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Effects of light duty gasoline vehicle emission standards in the United States on ozone and particulate matter

Krish Vijayaraghavan*, Chris Lindhjem, Allison DenBleyker, Uarporn Nopmongcol, John Grant, Edward Tai, Greg Yarwood

ENVIRON International Corporation, 773 San Marin Drive, Suite 2115, Novato, CA 94998, USA

HIGHLIGHTS

- ► Simulations of the incremental benefits of successive US LDV emissions standards.
- ► Tier 1, Tier 2, hypothetical nationwide LEV III standard and zero-out LDV scenario.
- ► Calculated ozone and PM reductions assuming each standard is prevailing in 2022.
- ► Tier 2 to LEV III switch offers very small benefit compared to Tier 1 to 2 change.
- ► Benefit of eliminating LDVs is smaller than the benefit from Tier 1 to 2 transition.

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ABSTRACT

More stringent motor vehicle emission standards are being considered in the United States to attain national air quality standards for ozone and $PM_{2.5}$. We modeled past, present and potential future US emission standards for on-road gasoline-fueled light duty vehicles (including both cars and light trucks) (LDVs) to assess incremental air quality benefits in the eastern US in 2022. The modeling results show that large benefits in ozone and $PM_{2.5}$ (up to 16 ppb (14%) reductions in daily maximum 8-h ozone, up to 10 ppb (11%) reductions in the monthly mean of daily maximum 8-h ozone, up to 4.5 μg m^{-3} (9%) reductions in maximum 24-h $PM_{2.5}$ and up to 2.1 μg m^{-3} (10%) reductions in the monthly mean $PM_{2.5}$) accrued from the transition from Tier 1 to Tier 2 standards. However, the implementation of additional nationwide LDV controls similar to draft proposed California LEV III regulations would result in very small additional improvements in air quality by 2022 (up to 0.3 ppb (0.3%) reductions in daily maximum 8-h ozone, up to 0.2 ppb (0.2%) reductions in the monthly mean of daily maximum 8-h ozone, up to 0.1 μg m^{-3} (0.5%) reductions in maximum 24-h $PM_{2.5}$ and up to 0.1 μg m^{-3} (0.5%) reductions in the monthly mean $PM_{2.5}$). The complete elimination of gasoline-fueled LDV emissions in 2022 is predicted to result in improvements in air quality (up to 7 ppb (8%) reductions in daily maximum 8-h ozone, up to 4 ppb (6%) reductions in the monthly mean of daily maximum 8-h ozone, up to 2.8 μg m^{-3} (7%) reductions in maximum 24-h $PM_{2.5}$ and up to 1.8 μg m^{-3} (8%) reductions in the monthly mean $PM_{2.5}$) from Tier 2 levels, that are generally smaller than the improvements obtained in switching from Tier 1 to Tier 2.

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1. Introduction

Emissions from on-road motor vehicles in the United States (US) have decreased significantly over the past four decades even with increases in traffic volume. For example, highway vehicle emissions of volatile organic compounds (VOCs) decreased by approximately 75% from 1970 to 2005 and emissions of particulate matter (PM) and nitrogen oxides (NOx) decreased by over 50% though total Vehicles Miles Traveled (VMT) for highway vehicles increased more than two-fold (Kryak et al., 2010). These emissions reductions have been due, in large part, to increasingly stricter emissions and fuel standards for gasoline-fueled light duty vehicles (LDVs) in the US since the 1970s. The aim of these standards is to improve ambient air quality as emissions of VOCs, NOx and PM from LDVs are often key precursors to ambient ozone (O_3) and fine particulate matter ($PM_{2.5}$). With the potential lowering of the National Ambient Air Quality Standards (NAAQS) for 8-h O_3 and $PM_{2.5}$, States would likely seek additional means to reach or stay in O_3 and PM attainment including possibly adopting more severe LDV emission standards.

* Corresponding author. Tel.: +1 415 899 0700.
E-mail address: krish@environcorp.com (K. Vijayaraghavan).

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Therefore, it is of interest to understand the incremental O_3 and $PM_{2.5}$ benefits of past and current LDV emissions standards and the additional air quality benefits of potential future LDV emissions standards in the US.

While other modeling studies have analyzed the contribution of motor vehicles to O_3 and/or $PM_{2.5}$ concentrations and the impact of vehicle fuel and emissions controls on these concentrations (e.g., EPA, 1999; Matthes et al., 2007; Koffi et al., 2010; Nopmongcol et al., 2011; Roustan et al., 2011; Collet et al., 2012), the current work provides a cohesive analysis of the effect of historical, current and potential future LDV emissions standards on O_3 and $PM_{2.5}$ in the US. We apply state-of-the-science emissions models and an advanced regional 3-D photochemical air quality model that simulates transport and dispersion, atmospheric chemical transformation, and deposition to the earth's surface of trace gases and aerosols, to estimate impacts of different LDV emissions standards on ozone and primary and secondary PM in the eastern US with a focus on Atlanta, Detroit, Philadelphia and St. Louis. A 2008 baseline is used for air quality model performance evaluation. Four future year emissions scenarios with increasingly stricter emission standards for gasoline-fueled LDVs are compared against each other to estimate the incremental and cumulative effect of LDV emissions controls on ambient air quality.

2. Methods

2.1. Modeling domain and emissions scenarios

The air quality simulations were conducted with the Comprehensive Air Quality Model with Extensions (CAMx) (ENVIRON, 2011) using on-road emissions inventories derived using the Motor Vehicle Emission Simulator (MOVES) (EPA, 2010a) and other model inputs as discussed below. We applied version 5.40 of CAMx with the Carbon Bond 5 (CB05) chemical mechanism and version 2010a of MOVES.

The geographic region studied here includes part of the eastern US with focus on four of thirteen urban areas discussed in EPA's PM Risk Assessment analysis (EPA, 2010b). The four areas selected are Atlanta, Detroit, Philadelphia and St. Louis. The CAMx modeling domain extends over the continental US (CONUS) and parts of Canada and Mexico at 36 km horizontal resolution with an inner nested domain at 12 km resolution over part of the eastern US including the four urban areas of interest. The domain and four urban areas are shown in Fig. 1. The domain has a pressure-based vertical structure with 26 layers with the model top at 145 mb or approximately 14 km above mean sea level.

To study the effect of historical, current and additional LDV emissions controls, we modeled a 2008 base case and four 2022 LDV emissions scenarios. 2008 was chosen as the baseline modeling year due to the availability of emissions from the National Emissions Inventory (NEI) (EPA, 2011a). The 2008 base case is used for air quality model performance evaluation. The four 2022 LDV scenarios modeled are:

1. 2022 Tier 1 scenario (assume that only US Tier 1 standards are implemented through 2022)
2. 2022 Tier 2 scenario (assume that the current emissions standards, up to US Tier 2 standards, are implemented through 2022)
3. 2022 LEV III scenario (assume that the draft proposed California LEV III standard is adopted nationwide)
4. 2022 LDV zero-out (LDVZ) scenario (assume there are no gasoline-fueled LDV emissions in 2022)

2022 was chosen as the future year for modeling because the proposed LEV III standard was originally scheduled to phase in completely by 2022 (this was subsequently revised to 2028 as discussed below). All simulations were conducted for a winter month (February) and summer month (July) to represent two time periods with typically high $PM_{2.5}$ and ozone concentrations.

The 2022 Tier 1 scenario aims to answer the question: "what if the US had not switched from Tier 1 to Tier 2 standards by 2022?" The 2022 Tier 2 case reflects a scenario with current Tier 2 emissions standards that are not revised through 2022. The 2022 LEV III scenario addresses the potential impact of further tightening LDV emission standards from Tier 2 to a nationwide LEV III standard. Emissions from all sources other than gasoline-fueled LDVs are held constant across the four 2022 scenarios.

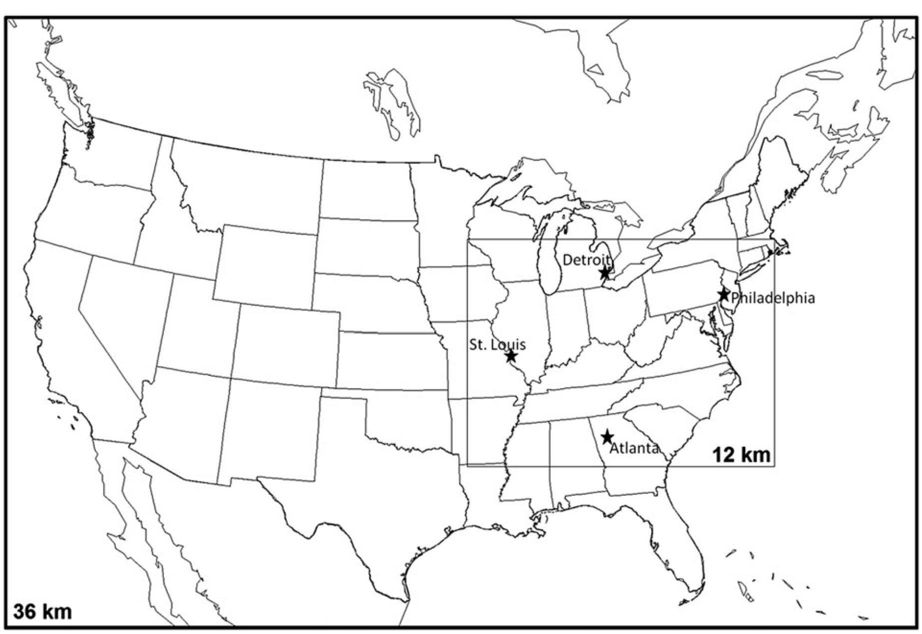

Fig. 1. Air quality modeling domain and urban areas analyzed.

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