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Impact of Heavy Duty Vehicle Emissions Reductions on Global Climate

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Prepared for the U.S. Environmental Protection Agency
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The impact of a specified set of emissions reductions from heavy duty vehicles on climate change is calculated using the MAGICC 5.3 climate model. The integrated impact of the following emissions changes are considered: CO2, CH4, N2O, VOC, NOx, CO, and SO2. This brief summarizes the assumptions and methods used for this calculation.

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 version of MAGICC used here uses parameterizations updated for use in the IPCC AR4. 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, the representations used in MAGICC are capable of reproducing the range of results from more complex carbon-cycle models (e.g. Smith and Edmonds 2006). Central values for carbon-cycle parameters were used for this calculation. The impact of pollutant emissions is felt both through changes in atmospheric chemistry that impact the lifetime of methane and some HCFC species, and through changes in tropospheric ozone, a greenhouse gas. These impacts are included using the methodology descried in Wigley, Smith, and Prather (2002).

Method and Data Sources

The primary data needed for this calculation are: 1) a reference scenario for all emissions and 2) a set of emissions reductions. The reference scenario is the GCAM (formerly MiniCAM) reference (no climate policy) scenario used as the basis for the Representative Concentration Pathway RCP4.5 (Thomson et al., in review). This scenario is used because it contains a comprehensive suite of greenhouse and pollutant gas emissions including carbonaceous aerosols. The GCAM reference scenario is based on scenarios presented in Clarke et al. (2007) with non-CO_2 and pollutant gas emissions implemented as described in Smith and Wigley (2006) and land-use change emissions as described in Wise et al. (2009). Base-year information has been updated to the latest available data for the RCP process.

The emissions reductions were supplied by EPA in spreadsheet form (nonGHGbyCY_NHTSAalts_20100803.xls; Climate inputs HD GHG - All alternatives - 20100729.xls). Emissions reductions were supplied for 7 pollutant and GHG species: CO_2, CH_4, CO, N_2O, VOC, NOx, and SO_2.

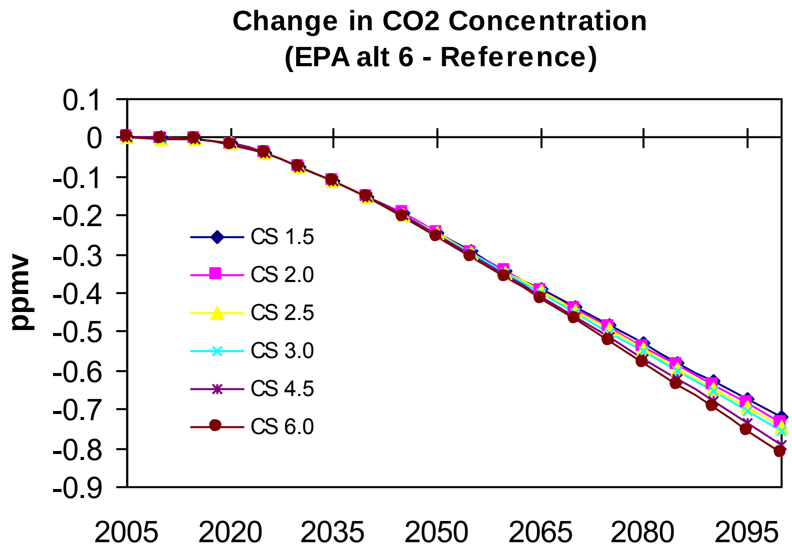
All emissions reductions were assumed to begin in 2014, with zero emissions change through 2013. For CO_2, CH_4, and N_2O, EPA supplied annual emissions reductions and these values were input directly. For CO, SO_2, and NO_x, emissions reductions were only provided for 2018, 2030, and 2050. We linearly scaled emissions reductions between the 0 input value in 2013 and the value supplied for 2018 to produce the reductions for 2014-2018. A similar scaling was used for 2019-2029 and 2031-2050. The emissions reductions past 2050 were scaled with total US road transportation fuel consumption from the GCAM reference scenario. This was chosen as a simple scale factor given that both direct and upstream emissions changes are included in the emissions reduction scenario provided. Road transport fuel consumption past 2050 does not change significantly and thus emissions reductions remain relatively constant from 2050 through 2100 (see spreadsheet "EPA Emissions – Interpolation.xls" for data and calculations).

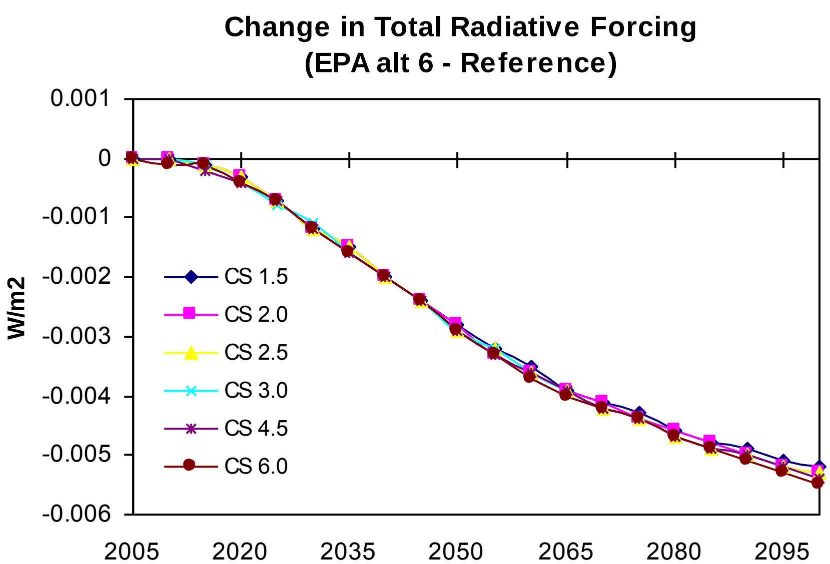
The calculation consisted of using the MAGICC model to determine seven pathways for 21st century greenhouse gas concentrations, radiative forcing, temperature change, and sea-level rise with six different climate sensitivity levels. The first pathway uses the reference scenario emissions. The six additional cases represented policy alternatives as requested by EPA (denoted as EPA Alt 2-7 in the spreadsheets). For these policy cases, the specified emissions changes were subtracted from global emissions for the years 2000-2100. The difference between the reference case and a policy case is the impact of that specific HDV emissions change. Results are reported for CO_2 concentration (ppmv), total radiative forcing (W/m^2), global mean temperature (degrees C), global mean sea level rise (cm), CH4 concentration (ppbv) and N2O concentration (ppbv).

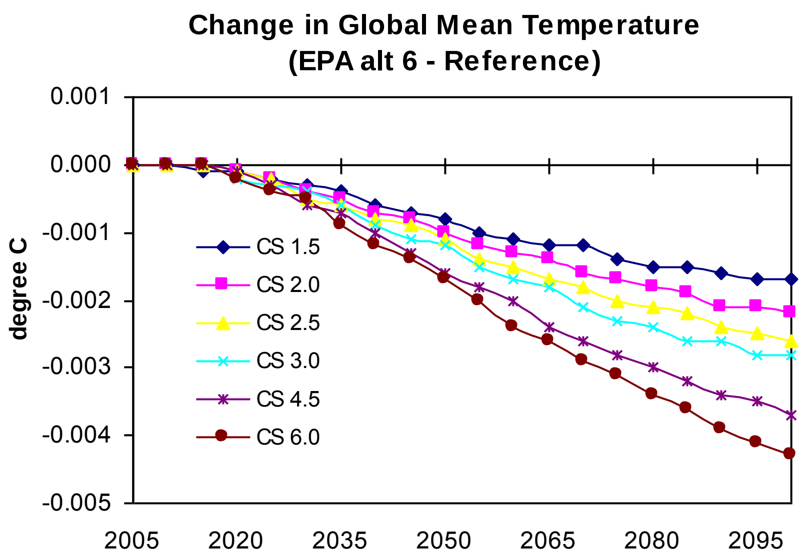
Results

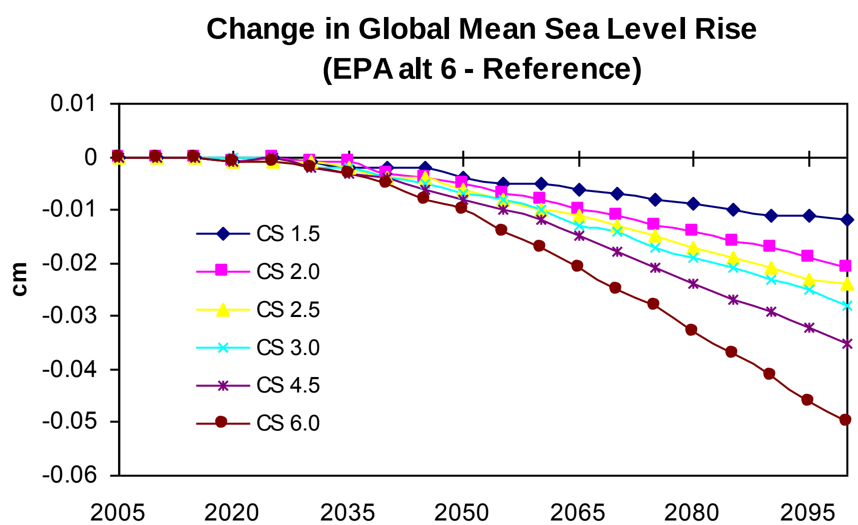
Comparison of results across the six policy scenarios indicates slight reductions from the baseline for the variables of interest. However, very little difference is observed between the different alternative policy scenarios in CO_2 concentration, total radiative forcing, global mean temperature and global sea level rise.

The result of the calculations for the scenario "EPA Alt 6" are shown below as different from the reference scenario (see Results_2.xls). Under this emissions reduction policy, global CO_2 concentration is reduced by 0.7-0.8 ppmv by 2100, and radiative forcing is reduced by 0.0053 to 0.0055 in the same time period. The range of reductions in global mean temperature and global sea level rise is larger due to the different climate sensitivity cases considered in MAGICC.


Change in CO2 Concentration
(EPA alt 6 - Reference)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
ppmv
CS 1.5
CS 2.0
CS 2.5
CS 3.0
CS 4.5
CS 6.0
2005
2020
2035
2050
2065
2080
2095


Change in Total Radiative Forcing
(EPA alt 6 - Reference)
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
W/m2
CS 1.5
CS 2.0
CS 2.5
CS 3.0
CS 4.5
CS 6.0
2005
2020
2035
2050
2065
2080
2095





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