The impact of spatial resolution on evaluating air pollution exposure disparities from power generation

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1. Motivation & Objective

Emissions from the power sector significantly contribute to ambient air pollution and its adverse effects on human health[1].

There are large air pollution exposure disparities between high and low-income groups mainly due to power plant placement in low-income areas[2].

Minority and low-income groups may experience higher PM2.5 concentrations than the national average during energy system transitions[2].

Few studies have evaluated the uncertainty in estimates of socioeconomic disparities arising from the spatial resolution of the air pollution modeling framework.

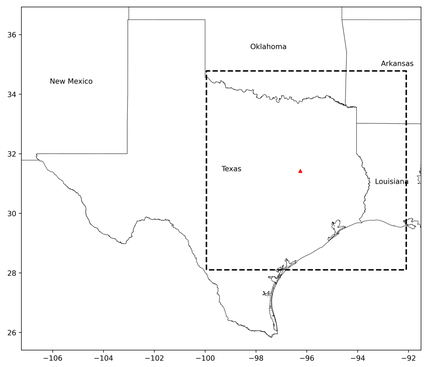


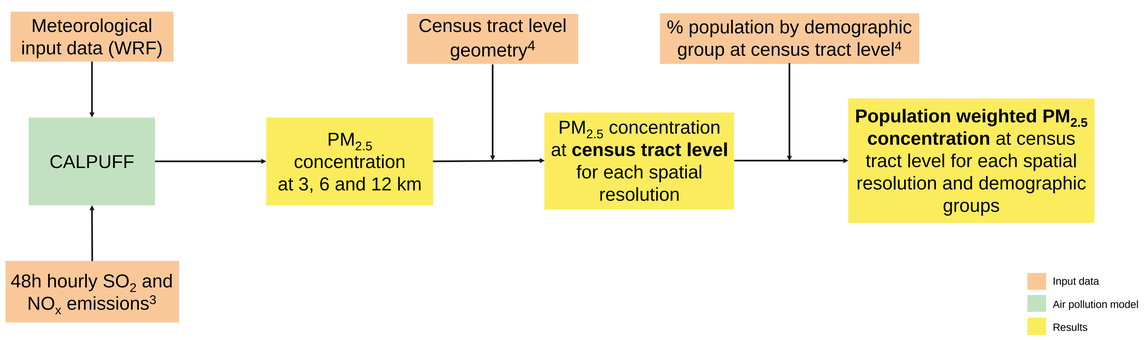
Figure 1. The location of the coal power plant and the 800 km x 800 km simulation domain used to model $PM_{2.5}$ concentrations.

Objective: To assess how estimates of racial-ethnic and income-based disparities in exposure to air pollution from electricity generation are affected by the spatial resolution of an air pollution modeling framework.

Research question: How does the spatial resolution of an air pollution modeling framework influence assessments of racial-ethnic and income-based disparities in air pollution exposure from electricity generation?

2. Methodology

- Case study of the Limestone Power Plant, located in Jewett, TX. It is a conventional steam coal facility with a capacity of 900 MW.
- CALPUFF Lagrangian puff modeling system used to simulate atmospheric pollution dispersion.
- Spatial resolutions: 3, 6 and 12 km.
- Hourly NO_x and SO_2 emissions were used to simulate ground-level secondary $PM_{2.5}$ concentrations.
- January 1st to 3rd of 2023 → 48h average $PM_{2.5}$ concentration.
- Population weighted concentrations (μg/m³) are calculated by summing the product of the population of a demographic group within a census tract and the air pollution concentration. This is then divided by the total population of a demographic group.



References

[1] Fann N, Fulcher C M and Baker K 2013 The recent and future health burden of air pollution apportioned across US sectors Environ. Sci. Technol. 47 3580–9.
[2] Goforth, Teagan, and Destenie Nock. "Air pollution disparities and equality assessments of US national decarbonization strategies." Nature Communications 13.1 (2022): 7488.
[3] US Environmental Protection Agency 2024 Clean Air markets program data (CAMPD) https://campd.epa.gov/data/custom-data-download (accessed 06 Mar 2024)
[4] US Census Bureau. American Community Survey (ACS). https://www.census.gov/programs-surveys/acs (2023)

Acknowledgments

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3. Results

5.1 48h average $PM_{2.5}$ concentration

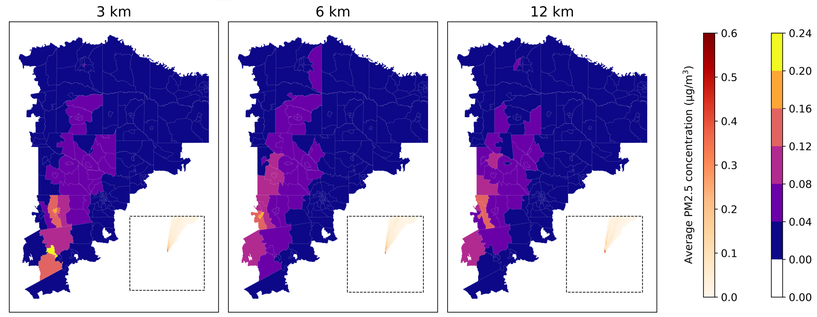

Figure 2. 48-hour average $PM_{2.5}$ concentration displayed at census tract level in the larger plot and at plume level within the domain in the smaller plot, across different resolutions.

- 3 km resolution shows the **highest** 48h average PM2.5 concentration.
- 12 km resolution shows the **lowest** 48h average PM2.5 concentration.

5.2 Population weighted concentration

Table 1. Population weighted average $PM_{2.5}$ concentration (μg.m^{-3}) for each demographic group.

Group	3 km	6 km	12 km
Total	0.024	0.020	0.019
Black	0.023	0.013	0.012
Asian	0.016	0.012	0.012
White	0.024	0.022	0.020
Hispanic	0.028	0.018	0.017
Low income	0.025	0.022	0.021

- The 3 km resolution reveals the highest population-weighted concentration (PWC) across all demographic groups.
- The most significant differences are observed for the **Black** and **Hispanic** groups when comparing the 3 km and 12 km resolutions, with differences of 48% and 40%, respectively.
- At the 6 km and 12 km resolutions, Hispanics have a lower PWC than Whites. However, at the 3 km resolution, Hispanics show a higher PWC compared to Whites.

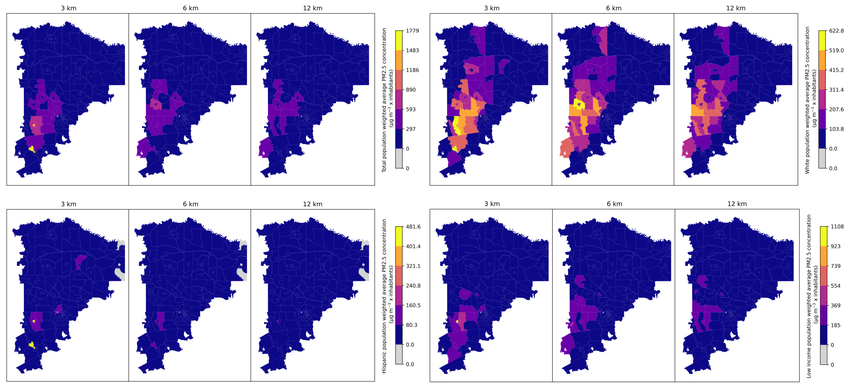

Figure 3. Population weighted average $PM_{2.5}$ concentration (μg.m^{-3} x inhabitants) by census tract level and demographic groups.

- The distribution of PWC varies significantly with the resolution.
- 3 km resolution results in highest PWC across census tracts.
- The largest spatial variation is observed in the **White** population.

4. Conclusions & Future work

- Simulating PM2.5 concentrations at different spatial resolutions resulted in different population weighted impacts.
- Changes in resolution can lead to different patterns in the distribution of population weighted impacts.
- Population weighted concentrations increase significantly with higher spatial resolution.
- Estimates for some population groups (e.g., Hispanic and Black residents) are more sensitive to model resolution, as they exhibit a greater difference in PWC between finer and coarser resolution results.
- Conclusions about disparities in exposure to air pollution from power generation may be misleading if inadequate resolution is used for modeling framework.
- **Future Work:** Conduct simulations for a complete electrical grid to investigate how different levels of resolution impact power systems' decision-making.