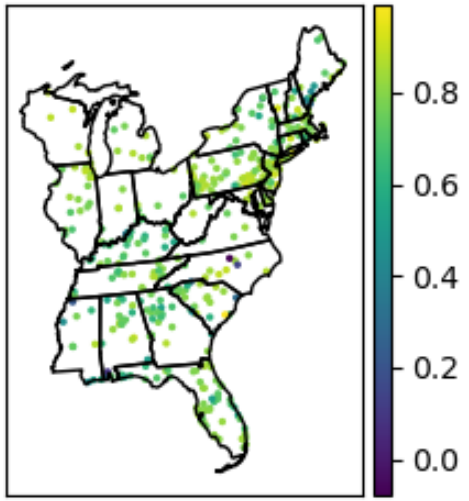


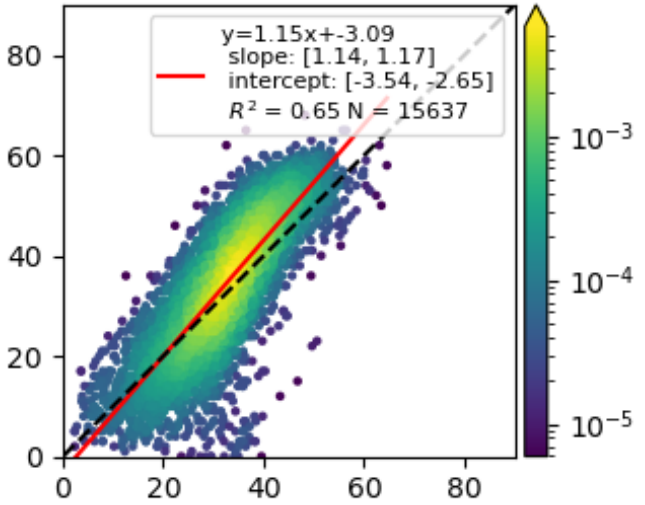


NMB = -2%

NME = 37%

MDA8 O_3 (ppb)

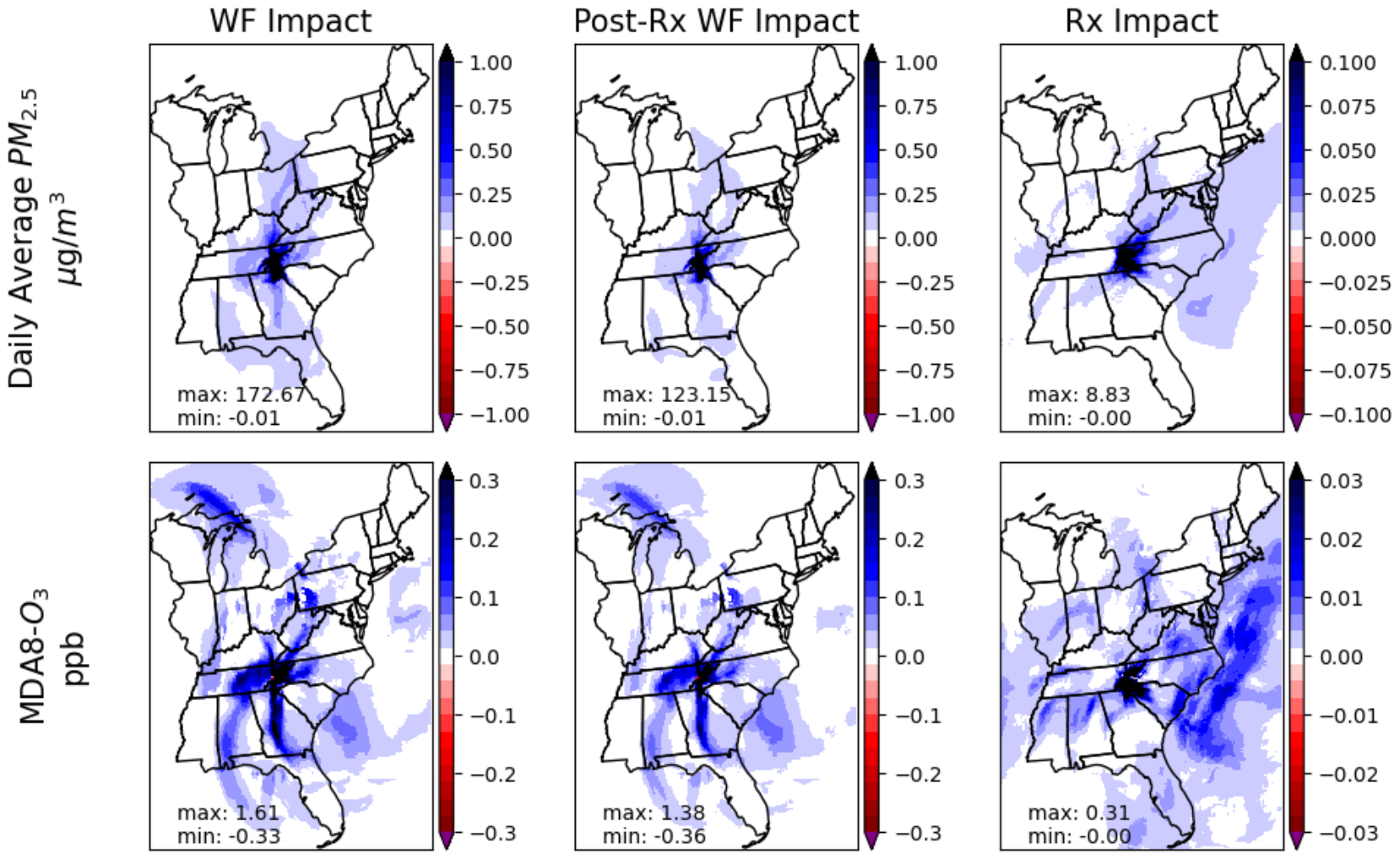




NMB = -6%

NME = 14%

Air Quality Impacts



Exposures: Person-days

- PD is the cumulative time individuals in a population are exposed to a certain pollutant concentration level.

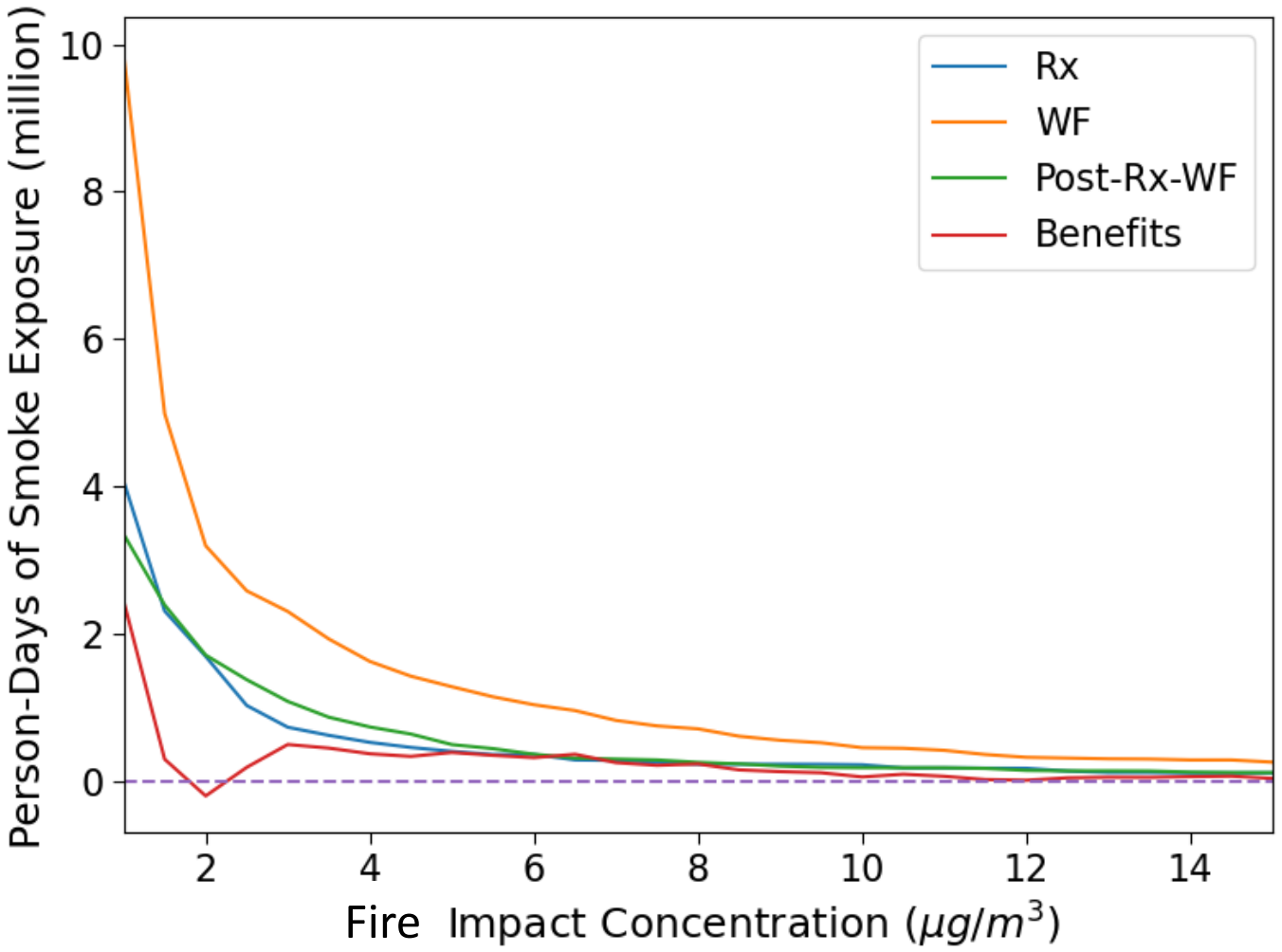
$$PD = \sum_{t} \sum_{i,j} pop_{i,j} \times H(c_{i,j,t} - threshold)$$

$$H(x) := \begin{cases} 1, & x \geq 0 \\ 0, & x < 0 \end{cases}$$

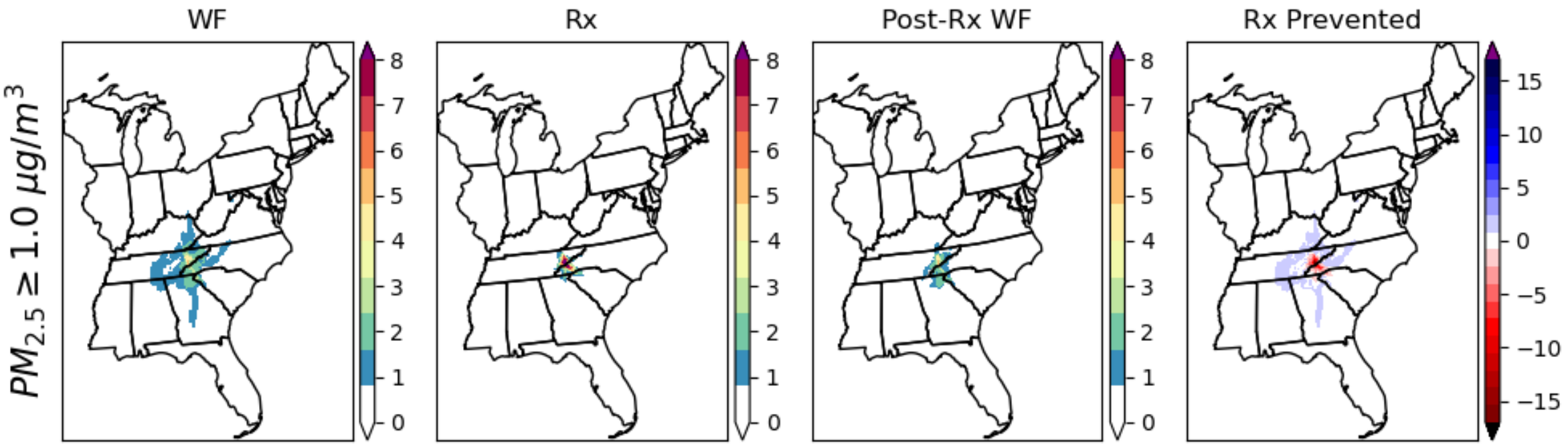
- Exposure benefit of prescribed fire treatment is:

$$PD_{WF} - (PD_{Rx} + PD_{post-WF})$$

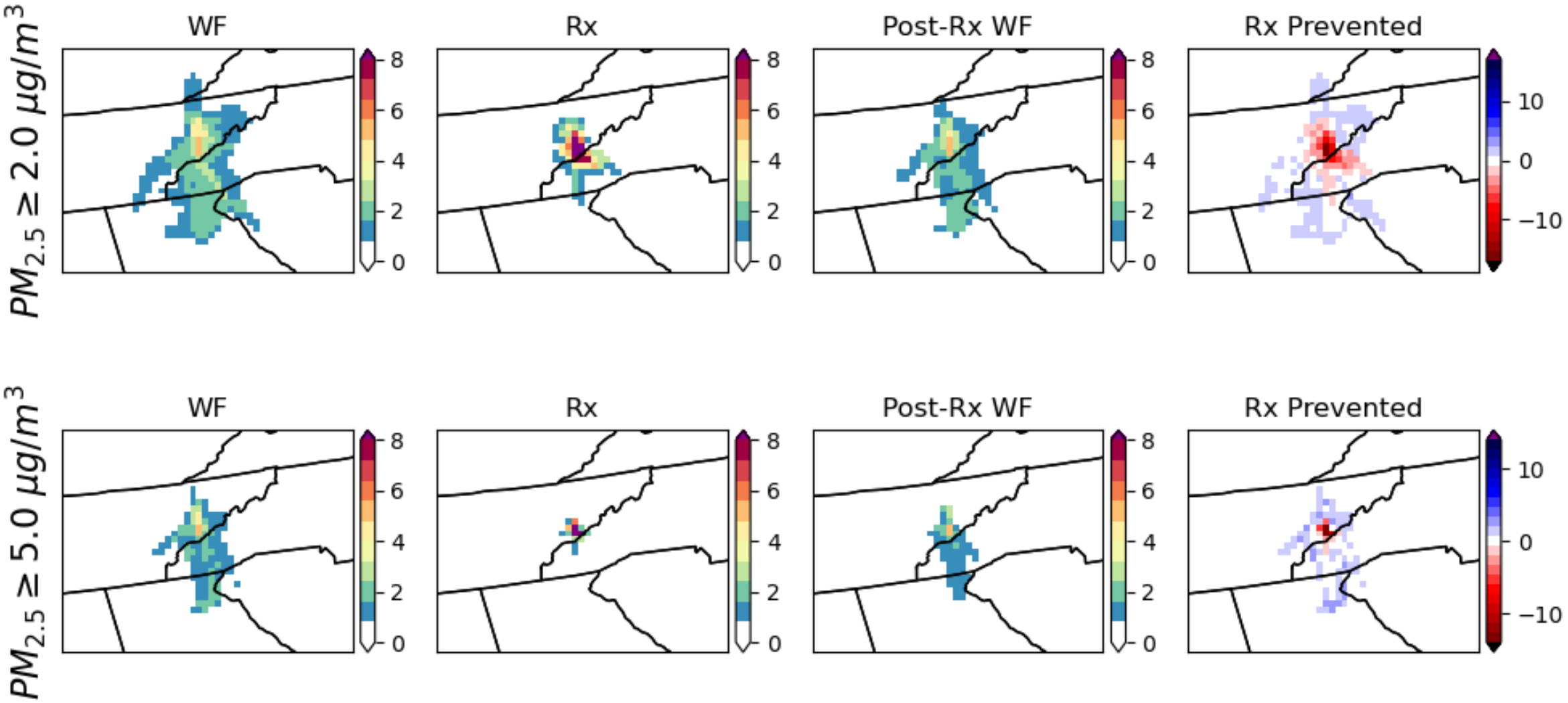
Person-days vs. fire $PM_{2.5}$



Exposure Durations (Days) for $PM_{2.5} \geq 1.0\ \mu g/m^3$



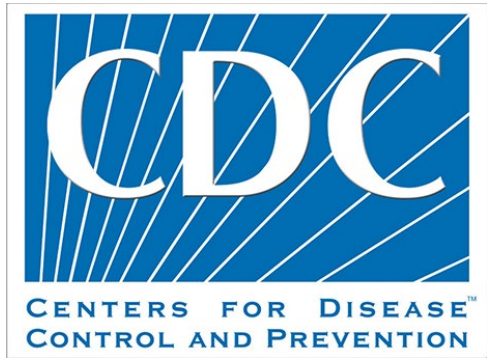
Exposure Durations for 2.0 and 5.0 μg/m³ $PM_{2.5}$ Levels

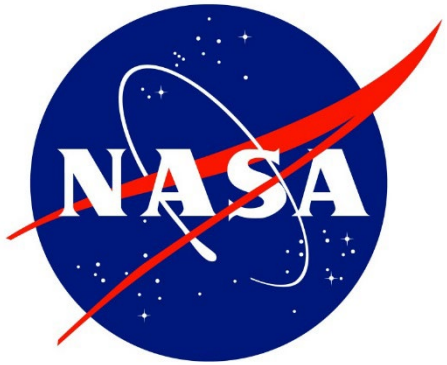


Conclusions

- A new modeling framework was applied to Gatlinburg Fires to evaluate the air quality tradeoffs of prescribed burning.
- Emissions, plume heights, and meteorological conditions were key factors affecting exposures.
- $PM_{2.5}$ was a much bigger concern than ozone.
- Prescribed fire had some benefits but they depended on distance from the fires and the level of exposure.
- While $PM_{2.5}$ levels generally decreased, exposures ~2 $\mu g/m^3$ level increased for the people living close to the fires.

Acknowledgements





Questions?