



# Investigating the Impacts of Smoke on Fine Particle Pollution in Chicago



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## 1 Abstract

Wildfires are an increasing issue around the world due to the changing climate. These fires emit a variety of pollutants, including particulate matter – which can be extremely harmful to human health. This study examined how fine particulate pollution (PM<sub>2.5</sub>) in Chicago, Illinois, was impacted by smoke resulting from wildfires and prescribed burning across North America. This issue has not been well studied due to the fact that Chicago and surrounding areas do not typically experience wildfires nor conduct prescribed burns. However, this does not prevent smoke from being transported into the area, thereby impacting air quality and raising health concerns. This study used the fire and smoke products from the Hazard Mapping System (HMS) developed by the National Weather Service and PM<sub>2.5</sub> data from the Environmental Protection Agency's Air Quality System (AQS) to compile a data set for the Chicago area. The dataset consists of PM<sub>2.5</sub> concentration and the level of smoke coverage (None, Light, Medium, and Heavy) for each day from 2019 through June 2023. We statistically assessed the relationship between PM<sub>2.5</sub> and smoke as well as examined the seasonal fluctuations of PM<sub>2.5</sub>. The results suggest that high levels of PM<sub>2.5</sub> in Chicago are often associated with smoke transported into the Chicago region. Using NASA's Worldview images and NOAA's Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) models, we conducted several case studies. This helped us associate elevated concentrations of PM<sub>2.5</sub> with wildfire smoke. More research is needed to differentiate smoke from wildfires and smoke from other sources to determine the extent to which wildfires are affecting air quality in Chicago.

## Motivation

- Personal experience with wildfire (Figure 1)
- Personal interest and literature review in climate change impact on wildfires
  - Climate change is fueling wildfires (Figure 2).
  - Wildfires have grown in frequency and intensity (Figure 3).
- Public health and safety concerns
  - Wildfire smoke contains many pollutants, such as CO, PM<sub>2.5</sub>, and NO<sub>x</sub>.
  - PM<sub>2.5</sub> is most harmful. It can penetrate deep into the lungs. This can lead to cardiovascular disease, respiratory illness, cancer and death.
- Lack of research on wildfires and PM<sub>2.5</sub> pollution in Chicago.
  - This topic is understudied due to the distance of the city to the more severe wildfires on the continent. Yet, smoke and PM<sub>2.5</sub> can travel thousands of miles, so its impact is not inhibited by transportation. Thus, it is necessary to further investigate this relationship.



Figure 1. Image of the air during a wildfire event in 2023 near Spokane Washington. [Photo taken by Nora Hartnett]



Figure 2. Depiction of how climate change impacts wildfire events. [Infographic: Wildfires and Climate Change. (2020, September 8). Union of Concerned Scientists.]

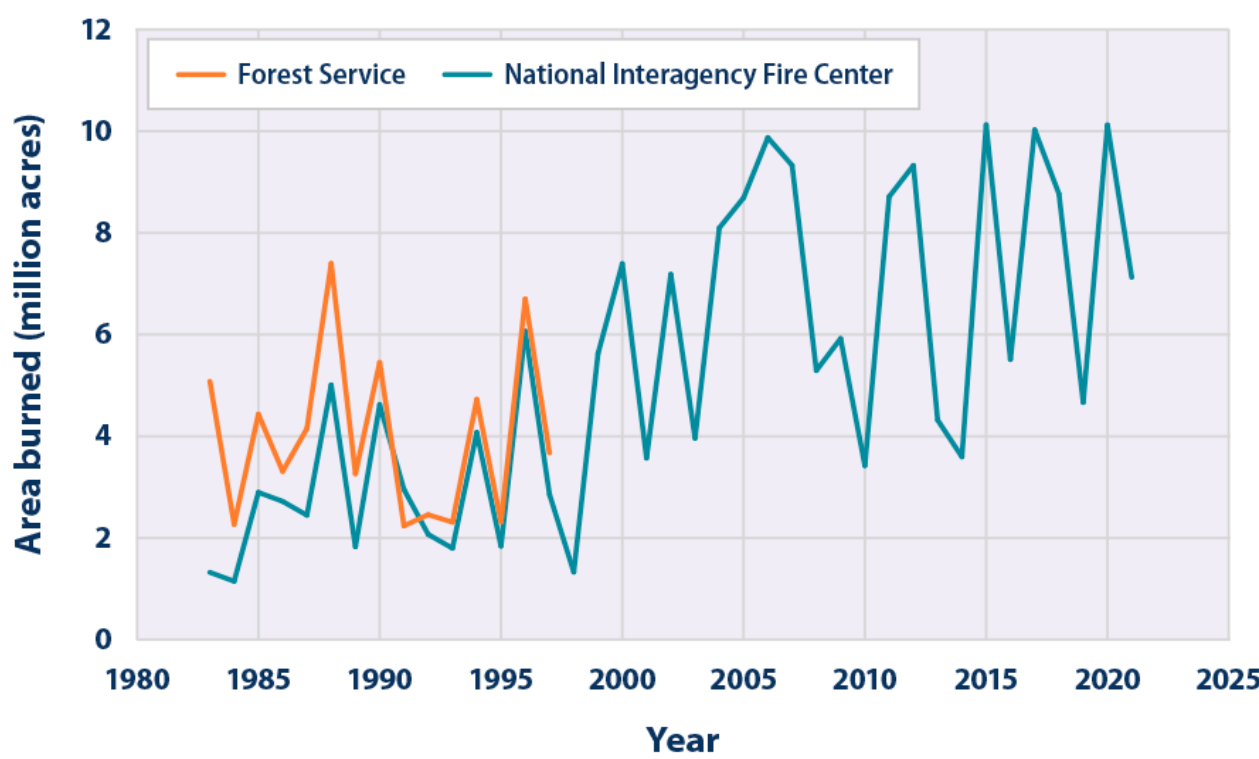
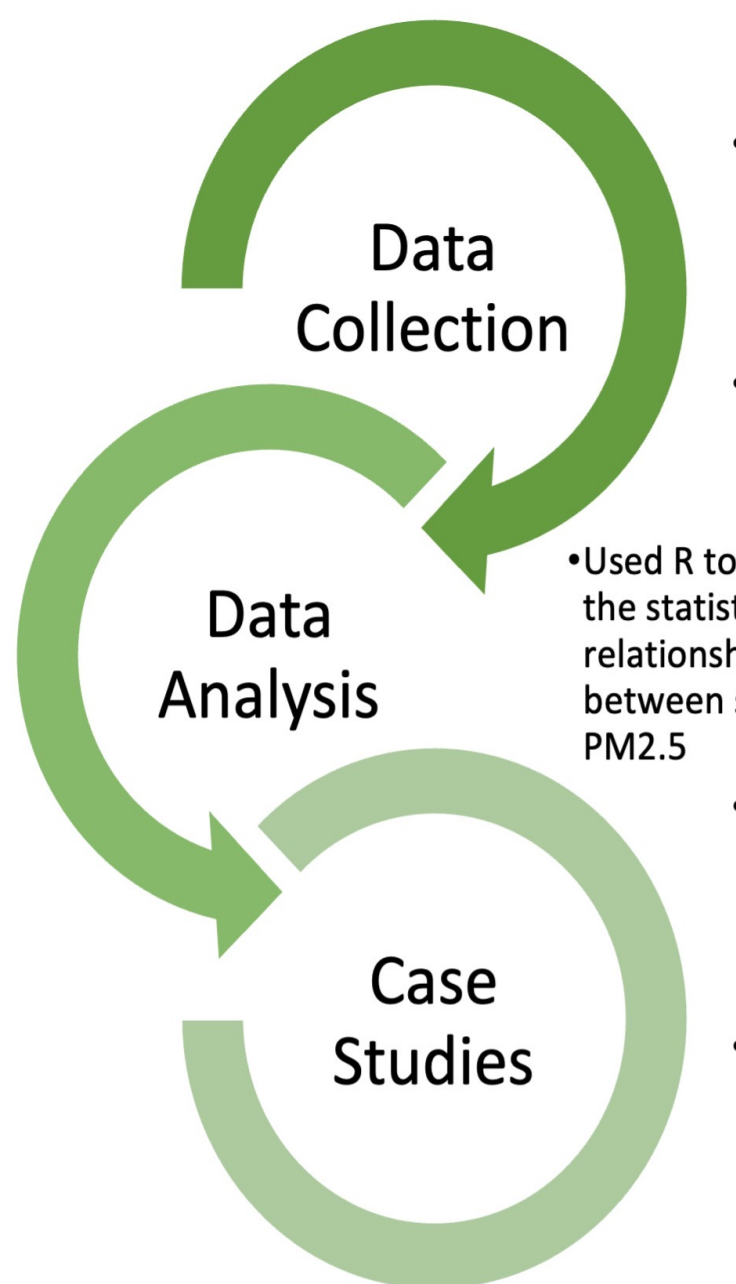


Figure 3. Land burned due to wildfires. [Climate Change Indicators: Wildfires | US EPA. (2023, July 21).]

### Hypothesis:

- Wildfires across North America led to high-PM<sub>2.5</sub> days in Chicago.

## 3 Methods



\*Created a data set compiled of PM<sub>2.5</sub> concentration and smoke presence for 2019 – June 2023  
\*Data collected from the EPA and NOAA

\*Used R to analyze the statistical relationship between smoke and PM<sub>2.5</sub>

\*Developed case studies to further show the relationship with smoke and PM<sub>2.5</sub>  
\*Collected data and imagery displaying wildfires, smoke coverage and air movement

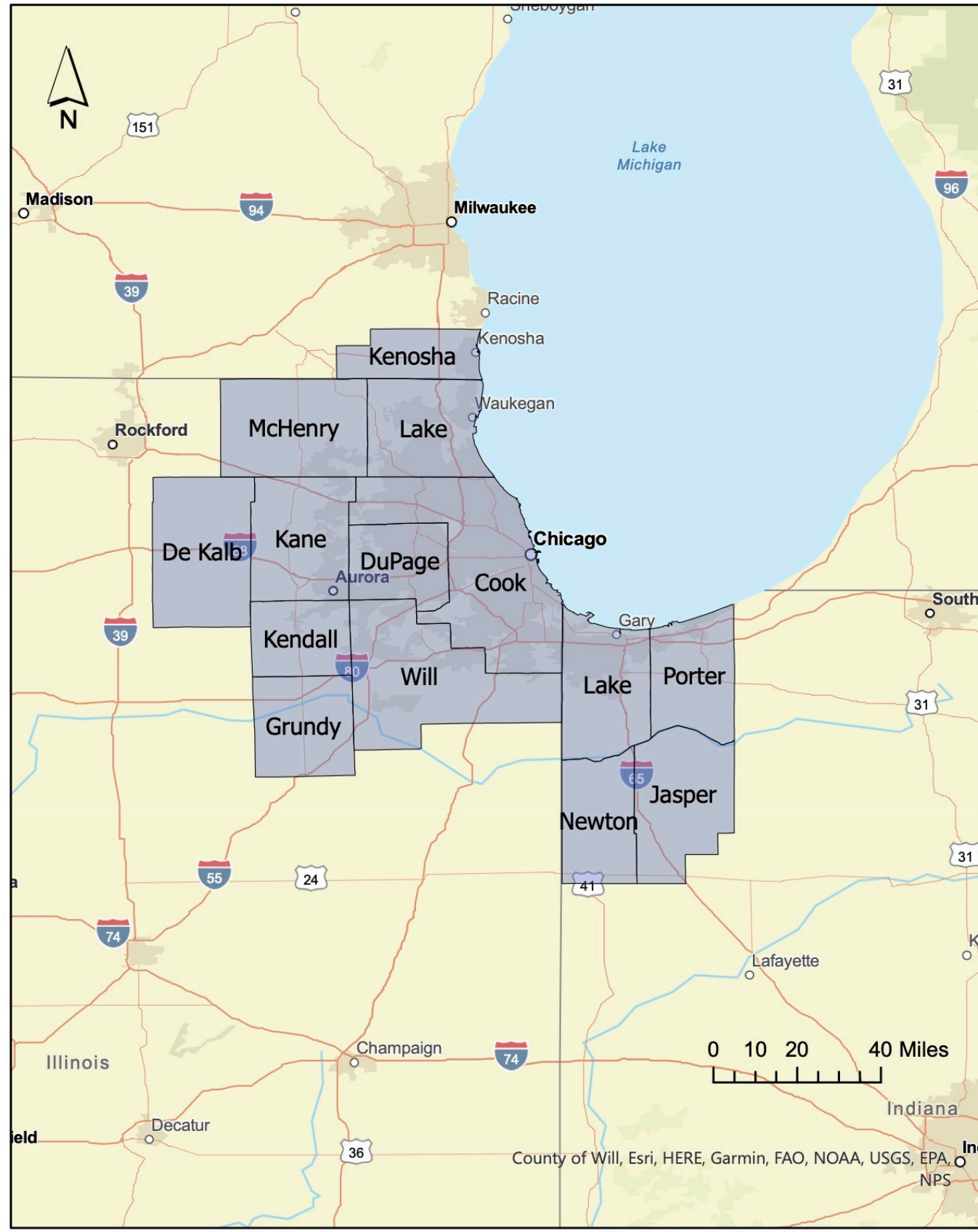


Figure 4. Map that shows the Chicago Metropolitan Area in grey shaded area - defined as "Chicago" in this study.

## Results

- The number of days with high PM<sub>2.5</sub> (>35 µg/m<sup>3</sup>) more than doubled (Figure 5).
- There is an 81% increase in days with smoke present.
- The increasing days with high PM<sub>2.5</sub> were most likely to have smoke present (Figure 6).

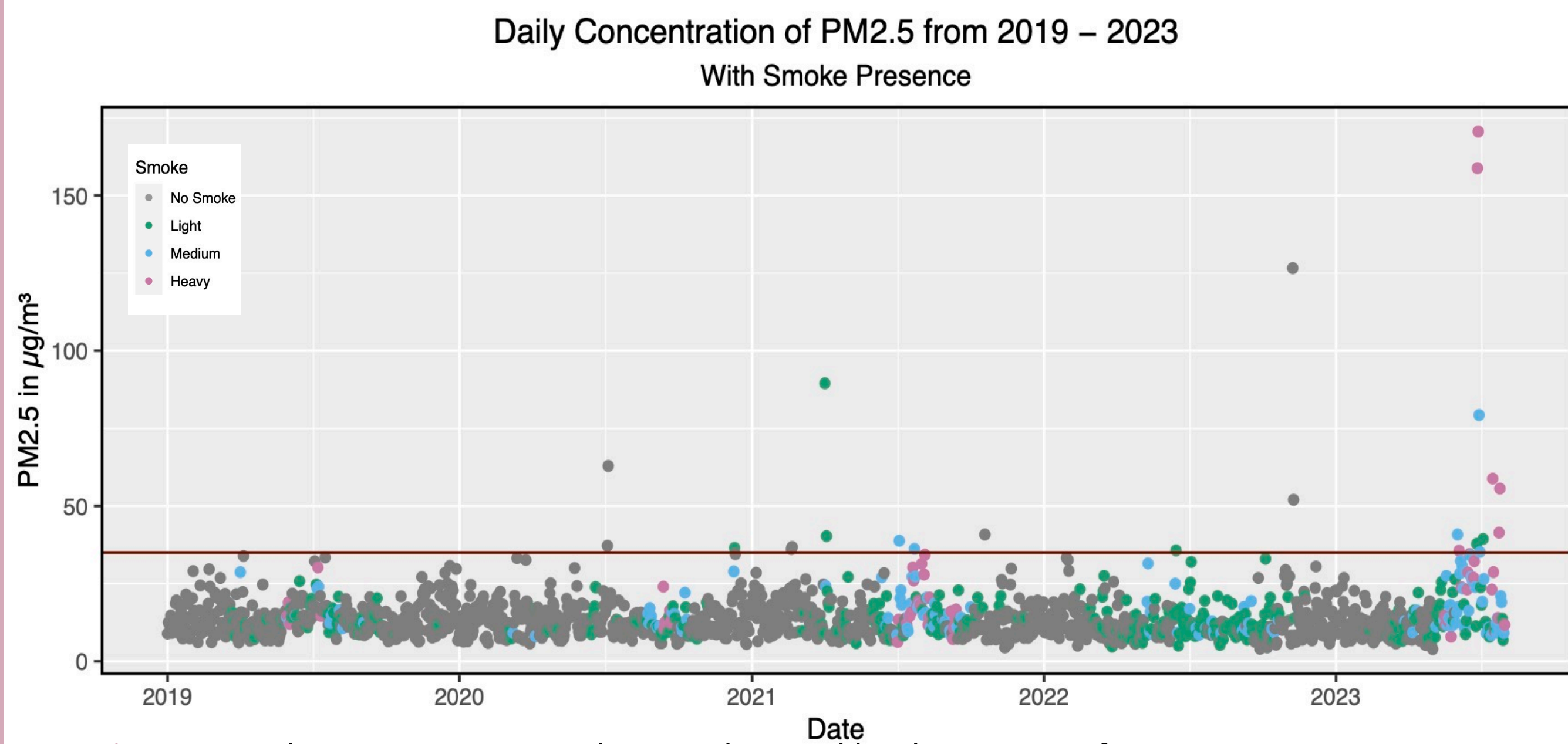


Figure 5. Daily average PM<sub>2.5</sub> in Chicago observed by the EPA AQS from 2019–2023.

### PM2.5 Concentration During Varying Smoke Presence

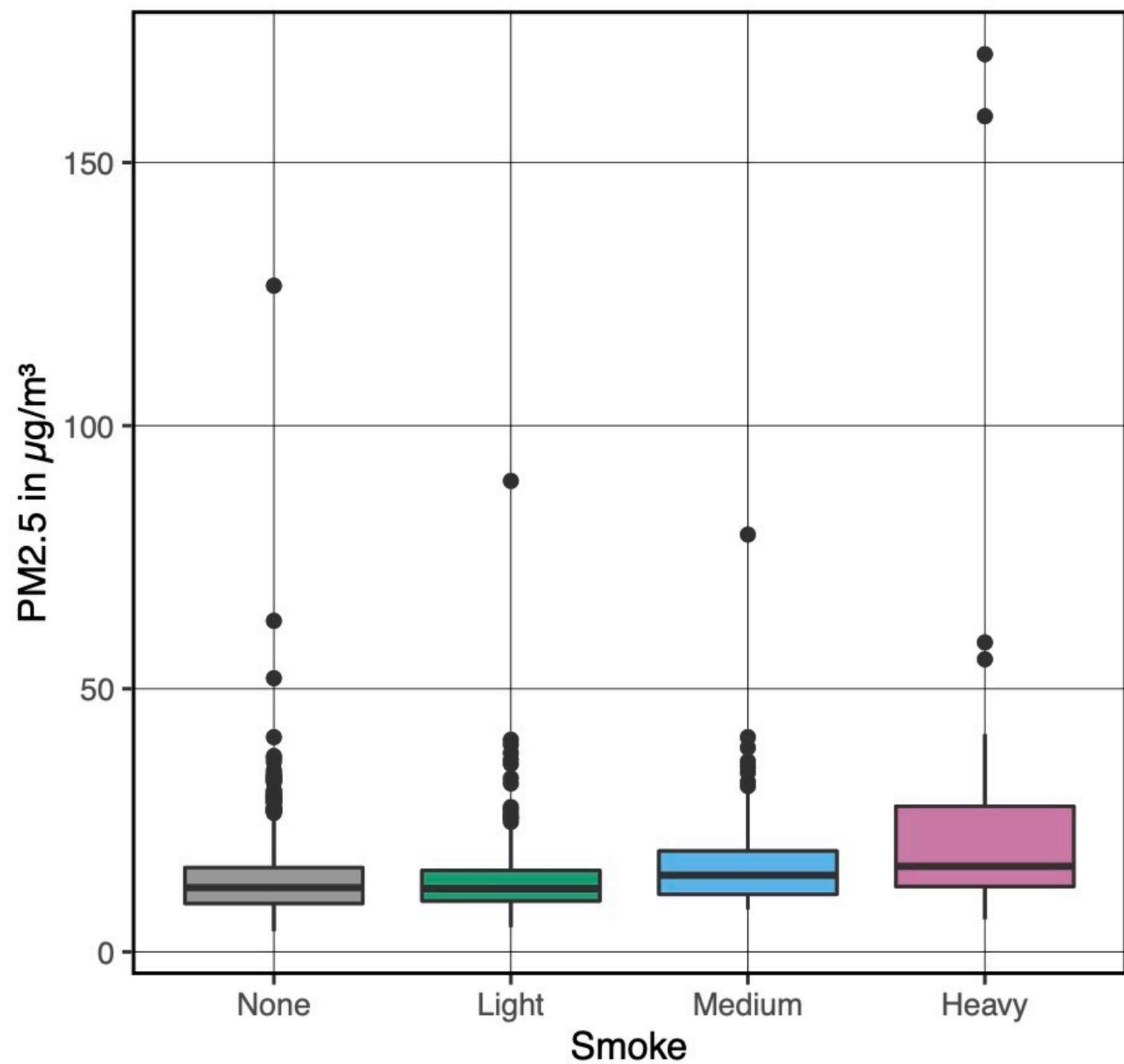


Figure 6. Boxplot showing the concentration of PM<sub>2.5</sub> during each level of smoke.

## 4 Two Case Studies

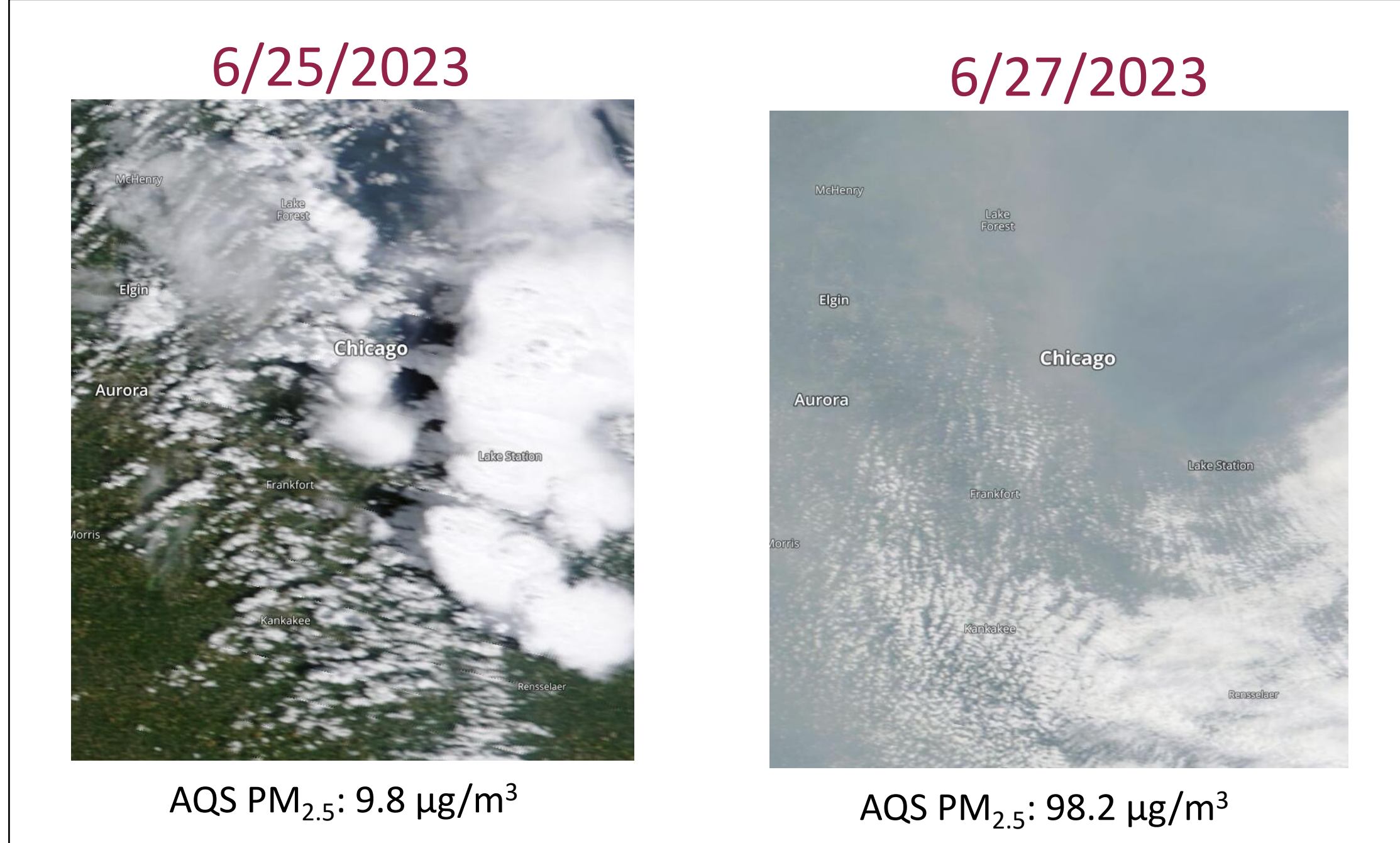


Figure 7. Satellite images of Chicago and surrounding area on (a) June 25, 2023 and (b) June 27, 2023 according to NASA Worldview.

### Case Study 1: June 25–27, 2023

- Difference of PM<sub>2.5</sub> and visual presence of smoke, only two days apart.
- The surface PM<sub>2.5</sub> concentration in Chicago became 10 times the level before the smoke influence.
- Thus, exemplifying the impact smoke has on Chicago's air quality.

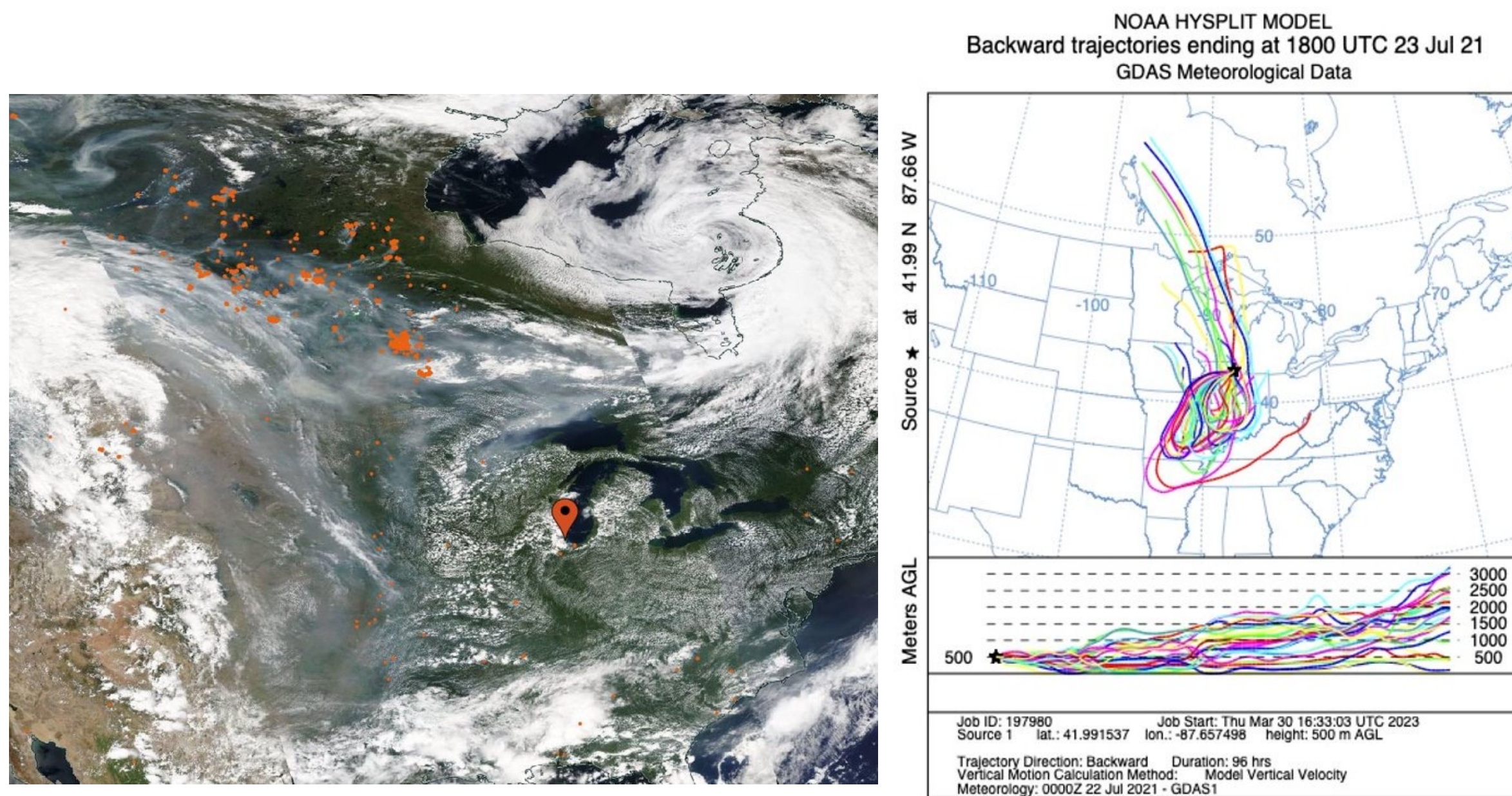


Figure 8. Satellite imagery of United States and Canada on July 23, 2021, according to NASA Worldview.

Figure 9. Trajectory of air movement leading to July 23, 2021, according to NOAA HYSPLIT.

### Case Study 2: July 23, 2021

- Satellite imagery to show the presence of smoke and fires across North America on July 23rd, 2021.
- The 96-hour back trajectory performed to show to smoke in Chicago is from the Canadian fires. PM<sub>2.5</sub>: 30.5 µg/m<sup>3</sup>
- This shows how wildfire smoke from across the continent is impacting Chicago.

## 5 Acknowledgments



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## References

