PNNL-16769

Pacific Northwest National Laboratory
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Impact of Light-Duty Vehicle Emissions on 21st Century Carbon Dioxide Concentrations

SJ Smith
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Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

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(9/2003)

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PNNL Research Brief

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G. Page Kyle

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Joint Global Change Research Institute
8400 Baltimore Avenue
College Park, Maryland 20740

Abstract

The impact of light-duty passenger vehicle emissions on global carbon dioxide concentrations was estimated using the MAGICC reduced-form climate model combined with the PNNL contribution to the CCSP scenarios product. Our central estimate is that tailpipe light duty vehicle emissions of carbon-dioxide over the 21st century will increase global carbon dioxide concentrations by slightly over 12 ppmv by 2100.

Overview of MAGICC

The MAGICC simple climate model (Wigley and Raper 1992, 2002; Raper *et al.,* 1996) as used in the IPCC Third Assessment Report (Cubasch *et al.,* 2001) was used for these calculations. The carbon-cycle component of the MAGICC model operates with a balanced global carbon cycle for both historical and future time periods. Input assumptions are specified for net anthropogenic deforestation and ocean fluxes for the decade of the 1980s as well as the strength of temperature-feedbacks. The MAGICC model then adjusts the strength of the carbon-dioxide feedback in order to balance the carbon-cycle over this decade (Wigley 1993). Terrestrial carbon-cycle feedbacks are included as temperature dependent reductions in carbon-pool timescales. A temperature feedback on respiration and gross primary productivity is also included. While the detailed behavior of climate feedbacks on the carbon cycle is undoubtedly complex, these representations are capable of reproducing the range of results from more complex carbon-cycle models. Central values for carbon-cycle parameters were used for this calculation.

Method and Data Sources

The primary data needed for this calculation are: 1) global historical CO_2 emissions, 2) historical emissions from the light-duty vehicle fleet for the United States, and 3) estimates of both quantities over the 21st century. Global emissions are needed to set an appropriate reference trajectory from which changes will be calculated.

Future CO_2 emissions were taken from the PNNL reference case CCSP scenario (Clarke et al. 2007). Global CO_2 emissions until 2004 were taken from Marland et al. (2006). Global historical emissions were extended to 2005 using energy consumption data from BP (2007) and cement consumption data from USGS (2006, 2007). CCSP scenario emissions were adjusted by a constant offset so that the future trajectory was equal to the historical 2005 inventory estimate.

Light duty vehicle tailpipe CO_2 emissions from 2000 to 2005 were taken from the latest EPA inventory (USEPA 2007). Light duty vehicles were defined as automobiles and light trucks. Total emissions from automobiles and light trucks are estimated to be 1,165 Tg CO_2 in 2005. Future emissions from light duty vehicles were estimated by using the detailed transportation module of the PNNL O^{bj}ECTS MiniCAM model (Kim et al. 2006). The O^{bj}ECTS MiniCAM was also used to construct the PNNL CCSP scenarios. The fraction of total transportation sector carbon emissions from light-duty vehicles (LDVs) from the detailed transportation model was then applied to the CCSP aggregate transportation sector CO_2 emissions to obtain a future time path for LDV emissions. LDV emissions thus estimated increase to 1,442 Tg CO_2 by 2095.

The LDV emissions from the O^{bj}ECTS transportation model matched the EPA inventory for 2005 within 1%. This small adjustment was applied so that the emissions path used was exactly equal the EPA inventory estimate in 2005. To be consistent with the EPA inventory only tailpipe emissions of CO_2 were considered. Upstream emissions from refineries or fuel extraction operations were not included for either historical years or the future emissions scenario.

The calculation consisted of using the MAGICC model to determine two pathways for 21st century CO_2 concentrations. The first pathway uses the reference scenario global CO_2 emissions and the second uses a scenario where US LDV CO_2 emissions were subtracted from global emissions for the years 2000-2100. The difference between these two results is the impact of US LDV emissions on global CO_2 concentrations. Note that, because the carbon-cycle is non-linear, this methodology is only strictly valid for small changes to global emissions. US LDV CO_2 emissions range from 4% to 2% of global emissions from 2000 – 2100, which means that any errors due to non-linearity in the carbon cycle will be small.

Results

The result of the calculation is shown in the Figure. US light-duty vehicle emissions steadily add to atmospheric carbon dioxide concentrations over the century, resulting in slightly more than 12 ppmv of additional atmospheric accumulation by 2100. The annual rate at which carbon dioxide is added varies slightly as vehicle emissions and the carbon-cycle change over time.

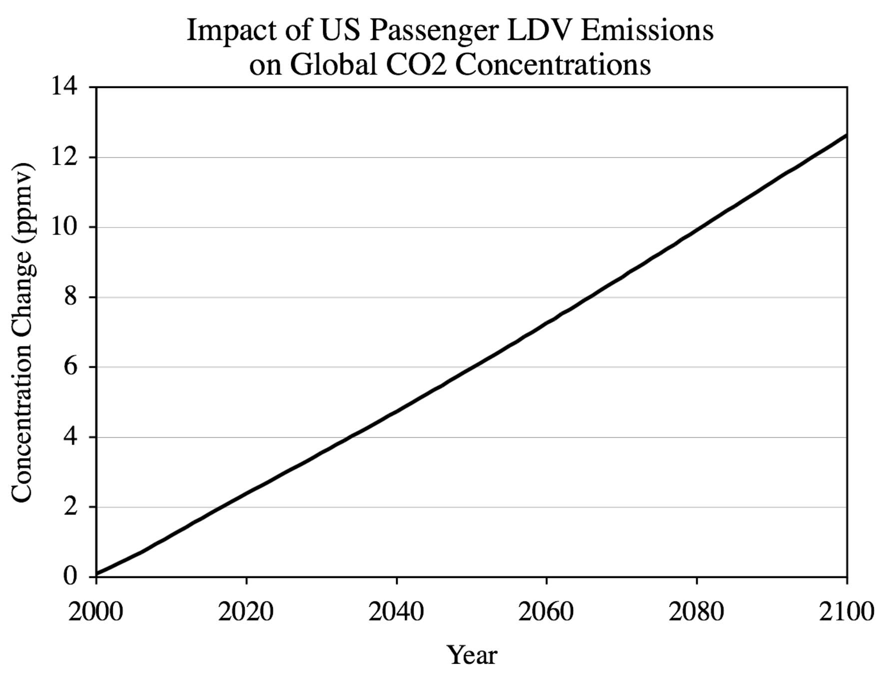

Figure 1 — Concentration increase due to U.S. light-duty passenger vehicle emissions.

Year	Conc Increment
2000	0.10
2001	0.19
2002	0.29
2003	0.40
2004	0.50
2005	0.61
2006	0.71
2007	0.83
2008	0.95
2009	1.07
2010	1.19
2011	1.31
2012	1.43
2013	1.56
2014	1.68
2015	1.80
2016	1.92
2017	2.04
2018	2.16
2019	2.27
2020	2.39

Table 1— Concentration increase due to U.S. light-duty passenger vehicle emissions for the years 2000 - 2020.

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