Inequitable Exposure to Air Pollution from Vehicles in California

Who Bears the Burden?
www.ucsusa.org/CA-air-quality-equity

Appendix: Methodology

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Air Quality Modeling

To assess chronic exposure to particulate air pollution in California, the Union of Concerned Scientists used a model of pollutant generation and transport (InMAP) to generate estimates of average annual concentrations of particulate matter smaller than 2.5 micrometers ($PM_{2.5}$) in California with a maximum resolution of one square kilometer (km^2) (Tessum, Hill, and Marshall 2017). InMAP models both the transport of primary $PM_{2.5}$ emissions and the formation of secondary $PM_{2.5}$ through atmospheric reactions. Tailpipe and refueling emissions (nitrogen oxides, sulfur oxides, $PM_{2.5}$, and volatile organics) from on-road vehicles were adapted from the US Environmental Protection Agency (EPA) National Emissions Inventory (NEI) (EPA 2014).

Exposure: Demographic Analysis

We mapped the resulting $PM_{2.5}$ concentrations to census block groups using area-weighted interpolation. We combined the concentrations with data from the 2012–2016 American Community Survey to determine particulate air pollution exposure by demographic group (CB 2018). We used the population-weighted annual average concentration as the primary metric of exposure to $PM_{2.5}$. Health impacts assumed a no-effect threshold concentration of zero micrograms per cubic meter, as there has not been a lower bound established for health effects of chronic $PM_{2.5}$ exposure (Pinault et al. 2016).

Considerations on Using a Reduced-Form Air Quality Model

The InMAP model is a "reduced-complexity national-scale air quality model with flexible grid resolution that allows computational resources to be dedicated to areas that have highly spatially variable pollutant concentrations and population densities" (Paolella et al. 2018).

Reduced-complexity models, in general, are less accurate in terms of absolute concentrations of pollutants than conventional chemical transport models (CTMs). However, InMAP has been shown to reproduce the results of conventional models to a reasonable degree (Tessum, Hill, and Marshall 2017). InMAP performs better on population-weighted metrics than it does on area-based concentration metrics (Table). Since we used InMAP to assess exposure and the equity of exposure, InMAP's ability to model population-weighted exposure is more important than its area-weighted performance.

Total Annual Average Predicted $PM_{2.5}$ Concentration Change: InMAP (one square kilometer grid) and CTM model (Weather Research and Forecasting model coupled to chemistry, 12 km^2 grid)

	Mean Fractional Bias	**Mean Fractional Error**	**Slope of Regression Line (InMAP vs. CTM)**
Area Weighted	-47%	49%	0.46
Population Weighted	6%	18%	0.73

While conventional CTMs do have greater accuracy, they are more computationally intensive. They often operate at a reduced spatial resolution or over a smaller area than a reduced-complexity model such as InMAP. The spatial resolution of the air quality model is important when attempting to assess the equity of air pollution (Paolella et al. 2018). It is common to use 12 km grid side lengths for a contiguous US CTM model analysis or four kilometer sides for a regional-level CTM analysis. InMAP has variable grid side lengths, allowing for one square kilometer grids to be used even for an analysis at the national level; it also has compute times of less than one day on a desktop computer. Being able to model at a fine spatial resolution such as one square kilometer allows for meaningful insight on the equity of exposure, especially in urban areas with racially or economically segregated populations.

InMAP also differs from more complex CTM analysis in that it calculates annual average concentration and exposure. It does not capture acute exposure or seasonal variations; however, the majority of health impacts of $PM_{2.5}$ exposure are linked to chronic exposure to the pollutant. Thus, the annual average exposure serves as a useful metric for estimating the burdens and equity of $PM_{2.5}$ pollution.

Another consideration when using InMAP is the baseline data used for the analysis. The model reduces complexity by using the output of a CTM run to derive physical and chemical information. InMAP is designed to model changes from these baseline data. The calculations from InMAP use baseline data generated from a full chemical transport model, based on the 2005 version of the EPA's NEI, while the UCS analysis uses emissions based on the 2014 version of the NEI. However, a recent study has shown that this combination of CTM baseline data derived from the 2005 NEI with 2014 NEI emissions inputs does provide reasonable results when compared with actual emissions data (mean fractional bias = 17 percent; mean fractional error = 35 percent; slope of regression = 0.78) (Paolella et al. 2018).

Additionally, the reduced-complexity model is designed to estimate marginal emissions changes from the baseline data, while we are exploring relatively large changes in emissions (all on-road vehicle emissions). However, the model has been tested not only for marginal changes but also with the complete US emissions inventory (Tessum, Hill, and Marshall 2017). Our analysis is of a change in emissions smaller than that test, and we would expect that model errors would be similar to the published analysis of model performance.

[References]

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