Quantifying Societal Health Benefits of Transportation Emission Reductions in the United States and Canada

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Introduction

One measure of the efficacy of an air pollution control option is the marginal benefit (MB) or benefit-per-ton (BPT) associated with the option, or the monetized societal benefits of reducing one metric ton of emissions through its implementation. BPTs depend heavily on the location of release; however, estimation of the location-specific impact is difficult, in part, due to the complex nature of atmospheric processes that govern source-receptor relationships. As an alternative to relying on simplified and reduced complexity models [1-3] to estimate location specific BPTs, we propose to use a multiphase adjoint model that accounts for all atmospheric processes in calculation of these BPTs for transportation and other major sectors in the U.S. and Canada.

Objectives

- Create a database of location-specific BPTs for transportation and other select sectors in the U.S. and Canada,
- Quantify the uncertainty in estimated BPTs,
- Examine the sensitivity to various assumptions made in estimation of BPTs,
- Develop an associated database of health co-benefits from reducing combustion-based CO_2, and
- Present per-vehicle MBs for various vehicle types and vintages.

Preliminary Results

Episode selection: Due to the high computational cost of adjoint modeling, conducting year-long simulations is not feasible. Instead seasonal BPTs are estimated for two-week episodes that are deemed representative of the season. We conduct a seasonal anomaly analysis of $PM_{2.5}$ and meteorological parameters to choose these episodes. The uncertainties associated with the episode selection are further examined as a sensitivity analysis.

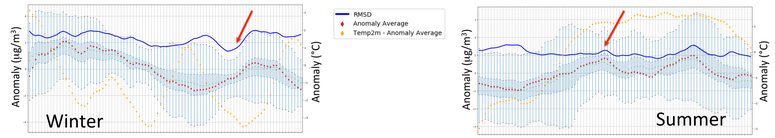

Figure 1: Anomaly analysis of Winter and Summer Seasons. The analysis is based on deviation of 2-week moving averages from seasonal averages in the form of anomaly (difference) and root mean square deviation (RMSD).

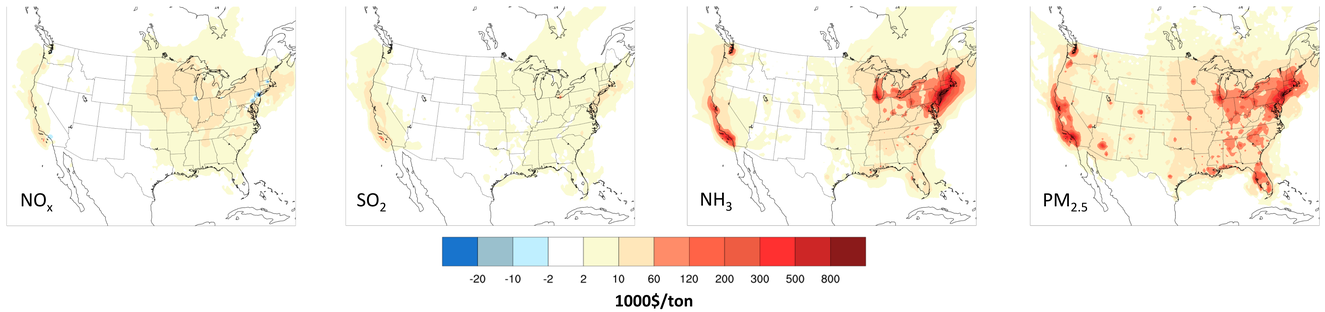

Figure 2: Preliminary BPT estimates due to chronic exposure to $PM_{2.5}$, based on a week-long simulation at a 36 km resolution in April 2008. $PM_{2.5}$ effect estimates are based ACS reanalysis [6]. BPT estimates represent valuated societal benefits to the U.S. from emission reductions at each location. BPTs are preliminary and are only shown for demonstration purposes.

Approach

BPT estimations: The adjoint of the U.S. EPA's Community Multiscale Air Quality (CMAQ) model is used to attribute the valuated societal damage of emitted species to sources at various locations and from different sectors [4-5]. BPTs are estimated for mortality due to long-term exposure to $PM_{2.5}$, O_3 (and NO_2 in Canada) at 12 km resolution for the year 2014.

BPT uncertainties: Location-specific uncertainties will be quantified, accounting for uncertainties in CMAQ and adjoint model simulations, epidemiologic effect estimates, and valuation.

Co-benefit estimates: BPT estimates will be linked to sector-specific emission profiles of criteria and CO_2 emission profiles to produce location-specific BPTs.

Sensitivity analyses: Sensitivity of the estimated BPTs will be examined with respect to the following choices and assumptions:

- *The choice of epidemiological model*, using concentration response functions (CRFs) from different cohorts and of various forms.
- *Resolution*, by estimating 4-km and 1-km BPTs for NY City and Los Angeles.
- *The choice of episodes*, by conducting year-long BPT simulations at a coarser resolution (36 km).
- *Emission inventory level*, by estimating BPTs for additional years of 2004 and 2024 (projected).

Per-vehicle damage: BPTs will be combined with detailed fleet and emission data to produce vintage and location-specific per-vehicle damage estimates.

Summary

- Databases for location-specific BPTs, CO_2 reduction co-benefits, and per-vehicle damage estimates will be developed.
- Uncertainties for the estimated BPTs will be quantified and their robustness against various assumptions will be examined.
- Spatial specificity of BPT estimates would allow decision makers to better differentiate between benefits associated with various policy options.

References: [1] Environ Sci Technol 50:6061–6070, 2016. [2] Am Econ Rev 101:1649–1675, 2011. [3] PLoS ONE 12: e0176131, 2017. [4] Environ Sci Technol 41:7807-7817, 2007. [5] Environ Health Perspect 121:572-579, 2013. [6] Health Effects Institute, 2009.

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