Is Your County's $PM_{2.5}$ Monitor Capturing Peak Concentration?

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Introduction

Monitoring $PM_{2.5}$ concentrations across the United States supports public health assessment and regulatory compliance. Most EPA monitoring sites are located in populated or industrial regions. Valid $PM_{2.5}$ monitoring data for 2023 were available for only 536 U.S. counties, representing approximately 17% of all counties. This limited spatial coverage constrains efforts to fully characterize national exposure patterns across all U.S. counties.

Satellite-derived $PM_{2.5}$ data provide contiguous spatial coverage at a ~1 km resolution. Here, we use these high-resolution data to evaluate whether the U.S. $PM_{2.5}$ monitors are effectively capturing the highest 10% of annual $PM_{2.5}$ concentrations within each county.

Study Objective:

Highlight the top 10% annual $PM_{2.5}$ within each county to assess spatial alignment with the EPA $PM_{2.5}$ monitoring network.

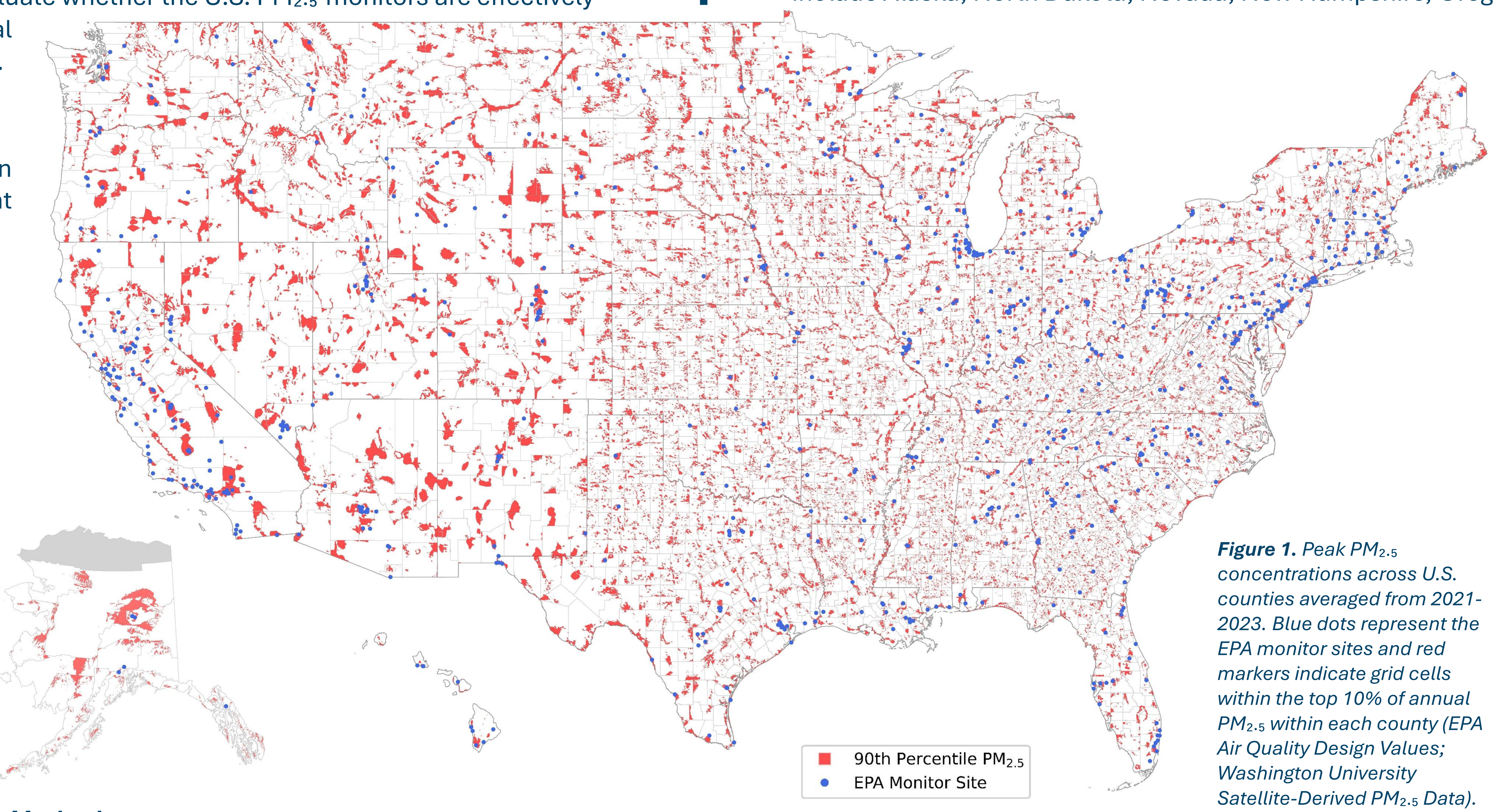

Figure 1. *Peak $PM_{2.5}$ concentrations across U.S. counties averaged from 2021-2023. Blue dots represent the EPA monitor sites and red markers indicate grid cells within the top 10% of annual $PM_{2.5}$ within each county (EPA Air Quality Design Values; Washington University Satellite-Derived $PM_{2.5}$ Data).*

Methods

Data:

- Washington University Satellite-Derived $PM_{2.5}$ V5.GL.05.02 for 2021, 2022, and 2023 (Figure 2).
- U.S. EPA Air Quality System (AQS) site-level design values for 2023, evaluated relative to the 2024 annual $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS).
- U.S. Census Bureau 2023 county boundary shapefiles.

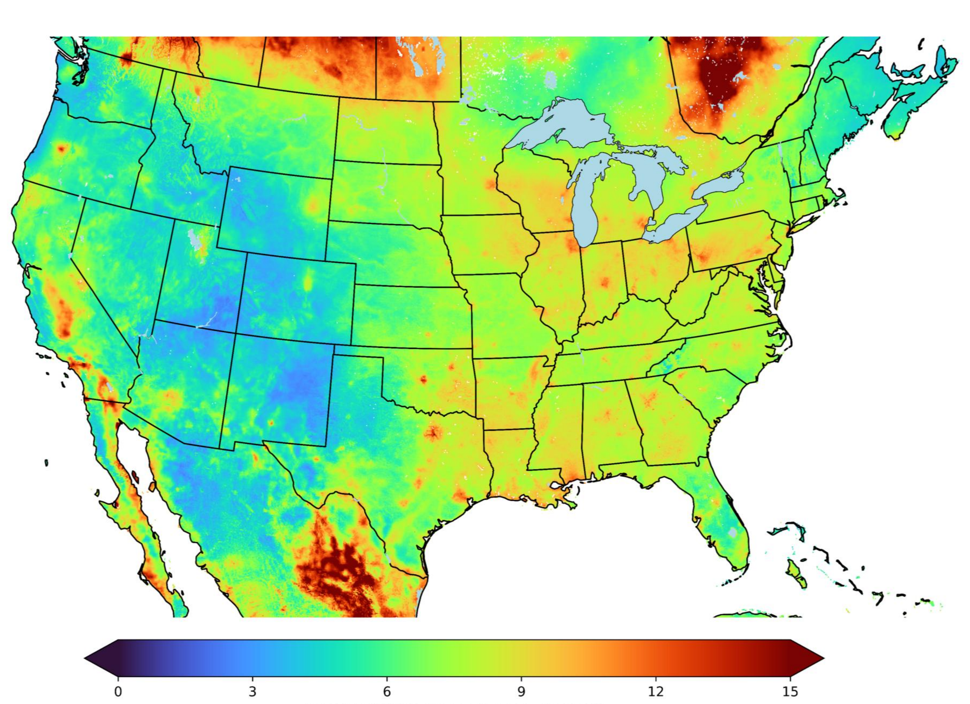

Figure 2. *Surface $PM_{2.5}$ concentrations across the contiguous U.S. during 2023 (Washington University Satellite-Derived $PM_{2.5}$ V5.GL.05.02).*

Methods:

- Processed 2021–2023 satellite-derived $PM_{2.5}$ data (0.01° × 0.01° spatial resolution, ~1 km^2 grid cells).
- Removed high-uncertainty values (>90%) and averaged annual data to produce 3-year mean $PM_{2.5}$ values.
- Estimated peak $PM_{2.5}$ exposure across all 3,143 U.S. counties, using the 90th percentile of $PM_{2.5}$ values.
- Flagged grid cells with $PM_{2.5}$ values ≥ 90th percentile threshold in red and plotted grid cells alongside EPA monitoring sites (Figure 1).
- Applied neighborhood-scale buffers (0.5–4 km) around each monitor to assess coverage (EPA, 40 CFR Part 58).
- Assigned monitor coverage to counties according to buffer intersection.

Results

- Using a 0.5 km buffer around monitor sites, 550 counties fall within range of a monitor, and 332 (60.4%) have at least one monitor capturing a ≥ 90th percentile $PM_{2.5}$ high-exposure grid cell.
- Increasing the buffer to 4 km widens the coverage to 640 monitored counties, of which 502 (78.4%) have at least one monitor capturing a ≥ 90th percentile $PM_{2.5}$ high-exposure grid cell.
- States with the best alignment (~100% of monitors capturing high-exposure grid cells) include Iowa, Arkansas, Idaho, and West Virginia, while states with the worst alignment (≤60% capture) include Alaska, North Dakota, Nevada, New Hampshire, Oregon, and Wyoming.

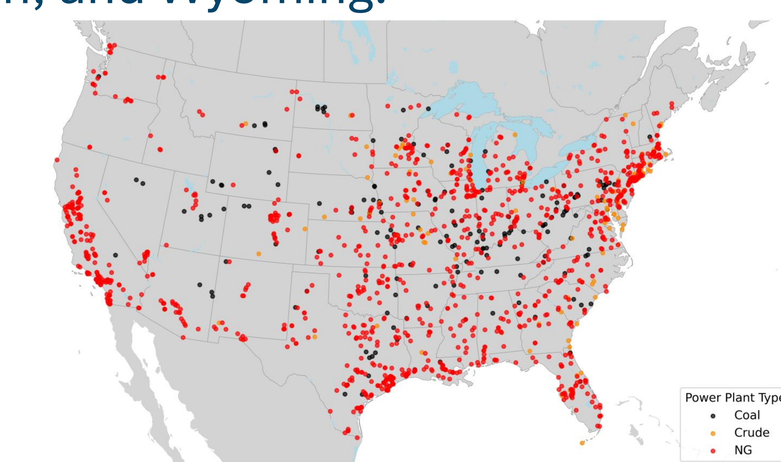

Figure 3. *Largest coal, crude oil, and natural gas power plants in the contiguous U.S. with a capacity of at least 25 MW (EIA).*

Figure 4. *Major rivers in the contiguous U.S. (Natural Earth Hydrography dataset).*

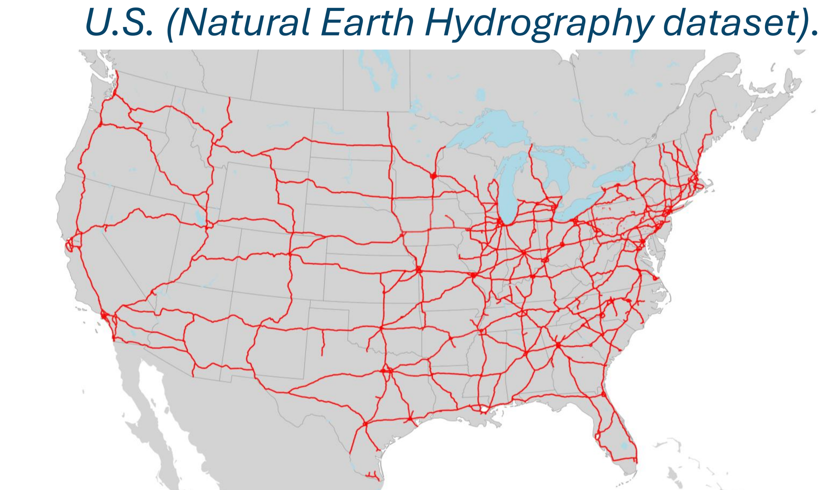

Figure 5. *Major U.S. interstate highways (National Highway System).*

- Existing $PM_{2.5}$ monitoring sites are often concentrated around major industrial areas with large emission sources such as coal, oil, and natural gas power plants. Western states show sparse monitor coverage, consistent with the patterns in Figure 3.
- $PM_{2.5}$ concentrations tend to peak along major river corridors (Figure 1; Figure 4). This includes the Mississippi River (Minnesota through Wisconsin, Illinois, Missouri, Arkansas, and Mississippi), the Snake River (Idaho, Washington, and Oregon), and the Rio Grande (New Mexico and Texas).
- Elevated $PM_{2.5}$ levels also follow major U.S. interstate highways. While many of these highways run parallel to rivers, distinct highway-related pollution patterns are visible even in non-river regions such as central Florida (Figure 1; Figure 5).
- **Next steps**: Incorporate 1 km resolution emissions data to examine the sources of emissions along river corridors.

Acknowledgements

This work is supported by the NASA Health & Air Quality program. We also thank Washington University in St. Louis for providing the satellite-derived $PM_{2.5}$ data and for their collaboration.