Evaluating County-Level $PM_{2.5}$ Monitor Placement in the U.S.

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Background

Ground-based monitoring of $PM_{2.5}$ concentrations supports health and regulatory assessment in the United States. EPA monitor data in 2021–2023 are available for only 630 (20%) of all U.S. counties. Alternatively, satellite-derived $PM_{2.5}$ data provide spatially contiguous (~1 km) coverage (Figure 1A). We use these data to determine whether monitors capture county-level $PM_{2.5}$ hotspots (top 10% of annual concentrations, Figure 1B). Monitors are *hotspot-aligned* if their measurement scales overlap hotspot grid cells. We further evaluate the spatial proximity of $PM_{2.5}$ hotspots to geographic features and emissions sectors.

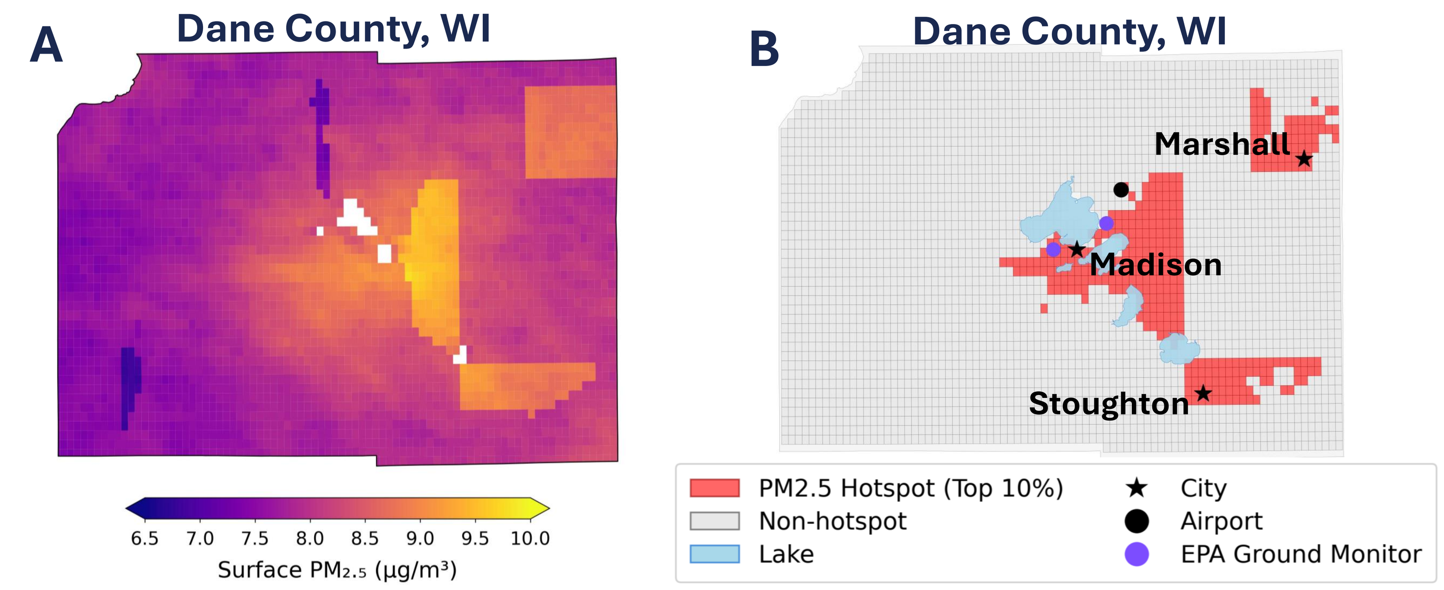
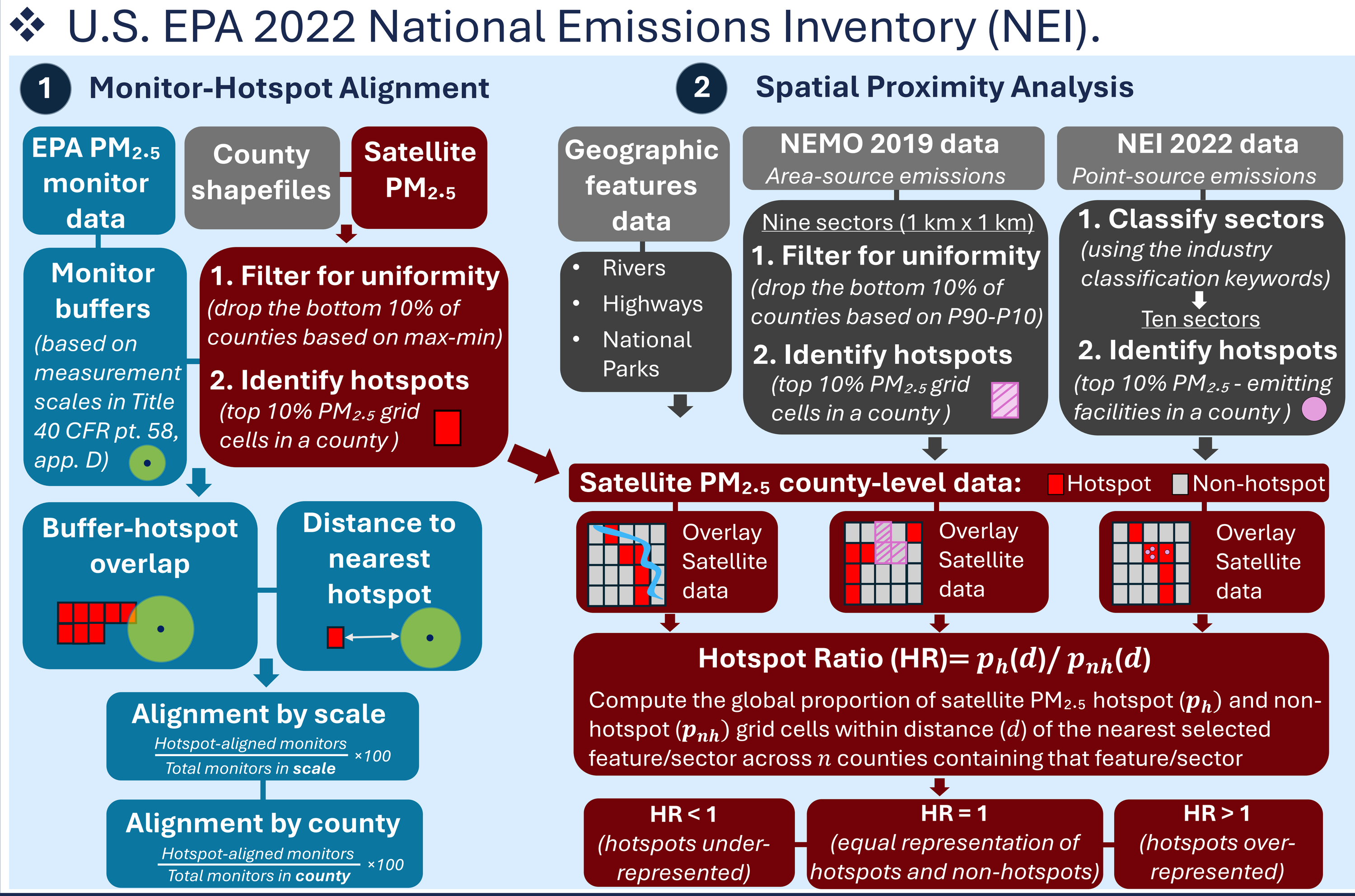


Figure 1. *Satellite-derived surface $PM_{2.5}$ averaged over 2021–2023 in Dane County (A), with hotspot grid cells (top 10% $PM_{2.5}$ in the county) shown in red (B).*

Data and Methodology

Data:

- WashU Satellite-Derived $PM_{2.5}$ V5.GL.05.02 from 2019–2023.
- EPA Interactive Map of Air Quality Monitors, active 2021–2023.
- U.S. Census Bureau 2023 county boundary shapefiles.
- U.S. Census 2023 TIGER/Line Shapefile for Primary Roads .
- HydroRIVERS vectorized global rivers (Lehner and Grill, 2013).
- U.S. National Parks boundaries (NPS National Parks Dataset).
- Neighborhood Emission Mapping Operation (NEMO) dataset.
- U.S. EPA 2022 National Emissions Inventory (NEI).



Monitor–Hotspot Alignment

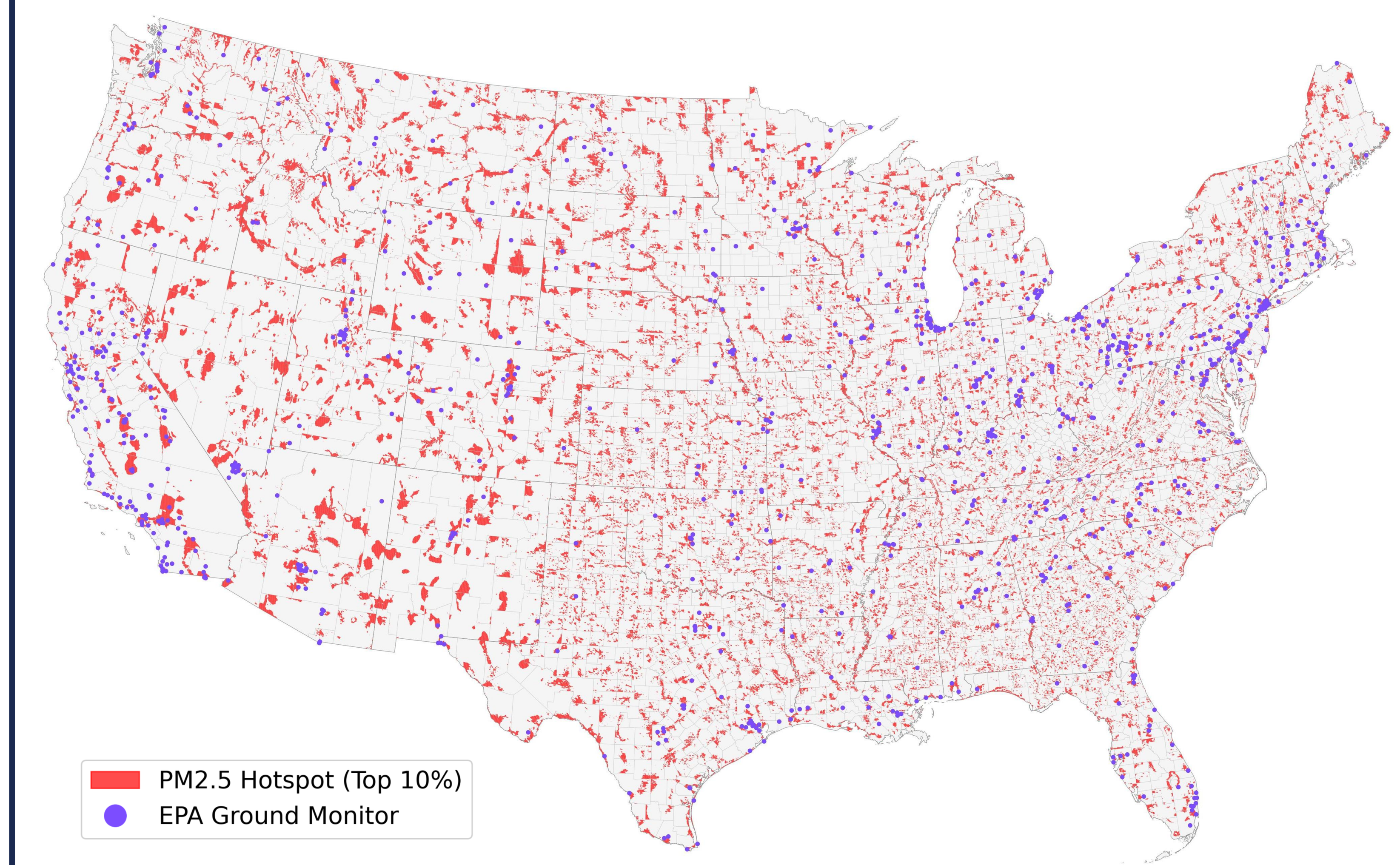


Figure 2. *County-level $PM_{2.5}$ hotspot grid cells derived from satellite-based $PM_{2.5}$ estimates averaged over 2021–2023 (red), with EPA monitoring sites active during 2021–2023 (purple).*

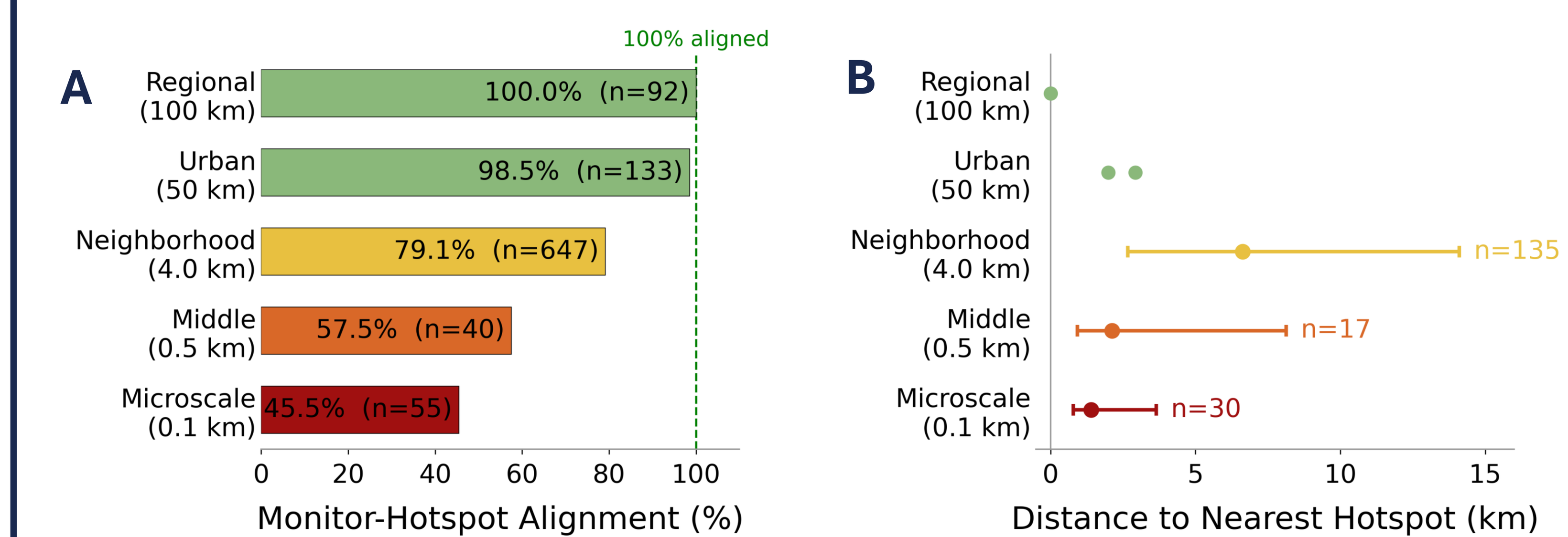


Figure 3. *Monitor-hotspot alignment (%) by measurement scale: microscale, middle, neighborhood, urban, and regional (A). Median distance between monitor buffer-edge and nearest $PM_{2.5}$ hotspot among non-aligned monitors, across measurement scales (B).*

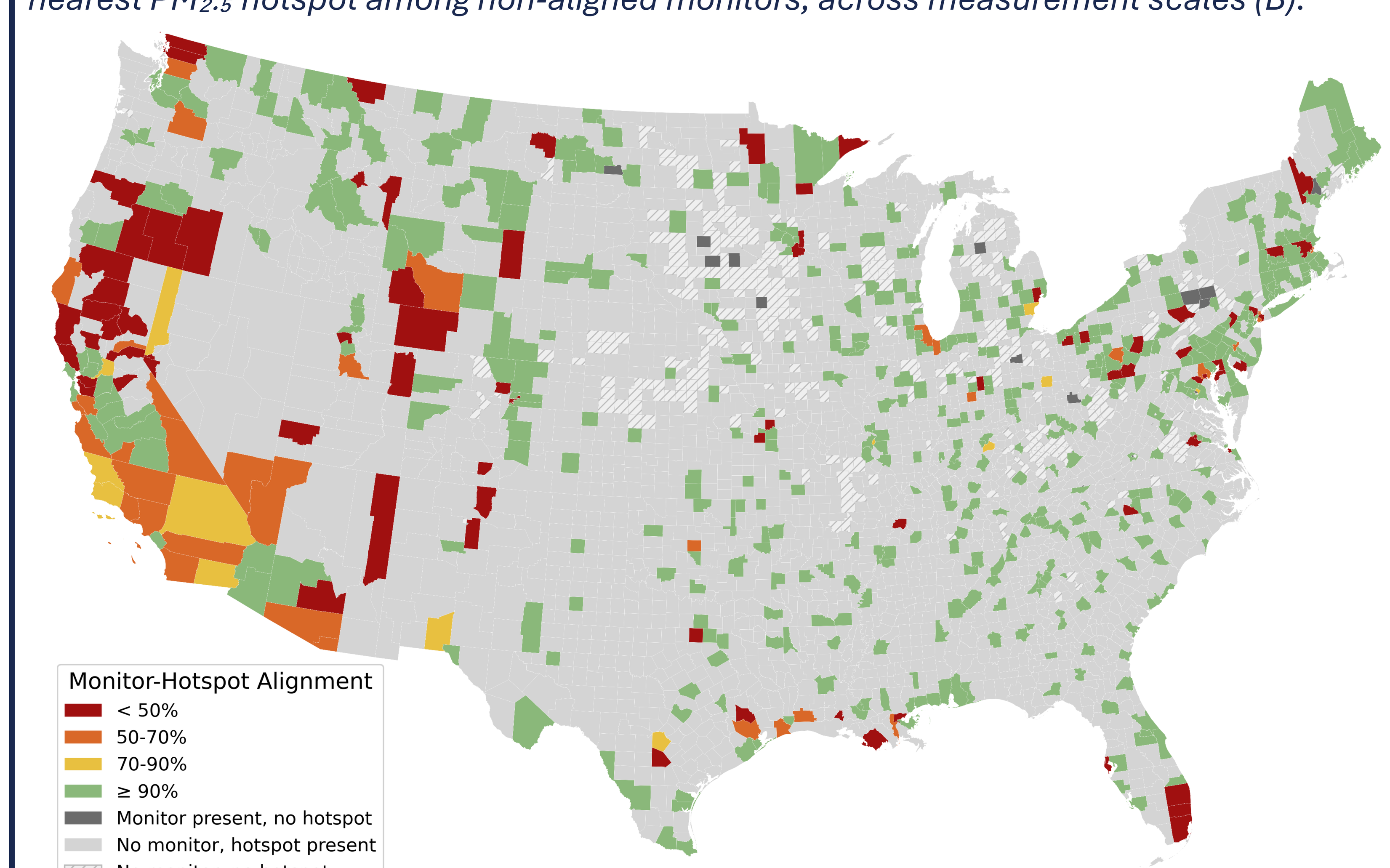


Figure 4. *County-level monitor-hotspot alignment, defined as the percentage of monitors per county with a measurement scale overlapping a $PM_{2.5}$ hotspot grid cell.*

Spatial Proximity Analysis

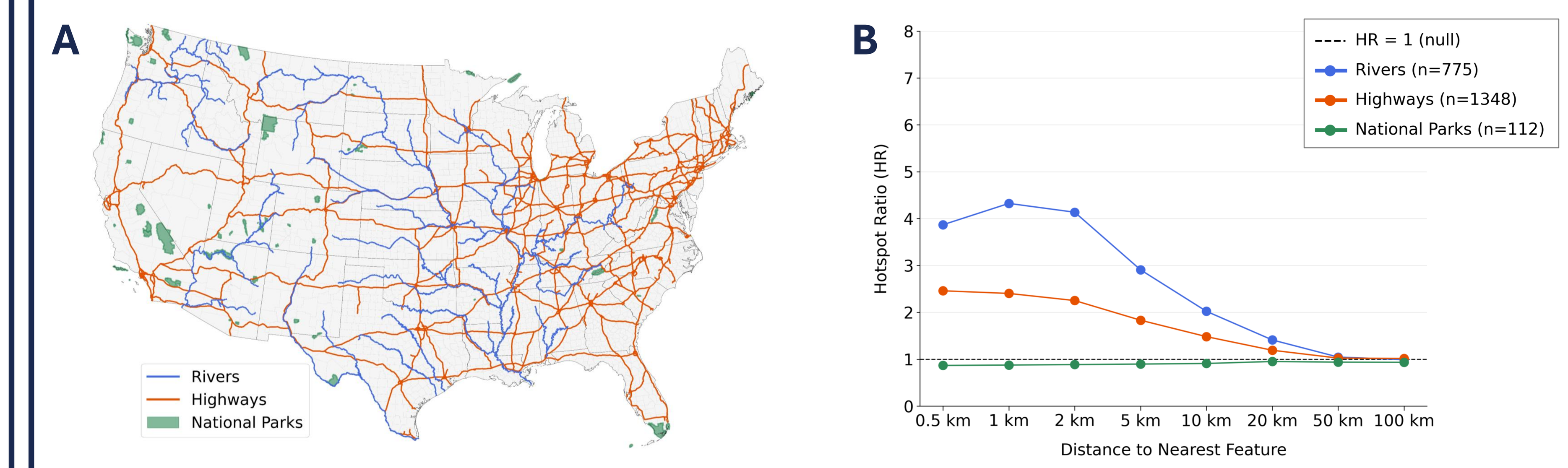


Figure 5. *Map of rivers, highways, and national parks across the U.S. (A). HR by distance, comparing the proportion of hotspot versus non-hotspot grid cells near each feature across (n) counties (B).*

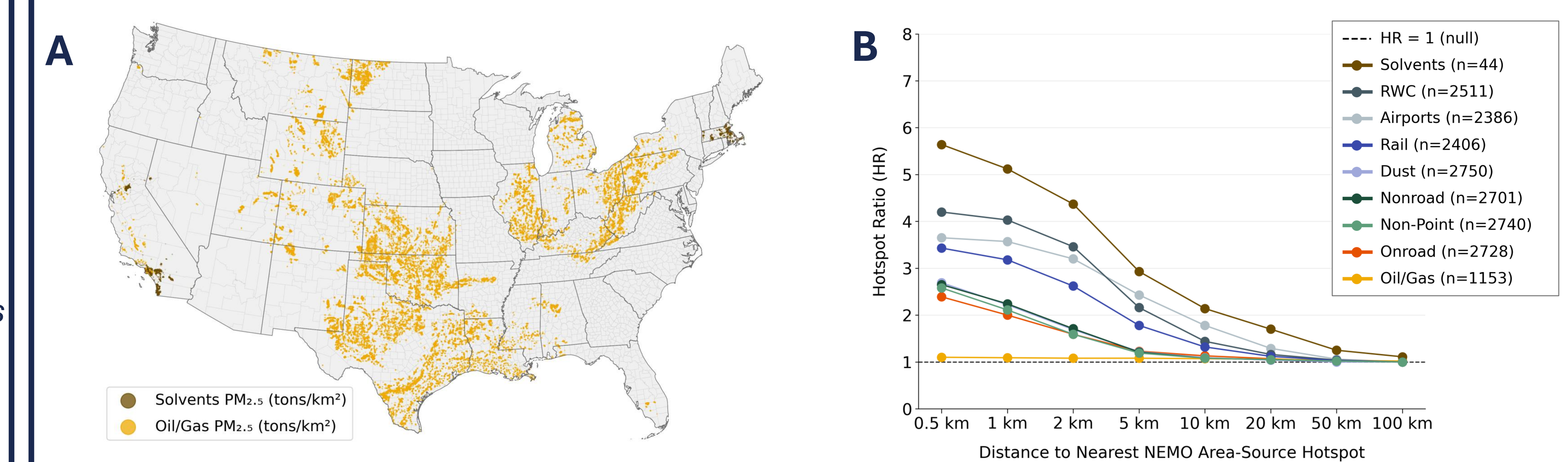


Figure 6. *Map of $PM_{2.5}$ emission hotspots (tons/km^2) for the solvents and oil/gas sectors from the NEMO area-source emissions dataset (A). HR by distance across nine sectors (B).*

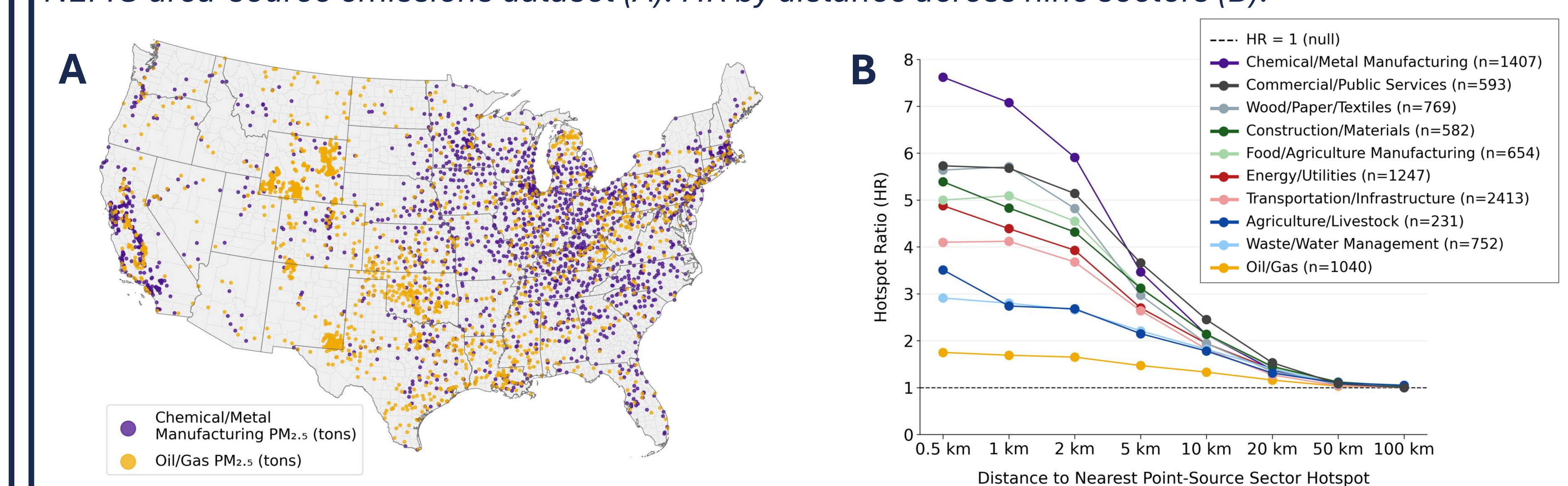


Figure 7. *Map of $PM_{2.5}$ emission hotspots (tons) for the chemical/metal manufacturing and oil/gas sectors from the NEI point-source emissions dataset (A). HR by distance across ten sectors (B).*

Conclusions

- EPA monitors broadly capture county-level $PM_{2.5}$ hotspots (Figure 2), though alignment varies by measurement scale – only 45.5% of microscale and 57.5% of middle scale monitors are hotspot-aligned (Figure 3A).
- Among non-aligned monitors, median buffer-edge to hotspot distances are modest for microscale (1.40 km) and middle scale (2.12 km) but larger for the neighborhood scale (6.62 km) (Figure 3B).
- County-level monitor-hotspot alignment varies, with misalignment occurring primarily among counties across the western U.S. (Figure 4).
- $PM_{2.5}$ hotspots are disproportionately located near riverways (HR ~5 at 1 km; Figure 5), solvent area-source emissions (HR ~6 at 0.5 km; Figure 6), and chemical/metal manufacturing point source emissions (HR ~8 at 0.5 km; Figure 7), with the proximity effect weakening at greater distances.

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