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Sensitivity Analysis of MOBILE6.0

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ABSTRACT

The Assessment and Standards Division (ASD) of the U.S. Environmental Protection Agency's (USEPA) Office of Transportation and Air Quality (OTAQ) has recently completed an update of its emissions model, MOBILE6[1]. This model estimates emissions of carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx) from roadway use of gasoline and diesel fueled automobiles, motorcycles, busses, and trucks. MOBILE6 is used by local and state governments to determine their compliance with the Clean Air Act[2]. Hence, the emissions results can have large impacts on transportation planning and budgeting.

MOBILE6 has the option for allowing the user to enter local data in lieu of default national data for several parameters. And, of course, resources are required to determine this local data. Hence, a prior knowledge of the relative importance of different MOBILE6 input parameters with respect to emission results can be an important factor in determining whether or not local data should be collected. This report presents a systematic study of the relative importance of various MOBILE6 input parameters.

TABLE OF CONTENTS

LIST OF FIGURES

Figure Page

LIST OF TABLES

Table Page

INTRODUCTION

Recently, the Assessment and Standards Division of the USEPA released its latest version, MOBILE6, of a computerized model which facilitates the determination of HC, CO, and NOx inventories from mobile sources for a given locale. MOBILE6 is a significant revision of the previous version, MOBILE5[3], both in the style and the type of user inputs. These inputs include a set of default data, based on national averages, which produce default emission results. However, these national input data differ between specific localities and regions of the country. Hence, the resulting MOBILE6 default emissions will not necessarily represent the mobile source emissions for a specific locale.

Efficient use of MOBILE6 will depend on the user's familiarity with the many different MOBILE6 input parameters and the USEPA's usage guidance[4,5], the location specific mobile source statistics (e.g., vehicle registrations, vehicle usage in terms of mileage, roadway types, fuel types, inspection and maintenance programs, etc.), and knowledge of the input parameters that make significant impacts on MOBILE6 emissions results. So, in an effort to expedite the use of MOBILE6 and its inputs, a systematic study has been done which allows users to compare the relative impact of each individual parameter on emissions results.

Because of the number of individual inputs and the many dimensional aspects of many of the inputs, the emissions results (except for temperature and humidity) were studied individually and, except for humidity and temperature, the interdependencies between parameters were not studied. That is, emissions changes due to variations of a single input parameter were calculated and then compiled. The results are listed in terms of percent increase or decrease in the MOBILE6 input with the ensuing percent increase or decrease in the emissions for Light-Duty Gasoline Vehicles (LDGV) and fleet wide vehicles (All Vehicles or emissions of all 28 MOBILE6 vehicle types weighted by vehicle mileage) relative to the MOBILE6 national default inputs and the resulting emissions. (For a complete description of the MOBILE6 vehicle classifications see the MOBILE6 users' guide[5].) For parameters without a default value, a single base value was used. Also, for some inputs the emissions in grams/mile are displayed as a function of the specific input parameter or the percent change in the input parameter relative to the default value. Calendar years from1975 through at least 2020 in increments of 5 to 20 years were considered for each input studied.

This report summarizes the complete results for MOBILE6 LDGV and the All Vehicle categories "composite" emission results. "Composite" emissions for carbon monoxide and nitrogen oxide emissions means cold start emissions plus hot, stabilized running emissions. For hydrocarbon emissions the "composite" emissions are comprised of evaporative emissions plus cold start emissions and hot, stabilized running emissions.

The emissions results presented in this work are from a draft version (September 10, 2001) of MOBILE6. So, the absolute magnitudes of the emission results in this work may vary slightly from updated versions of MOBILE6. However, in general, the trends presented here will be consistent with emissions estimations being produced by current versions of MOBILE6.

Because of the breadth of inputs, all of the MOBILE6 input parameters were not considered in this report. Some of the parameters not considered here are inspection and maintenance program parameters, diesel and natural gas vehicle fractions, engine start soak times, trip lengths, and hot soak durations. (A complete list of the parameters considered is given in the Appendix, Table A.1.)

The input parameters are grouped, in this report, by the magnitude of their effects. We divided the effects into three groups: major effects, moderate effects, and minor effects. In order to develop working definitions of those somewhat vague terms, we examined the effects on emissions (HC, CO, and NOx separately) when we varied the input values by 20 percent (from the default values). (The choice of that size of change, 20 percent, was arbitrary.) We then defined:

(1) An input parameter will be said to have a "major" effect on one of the three pollutants (HC, CO, or NOx) if that (arbitrary) 20 percent change in that input parameter resulted in at least a 20 percent change in the emissions of that pollutant (relative to the emissions when the default values were used). Thus, a change in one of the input parameters that has a "major" effect will, in general, produce a change in emissions that is at least as great (proportionately) as the change in that parameter. In general, the ratio between the change in emissions to the change in input value needed to be greater than or equal one and the emission changes needed to reach a value of 20%.

(2) An input parameter will be said to have a "minor" effect on one of the three pollutants if that (arbitrary) 20 percent change in that input parameter resulted in less than a 5 percent change in the emissions of that pollutant. Thus, a change in one of the input parameters that has a "minor" effect will, in general, produce a change in emissions that is <u>much</u> smaller (proportionately) than the change in that parameter.

(3) An input parameter will be said to have an "intermediate" effect on one of the three pollutants if that (arbitrary) 20 percent change in that input parameter resulted in a change of between 5 and 20 percent in the emissions of that pollutant. Thus, a change in one of the input parameters that has an "intermediate" effect will, in general, produce a change in emissions that is somewhat smaller (proportionately) than the change in that parameter.

Since the factors affecting the presence of HC, CO, and NOx are different, it is reasonable that these groupings (major, intermediate, and minor) will be different for each pollutant. The details of the analysis methodologies and the results for these parameters are presented below.

METHODS

MOBILE6 inputs have a variety of formats and requirements. They could consist of a single number/character, sets of numbers, or simply the input command acting as an "on/off" switch. Hence, there was no single standard method of changing the inputs to get understandable and useful information from the resulting changes in emissions. However, once a method of changing the inputs was decided upon, the results were quantified in terms of a percentage change in the input relative to the MOBILE6 default values versus a percentage change in emissions relative to emissions calculated from the default input values.

As mentioned above, many of the MOBILE6 inputs consist of a set of numbers. And determining how to make changes to the input so that the resulting changes in emissions could be quantified and useful to potential users of MOBILE6 varied from input to input. For example, the hourly temperature values or daily minimum and maximum temperature inputs determine a daily temperature cycle which is based on 24 standard temperature increments/ decrements from the National Weather Service. MOBILE6 uses these 24 values with the MIN/MAX TEMP input command to construct a daily temperature cycle (scaled according to the user supplied minimum and maximum temperatures) with the minimum and maximum temperatures occurring between 6am and 7am and 3pm and 4pm, respectively. The temperature inputs can thus vary the average daily temperature, the 24˚F temperature cycle, and the individual hourly temperatures. All of these input variations have different effects on the emissions results. As a result, each of these variations were analyzed independently to determine their individual effects on the emissions. Figure 1 (below) illustrates the base (i.e., default) temperature cycle in which hourly temperatures rise and fall over a 24˚ Fahrenheit range (i.e., cycling between 72˚F and 96˚F), as well as three alternate cycles with variations in the daily temperature of 34˚F daily temperature rise and fall (i.e., a 42 percent increase from the default), a 14˚F daily temperature rise and fall (i.e., a 42 percent decrease from the default), and a constant temperature for each hour of the day (i.e., a 100 percent decrease from the default). Figures 2 and 3 (below) illustrate the changes in NOx emissions that correspond to those daily temperature cycles.

In Figure 2, each of the lines represents one of the four different temperature cycles at 5 different average daily temperatures. Different average daily temperatures were determined by varying the daily minimum and maximum temperatures of the four different daily temperature cycles. In other words, the temperature cycles were moved up and down the temperature axis of Figure 1 to determine the NOx emissions values at average daily temperatures of 101˚F, 92˚F, 82˚F, 72˚F, and 42 ˚F. Note that each of the lines decrease with increasing temperature; higher composite NOx emissions at lower (average daily) temperatures.

For this part of the work (i.e., temperature cycle induced changes on emissions), the emissions comparisons made were relative to the standard 24 degree Fahrenheit temperature cycle. Emissions differences were found and then the percentages relative to the standard cycle were determined. The graphs in Figure 3 illustrate these results for a number of different calendar years and average daily temperatures. Because the input variations never lead to emissions variations (increases or decreases) of more than 5%. The temperature cycles were considered to have minor effects on MOBILE6 emissions results.

Similar methods were determined for each MOBILE6 input which would make possible a practical quantification of the changes in MOBILE6 emissions output.

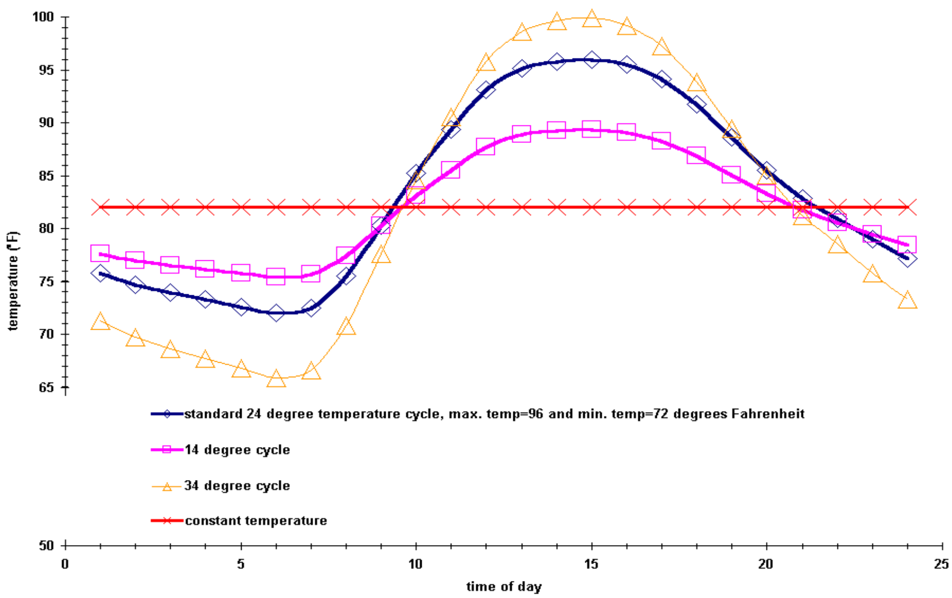
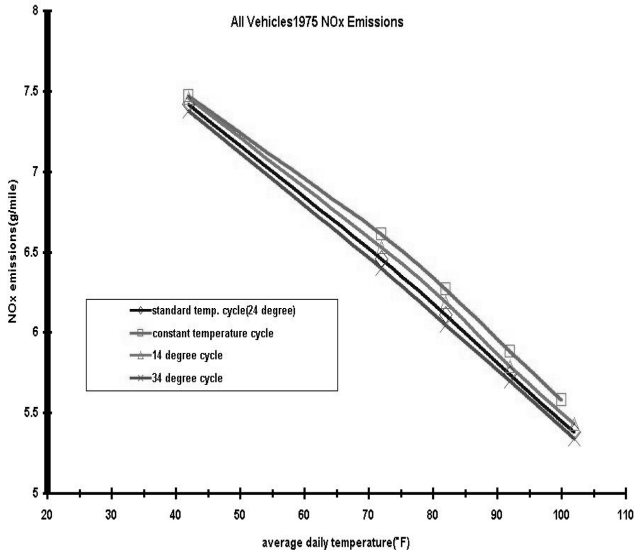


Figure 1. To determine how differences in the 24 hour temperature cycle affects emissions, four cycles were considered. The cycles had minimum and maximum temperatures which differed by 0˚F (or a constant temperature), 14˚F, 24˚F, and 34˚F over the entire day. The average daily temperature of each of the curves is kept at 82˚F.



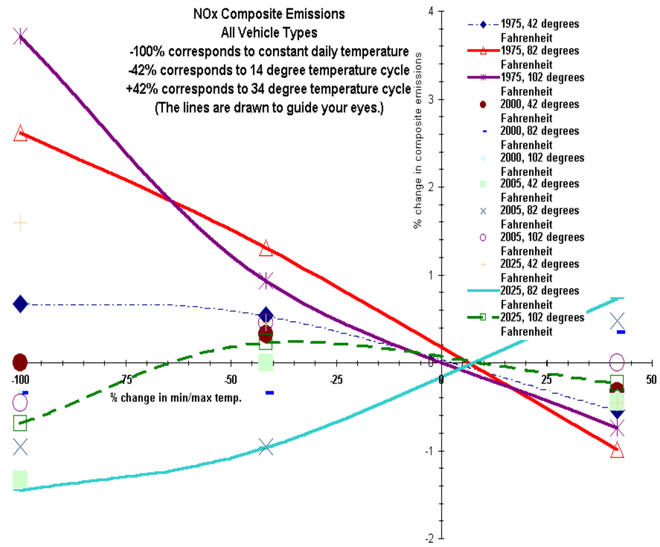


Figure 2. This graph illustrates 1975 All Vehicle NOx emissions as a function of average daily temperature for each of the four different temperature cycles in Figure 1. The different average daily temperatures were defined by varying the minimum and maximum temperatures of the four different daily temperature cycles.

Figure 3. This figure shows the relationship between All Vehicles NOx emissions and changes in the hourly temperature cycles depicted in Figures 1 and 2. It shows that NOx emissions are not highly dependent on the shape of the temperature cycle. As indicated in the graph each curve is associated with a calendar year and an average daily temperature.

In Figure 2, each of the lines represents one of the four different temperature cycles at 5 different average daily temperatures. Different average daily temperatures were determined by varying the daily minimum and maximum temperatures of the four different daily temperature cycles. In other words, the temperature cycles were moved up and down the temperature axis of Figure 1 to determine the NOx emissions values at average daily temperatures of 101˚F, 92˚F, 82˚F, 72˚F, and 42 ˚F. Note that each of the lines decrease with increasing temperature; i.e., higher composite NOx emissions at lower (average daily) temperatures.

For this part of the work (i.e., temperature cycle induced changes on emissions), the emissions comparisons made were relative to a 24 degree Fahrenheit temperature cycle. Emissions differences were found and then the percentages relative to the standard cycle were determined. The graphs in Figure 3 illustrate these results for a number of different calendar years and average daily temperatures. Because the input variations never lead to emissions variations (increases or decreases) of more than 5%. The temperature cycles were considered to have minor effects on MOBILE6 emissions results.

Similar methods were determined for each MOBILE6 input which would make possible a practical quantification of the changes in MOBILE6 emissions output.

RESULTS

In the Appendix, Tables A.1 and A.2 contain full summaries of the LDGV and All Vehicle sensitivity analysis results, respectively. They list the MOBILE6 input considered, an abbreviated description of how its values were changed relative to the default values, and the percent changes in emissions for each of the three pollutants, i.e., non-methane hydrocarbons (NMHC) [volatile organic compounds (VOC) for the Average Speed command], carbon monoxide (CO), and oxides of nitrogen (NOx). Results in these tables were derived from the standard MOBILE6 descriptive output. As mentioned above, the emissions values are the "composite" emission results which are cold start emissions plus hot, stabilized running emissions for NOX and CO. For hydrocarbon emissions the "composite" emissions include evaporative emissions along with cold start emissions and hot, stabilized running emissions.

This report will describe both the methodologies used to change the inputs and the impacts these changes have on emissions (relative to the default MOBILE6 values or some standard value) for the three MOBILE6 pollutant types, i.e., HC, CO, and NOx. (As mentioned above, except for the results of the Average Speed command the hydrocarbon emissions considered are all in the form of non-methane hydrocarbons or NMHC. The Average Speed command results are in terms of hydrocarbon volatile organic compounds or VOC.)

A. PARAMETERS WITH MAJOR EFFECTS ON EMISSIONS (GREATER THAN 20% CHANGES)

Table 1 (below) lists those input parameters which have the greatest effect on both LDGV and All Vehicle emissions. It also contains a short description of the input changes and the magnitude of emissions changes relative to MOBILE6 default results. Changing any one of those parameters will have relatively large affects on the emission rates, i.e., an emissions change-to-input change ratio of one or greater and at least a 20% change in emissions. This section will discuss these results in detail.

Table 1. Summary of LDGV and All Vehicle results with input parameters which have a "major" effect on emissions. (The parameters are sorted in alphabetic order not in order of the magnitude of their effect on emissions.)

HC	CO	NOx
Average Speed Command - low speeds (15mph), Arterial roadways , Area Wide roadways and Freeways : 20% to 80% emissions increases	**Average Speed Command** - low speeds (10mph), Arterial roadways , Area Wide roadways and Freeways : 15% to 40% emissions increases	**Average Speed Command** - low speeds (10mph), Arterial roadways , Area Wide roadways and Freeways : 20% to 50% emissions increases
Fuel Reid Vapor Pressure(RVP) (The RVP was increased from 6.5lb/in^2 to 11.5lb/in^2 for a number of calendar years between 1975 and 2050 with minimum and maximum temperatures 72°F and 92°F, respectively. Percent differences were determined relative to 7.5lb/in^2) Emissions decreases of -3%(1985) to -6%(2005) at 6.5lb/in^2 Emissions increases of 77%(2005) to 38%(1985) at 11.5lb/in^2	**Fuel Reid Vapor Pressure(RVP)** (The RVP was increased from 6.5lb/in^2 to 11.5lb/in^2 for a number of calendar years between 1975 and 2050 with minimum and maximum temperatures 72°F and 92°F, respectively. Percent differences were determined relative to 7.5lb/in^2) No emissions changes at 6.5lb/in^2 Emissions increases of 101%(2050) to 2%(1975) at 11.5lb/in^2	**Min/Max Temperature Command** - Average daily temperature (vary the average daily temperature from 12°F to 107°F by shifting the standard temperature cycle) emissions increases up to 20% to 50% at low average daily temperature (12°F); this variability decreases with increasing calendar year and increasing temperatures
Min/Max Temperature Command - Average daily temperature (vary the average daily temperature from 12°F to 107°F by shifting the standard temperature cycle) emissions increases up to 25% for calendar years around 1995 (the variability lessens with increasing calendar years)	**Min/Max Temperature Command** - Average daily temperature (vary the average daily temperature from 12°F to 107°F by shifting the standard temperature cycle) emissions increases up to 200%(average daily temperature of 12°F) with temperature decreasing below 55°F; this variability increases with increasing calendar year	
Registration distribution (decrease newer vehicle fractions and increase older vehicle fractions) 20% age shift to older vehicles can yield about a 50% increase in emissions depending on the calendar year of evaluation	**Registration distribution** (decrease newer vehicle fractions and increase older vehicle fractions) 20% age shift to older vehicles can yield about a 50% increase in emissions depending on the calendar year of evaluation	**Registration distribution** (decrease newer vehicle fractions and increase older vehicle fractions) 20% age shift to older vehicles can yield about 40% increase in emissions depending on the calendar year of evaluation
Speed VMT Command(Arterial Roadways): -3% - null low speed vehicle fractions; 9% - equal vehicle fractions for all speeds 14% - increase low speed vehicle fraction by 10% 21% - increase low speed vehicle fraction by 20% 29% - increase low speed vehicle fraction by 30%) : emissions change on at least a 1-to-1 ratio up to 44% increase in emissions with a 30% change in the fraction of vehicles from higher non-congested speeds to lower speeds; the 3% change from lower speeds to higher speeds yielded a 3% reduction in emissions		

A.1 HC EMISSIONS

MOBILE6's estimation of hydrocarbon emissions are most affected by the age distribution of the fleet (Registration Distribution command; see Figures 4, 5, and 6), low vehicle speeds (Average Speed and Speed VMT commands; see Figures 7 through 10), high average daily temperatures (Min/Max temperature or Hourly Temperature commands; see Figures 11 and 12), and fuel RVP (Reid Vapor Pressure).

Registration Distribution Command

The vehicle age distributions (Registration Distribution command) were changed by increasing the fraction of vehicles with ages greater than 13 years old and subtracting the same fraction from the vehicles which are younger than 13 years old. Each vehicle age had an equal fraction added to or subtracted from it. Figure 4 displays the MOBILE6 default age distribution (the dark blue line with diamond shaped symbols) and how it was modified to obtain age distributions shifted by 5, 10, 15, and 20 percent. Figures 5 and 6 show the relationship between vehicle age and hydrocarbon emissions. They show the impact of the main MOBILE6 assumption, i.e., the emission rates deteriorate with vehicle age or mileage together with shifting vehicles to less restrictive emissions standards and older emissions reduction technologies.

Note that the for calendar years greater than 1975 these MOBILE6 all (or fleet wide) vehicle types have at least a 1-to-1 emissions-to-input percentage rate response for changes in the emissions due to changes in vehicle age. Again this demonstrates that as lower emissions standards and better emissions technologies are taken out of the fleet the emissions increases are substantial. In fact the changes are greater than a one-to-one ratio. LDGV numbers are similar to the All Vehicles type age and NMHC emissions relationship.

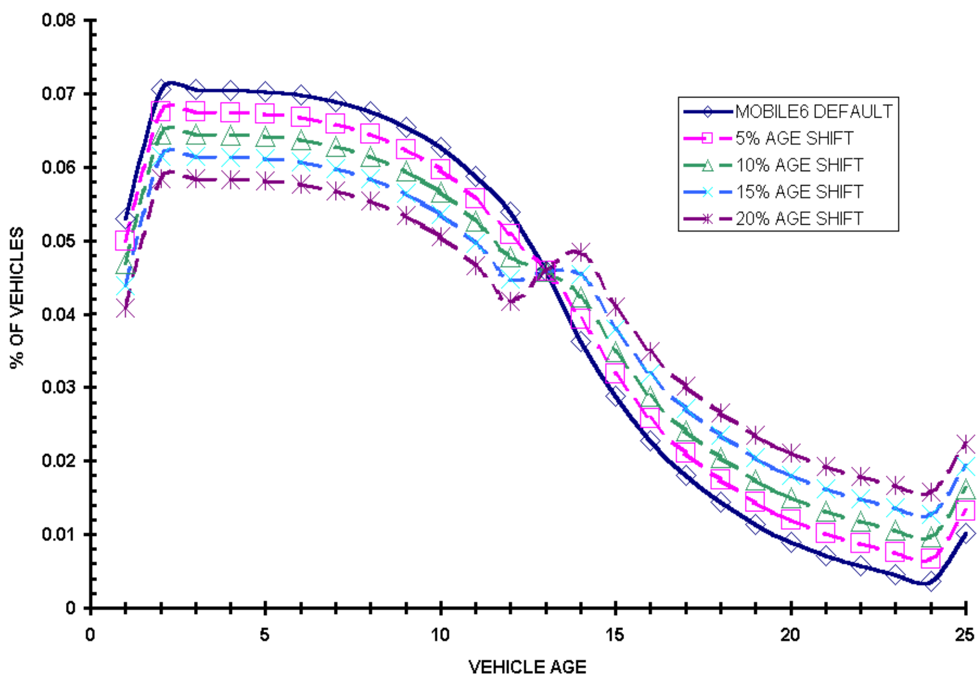


Figure 4. The MOBILE6 default vehicle registration fractions were shifted from newer to older vehicles in increments of 5%. The age thirteen vehicle fractions were unchanged. Although All Vehicle registration fractions were changed, this figure illustrates the Light-Duty Gasoline Vehicle fractions.

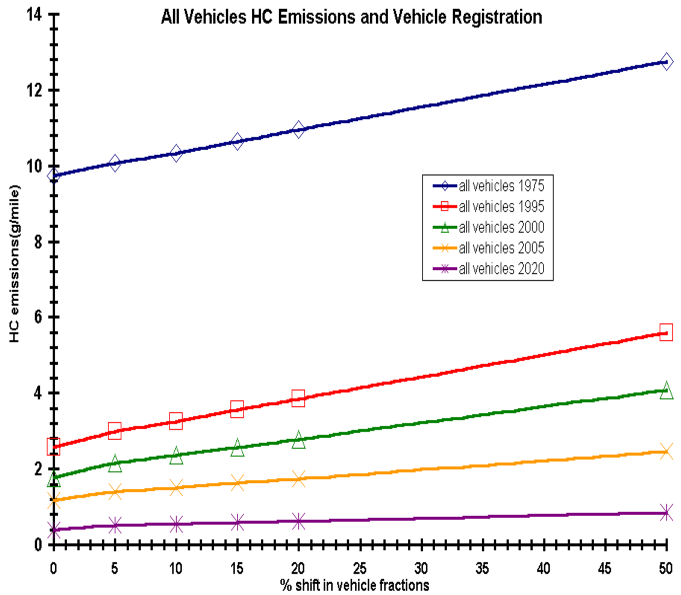


Figure 5. All Vehicle hydrocarbon emissions as a function of the percent change in the MOBILE6 vehicle type registration fractions.

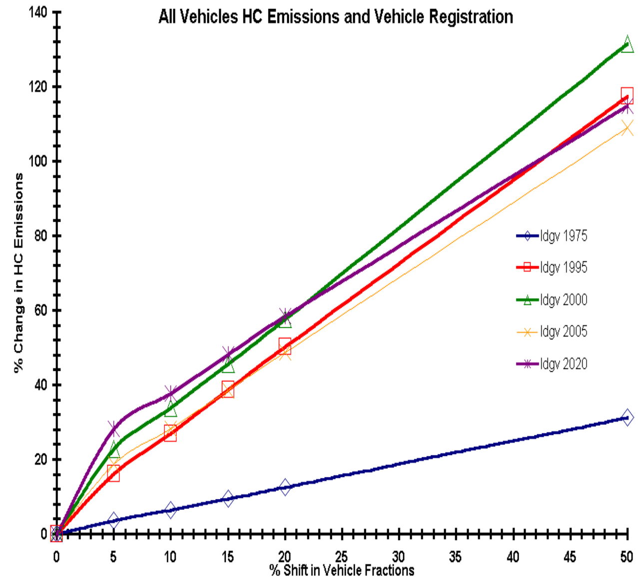
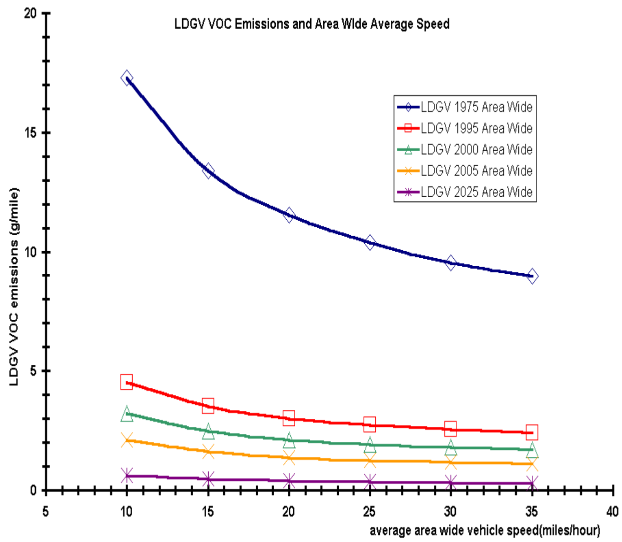


Figure 6. The same as Figure 5 except the percent differences in emissions are given as a function of the percent change in the All Vehicle type registration fractions. For each of the different MOBILE6 vehicle types the fractions were shifted from newer to older vehicles as illustrated for Light-Duty Gasoline Vehicles in Figure 4 above.

Average Speed Command

Next in importance for hydrocarbon emissions is the dependence on vehicle speed through the Average Speed command. This relationship is due to both an activity factor, i.e., the fraction of vehicles driving at a particular speed (MOBILE6 has a set of 14 different speeds, i.e., 2.5, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, and 65 miles/hour) for each hour of the day (see e.g., Figures 14, 15, and 16), and a functional vehicle emissions-vehicle speed relationship[6]. For each roadway type (freeways, local roadways, arterial roadways, and freeway ramps) in MOBILE6 a cycle was developed to model driving behavior and the resultant emissions[6]. Emissions from these cycles were then used to determine corrections to the LA4[7] cycle. Hourly vehicle fractions[8] for the different roadway types apportion the vehicles traveling at different speeds on the different roadways and hence the speed corrections applied to the particular roadway type. (The sum of the fractions for each roadway type is one.) Both of the above factors come into play when considering the difference between default emissions and those emissions resulting from changing the MOBILE6 defaults by using the Average Speed and Speed VMT commands.

The Average Speed command (and the Speed VMT command) set(s) the fraction of vehicles which are operating at a given speed on the different MOBILE6 roadway types. The graphs in Figure 7 show the LDGV and All Vehicle hydrocarbon volatile organic compound (VOC) emissions dependence on speed using the Average Speed command for area wide roadway types at speeds ranging from 10 to 35 mph. Figure 8 shows a similar dependence for Light-Duty Gasoline Vehicles on freeways with speeds varying



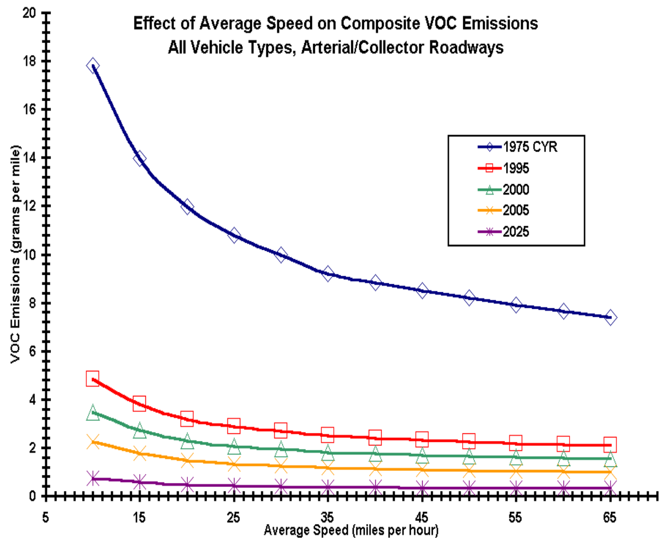


Figure 7.

a. Light-Duty Gasoline Vehicle hydrocarbon volatile organic compound (VOC) emissions as a function of Area Wide speed supplied in the Average Speed command.

b. All Vehicles hydrocarbon volatile organic compound (VOC) emissions as a function of Area Wide speed supplied in the Average Speed command.

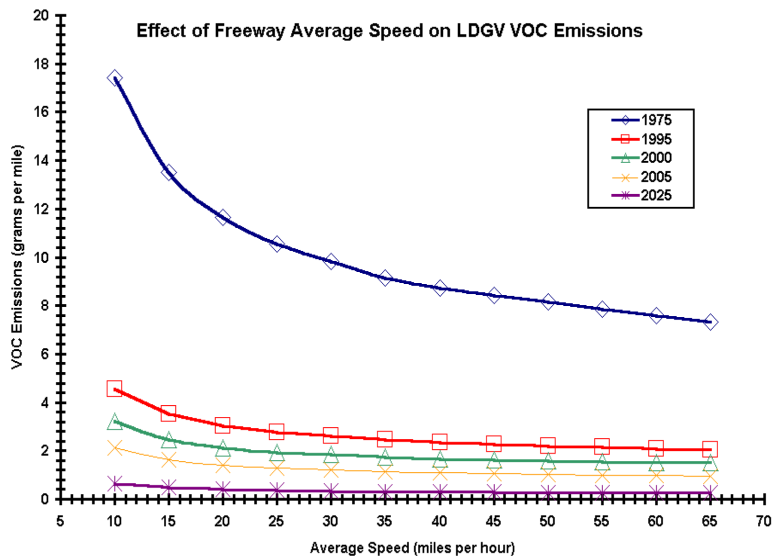


Figure 8. Light-Duty Gasoline Vehicle hydrocarbon volatile organic compound (VOC) emissions as a function of Freeway speed supplied in the Average Speed command.

from 10 to 65 miles per hour. There are results for five calendar years, i.e., 1975, 1995, 2000, 2005, and 2025.

The emissions results from Figures 7 and 8 above can be used to establish how the VOC emissions differ from emissions calculated using the default speed data. MOBILE6 default results are based on an average speed distribution rather than a single average speed. The average daily speed of these default distributions for all (or area wide) roadway types is about 28mph[8]. Figures 14 and 15 display the MOBILE6 default vehicle speed-roadway fractions for arterial roadways between the hours of 4am to 5am, 7am-8am, and 4pm to 5pm. Changing average vehicle speeds using the Average Speed command changes the proportion of vehicles travelling on MOBILE6 roadway types and has relatively large effects on emissions when compared to MOBILE6 emissions results calculated with the default vehicle roadway-average speed fractions. Figures 9 and 10 display the percent changes in VOC emissions relative to default MOBILE6 results as a function of vehicle speeds via the Average Speed command. These figures display results for VOC from all MOBILE6 vehicle types using the Average Speed command for Area Wide roadways and Freeways.

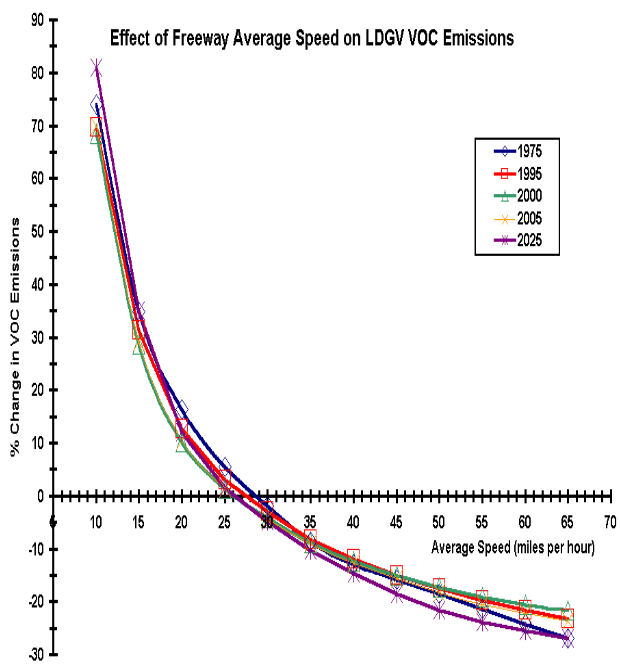


Figure 9. Percent change in LDGV VOC emissions relative to MOBILE6 default emissions as a function of average freeway using the MOBILE6 Average Speed command. (The All Vehicle emission results are similar.)

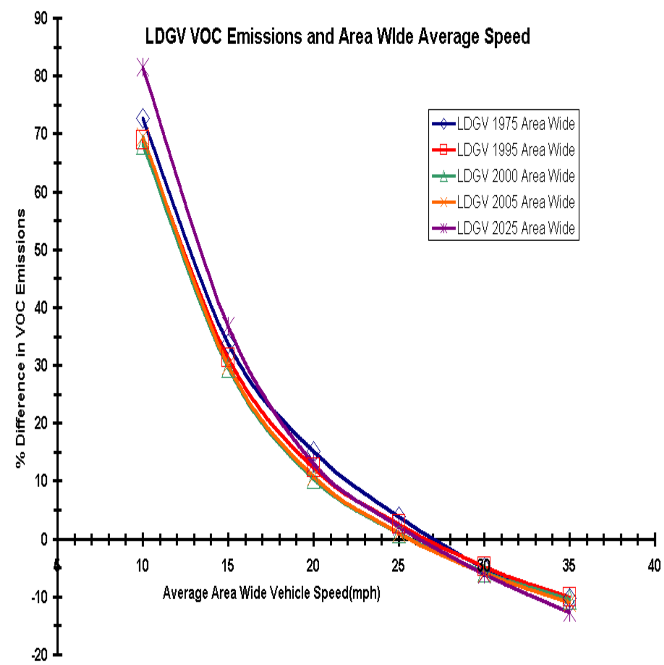


Figure 10. Percent change in LDGV VOC emissions relative to the MOBILE6 default results as a function of LDGV average area wide speed supplied in the Average Speed command. (The All Vehicle emission results show similar trends.)

Min/Max Temperature Command
The third input parameter that has substantial effects on hydrocarbon emissions when changed from a base value (of 82˚F) is the average daily temperature (Min/Max Temperature command). As mentioned above (see e.g., Figure 1) each hour of the day has a unique temperature value and is determined by the Min/Max Temp or the Hourly Temperature commands. These inputs determine a set of 24 hourly temperature differences. By shifting the maximum and minimum daily temperatures to higher or lower temperatures the average daily temperature can also be changed. The All Vehicles hydrocarbon emissions dependence on the average daily temperature is displayed in Figure11. Percent differences in All Vehicle emissions due to changes in temperature as a function of the percent difference in average daily temperature relative to a base value of 82˚F with a temperature range of 70.6˚F to 94.6˚F are displayed in Figure 12. Each figure has results for calendar years of 1975, 1995, 2000, 2005, and 2025. Figure 13 illustrates the same results in terms of the percent change in average daily temperature and percent change in emissions relative to emissions estimated with an average daily temperature of 82˚F.

Because MOBILE6 estimates tailpipe emissions and evaporative emissions, low temperatures and higher temperatures yield relatively higher emissions compared to more moderate temperature range. The emissions at lower temperatures should reflect catalyst driven cold start emissions. Because the air conditioning correction is automatically applied, the higher temperatures will be exhibiting effects due to both air conditioning usage and higher evaporative emission rates. Actually, the emissions effects of air conditioning will be discussed later in this report. More importantly, however, the MOBILE6 temperature correction[9] has an exponential dependence on ambient temperature. So, for temperatures above about 75˚F the emissions reflect this exponential increase and this characterizes the emissions at higher temperatures.

Although the emissions dependence on the average number of vehicle starts per day is listed in the intermediate effects section, at lower temperatures (temperatures less than 45˚F) the start emissions increase dramatically (e.g., a 5˚F increase in temperature yields about a 5% to 15% increase in emissions) with temperature decreases. Thus, at lower temperatures they become a larger fraction of the composite [start plus running (plus evaporative for HC)] emissions. Hence, the ratio of the change in emissions to the change in starts per day will also increase at these lower temperatures and may be considered to have a major effect parameter.

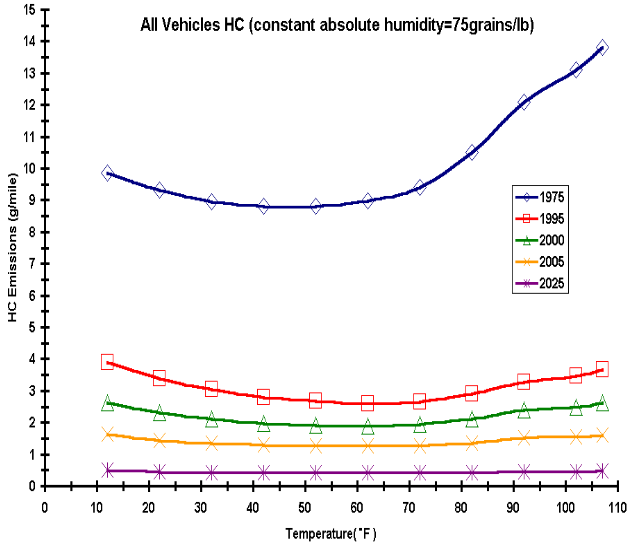


Figure 11. All Vehicle NMHC emissions as a function of average daily temperature. The daily temperatures were changed by shifting the average daily temperature, but keeping the default 24˚F temperature cycle (e.g., Figure 1). (The LDGV results are similar.)

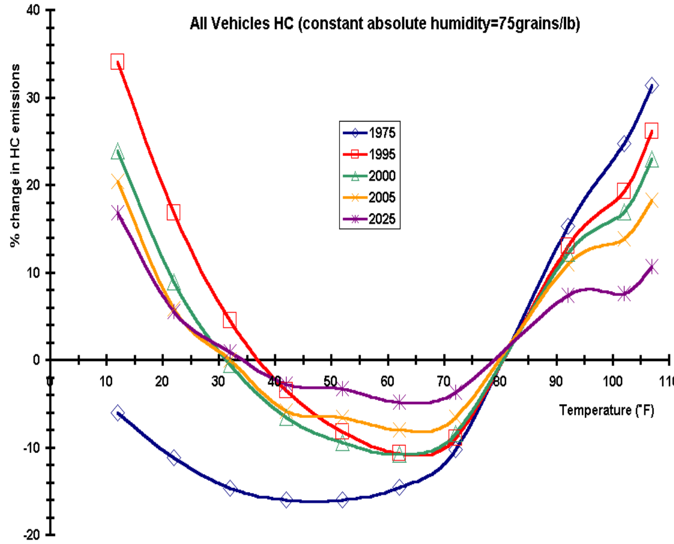


Figure 12. Percent changes in All Vehicles NMHC emissions as function of the percent change in average daily temperature relative to the MOBILE6 default 24˚F temperature cycle with an average daily temperature of 82˚F (e.g., Figure 1). Each of the different average daily temperatures undergo a 24˚F daily temperature cycle.

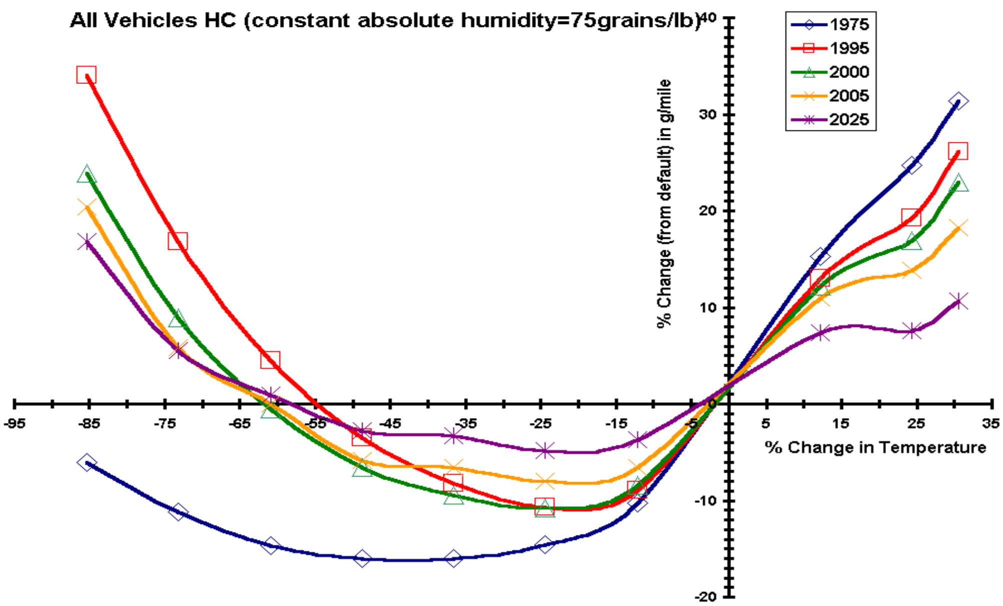


Figure 13. All Vehicle percent changes in NMHC emissions as a function of percent change in the average daily temperature relative to 82˚F with a 24˚F daily temperature cycle. This graph is derived from the two Figures above. (The LDGV results are similar.)

Speed VMT command
Next, the SPEED VMT command for arterial roadway types can yield relatively large changes in hydrocarbon emissions when varied from the MOBILE6 default values. The SPEED VMT command allows users to input the fraction of vehicles travelling at 14 different speeds (2.5, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, and 65 miles/hour) for each hour of the day on arterial roadways and freeways. Figure 14 illustrates two (4am to 5am and 4pm to 5pm) of the twenty-four hours of MOBILE6 default vehicle fractions at the 14 different speeds on arterial roadways.

Next, Figures15 and 16 depict how the vehicle fractions were changed relative to the MOBILE6 defaults. Vehicle fractions from two "congested" or "rush" hour intervals (7am to 8am and 4pm to 5pm) were averaged together. Then, from this average congested hourly interval of vehicle fractions, fractions of vehicles were moved from the middle range of speeds (30, 35, 40, 45, and 50mph) and distributed amongst the lower speeds (2.5, 5, 10, and 15mph). These vehicle fraction shifts of 10, 20, and 30 percent resulted in 14, 21, and 29 percent reductions in the daily average of hourly speed, respectively (see Figure 16). A fourth set of fractions were constructed by shifting 17percent of the vehicle fractions from the lower speeds (2.5, 5, 10, 15, 20, and 25 mph) to the higher speeds (30, 35, 40, 45, 50, 55, 60, and 65 mph) (the 17 percent decrease in lower speeds). This fourth redistribution yielded a 3 percent increase in daily average of hourly speed. The fifth set of fractions were all set equal to 1/14. That is, all speeds had an equal fraction of vehicles. This resulted in a 9 percent decrease in average hourly speed. These vehicle fractions for different speeds on arterial roadways were used for each hour of the day. The MOBILE6 default values, of course, varied for each hour of the day as can be inferred from Figure 14.

Emissions were determined from the changed arterial vehicle fractions and compared to the MOBILE6 defaults. Figures 17 and 18 depict Light Duty Gasoline Vehicle (LDGV) and All Vehicle emissions relative to the MOBILE6 default values as a function of the percent change in the daily average of hourly arterial roadway vehicle speeds. Figure 19 illustrates the percent change in All Vehicles HC emissions as a function of the change in the daily average of hourly vehicle arterial roadway speeds. (Again, the lines are drawn to guide the reader's eyes.) Except for the flat distribution of speeds which shows about a 9 percent reduction in the daily average of hourly arterial vehicle speeds, the emissions percent differences from the default values have a nearly linear relationship with changes in these average speeds. In general, the results show that a mixing of vehicles at different speeds yield higher emissions, especially when more vehicles are in the lower speed ranges.

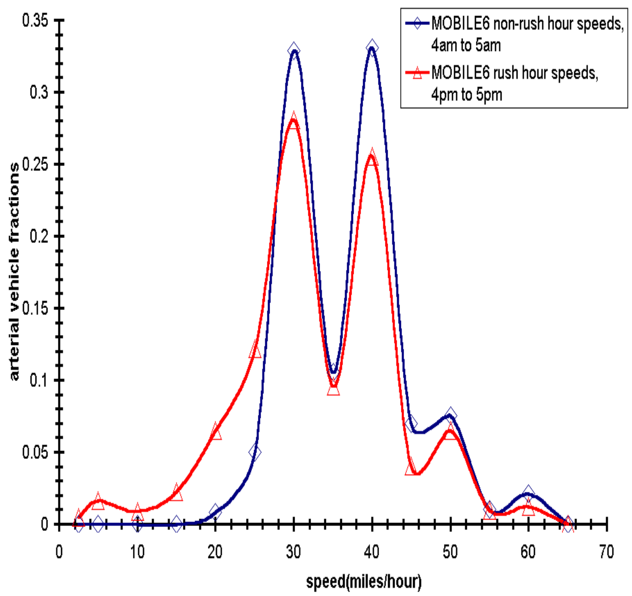


Figure 14. Each hour of the day has a set of 14 fractions, one for each of the 14 different speed values. The two default MOBILE6 values illustrated above are for arterial roadways during a "rush" hour, 4pm to 5pm, and during a "non- rush" hour, 4am to 5am.

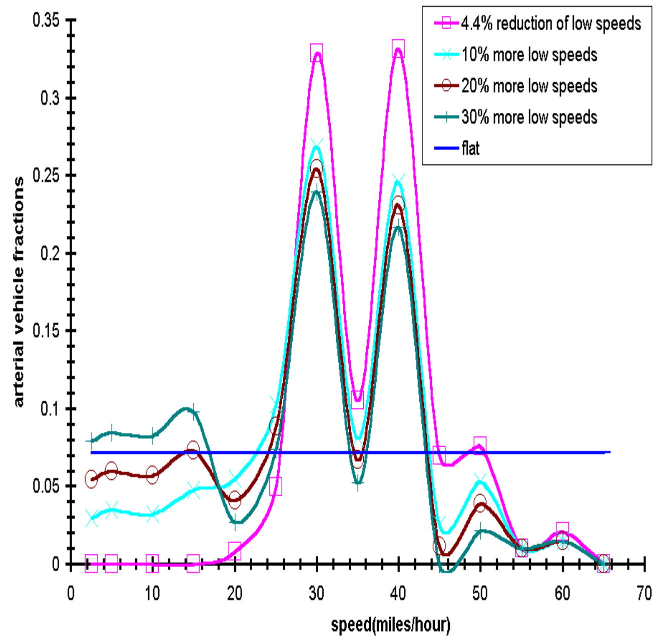


Figure 15. The. 5 curves represent how the MOBILE6 default values were changed. Fractions of vehicles from an average of hours 2(7am-8am) and 11(4pm-5pm) were shifted from the lower speeds to the higher speeds and vice versa. Also, each hour of the day had the same vehicle fractions, whereas the default hourly fractions varied (see e.g., Figure 16 below).

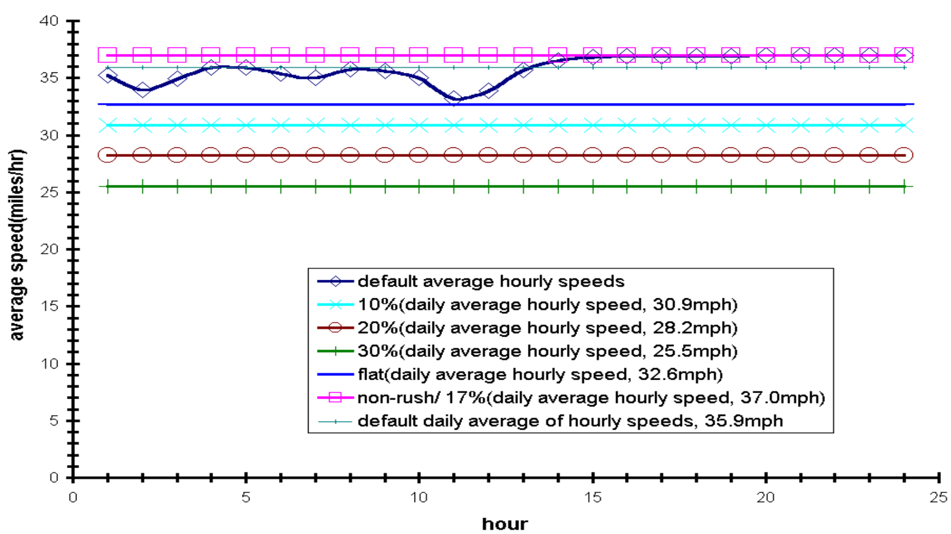


Figure 16. This illustrates the effective (vehicle fraction weighted) average speed of the vehicles on arterial roadways for each hour of the day. The default hourly and daily average of the hourly values are shown along with the values from the 5 curves of Figure 15.

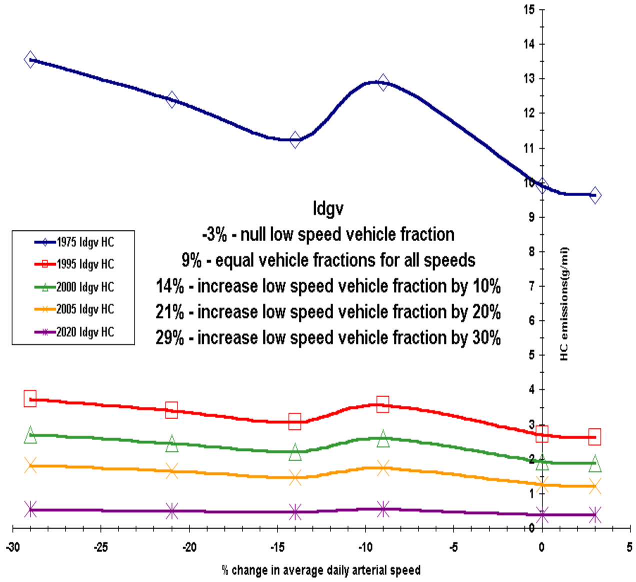


Figure 17. Hydrocarbon emissions as a function of the change in vehicle fraction weighted speed on arterial roadways.

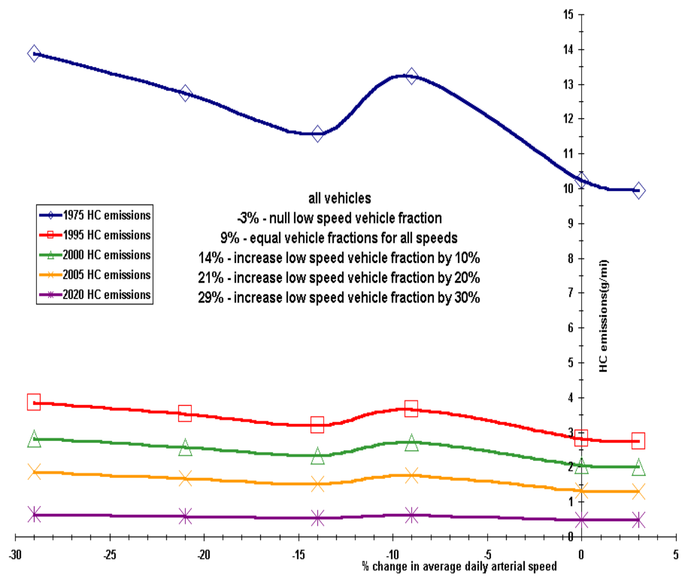


Figure 18. Hydrocarbon emissions as a function of the change in vehicle fraction weighted speed on arterial roadways.

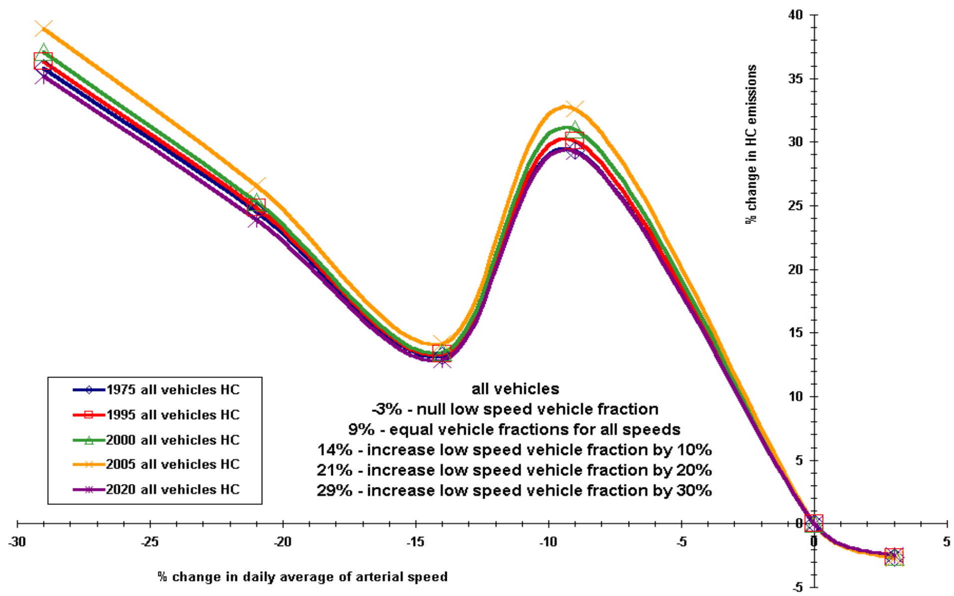


Figure 19. Percent change in All Vehicles hydrocarbon emissions from MOBILE6 default values as a function of percent change in the daily average of hourly arterial vehicle speeds relative to the MOBILE6 default values.

Fuel RVP (Reid Vapor Pressure)
As with temperature and calendar year, fuel RVP is a required input. For exhaust emissions the RVP dependence is actually intertwined with the temperature correction factor[5,9]. In other words, the MOBILE6 temperature correction is a function of RVP (and temperature) and hence any variation of fuel RVP varies the temperature correction factor at a specific temperature and thus changes the exhaust emissions. There are also, of course, evaporative emissions dependencies on RVP. However, at temperatures below 45°F, fuel evaporation becomes negligible and RVP is assumed to have no effect on emissions.

Figures 20 and 21 display results for the emissions and the percent difference in emissions relative to a standard RVP value of 7.5psi, respectively. The main effects are for RVP values above 9 pounds per square inch (psi). There is a steep increase in emissions for RVP values above 9psi. This is indicative of the exponential dependence of the temperature correction factor on fuel RVP. However, RVP effects are the same for all RVP values greater than 11.7psi. Hence the curves would flatten out from 11.7psi through 15.2psi (15.2psi is the maximum value of RVP allowed in MOBILE6).

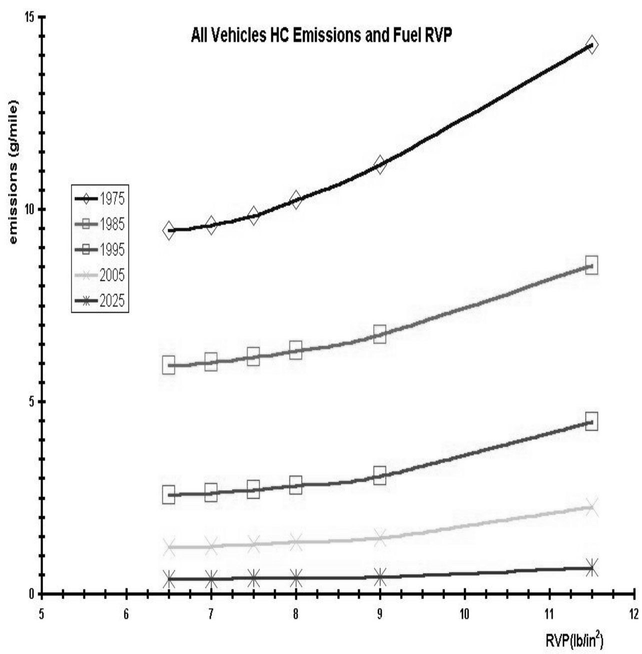


Figure 20. Hydrocarbon emissions as a function of the fuel Reid Vapor Pressure (RVP).

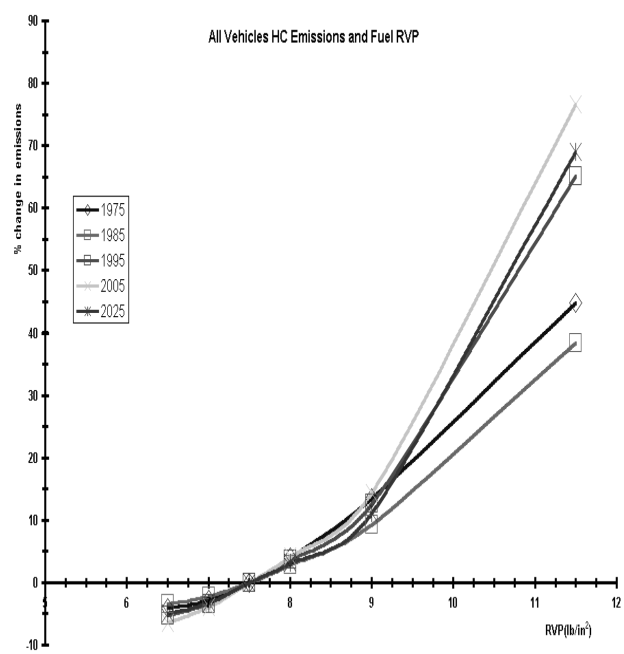


Figure 21. Percent change in hydrocarbon emissions relative to the emissions at 7.5psi as a function of the fuel Reid Vapor Pressure (RVP).

A.2 CO EMISSIONS

Average daily temperatures below 50˚F (Min/Max Temperature or Hourly Temperature commands) have a very significant effect on carbon monoxide emissions (see Figures 22, 23, and 24 below). So, average daily temperature has a major effect on CO emissions. Also, the age distribution of the fleet (Registration Distribution Command; see Figure 27), Reid Vapor Pressure (Figures25 and 26), and low vehicle speeds (Average Speed command; see Figures 28 and 29) have effects on emissions which are relatively large and can reach values greater than 20 percent with input changes of the same or smaller magnitude.

Min/Max Temperature

As described above for hydrocarbon emissions the average daily temperature can be varied with the Min/Max Temperature or the Hourly Temperature commands. Furthermore, as with HC emissions, these CO emission results were compared to CO emissions that were determined with an average daily temperature of 82˚F over a 24˚F daily temperature cycle, i.e., 70.6˚F to 94.6˚F. Figures 22 through 24 display the affect of temperature on CO emissions. The average daily temperatures ranged from 12˚F to 107˚F and the absolute humidity was held constant at 75 grains/pound. [Of course, humidity and temperature (and atmospheric pressure) are interrelated. At higher temperatures the atmosphere can more readily contain higher proportions of water vapor, whereas at cooler temperatures, water vapor will more easily condense out of the air. In MOBILE6 ambient humidity mainly affects NOx emissions.

As mentioned in the HC temperature dependence section, the start emissions increase with decreasing temperature. However, the start CO emissions affects due to the average number of vehicle starts per day is listed in the intermediate effects section. But, at decreasing temperatures (temperatures less than 60˚F) the start emissions begin to increase and begin to be the major influence on CO emissions. For example e.g., a 5˚F decrease in temperature yields about a 10% to 20% increase in emissions depending on the model year. And just as in the case for HC, the CO start emissions will become a larger fraction of the composite [start plus running (plus evaporative for HC)] emissions at these lower temperatures. In fact, as illustrated in Figure 24 the effect is more pronounced than in the case of HC emissions.

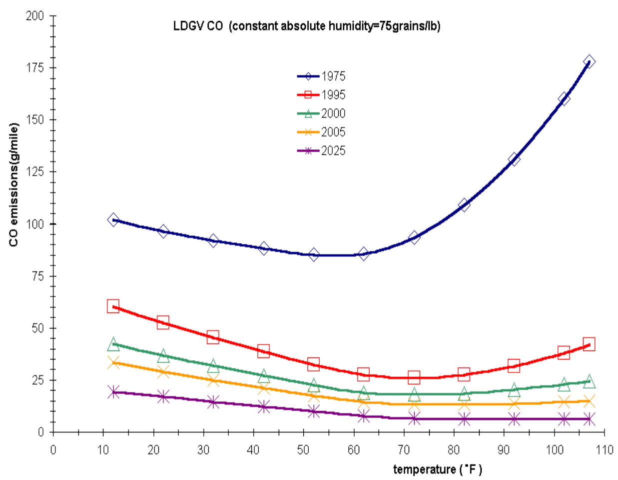


Figure 22. LDGV CO emissions as a function of average daily temperature using the MIN/MAX Temperature command.

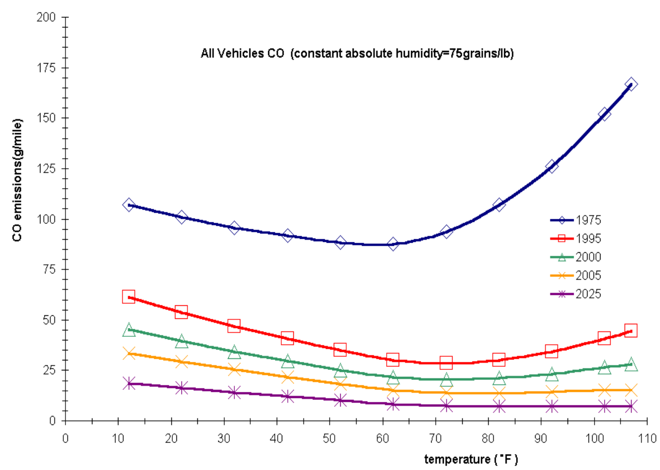


Figure 23. MOBILE6 All Vehicle types CO emissions as a function of average daily temperature using the MIN/MAX Temperature command.

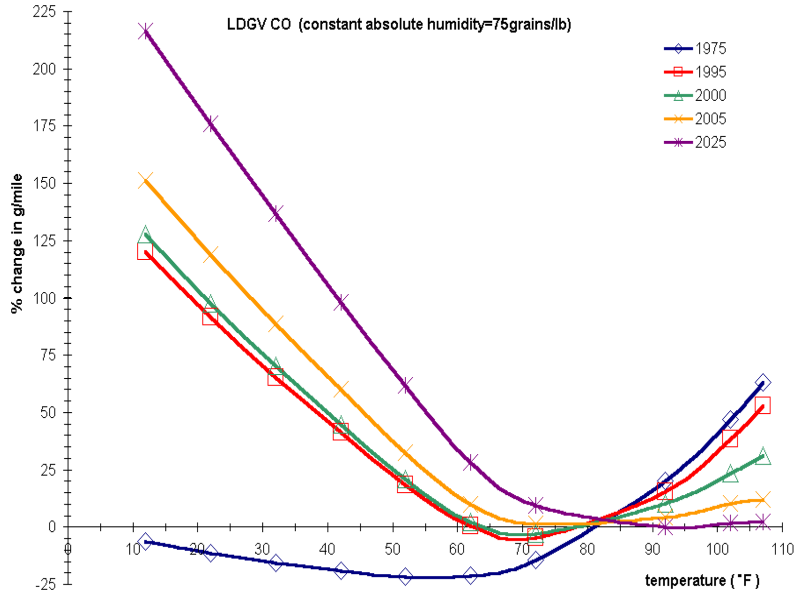


Figure 24. The relationship between the percent change in CO emissions and average daily temperature. The percentage differences were determined by comparing CO emissions at an average daily temperature of 82˚F and the temperature with emissions at temperatures ranging from about 10˚F to 110˚F. A 24˚F temperature cycle was used for each of the different average daily temperatures(see, e.g., Figure 1).

Fuel RVP (Reid Vapor Pressure)

As mentioned above in the hydrocarbon section fuel RVP is a required input and for exhaust emissions the RVP dependence is contained with the temperature correction factor[5,9]. And this correction is also applied to CO emissions. Varying fuel RVP will vary the temperature correction factor at a specific temperature and the exhaust CO emissions.

Figures 25 and 26 display graphical results for the CO emissions and the percent difference in CO emissions relative to a standard RVP value of 7.5psi, respectively. The main effects are for RVP values above 9 pounds per square inch (psi). There is a steep increase in emissions for RVP values above 9psi. This is again indicative of the exponential dependence of the temperature correction factor on fuel RVP. However, RVP effects are the same for all RVP values greater than 11.7psi. So, the curves would flatten out from 11.7psi through 15.2psi (15.2psi is the maximum value of RVP allowed in MOBILE6).

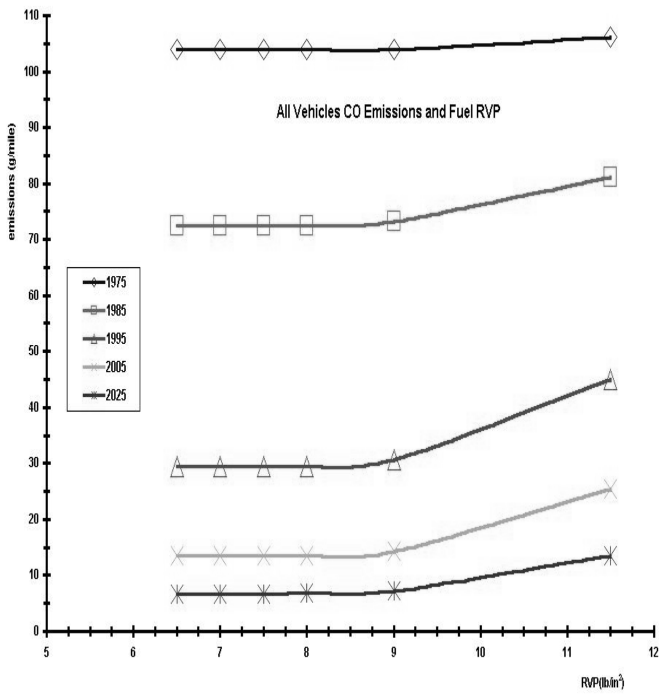


Figure 25. Carbon monoxide emissions as a function of the fuel Reid Vapor Pressure (RVP).

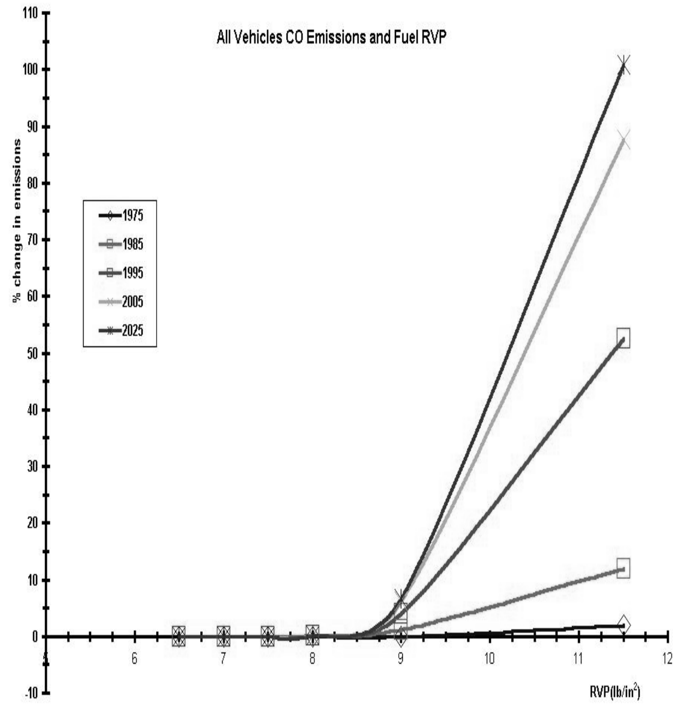


Figure 26. Percent change in carbon monoxide emissions relative to the emissions at 7.5psi as a function of the fuel Reid Vapor Pressure (RVP).

Registration Distribution command

As with HC emissions, CO emissions are affected by changes in the distribution of vehicle ages for a given year. And again, this reflects the deterioration of emissions with vehicle age which is the main assumption in MOBILE6 emissions calculations. Figure 27 displays the percent change in CO emissions versus the percent change in the vehicle age fractions for All Vehicles. The Light-Duty Gasoline Vehicle relationships are similar.

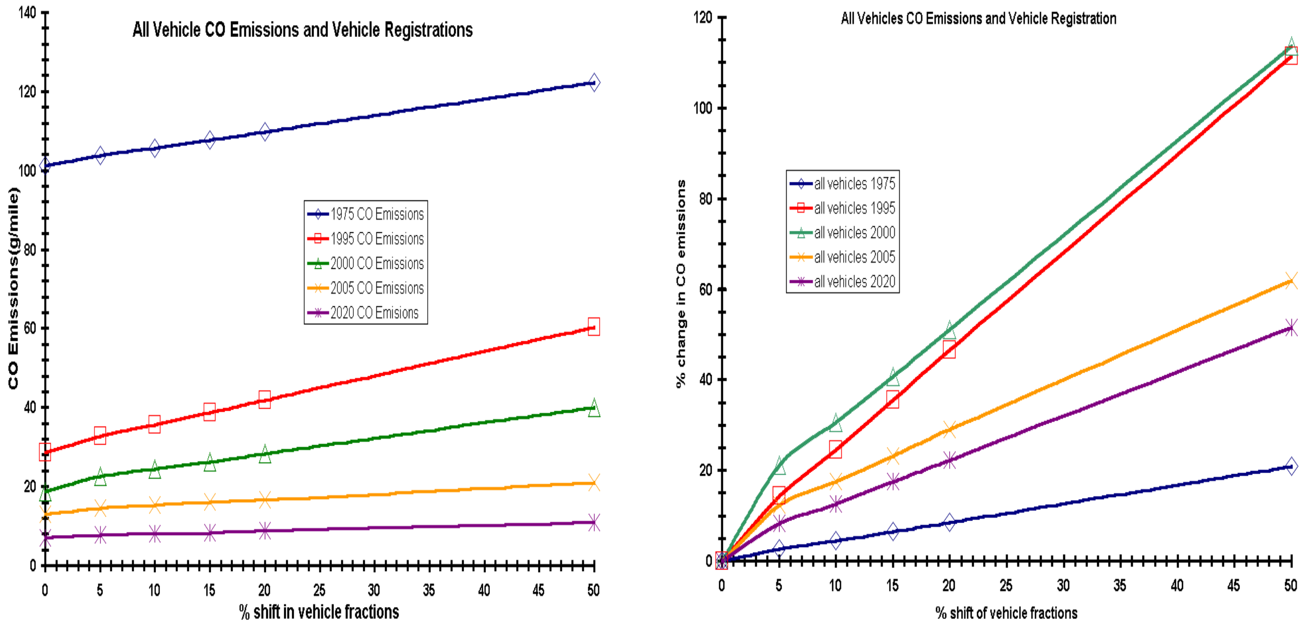


Figure 27.

(a.) All Vehicle CO emissions as a function of the percent change in the fraction of registered vehicles with a given age. The percentage is determined relative to the MOBILE6 default registration and the emissions determined with those default vehicle age fractions. (See also Figure 4 which illustrates the MOBILE6 vehicle age fractions.)

(b.) All Vehicle CO emissions as a function of the percent change in the fraction of registered vehicles with a given age. The percentage is determined relative to the MOBILE6 default registration and the emissions determined with those default vehicle age fractions. (See also Figure 4 which illustrates the MOBILE6 vehicle age fractions.)

Average Speed Command

The last input parameter in this major affects section for carbon monoxide is the emissions dependence on vehicle speed through the Average Speed command. Again, the MOBILE6 speed dependence is due to both an activity factor and a functional vehicle emissions-vehicle speed factor. The Average Speed command (and the Speed VMT command) set(s) the fraction of vehicles which are operating at a given speed on the different MOBILE6 roadway types. These fractions in turn apportion the speed correction factors for different vehicle speeds applied to the CO emissions. Figures 14 through 16 illustrate the default speed-vehicle fractions used in MOBILE6 for arterial roadways. The freeway fractions are slightly different and have a higher fraction of vehicles at the speeds above 30mph.

As with HC emissions, variation of the vehicle speed fractions using the Average Speed command has relatively large effects on CO emissions when compared to the MOBILE6 defaults. This is especially true when the average speed on a particular roadway type is reduced below 20 mph or increased above 50 mph. Figure 28 shows the MOBILE6 All Vehicle types CO emissions dependence on speed using the Average Speed command for arterial roadways, freeway, and area wide (or all MOBILE6) roadways. The variations of the average speeds on arterial roadways and freeways ranged from 10 to 65 mph and average speeds on all or area wide roadway types ranged from 10 to 35 mph. For the sake of comparison, Figure 29 shows the percent difference in CO emissions relative to the MOBILE6 defaults for LDGV freeways, All Vehicles freeways, and All Vehicles area wide roadways. The freeway results for LDGV and ALL Vehicles show very similar trends. Results for five calendar years, i.e., 1975, 1995, 2000, 2005, and 2025, are displayed in each of the aforementioned figures.

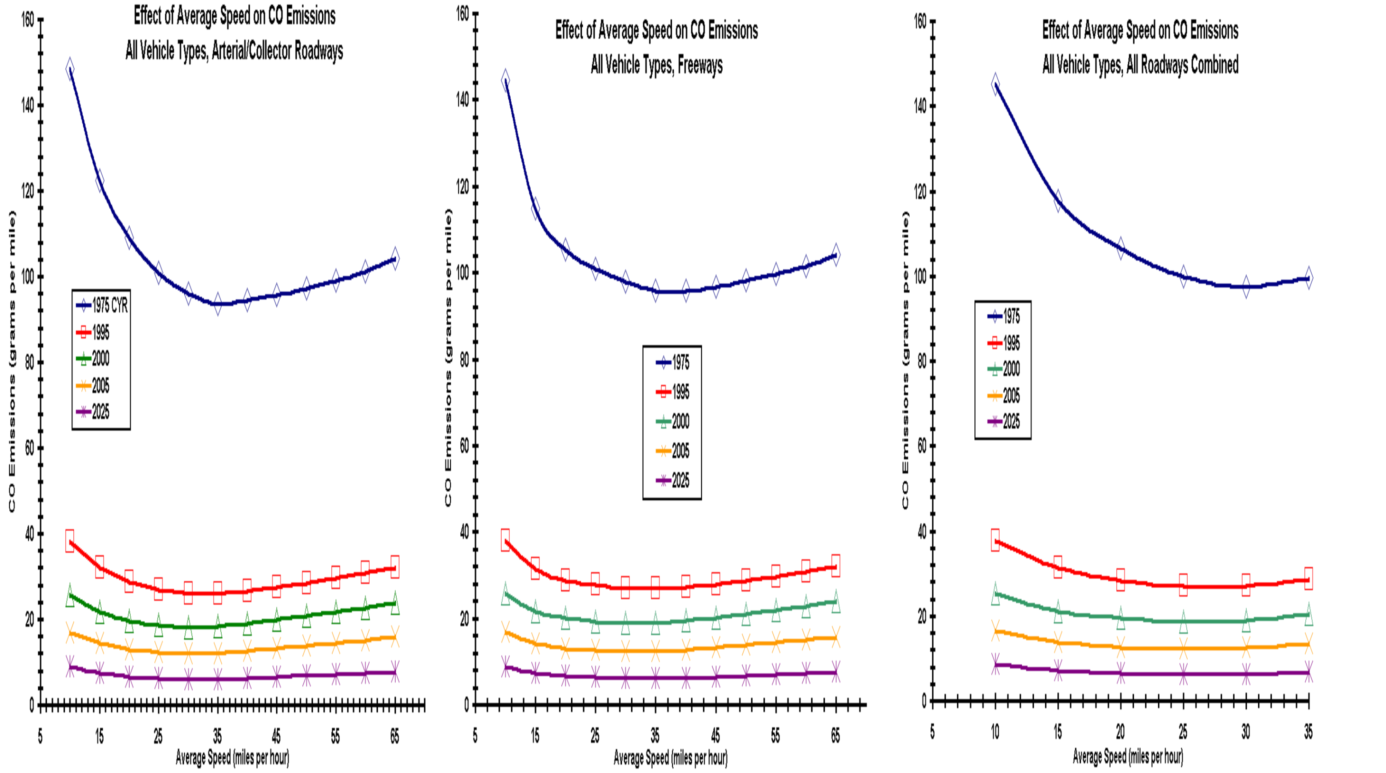


Figure 28.

(a). All MOBILE6 vehicle types CO emissions as a function of speed on arterial roadways using the Average Speed command.

(b). All MOBILE6 vehicle types CO emissions as a function of speed on freeways using the Average Speed command.

(c). All MOBILE6 vehicle types CO emissions as a function of speed on all MOBILE6 roadway types combined or (area wide roadways) using the Average Speed command.

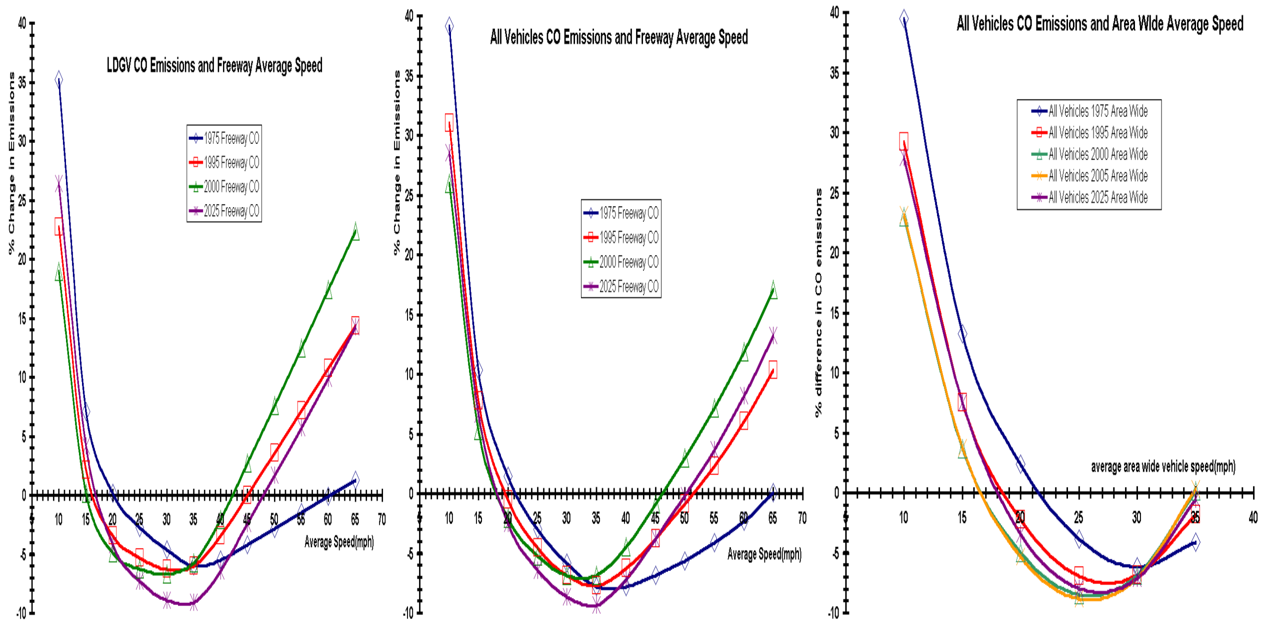


Figure 29.

(a). LDGV CO emissions as a function of freeway speed using the Average Speed command.

(b). All MOBILE6 vehicle types CO emissions as a function of freeway speed using the Average Speed command.

(c). All MOBILE6 vehicle types CO emissions as a function of area wide speed in the using the Average Speed command.

A.3 NOx EMISSIONS

The final pollutant considered in this major emission affects section is oxides of nitrogen or NOx. As with HC and CO the parameters which most impact NOx emissions are the age distribution of the fleet (Registration Distribution command; see Figures 30 and 31), low vehicle speeds (Average Speed command; see Figures 32 through 36), and low average daily temperatures (see Figures 37 and 38).

Registration Distribution command

NOx emissions trends relative to changes in the distribution of vehicle ages for a given year are similar to those exhibited in HC and CO. As with CO and HC, NOx emissions increase with vehicle age. The dependence is nearly linear as vehicle age shifts from newer to older vehicles. Again, this demonstrates the basic MOBILE assumption concerning deterioration of emissions along with shifting vehicles to less restrictive emissions standards and older emissions reduction technologies. Figure 4 above illustrates how the vehicle ages were changed relative to the MOBILE6 default registration distributions. Figure 30 illustrates the All Vehicle NOx emissions dependence on the percent change in vehicle fractions. Figure 31 displays the percent change in NOx emissions relative to the MOBILE6 default vehicle age distributions. (As a reminder, the lines are only drawn to guide your eyes.)

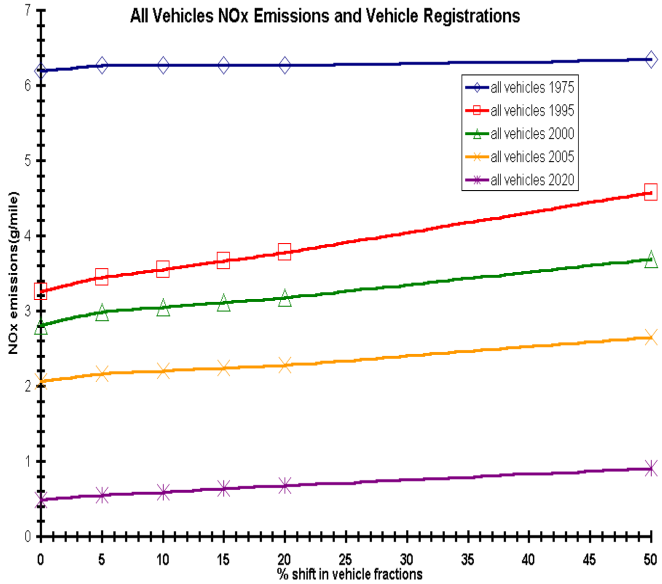


Figure 30. All Vehicles NOx emissions as a function of percent increases in the fraction of older vehicles relative to MOBILE6 default vehicle age fractions. (See also Figure 4 which illustrates the MOBILE6 LDGV age fractions.)

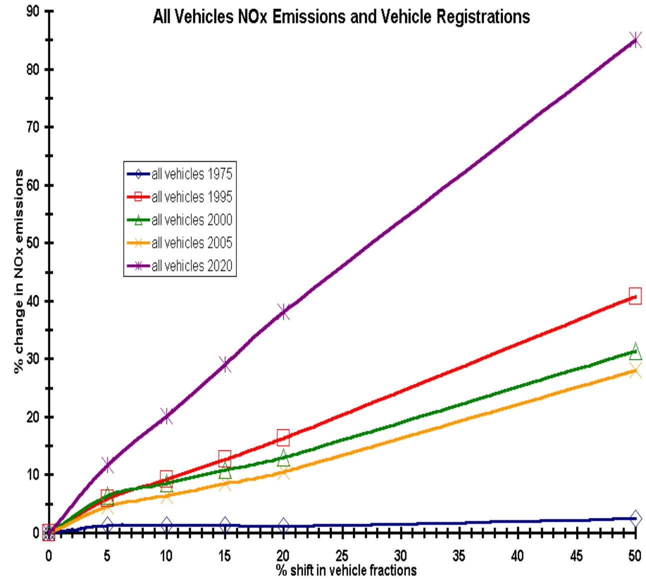


Figure 31. Percent changes in All Vehicle NOx emissions as a function of increases in the fraction of older vehicles relative to MOBILE6 default vehicle age fractions. (See also Figure 4 which illustrates the MOBILE6 LDGV age fractions.)

Average Speed Command

Next, Figures 32, 33, and 34 show NOx emissions dependence on Light-Duty Gasoline Vehicle, Heavy-Duty Diesel Vehicle (HDDV), and All Vehicles freeway speed using the Average Speed command for five calendar years, i.e., 1975, 1995, 2000, 2005, and 2025. There is a distinguishing characteristic for the NOx emissions when compared to the results already seen for CO and HC emissions. That is, at higher speeds (speeds greater than 40mph) the All Vehicle NOx emissions increase considerably at speeds greater than 40mph due to the inclusion of diesel vehicles. This is apparent when the NOx emissions for LDGV, heavy duty diesel, and all vehicles are compared (see Figures 32, 33, and 34). The is only true for NOx emissions when using the Average Speed command on arterial and freeways. The Area Wide roadway option only allows for average roadway speed inputs below 40mph (see Figures 35 and 36).

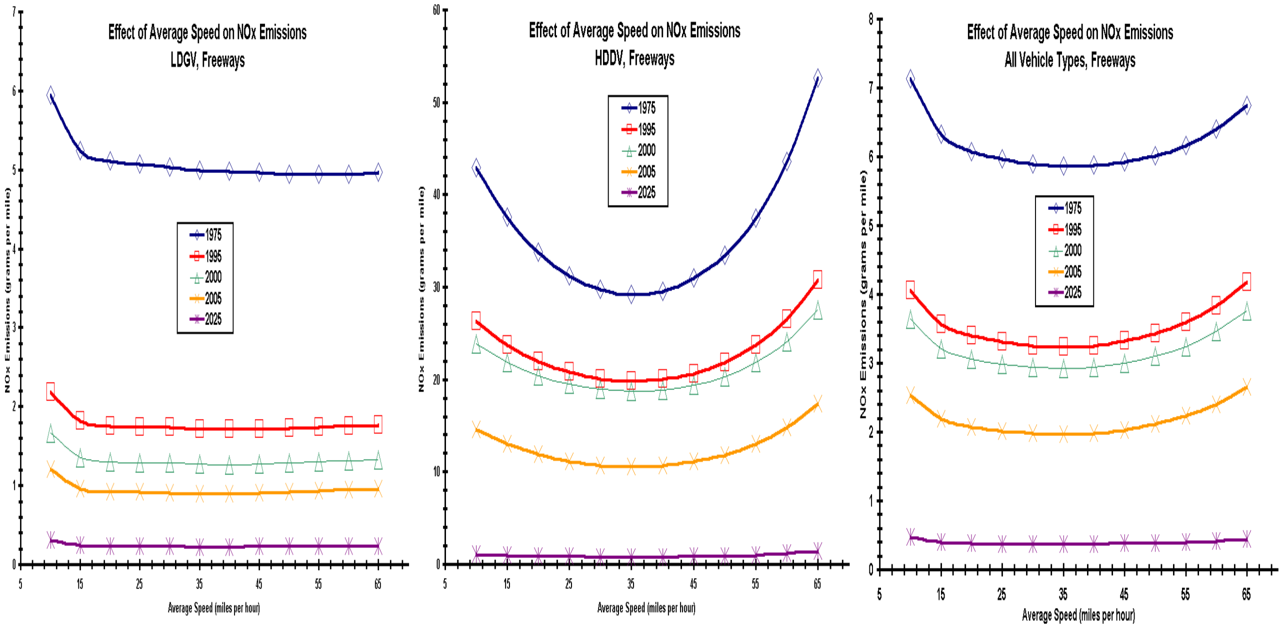


Figure 32.

(a). LDGV NOx emissions as a function of freeway speed using the Average Speed command.

(b). HDDV NOx emissions as a function of freeway speed using the Average Speed command.

(c). All MOBILE6 vehicle types NOx emissions as a function of freeway speed in the using the Average Speed command.

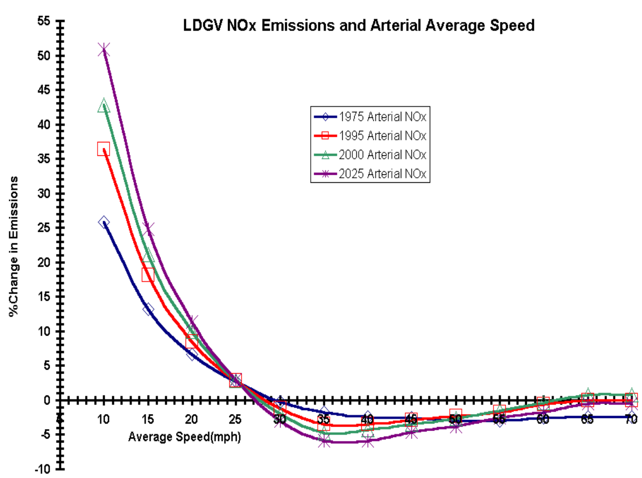


Figure 33. Percent change in Light-Duty Gasoline Vehicle NOx emissions as a function of the speed on arterial roadways using the Average Speed command (The percent differences are relative to emissions determined with the default vehicle roadway speed fractions.)

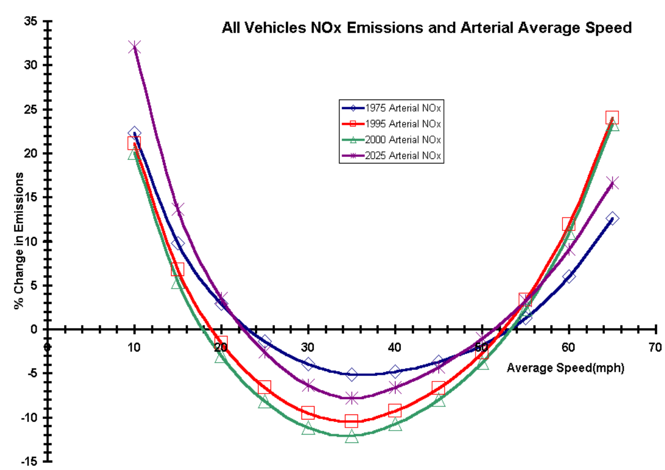


Figure 34. Percent change in All Vehicle NOx emissions as a function of the speed on arterial roadways using the Average Speed command. (The percent differences are relative to emissions determined with the default vehicle roadway speed fractions.)

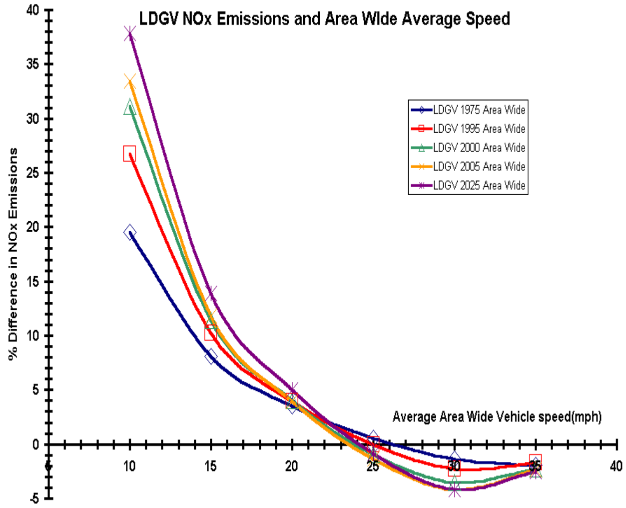


Figure 35. Percent change in Light-Duty Gasoline Vehicle NOx emissions as a function of the vehicle speed on Area Wide roadways using the Average Speed command. (The percent differences are relative to emissions determined with the default vehicle roadway speed fractions.)

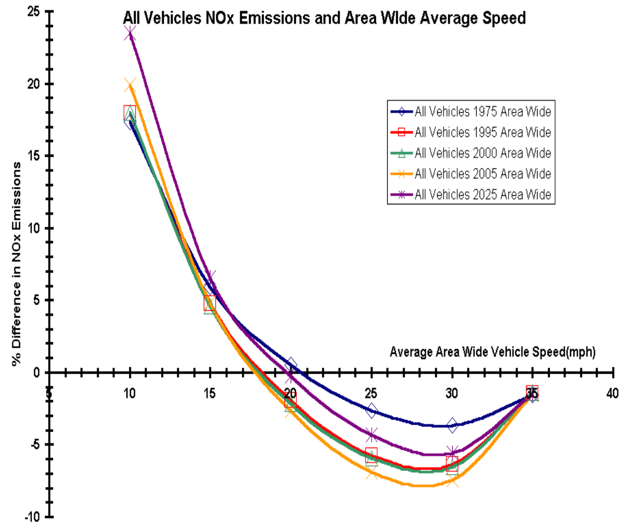


Figure 36. Percent change in All Vehicle NOx emissions as a function of speed on Area Wide roadways using the Average Speed command. (The percent differences are relative to emissions determined with the default vehicle roadway speed fractions.)

Min/Max Temperature Command

Although the one-to-one correspondence between input variation and output variation for temperature and NOx is typically less than one, the last input parameter-emissions relationship considered in this major parameter section is the relationship between NOx and average daily temperature. This input parameter is complicated because the corrections to NOx emissions are also dependent on humidity. High values of humidity which are more likely with higher ambient temperatures tend to decrease the formation of NOx. However, the temperature (MIN/MAX temperature command) and the humidity (ABSOLUTE humidity command) values are not inter-related in MOBILE6 calculations. Hence, the humidity-temperature interaction when using either of those commands does not have a significant affect on NOx emissions. In the high ambient temperature region for the calendar years relevant to any current emissions calculations the interplay between humidity and temperature is relatively small. (Recently, a command and related coding has been added to MOBILE6 allow for the inter-relationship between humidity and temperature[5].)

Figures 37a, 37b, and 37c show the MOBILE6 LDGV, HDDV, and all vehicles NOx emissions as a function of temperature while holding the absolute humidity constant. Also, Figures 38a and 38b show the LDGV NOx emissions percent change as a function of temperature and temperature percent changes, respectively. They show that the MOBILE6 NOx emissions increase most dramatically for ambient temperatures below 30˚F and that these increases decrease with calendar year. The calendar year dependence is due to the implementation of improved emissions control technologies and emissions regulations. Especially noticeable are those calendar years greater than 1975 which show a temperature range between 50˚F and 70˚F where NOx emissions are relatively constant. Outside of this range NOx emissions tend to increase. As with HC and CO, the MOBILE6 temperature correction factor[9] for NOx is an exponential function dependent on both temperature and fuel RVP for temperatures above 75˚F and is only temperature dependent for temperatures below 75˚F.

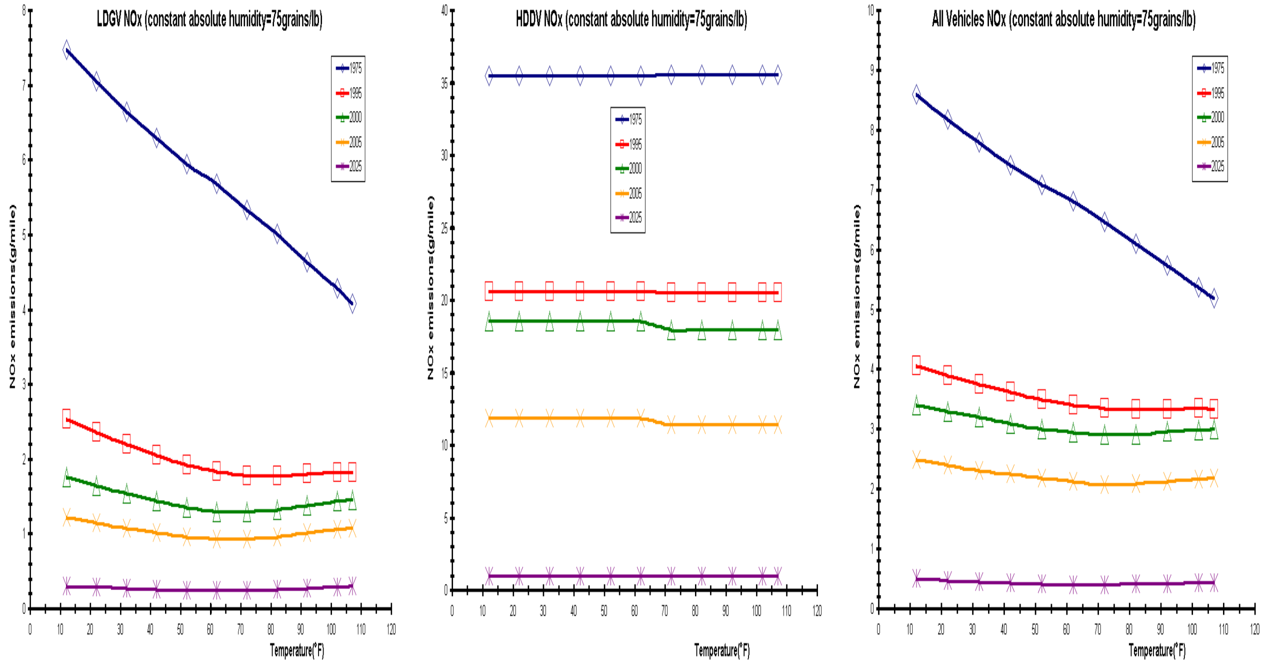


Figure 37.

(a). LDGV NOx emissions as a function of average daily temperature using the Min/Max Temperature command.

(b). HDDV NOx emissions as a function of average daily temperature using the Min/Max Temperature command.

(c). All MOBILE6 vehicle types NOx emissions as a function of average daily temperature using the Min/Max Temperature command.

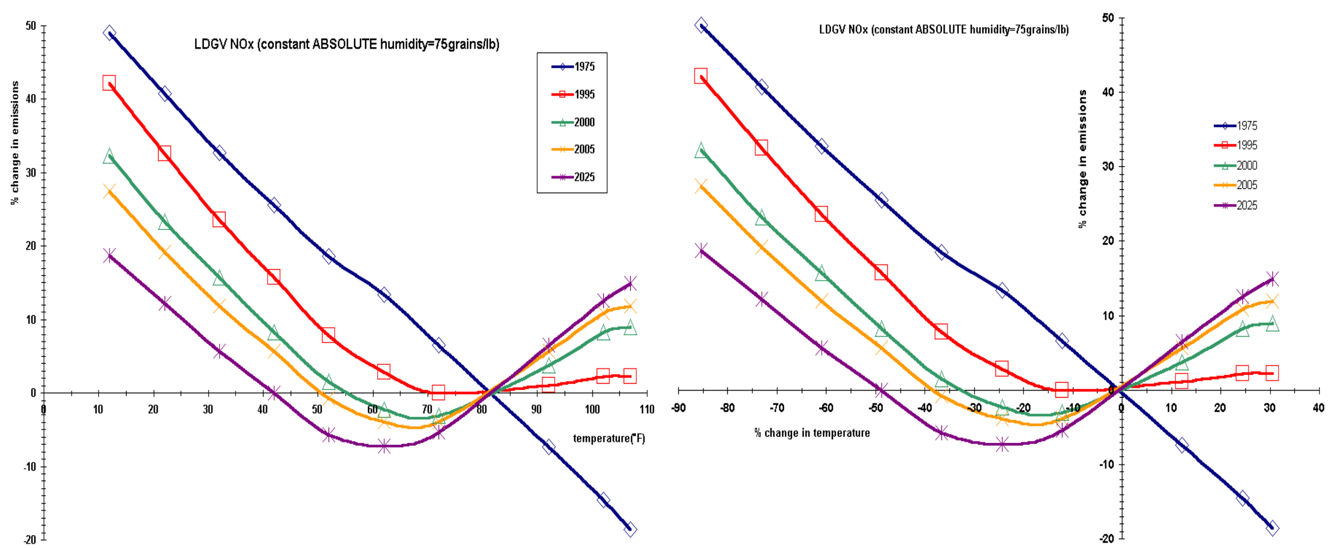


Figure 38.

a. The relationship between the percent change in NOx emissions and average daily temperature when the absolute humidity is kept at a constant value of 75 grains/lb.

b. The relationship between the percent change in NOx emissions and percent change average daily temperature when the absolute humidity is kept at a constant value of 75 grains/lb.

As with HC and CO at lower temperatures, NOx start emissions begin to increase between 40°F and 50°F and hence become a larger fraction of the composite (start plus running). And the NOx start emissions effects due to the average number of vehicle starts per day is listed in the intermediate effects section. However, at lower temperatures these start emissions will become more important in the emissions total as will the number of starts per day.

A.4 Major Parameter Summary

Four MOBILE6 input parameters, vehicle age or registration distribution, average daily temperature, vehicle speed when changed via the Average Speed command, and fuel RVP, can have large affects (changes in emissions of 20 percent or more relative to the emissions calculated with default input values) on emissions results calculated by MOBILE6. The above results presented represent only those inputs which have at least a 1-to-1 emissions-to-input percentage rate response and lead to an emissions increase of at least 20 percent. All pollutant types, CO, HC, and NOx, have a high dependence on the vehicle registration distribution. This is mainly due to the basic assumptions that older technology vehicles have higher emissions than newer technology vehicles and that vehicle emissions worsen as vehicles age. Next, CO emissions increase rapidly with temperature once the average daily temperature moves below 55°F. Hydrocarbon and oxides of nitrogen emissions also have relatively high emissions at very low temperatures, i.e., average daily temperatures below 20°F. Increases in emissions due to temperature changes at higher temperatures (above 75°F) is exponential and at lower temperatures is due to cold start emissions. Fuel RVP values between 9psi and 11.5psi effect the temperature correction factor exponentially and is reflected in the large increase in CO, HC, and NOx emissions. Finally, the Average Speed command changes the default values of speed and the fractions of vehicles travelling on different MOBILE6 roadways types which produces significant changes in emissions especially at speeds near 10mph.

B. PARAMETERS WITH INTERMEDIATE EFFECTS ON EMISSIONS (5% TO 20%)

In this section a discussion is given of the parameters which induce intermediate changes in emissions. Table 2 below lists the inputs which fall into this intermediate level of affects on emissions and the rates at which they effect emissions for Light-Duty Gasoline Vehicles (LDGV). These parameters have at about a 1-to-1 emissions-to-input percentage rate response and lead to an emissions increase of at least 5 percent but less than 20 percent when the input parameter is changed by 20 percent.

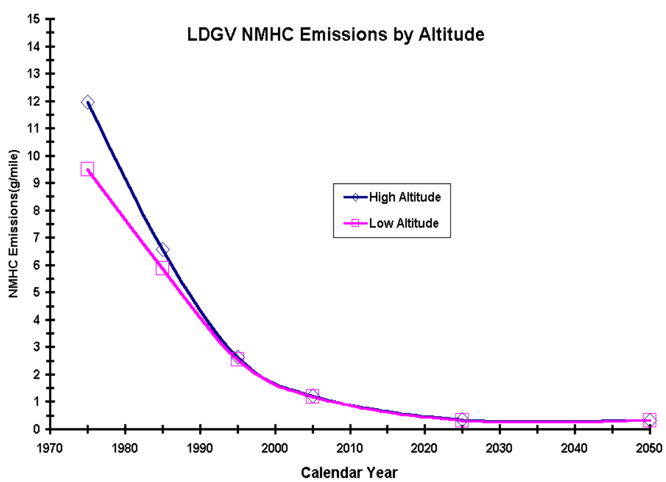
Table 2. Summary of LDGV and All Vehicle results with input parameters which have an "intermediate" effect on emissions

COMMAND	**Change in Input**		**Change in Hydrocarbon emissions**	**Change in CO emissions**	**Change in Oxides of Nitrogen emissions**
>5% and <20%					
Absolute Humidity [Use high and low humidity values from August morning and afternoon average relative humidity values from Atlanta and Tucson (National Weather Service data).]	min.	-28% (54grains/lb)	Third Level	Third Level	ldgv running 5%(2025) to 6%(1975)
	max.	100% (149grains/lb)	Third Level	Third Level	ldgv running -14%(1975) to -10%(2025)
Air Conditioning	Emissions Differences with Air Conditioning Correction Applied and Not Applied		Low Level	16%(1975) 20%(2005) 5%(2050)	5%(1975) 10%(19995) 18%(2025)
Altitude	Emissions Differences Between High Altitude and Low Altitude		26%(1975) 4%(1995) <1%(2025)	41%(1975) 8%(1995) 0%(2005)	-31%(1975) -4%(1995) 0%(2005)
Mileage Accumulation(increase and decrease mileage accumulation relative to the MOBILE6 defaults)	min.	20% decrease	Third Level	-2.5%(1985) to -11%(2020)	0%(1990) to -24%(2020)
	max.	20% increase	Third Level	1%(1980) to 9%(2020)	1%(1990) to 22%(2020)
Speed VMT (Arterial; -3% - null low speed vehicle fractions 9% - equal vehicle fractions for all speeds 14% - increase low speed vehicle fraction by 10% 21% - increase low speed vehicle fraction by 20% 29% - increase low speed vehicle fraction by 30%)	min.	-3% (free-flow/ all day non-rush hour speeds)	Third Level	Third Level	Third Level
	max.	29%(congested traffic flow,i.e., 30% more vehicles at the lower speeds)	First Level	Third Level	5%(1975) to 8%(2050)
Speed VMT (Freeway; reduce fraction of vehicles from high speeds to lower speeds)	min.	-50% (equal distribution of speeds)	(NMHC) +13%(1975) to 5%(2050)	Third Level	Third Level
	max.	10%(most vehicles at the higher speeds)	Third Level	Third Level	Third Level
Starts Per Day(change the number of starts per day from -50% to +50% in increments of 10% for each vehicle type)	min.	-50%	(NMHC) -17%(2025) to -12%(1975)	-15%(1975) to -11%(2025)	-13%(1975) to -7%(2025)
	max.	50%	(NMHC) 17%(2025) to 12%(1975)	11%(2025) to 15%(1975)	13%(1975) to 7%(2025)

B.1 HC EMISSIONS

Altitude

Internal combustion engines essentially work on the air mass that moves through it and the fuel that supplies heat. Ambient air conditions such as pressure and temperature effect both the density of air and hence the supply of air (mass) to the engine. The pressure of the air is of course dependent on altitude. In mobile6 an altitude correction factor for high altitude regions[10] (approximately 4,000 feet above sea level) is used to account for this ambient condition. In this work, high altitude emissions were compared with the MOBILE6 default low altitude emissions. The emissions results for Light-Duty Gasoline Vehicles and All Vehicle types as a function of calendar year are displayed in Figure 39 below. The percent differences relative to the default low altitude for both Light-Duty Gasoline Vehicles and All Vehicle types are displayed in Figure 40. Altitude has little effect on Light-Duty Gasoline Vehicle emissions for calendar years after 1995. However, the All Vehicle emissions percent differences imply that the MOBILE6 Heavy Duty Vehicles even for calendar years greater than 1995 have emissions which are about 10 percent higher than the low altitude option.



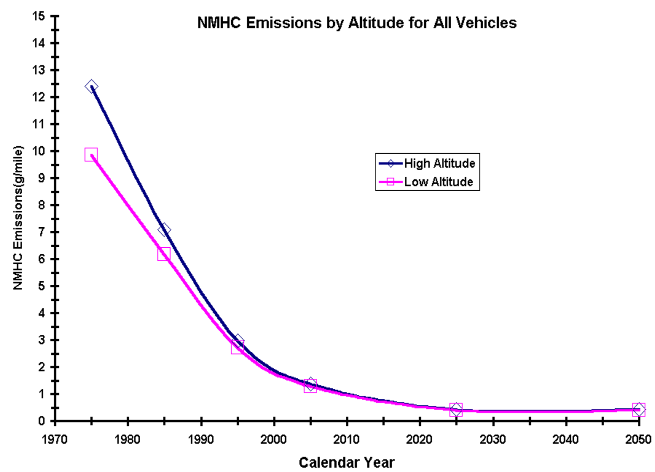


Figure 39.

(a). Low and high altitude NMHC emissions for MOBILE6 Light-Duty Gasoline Vehicles

(b). Low and high altitude NMHC emissions for the MOBILE6 All Vehicle types.

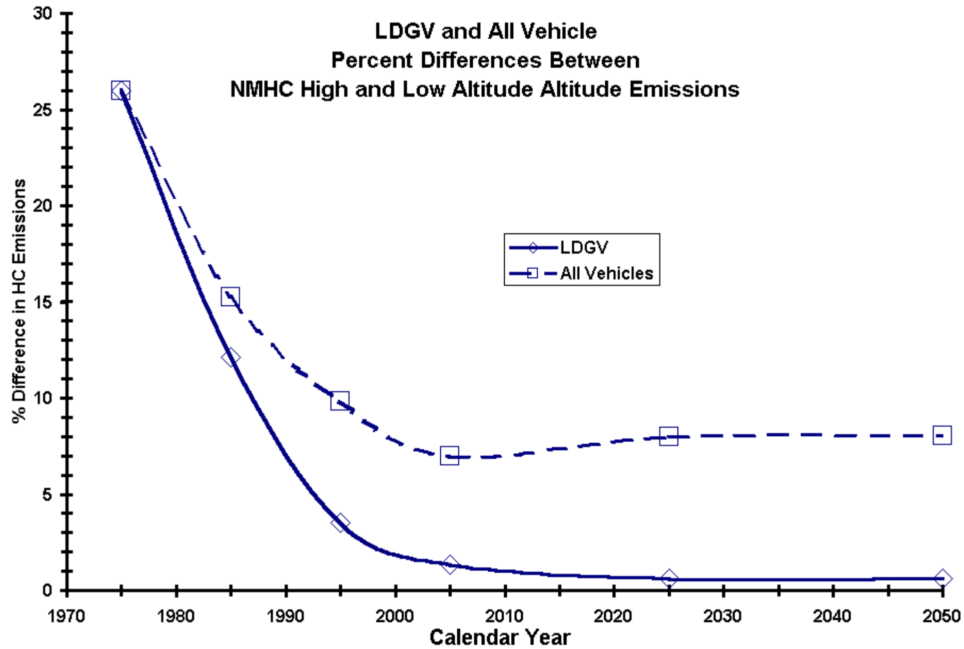


Figure 40. Percent differences between NMHC emissions at low and high altitudes.

Speed VMT Command

MOBILE6 NMHC emissions also have medium level association with the SPEED VMT command for freeways mainly in earlier calendar years. In a manner similar to what was described in changes in the SPEED VMT command for arterial roadways for NMHC emissions (see Figures 14, 15, and 16), the MOBILE6 default fraction of vehicles travelling at speeds of 2.5, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, and 65 miles/hour on freeways were varied from higher speeds to lower speeds and the resultant MOBILE6 emissions were compared. Figure 41 displays Light-Duty Gasoline Vehicle emissions results as a function of the percent change in vehicle fractions relative to MOBILE6 default fractions. Figures 38 and 39 show the percent difference in NMHC emissions relative to emissions produced with default vehicle fractions.

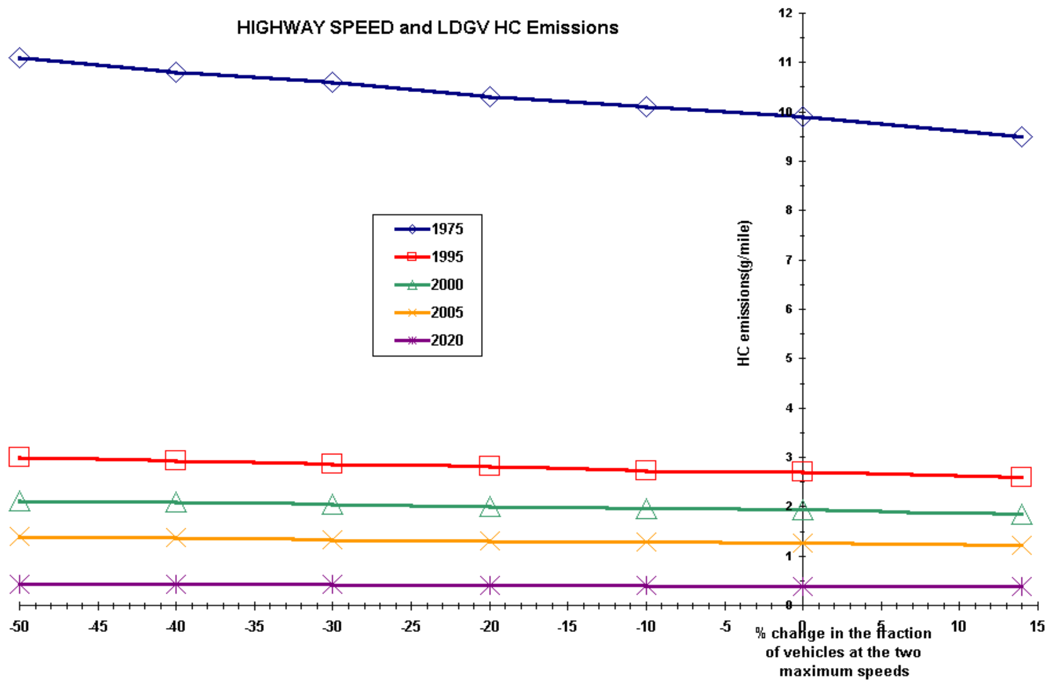


Figure 41. NMHC emissions from LDGV as a function of changing the fraction of vehicles travelling at higher speeds. MOBILE6 default vehicle fractions vary by hour of the day whereas the changed vehicle fractions are constant for each hour of the day. (See also Figures 14 through 16.)

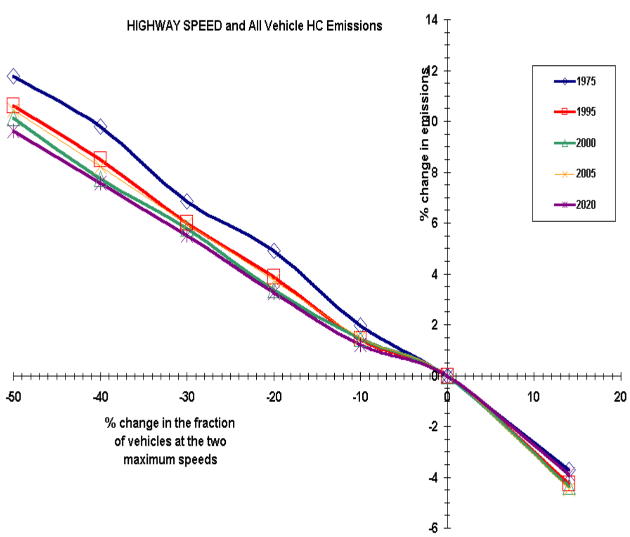


Figure 42. NMHC percent changes in LDGV emissions relative to MOBILE6 defaults as a function of varying the fraction of vehicles travelling at higher speeds. The vehicle fractions were also held constant through each hour of the day. (See also Figures 14 through 16.)

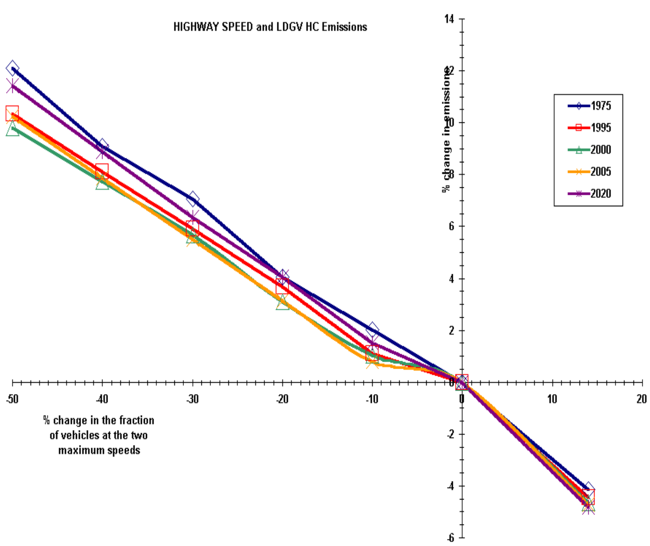


Figure 43. NMHC percent changes in All Vehicle emissions as a function of changing the fraction of vehicles travelling at higher speeds relative to MOBILE6 defaults. The vehicle fractions were also held constant for each hour. (See also Figures 14 through 16.)

Starts per Day

A new feature of MOBILE6 is the ability to separate emissions into cold start emissions and hot stabilized running emissions. Consequently, the number of starts per day that a vehicle experiences can be changed by the MOBILE6 user. So, the impact of start emissions on total vehicle emissions (start emissions plus running emissions) can be studied with MOBILE6. In Figures 44 through 46 NMHC emissions determined using MOBILE6 are depicted as a function of starts per day. The figures include results for Light-Duty Gasoline Vehicles and for all MOBILE6 vehicle types. The NMHC emissions in these figures are total emissions from NMHC cold start emissions, NMHC hot stabilized emissions, and contributions from NMHC evaporative emissions. The relationship for the span of calendar years, 1975 through 2025, is linear. As mentioned in the major affects sections on temperature, there is a sharp increase in emissions below 45°F which is due to cold start emissions. At these lower temperatures, the starts per day will contribute significantly to the total emissions.

Although they are not shown, the percent increase/decrease in start emissions alone have a one-to-one correspondence with the percent increase/decrease in the number of starts per day. That is, a one percent increase in the number of starts per day will yield a one percent change in emissions. Moreover, this one percent increase in start emissions is the sole factor for increases in the total (start plus running) emissions illustrated in Figures 44 through 46 below.

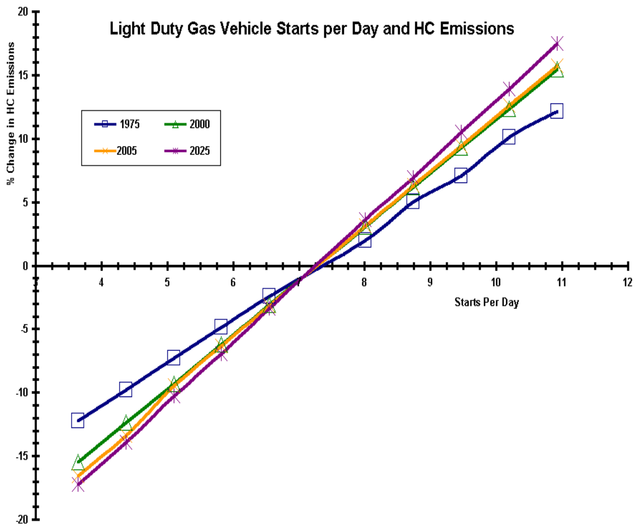


Figure 44. Percent change in LDGV emissions as a function of the number of LDGV starts per day. The MOBILE6 default average number of LDGV weekday starts per day is 7.28.

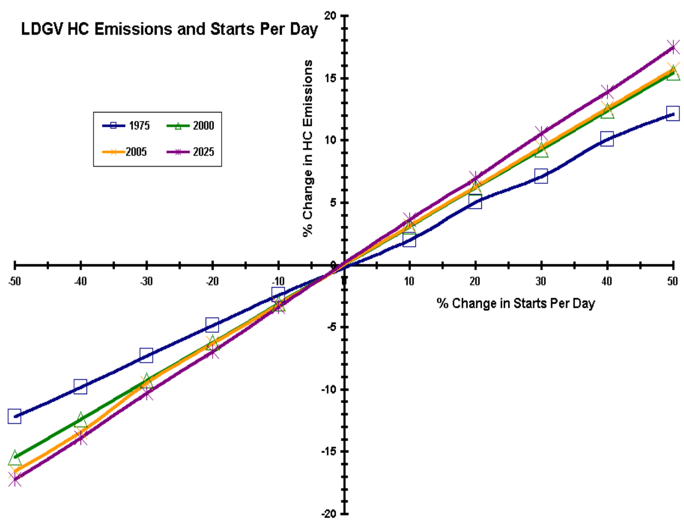


Figure 45. Percent change in emissions as a function of the percent change in the number of LDGV starts per day relative to the default number of LDGV starts per day.

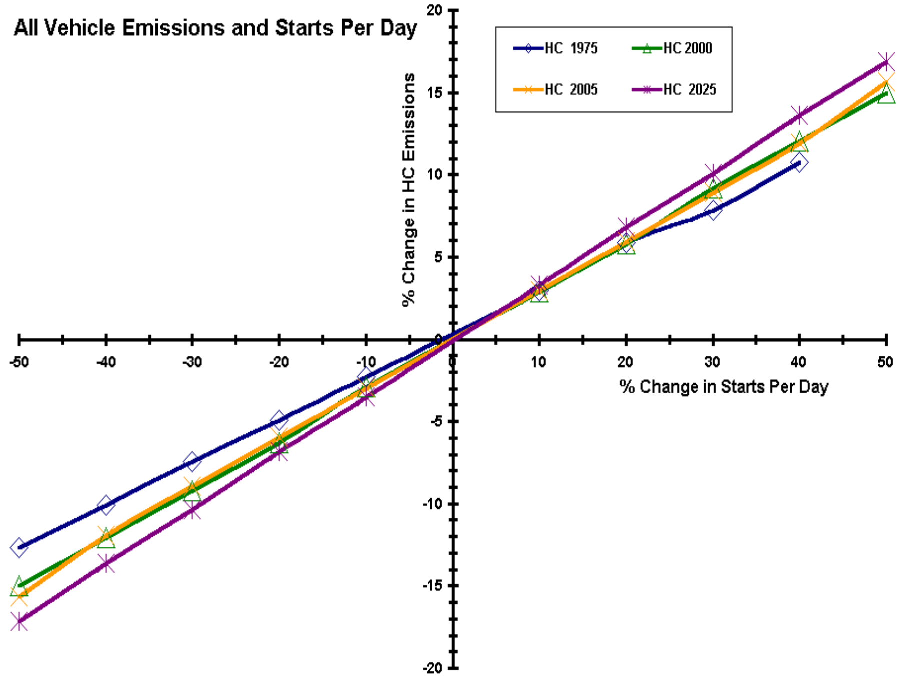


Figure 46. Percent change in emissions as a function of the percent change in All Vehicle starts per day. Most vehicle types have differing numbers of starts per day. For each vehicle class a percentage of starts per day was either subtracted (or added). The emissions were then determined by running MOBILE6 with the starts per day for each vehicle type changed by a certain given percentage as indicated in the graph.

B.2 CO Emissions

Air Conditioning

Another new feature of MOBILE6 is the ability to approximate the emissions due to engine air conditioning load. Part of the correction depends on air conditioning usage which is determined with what is termed a "heat index". The heat index is dependent on both ambient temperature and humidity. Hence, the MOBILE6 temperature range and the absolute humidity values impact the air conditioning correction. However, the temperature and humidity interaction with the air conditioning correction was not studied here. In this analysis, to determine the impact of the MOBILE6 air conditioning correction on emissions, a temperature range of 72°F to 92°F with an absolute humidity value of 75grains/lb was used to compare MOBILE6 CO emissions estimations with and then without the air conditioning correction. The comparison as a function of calendar year is displayed in Figures 47 through 49. Figures 47 and 48 illustrate the emissions in grams/mile for Light-Duty Gasoline Vehicles and all MOBILE6 vehicle types, respectively, with and without the air conditioning correction. Figure 49 depicts the percent increase in emissions due to MOBILE6 air conditioning correction as a function of calendar year.

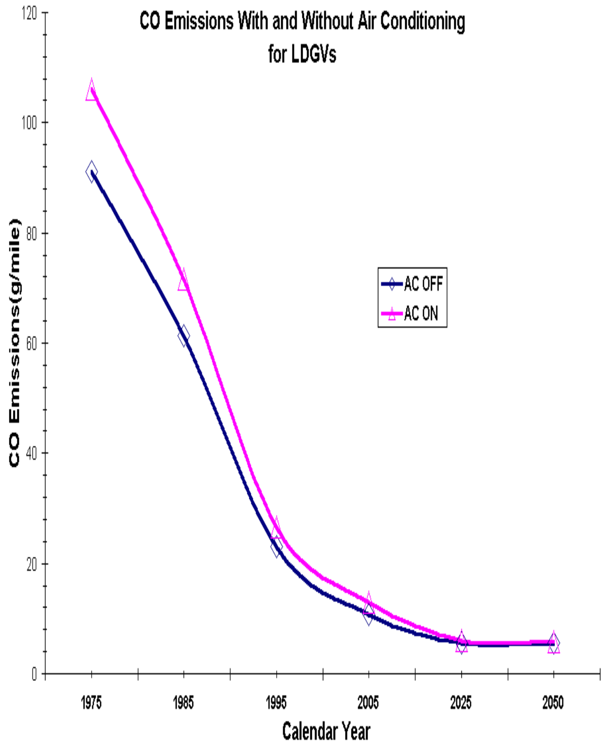


Figure 47. A comparison of LDGV CO by calendar year with MOBILE6 air conditioning correction on or off.

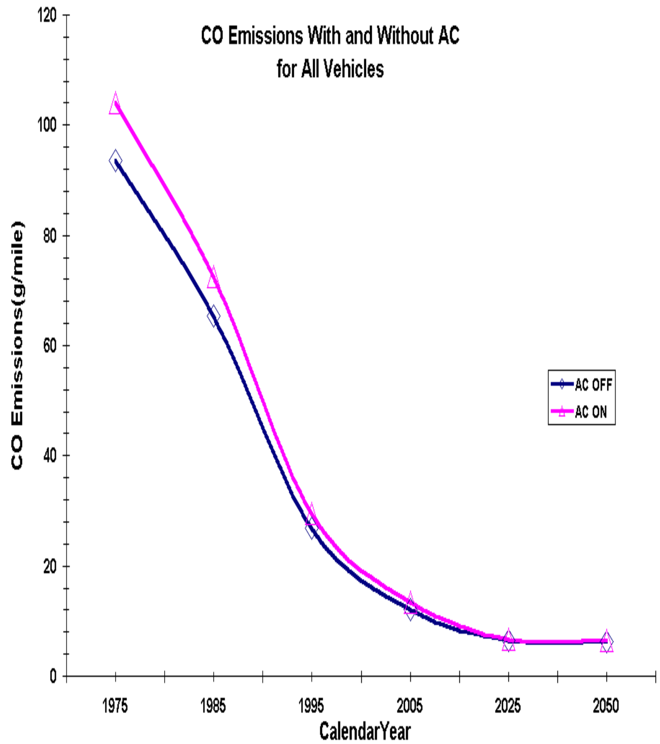


Figure 48. A comparison of All Vehicle CO emissions by calendar year with MOBILE6 air conditioning correction on or off.

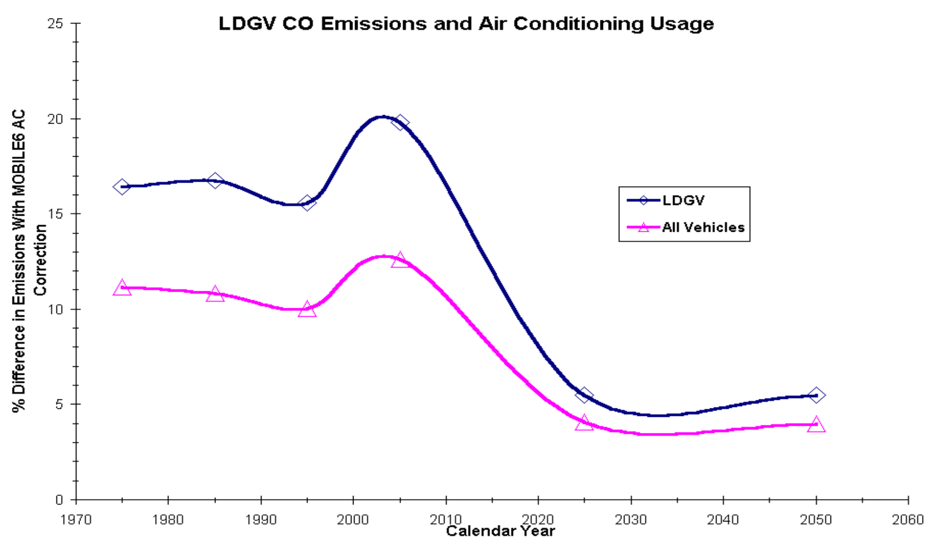


Figure 49. Percent difference in CO emissions due to MOBILE6 air conditioning correction as a function of calendar year for both LDGV and All Vehicles.

Altitude

MOBILE6 includes an altitude correction option. The choices are either high altitude or low altitude(default). The MOBILE6 CO emission comparisons between low altitude (regions below 4,000 feet[10]) and high altitude regions are shown in Figures 50, 51, and 52 for both Light-Duty Gasoline Vehicles and the MOBILE6 All Vehicle types. Figures 50 and 51 illustrate the emissions in grams/mile for Light-Duty Gasoline Vehicles and All Vehicle types, respectively, at high and low altitude regions. Figure 52 depicts the percent increase in emissions due to the MOBILE6 high altitude correction as a function of calendar year.

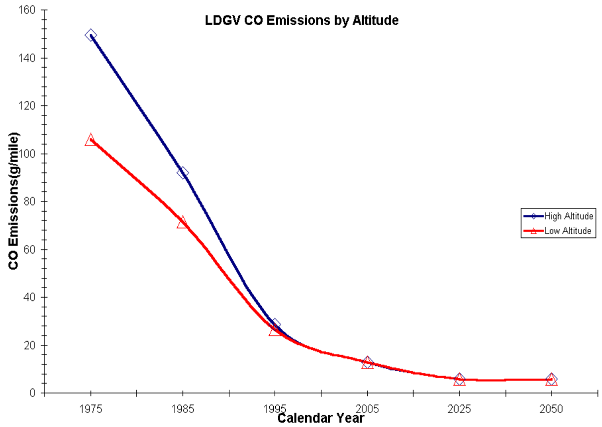


Figure 50. MOBILE6 altitude effects on LDGV CO emissions as a function of calendar year.

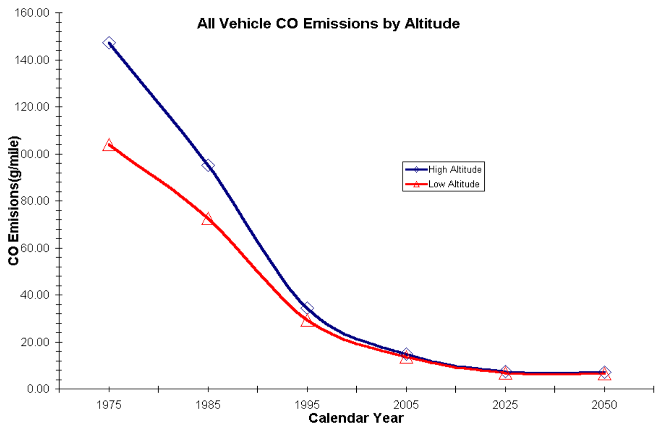


Figure 51. MOBILE6 altitude effects on All Vehicle types CO emissions as a function of calendar year.

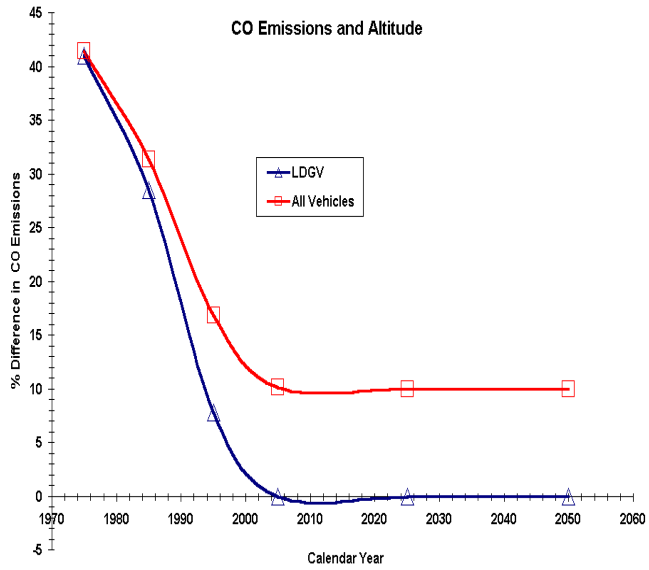


Figure 52. Percent difference in CO emissions due to MOBILE6 altitude correction as a function of calendar year for both LDGV's and and All Vehicles.

Mileage Accumulation

Mileage for each of the 28 different vehicle classes is determined by calendar year. In particular, each vehicle class has a 25-year range of mileage accumulation rates. In other words, in MOBILE6 vehicles are classified by age, and the age determines how much the vehicle is used in terms of how many miles it has traveled. Figure 53 displays the default MOBILE6 Light-Duty Gasoline Vehicle mileage as a function of vehicle age; the dark blue line with open circles. To illustrate the MOBILE6 emissions dependence on vehicle mileage, the default LDGV mileage was changed by increasing and decreasing the mileage for each vehicle age. Figure 53 also displays the LDGV mileage curves for each vehicle age after the changes. In 5 percent increments of the default mileage values, mileage was added to and subtracted from the default MOBILE6 mileage values. This procedure was duplicated for each of the different MOBILE6 vehicle categories. That is, the CO emissions were estimated using MOBILE6 with the Mileage Accumulation command used to increase and decrease all of the different MOBILE6 vehicle types default mileages in increments of 5 percent through a range of 40%.

Figures 54 and 55 display results for Light-Duty Gasoline Vehicles and the All Vehicle types, respectively, in terms of percent change in CO emissions versus percent change in mileage. Again, the lines are drawn to guide the reader's eyes. In general, the trends show a nearly linear increase/decrease in CO emissions with increases/decreases in mileage for each of the calendar years, 1975,1995, 2000, 2005, and 2025. For both the All Vehicles category and the Light-Duty Gasoline Vehicles category CO emissions show similar functional dependence on mileage.

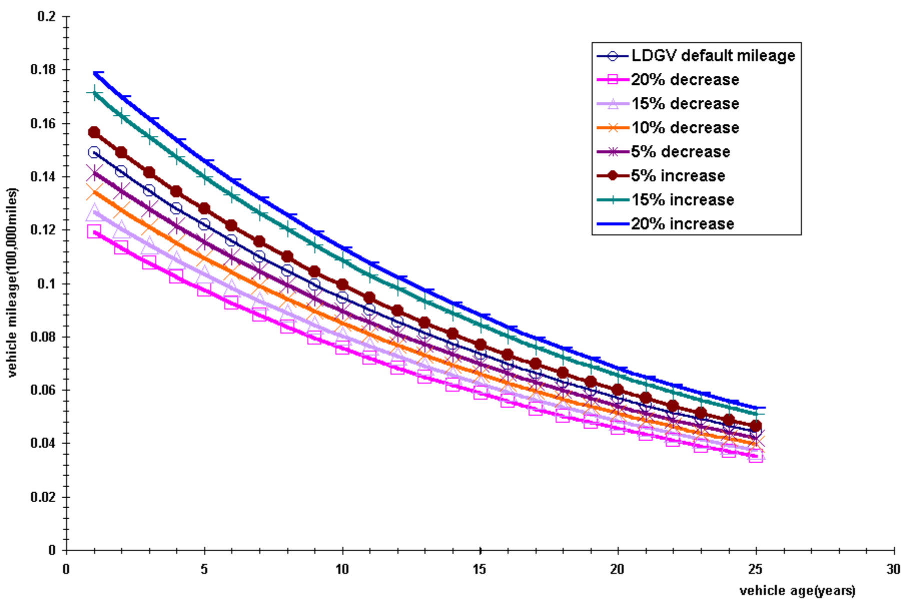


Figure 53. In MOBILE6 each calendar year is associated with a set of vehicles of ages 1 through 25. The mileage traveled by a MOBILE6 vehicle type decreases with age as illustrated in the above graph. The blue line with open circles depicts the default mileage traveled by LDGV of a particular age. To determine how changes in this default mileage distribution affects emissions, the default numbers were increased and decreased in increments of 5 percent as illustrated in this figure for LDGV's. Figures 54 and 55 illustrate the percent changes in CO emissions from MOBILE6 default values.

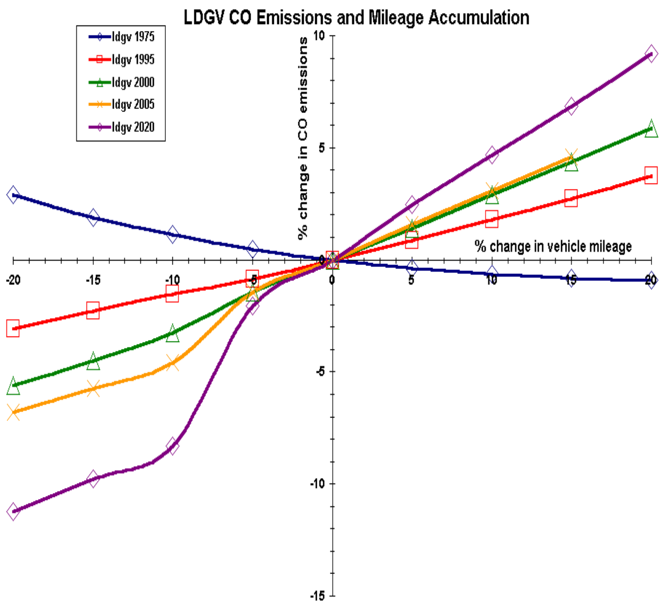


Figure 54. Percent change in LDGV CO emissions as the default mileage is changed. Figure 47 above illustrates how the mileage changed from the MOBILE6 LDGV default mileages.

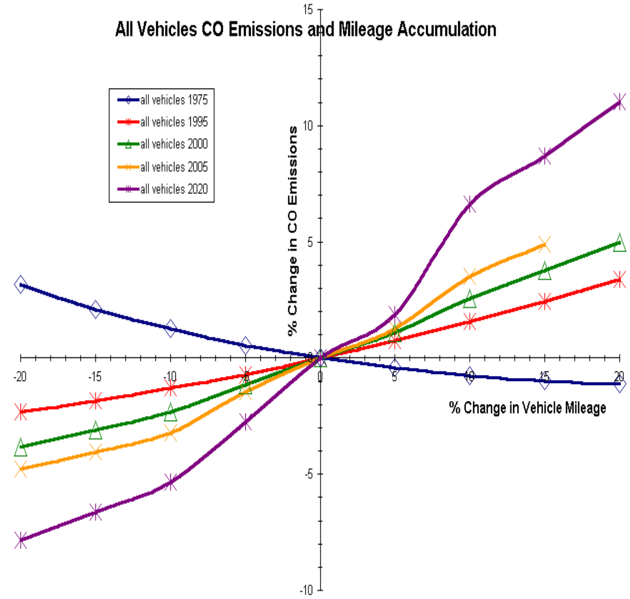


Figure 55. Percent change in All Vehicle CO emissions as the default mileage is changed for All Vehicle types. See Figure 47 for an illustration of how the mileages were varied relative to the MOBILE6 default values.

Vehicle Starts Per Day

As with NMHC emissions Starts Per Day is a new feature of MOBILE6 and CO emissions can now be separated into cold start emissions and hot stabilized running emissions. Also, the number of Starts Per Day that a vehicle experiences can be changed by the MOBILE6 user. So, the impact of start emissions on the total vehicle CO emissions (start CO emissions plus running CO emissions) can be estimated using MOBILE6. In Figures 56 through 58, CO emissions determined using MOBILE6 are depicted as a function of Starts Per Day. The figures include results for Light-Duty Gasoline Vehicles and for all MOBILE6 vehicle types. The CO emissions in these figures are total emissions and include both start and running emissions. The relationship for the span of calendar years, from 1975 through 2025 at an average daily temperature of about 82˚F (minimum temperature of 72˚F and a maximum temperature of 92˚F) is linear. As mentioned in the major affects sections on temperature, there is a sharp increase in emissions below 45˚F which is due to cold start emissions. At these lower temperatures, the starts per day will contribute significantly to the total emissions.

Although they are not shown, the percent increase/decrease in start emissions alone has a one-to-one correspondence with the percent increase/decrease in the number of Starts Per Day. That is, a one percent increase in the number of starts per day will yield a one percent change in emissions. Moreover, this one percent increase in start emissions is the sole factor for increases in the total (start plus running) emissions illustrated in Figures 56 through 58.

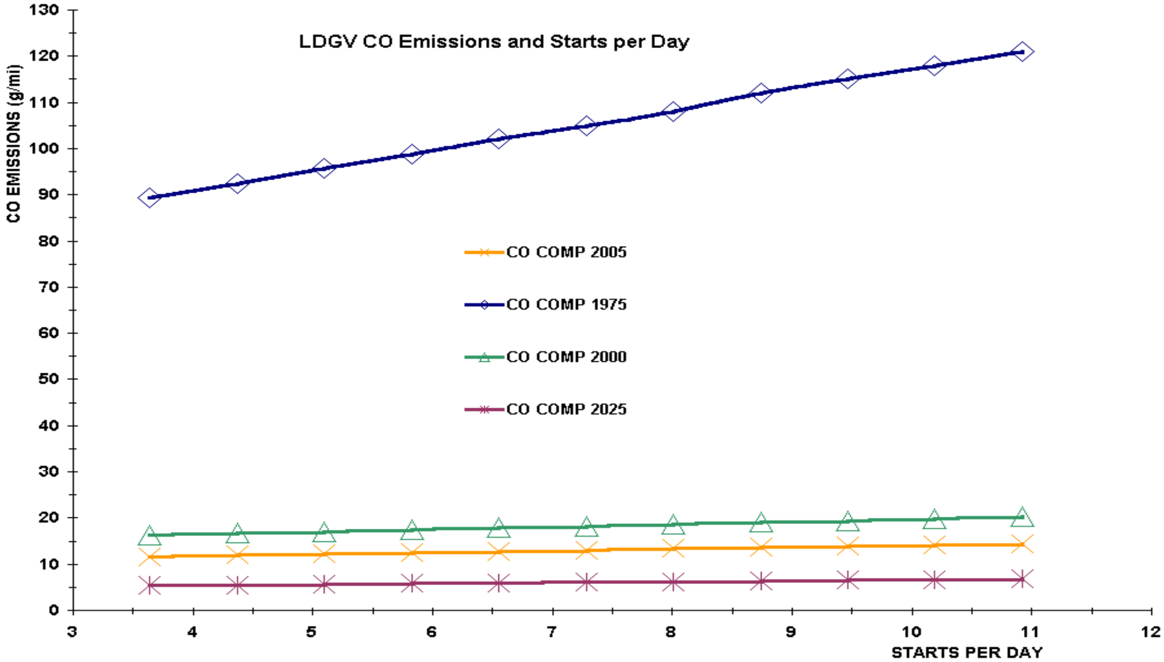


Figure 56. LDGV CO emissions as a function of the number of starts per day. These emissions include both start emissions and running emissions. (The percent change in start emissions increases by a one-to-one ratio with percent increase in the MOBILE6 deault number for Starts Per Day.)

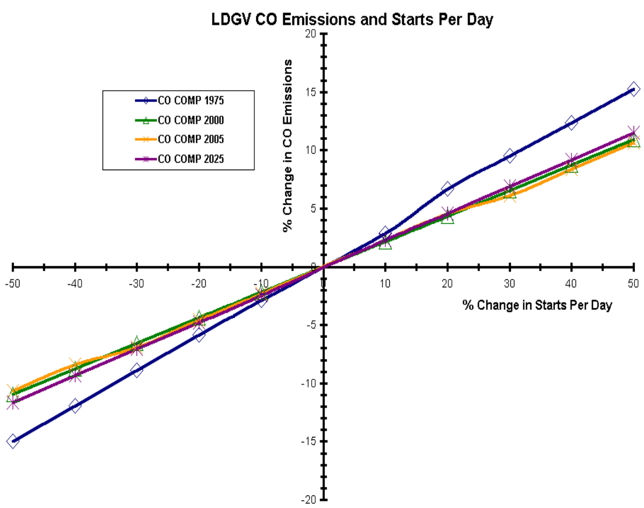


Figure 57. Percent increase in LDGV CO (running plus start) emissions as a function of the percent change in default MOBILE6 start emissions.

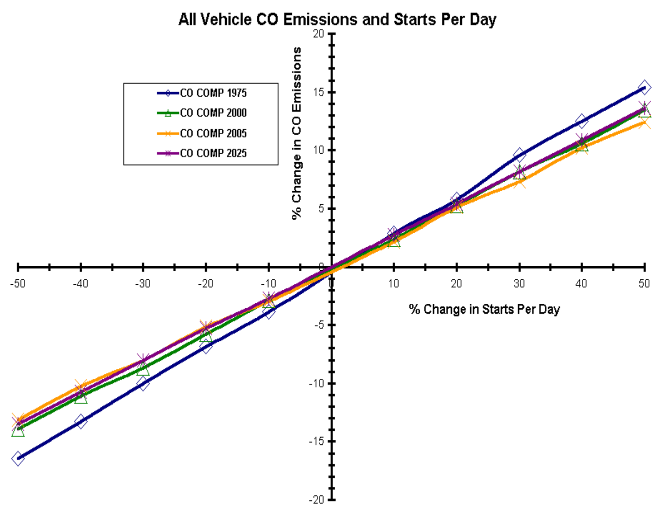


Figure 58. Percent increase in All Vehicles CO (running plus start) emissions as a function of the percent change in default MOBILE6 start emissions.

B.3 NOx EMISSIONS

This section discusses MOBILE6 commands which effect NOx emissions between 5 percent and 20 percent, i.e., medium or intermediate level commands. They are absolute humidity, air conditioning, altitude, and mileage accumulation.

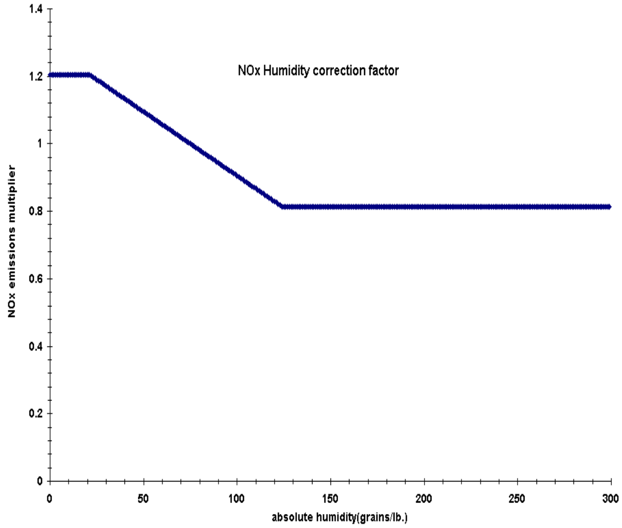
Absolute Humidity

High ambient air moisture or humidity levels suppress the creation of NOx emissions by reducing the available heat needed to create nitrogen oxides during the combustion process. All versions of MOBILE have contained an algorithm[10] to account for this NOX emissions reduction process. Figure 59 displays the MOBILE6 NOx humidity correction factor as a function of absolute humidity. (In many references the MOBILE6 absolute humidity is referred to as specific humidity. This quantity has units of grains of water per pound of air.) Also in Figure 59, the humidity correction affect on Light-Duty Gasoline Vehicle NOx emissions is displayed as a function of absolute humidity in grains/lb. These LDGV emissions results are for relative humidity values between about 33%(55 grains/lb. absolute humidity) and 90% (150grains/lb absolute humidity). A 20 degree Fahrenheit daily temperature cycle defined by minimum and maximum temperatures of 72 and 92, respectively, was used to compute the emissions. These values were taken from monthly average temperatures and humidity values in August for Tucson and Atlanta. The NOx emissions construe to the humidity correction factor. MOBILE6 assumes a default value for absolute humidity of 75 grains/lb. Figures 60 and 61 display the percent change in emissions from default values (determined with the default value of absolute humidity) as a function of the percent change in absolute humidity relative to the default value.

ABSOLUTE HUMIDITY is a new input parameter for MOBILE6 and only allows input of a single value of absolute humidity. (MOBILE6 has been updated to allow hourly values of humidity; see the discussion below.) However, as with the ambient temperature, this atmospheric parameter can vary from hour to hour during the day. Analysis of the temperature and humidity interdependency on MOBILE6 when using the ABSOLUTE HUMIDITY command showed that emissions variations of less than 5 percent (thus, falling into the category of "minor" effects). This is true for all pollutants, hydrocarbons, carbon monoxide, and oxides of nitrogen. Although details of the temperature-humidity interaction analysis will not be contained in this discussion, humidity when input through the ABSOLUTE HUMIDITY command does not effect CO, HC and NOx emissions strongly when considering variations in the daily average temperature. The ABSOLUTE HUMIDITY parameter only affects NOx emissions directly though the NOx correction factor which lowers NOx emissions at higher humidity values. Temperature and humidity do affect CO, HC, and NOx emissions indirectly through the air conditioning load affect which is discussed elsewhere.

Because relative humidity is the measure of air moisture content which is most readily available to the public, an additional humidity command, RELATIVE HUMIDITY, was added to MOBILE6. It allows input of hourly relative humidity values. Internally, MOBILE6 converts the relative humidity values to absolute humidity using hourly temperature values and an average daily value of barometric pressure which has a default value of 29.92 inches of mercury, i.e., barometric pressure at sea level. Along with the relative humidity values, barometric pressure can also be varied with the BAROMETRIC PRES command.

For a given value of relative humidity, varying barometric pressure and temperature, of course, varies the absolute humidity. This subject is usually referred to as psychrometry[11,12,13] and the graphical representation of these relationships is called a psychrometric chart. In Figure 62, a few curves depicting the relationship between temperature, absolute humidity, and pressure are illustrated. The mathematical form of the dependencies are derived from the thermodynamics of ideal gases and partial pressure



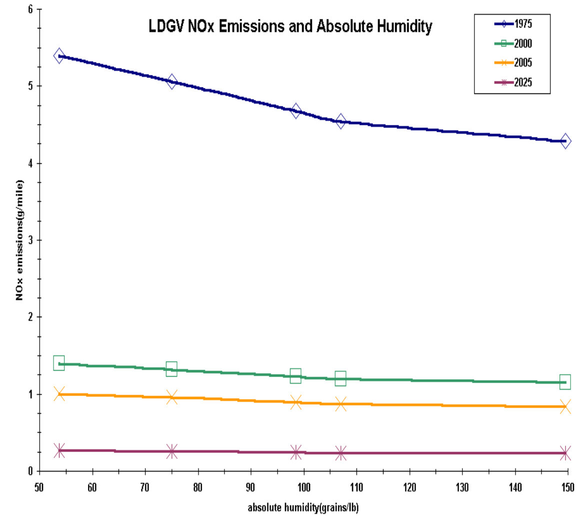


Figure 59.

(a.) MOBILE6 NOx humidity correction factor as a function of absolute humidity.

(b.) MOBILE6 LDGV NOx emissions as a function of absolute humidity for calendar years 1975, 2000, 2005, and 2025. An absolute humidity value of 75 grains of water per pound of dry air is the MOBILE6 default value of absolute humidity.

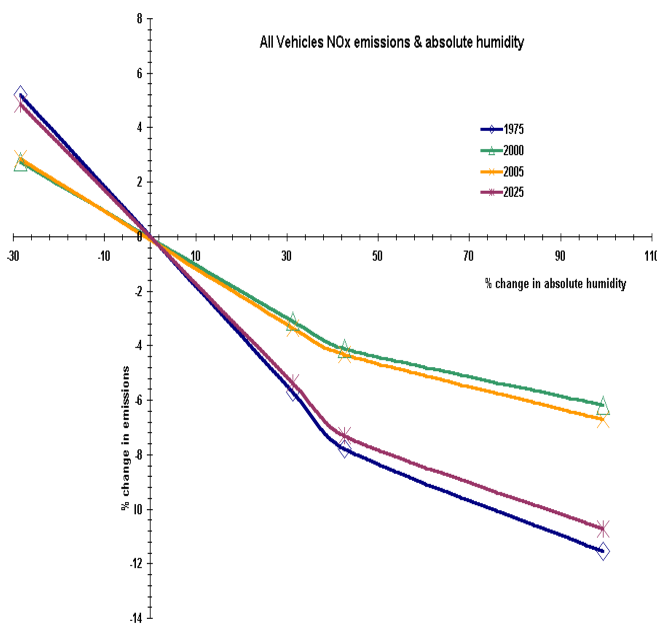


Figure 60. Percent change in MOBILE6 All Vehicle types NOx emissions as a function of the percent change in absolute humidity from the default value of 75 grains/pound.

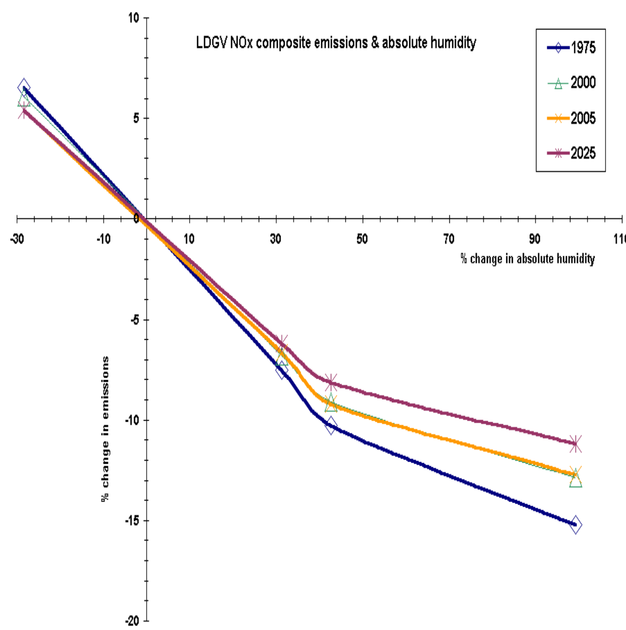


Figure 61. Percent change in MOBILE6 Light-Duty Gasoline Vehicles NOx emissions as a function of the percent change in absolute humidity from the default value of 75 grains/pound.

relationships of mixtures of gases. Extending the curves over the entire range of pressures, temperatures, and humidity values would produce a psychrometric chart.

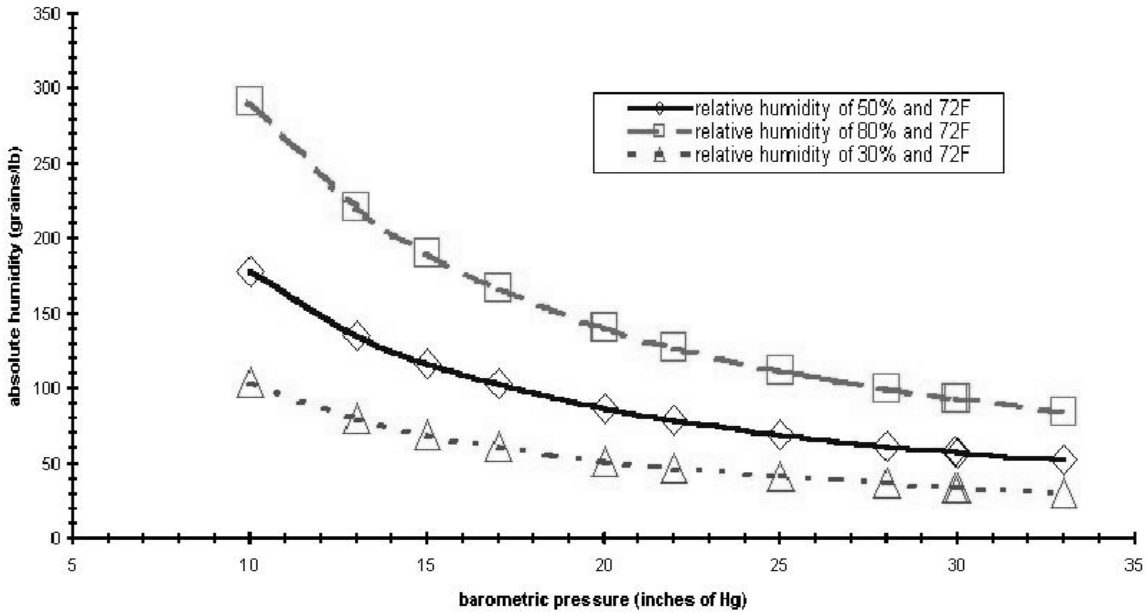


Figure 62. An Illustration of the relationship between absolute humidity and barometric pressure for three different values of relative humidity, 30%, 50%, and 80%. The temperature is held constant at 72°F. When this graphical representation of the dependence of specific or absolute humidity on temperature and pressure is extended for all temperatures and pressures, it is called a psychrometric chart.

Air Conditioning

NOx emissions with and without the MOBILE6 air conditioning correction applied are displayed in Figures 63 through 65 as a function of calendar year. As mentioned above in the section on air conditioning affects on CO emissions, part of the correction depends on air conditioning usage which is determined by a heat index. Hence, the MOBILE6 air conditioning correction depends on temperature range and absolute humidity values. For this analysis, the temperature range used was 72°F to 92°F with an absolute humidity value of 75grains/lb. Figure 65 depicts the percent increase in emissions due to the MOBILE6 air conditioning correction as a function of calendar year. Although the NOx emissions decrease considerably in later calendar years, the proportion of NOx emissions due to air conditioning engine increases with calendar year for Light-Duty Gasoline Vehicles and for All Vehicle types as shown in Figure 65.

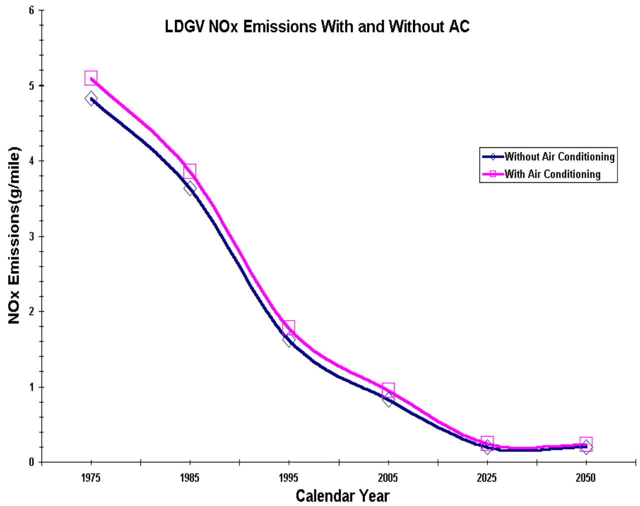


Figure 63. MOBILE6 air conditioning effects on LDGV NOx emissions as a function of calendar year.

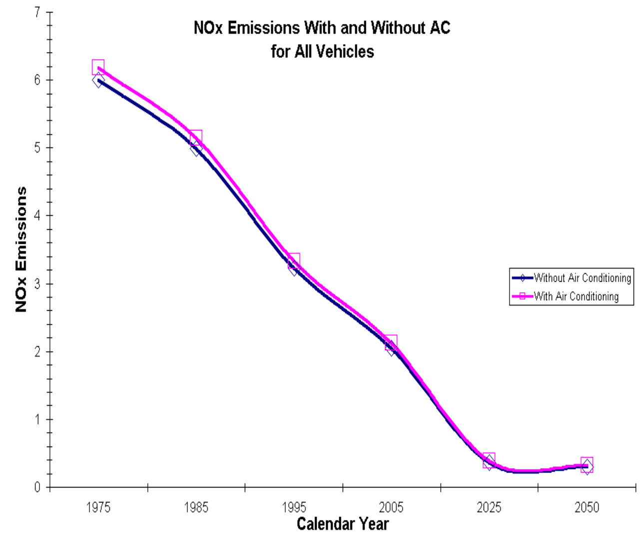


Figure 64. MOBILE6 air conditioning effects on All Vehicle NOx emissions as a function of calendar year.

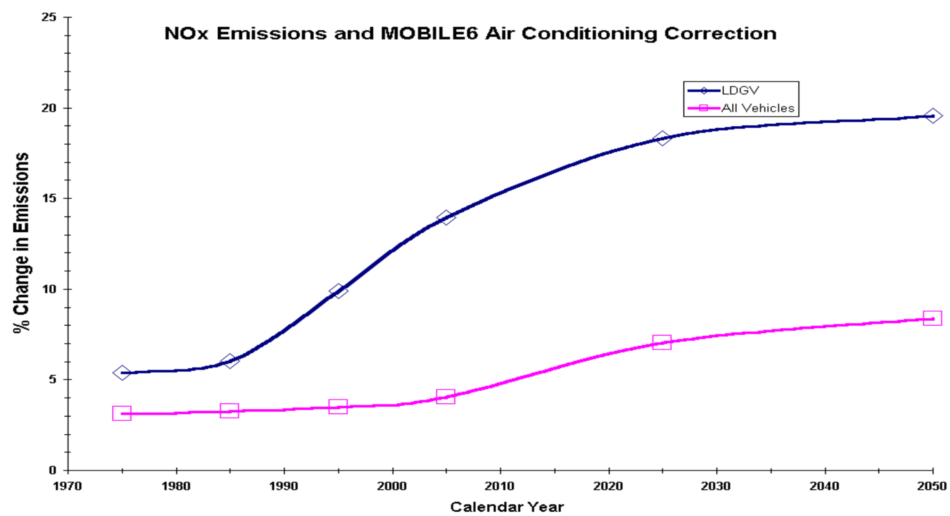


Figure 65. Percent difference in NOx emissions due to MOBILE6 air conditioning correction as a function of calendar year for both LDGV and and All Vehicles.

Altitude

MOBILE6 includes a choice for selecting the Altitude parameter. The two choices are, either high altitude or the default low altitude. The MOBILE6 CO emission comparisons for the low altitude (regions below 4,000 feet[10]) and high altitude regions are shown in Figures 66, 67, and 68 for both Light-Duty Gasoline Vehicles and All Vehicle types.

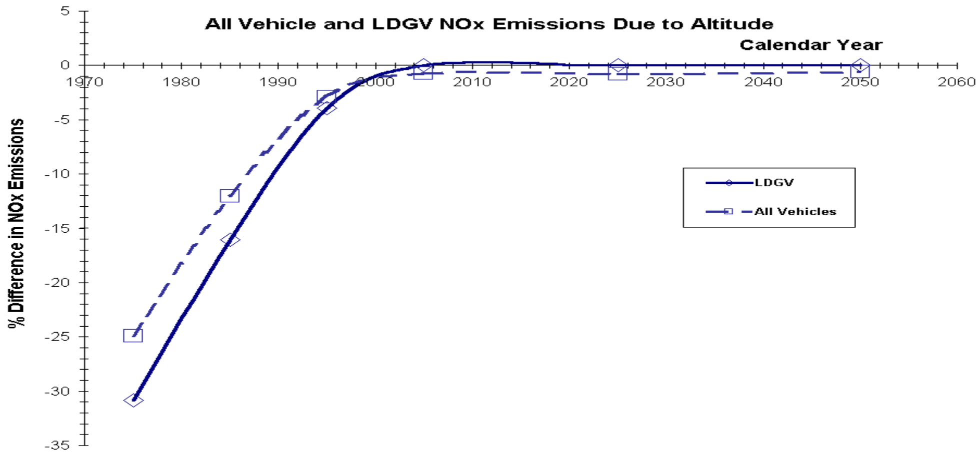


Figure 66. Percent difference in NOx emissions due to MOBILE6 altitude correction as a function of calendar year for both LDGV and All Vehicle types.

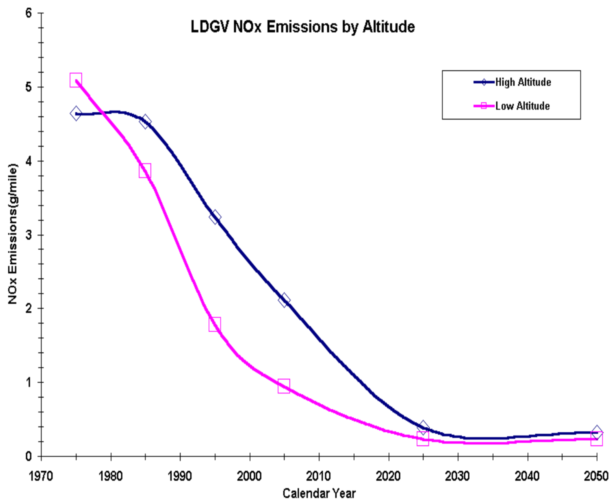


Figure 67. MOBILE6 altitude effects on LDGV NOx emissions as a function of calendar year.

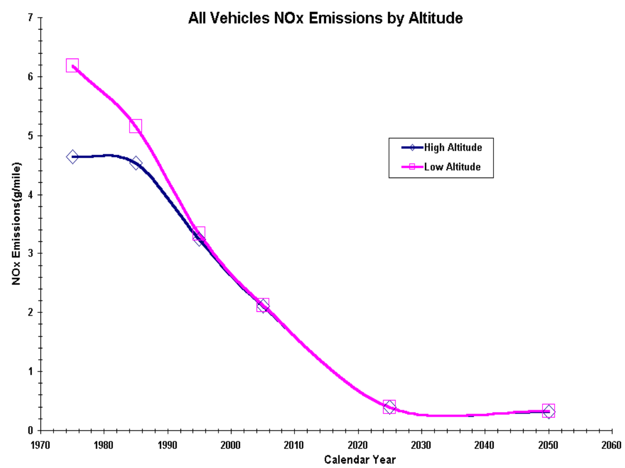


Figure 68. MOBILE6 altitude effects on All Vehicle types NOx emissions as a function of calendar year.

Mileage Accumulation

Mileage for each of the 28 different vehicle classes is stored in MOBILE6 by calendar year. That is, each vehicle class has a 25-year set of mileage rates. Vehicles are classified by age and the age determines usage or mile traveled. Figure 53 displays the default MOBILE6 Light-Duty Gasoline Vehicle mileage as a function of vehicle age; they are displayed with a dark blue line and open circles. Figure 53 also displays how the mileage for each vehicle age was changed to determine the emissions dependence on mileage accumulation. In 5 percent increments of the default mileage values, mileage was added to and subtracted from the default MOBILE6 mileage values. To determine the NOx emissions dependence this was duplicated for each of the different MOBILE6 vehicle categories and then emissions were estimated using MOBILE6 with all of the vehicle mileage changed by a given incremental 5 percent change.

For five specific calendar years, Figure 69 shows the trend in Light-Duty Gasoline Vehicle gram/mile NOx emissions relative to percent increase/decrease in vehicle mileage as displayed in Figure 53. Figures 70 and 71 display the results for Light-Duty Gasoline Vehicles and for All Vehicle types in terms of percent changes in NOx emissions versus percent change in mileage. (Again, the lines are drawn to guide the reader's eyes.) In general, the trend shows a nearly linear increase/decrease in NOx emissions with increases/decreases in mileage for each of the calendar years, 1975,1995, 2000, 2005, and 2025, as shown in the graphs. NOx emissions for both the All Vehicles and the Light-Duty Gasoline Vehicles categories show similar functional dependence on mileage.

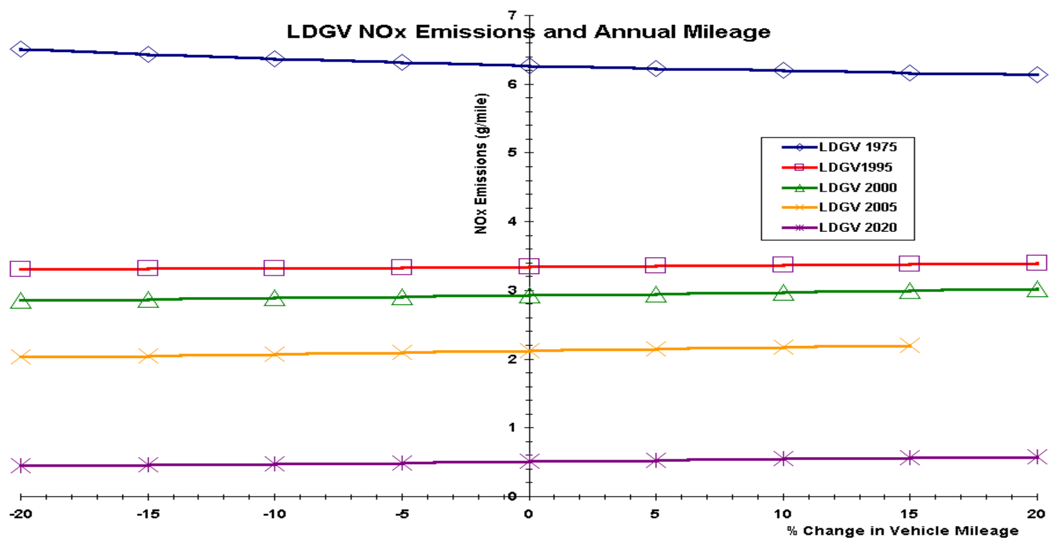


Figure 69. Light-Duty Gasoline Vehicle grams/mile emissions as a function of the percent change in Light-Duty Gasoline Vehicle mileage.

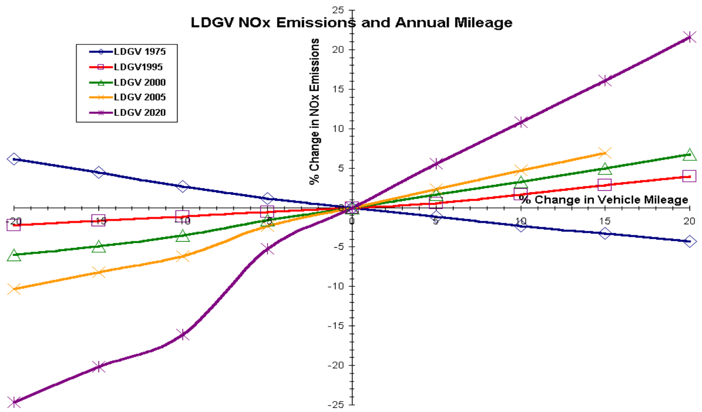


Figure 70. Percent change in LDGV NOx emissions as the default mileage is changed. Figure 53 illustrates how the mileage changed from the MOBILE6 LDGV default mileage.

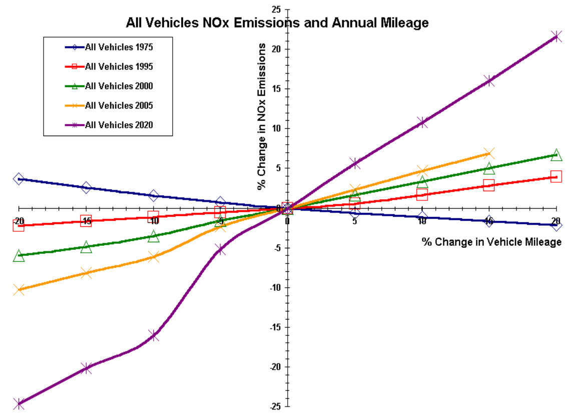


Figure 71. Percent change in All Vehicle NOx emissions as the default mileage is changed for All Vehicle types. See Figure 53 for an illustration of how the mileage were varied relative to the MOBILE6 default values.

C. PARAMETERS WITH MINOR EFFECTS ON EMISSIONS (LESS THAN 5%)

The third and last category of MOBILE6 parameters which have a "minor" (i.e., less than 5%) effect on emissions are listed in Table 3 below. A complete list of the MOBILE6 commands and a description of how the inputs were changed is listed in the Appendix, Table A.2. Because of the relatively small emissions effects the general trends are listed in the table but are not graphically illustrated.

Table 3. List of low level MOBILE6 commands or parameters

HC Emissions :	**CO Emissions :**	**NOx Emissions :**
Absolute Humidity	Absolute Humidity	Facility VMT
Air Conditioning	Facility VMT	Fuel Program/Sulfur Content*
Facility VMT	Fuel Program/Sulfur Content*	Fuel RVP
Fuel Program/Sulfur Content*	Hourly Temperature	Hourly Temperature
Hourly Temperature	Oxygenated Fuels	Oxygenated Fuels
Mileage Accumulation	Sulfur Content*	Sulfur Content*
Oxygenated Fuels	Start Distribution	Start Distribution
Sulfur Content*	Temperature Cycles	Temperature Cycles
Start Distribution	Temperature and Humidity	Temperature and Humidity
Temperature Cycles		
Temperature and Humidity		

* In MOBILE6 sulfur content of fuel can be changed in two different calendar year ranges, (1) calendar years less than or equal to 1999 and (2) calendar years greater than 1999. The Fuel Program/Sulfur Content command is used for post 1999 calendar years and the Sulfur Content is used for calendar years1999 and earlier. Sulfur content deteriorates the catalyst. Its effects on hydrocarbon, carbon monoxide, and nitrogen oxide emissions are small. However, it enables the production of sulfur oxides and particulate matter which is not within the scope of this report.

CONCLUSIONS

A thorough examination of the relationship between MOBILE6 input parameters and the relative importance each has on MOBILE6 CO, HC, and NOx emissions estimations has been undertaken. Each parameter evaluated was varied and the resulting MOBILE6 emissions were compared to emissions determined with default or some base value input. These results were then subdivided into three categories, major effects, intermediate effects, and minor effects on emissions. There are four MOBILE6 input parameters, Vehicle Age or Registration Distribution, Average Daily Temperature, fuel RVP, and vehicle speed when changed via the Average Speed command, which fall into the major affects (changes in emissions of 20% or more relative to the emissions calculated with default input values) category. The major affects category has the additional caveat that the emissions percent change-to-input percent change must be greater than or equal to one. Seven Mobile6 input parameters, Absolute Humidity, Air Conditioning, Altitude, Mileage Accumulation, Speed VMT, and Starts Per Day, have intermediate affects (changes in emissions between 5% and 20% relative to the emissions calculated with default or a base input value). Lastly, depending on the pollutant there are about eight to ten input parameters which effect emissions at the minor level (changes in emissions of less than 5%). These latter parameters are listed in Table 3 above.

This study was completed to facilitate the use of MOBILE6 and should be used in conjunction with MOBILE6 technical guidance documentation. It is meant to be a resource for MOBILE6 users so that they can (a) better evaluate how MOBILE6 input parameters affect the emissions results, (b) formulate well informed emissions reductions programs through the use of MOBILE6, and (c) efficiently make accurate emissions inventories by paying attention to how inputs affect emissions and what local data may be important when using MOBILE6 to make emissions estimations.

APPENDIX

Table A.1. Summary of the LDGV results.

COMMAND	Change in Input		Change in Hydrocarbon emissions	Change in CO emissions	Change in Oxides of Nitrogen emissions
Absolute Humidity [Use high and low humidity values from August morning and afternoon average relative humidity values from Atlanta and Tucson (National Weather Service data).]	min.	-28% (54grains/lb)	(NMHC) <-1% ldgv total:<0.5%	ldgv running -1.9%(2000) to -0.6%(2025)	ldgv running 5%(2025) to 6%(1975)
	max.	100% (149grains/lb)	(NMHC) ldgv running:4% ldgv total:<0.5%	ldgv running 2.3%(2025) to 8.4%(2000)	ldgv running -14%(1975) to -10%(2025)
Air Conditioning	Emissions Differences with Air Conditioning Correction Applied and Not Applied		2%(1975) 2%(2005) 0%(2025)	16%(1975) 20%(2005) 5%(2050)	5%(1975) 10%(19995) 18%(2025)
Altitude	Emissions Differences Between High Altitude and Low Altitude		26%(1975) 4%(1995) <1%(2025))	41%(1975) 8%(1995) 0%(2005))	-31%(1975) -4%(1995) 0%(2005))
Average Speed (Arterial roadways)	min.	10mph	(VOC) 68%(1975) 83%(2025)	39%(1975) 18%(2000) 30%(2025)	26%(1975) 51%(2025)
		30mph		-6%(1975) -12%(2025)	-2%(1975) -6%(2025)
	max.	70mph	(VOC) -24%(2000) -29%(2025)	0%(1975) 21%(2000) 15%(2025)	-2%(1975) 0%(2025)
Average Speed (Area Wide roadways)	min.	10mph	(VOC) 73%(1975) 68%(2000) 81%(2025)	35%(1975) 14%(2000) 26%(2025)	19%(2025) 38%(2025)
	max.	35mph	(VOC) -12%	-3%(1975) 1%(2005) 0%(2025)	-3%
Average Speed (Freeways)	min.	10mph	(VOC) 74%(1975) 68%(2000) 81%(2025)	40%(1975) 28%(2025)	17%(1975) 32%(2025)
		35mph		-8%	-1%(1975) -5%(2025)
	max.	70mph	(VOC) -27%(1975) -22%(2000) -27%(2025)	0%(1975) 17%(2000) 13%(2025)	-2%(1975) 1%(2000) 0%(2025)
Facility VMT (Add and subtract fraction of vehicles to/from freeways and arterials: New_freeway + new_ramp=(old_freeway + old_ramp) + x*old_arterial New ramp= 0.08*(new_ramp + new_freeway) new_freeway=(0.92/0.08) * new_ramp New_arterial=(1-x)*old_arterial	min.	subtract 40% from arterials	(NMHC) -1%(1975) 0%(2000)	2%(1975) 4%(2000) 3%(2020)	1%(1975) 5%(2000) 2%(2020)
	max.	add 40% to arterials	(NMHC) 1%(1975) 0%(2007)	-1%(1975) -4%(2005) -3%(2020)	-1%(1975) -5%(2000) -2%(2020)
Fuel Program/Sulfur Content (calendar years 2000 and later; for default conventional eastern program reduce sulfur content by 10%, 20%, and 30%)	min.	-10%	(NMHC) -0.5% (2000) to 0%(2025)	-1.6%(2000) to -0.6%(2025)	-0.7%(2000) to 0%(2025)
	max.	-30%	(NMHC) -1.5%(2000) to -0.5%(2025)	-4.7%(2000) to -2%(2025)	-2.2%(2000) to -3.7%(2025)

Table A.1. Summary of the LDGV results. (Continued)

COMMAND	Change in Input		Change in Hydrocarbon emissions	Change in CO emissions	Change in Oxides of Nitrogen emissions
Fuel Reid Vapor Pressure(RVP) (The RVP was increased from 6.5lb/in^2 to 11.5lb/in^2 for a number of calendar years between 1975 and 2050 with minimum and maximum temperatures 72°F and 92°F, respectively. Percent differences were determined relative to 7.5lb/in^2)	min.	6.5lb/in^2	approx. -5% (1975-2025)	0% (1975-2025)	approx. 0% (1975-2025)
	max.	11.5lb/in^2	70%(2025) to 40%(1975)	107%(2025) to 2%(1975)	5%(2025) to 0%(1985)
Mileage Accumulation(increase and decrease mileage accumulation relative to the MOBILE6 defaults)	min.	20% decrease	(NMHC) 3%(1980) 5%(2005) 1%(2015) -2%(2020)	-2.5%(1985) to -11%(2020)	0%(1990) to -24%(2020)
	max.	20% increase	(NMHC) 1%(1990) -2%(2000) -3%(2005) 2%(2020)	1%(1980) to 9%(2020)	1%(1990) to 22%(2020)
Oxygenated Fuels (ether concentration from 1% to 2.7%; market share variations from 5% to 50%)	min.	5% mkt, 1%ether, 0% alcohol	(NMHC) 0%(2005&2020)	Approximately 0% (all years)	0%
	max.	50% mkt, 0%ether, 2.7% alcohol	(NMHC) -2% (2000) to -2%(2020)	-5%(2000) to -3%(2020)	0%
Oxygenated Fuels (alcohol concentration from 0.7% to 3.5%; market share variations from 5% to 50%)	min.	50% mkt, 0%ether, 0.7% alcohol	(NMHC) 1% (2000) to 2%(2020)	0.3%(2000) to 2%(2020)	0%
	max.	50% mkt, 0%ether, 3.5% alcohol	(NMHC) Approximately 0% (all years)	-5%(2000) to -2.5%(2020)	0%
Registration Distribution(decrease newer vehicle fractions and increase older vehicle fractions)	min.	5% age shift	(NMHC) 4%(1985) to 25%(2015)	2%(1980) to 16%(2000)	0%(1985) to 14%(2020)
	max.	20% age shift	(NMHC) 12%(1975) to 80%(2015)	7%(1975) 52%(1995) 24%(2020)	-1%(1980) to 50%(2020)
Speed VMT (Arterial; -3% - null low speed vehicle fractions 9% - equal vehicle fractions for all speeds 14% - increase low speed vehicle fraction by 10% 21% - increase low speed vehicle fraction by 20% 29% - increase low speed vehicle fraction by 30%)	min.	-3% (free-flow/ all day non-rush hour speeds)	(NMHC) -3%(all years)	3% (all years)	-1% to 0% (all years)
	max.	29%(congested traffic flow,i.e., 30% more vehicles at the lower speeds)	(NMHC) 32%(1985) to 44%(2050)	-2%(2005) to +3%(1975)	5%(1975) to 8%(2050)
Speed VMT (Freeway; reduce fraction of vehicles from high speeds to lower speeds)	min.	-50% (equal distribution of speeds)	(NMHC) +13%(1975) to 5%(2050)	3%(1975) to -2%(2005)	-1.1%(2050) to -0.5%(1985)
	max.	10%(most vehicles at the higher speeds)	(NMHC)- 3.5%(1975) to - 1%(2010)	< 0% and >-2%	+1.6%(1985) to 2%(2050)
Starts Per Day(change the number of starts per day from -50% to +50% in increments of 10% for each vehicle type)	min.	-50%	(NMHC) -17%(2025) to -12%(1975)	-15%(1975) to -11%(2025)	-13%(1975) to -7%(2025)
	max.	50%	(NMHC) 17%(2025) to 12%(1975)	11%(2025) to 15%(1975)	13%(1975) to 7%(2025)

Table A.1. Summary of the LDGV results. (Continued)

COMMAND	Change in Input		Change in Hydrocarbon emissions	Change in CO emissions	Change in Oxides of Nitrogen emissions
Start Distribution	compare emissions with default hourly start fractions to a constant fraction of starts for each hour of the day		(NMHC) 4.5%(1975) to 0.4%(2025)	3%(1975) to 0%(2025)	3%(1975) to 1%(2025)
Sulfur Content (calendar years 1999 and earlier)	min. (300ppm)	0%	(NMHC) 0% (1975) to -0.5%(1999)	0%(1975) to -1%(1999)	0%(1975) to -1%(1999)
	max. (30ppm)	-90%	(NMHC) 0% (1975) to -3.5% (1999)	0%(1975) to -1%(1999)	0%(1975) to -7%(1999)
Temperature, Average Daily (standard temperature cycle and vary average daily temperature 12°F to 107°F)	min.	12°F	(NMHC) 10%(2025) 37%(1995) -13%(1975)	-6%(1975) to 216%(2025)	49%(1975) to 19%(2025)
	max.	107°F	(NMHC) 0%(2025) 24%(1995) -34%(1975)	63%(1975) to 2%(2025)	-19%(1975) to 15%(2025)
Temperature Cycles (keep average daily temperature a constant and vary the standard temperature cycle)	min.	constant temperature (-100%)	(NMHC) -3%(1975,102°F) -2%(1975,42°F) 14%(2025,102°F) -1%(2025,42°F) -8%(2005,82°F)	-11%(1975,102°F) -2%(1975,42°F) -0.5%(2025, 102°F) 5%(2025,42°F) 5%(2005,42°F)	5%(1975,102°F) 1%(1975,42°F) -1.4%(2025,102°F) 1%(2025,42°F) -8%(2025,75°F)
	max.	34°F temperature range (+42%)	(NMHC) 3%(1975,102°F) 2%(1975,42°F) 3%(2025,102°F) 2%(2025,42°F) 6%(2005,82°F)	4%(1975,102°F) 1%(1975,42°F) -0.3%(2025, 102°F) -2%(2025,42°F) -2%(2005,42°F)	-1%(1975,102°F) -1%(1975,42°F) -1%(2025,102°F) -1%(2025,42°F) 8%(2025,75°F)
Temperature, Hourly (hourly temperatures using temperature cycle variations: The percent differences here are for a given hour of the day and model year. They are not results which have been averaged over an entire day. The daily averages tend to lessen the effects.)	min.	constant temperature (-100%)	(NMHC) 12% to -13% (102°F)	-35%((102°F) to 27%(92°F)	-24%(102°F) to 11%(92°F)
	max.	34°F temperature range (+42%)	(NMHC) -5%(102°F) to 3%(72°F)	-11%(92°F) to 7%(72°F)	-5%(92°F) to 4%(72°F)
Temperature, Average Daily and Humidity [For each of a set of daily average temperatures (42, 72, 82, 92, 102, and 107°F) with a 24°F temperature range (the difference between the minimum and maximum temperatures is 24°F) variations of absolute humidity are made. Emission results are determined and compared for each of these average daily temperatures with the absolute humidity set to 53.7, 75, 98.5, 107, and 149.5 grains/lb. for a range of calendar years.]	min.	-28% (54grains/lb)	(NMHC) –1% to 0% (all temperatures and all years)	–2% to 0% (all temperatures and all years)	6%(2025) 7%(2005) 7%(2000) 7%(1975)
	max.	100% (150grains/lb)	(NMHC) 0% to 1% (all temperatures and all years)	0% to 6% (all temperatures and all years)	-14%(2025) -15%(2005) -15%(2000) -16%(1975)

Table A.2. All Vehicle Summary

COMMAND	Change in Input		Change in Hydrocarbon emissions	Change in CO emissions	Change in Oxides of Nitrogen emissions
Absolute Humidity [Use high and low humidity values from August morning and afternoon average relative humidity values from Atlanta and Tucson (National Weather Service data).]	min.	-28% (54grains/lb)	(NMHC) approx. 0%	-1%	5%(1975) 3%(2005)
	max.	100% (149grains/lb)	(NMHC) approx. 0%	3%(1975) 4%(2000) 1%(2025)	-11%(1975) -7%(2005) -11%(2025)
Air Conditioning	Differences Due to MOBILE6 Air Conditioning Correction		(NMHC) 1%(1975) 1%(2005) 0%(2050)	11%(1975) 13%(2005) 4%(2050)	3%(1975) 4%(2005) 8%(2050)
Altitude	Emission Differences Between High Altitude and Low Altitude		(NMHC) 26%(1975) 10%(1995) 7%(2005)	41%(1975) 17%(1995) 10%(2005)	-25%(1975) -3%(1995) -1%(2005)
Average Speed (Arterial roadways)	min.	10mph	(VOC) 69%(2000) 75%(2025)	43%(1975) 26%(2000) 32%(2025)	22%(1975) 20%(2000) 32%(2025)
		35mph	-11%	-11%	-5%(1975) -12%(2000) -8%(2025)
	max.	65mph	(VOC) -28%(1975) -24%(2025)	0%(1975) 17%(2000) 15%(2025)	13%(1975) 23%(2000) 17%(2025)
Average Speed (Area Wide roadways)	min.	10mph	(VOC) 72%	40%(1975) 23%(2000) 28%(2025)	17%(1975) 24%(2025)
	max.	35mph	(VOC) -10%	-4%(1975) 0%(2005) 0%(2025)	-2%
Average Speed (Freeways)	min.	10mph	(VOC) 75%(1975) 68%(2005) 72%(2025)	39%(1975) 26%(2000) 28%(2025)	16%(1975) 25%(2000) 21%(2025)
		35mph	-9%	-8%	-5%(1975) 0%(2000) -6%(2025)
	max.	65mph	(VOC) -26%(1975) -22%(2025)	0%(1975) 17%(2000) 13%(2025)	10%(1975) 29%(2000) 14%(2025)
Facility VMT (Add and subtract fraction of vehicles to/from freeways and arterials: new_freeway + new_ramp=(old_freeway + old_ramp) + x*old_arterial new ramp= 0.08*(new_ramp + new_freeway) new_freeway=(0.92/0.08) * new_ramp new_arterial=(1-x)*old_arterial	min.	subtract 40% from arterials	(NMHC) -1%(1975) -0.5%(2020)	1%(1975) 3%(2025)	1%(1975) 5%(2000) 2%(2020)
	max.	add 40% to arterials	(NMHC) 1%(1975) 0%(2007)	-2%(1975) -3%(2025)	-1%(1975) -5%(2000) -2%(2020)
Fuel Program/Sulfur Content (calendar years 2000 and later; for default conventional eastern program reduce sulfur content by 10%, 20%, and 30%)	min.	-10%	(NMHC) 0% (2010) to -0.5%(2000)	-0.2%(2010) to -1.3%(2000)	-0.4%(2000) to -0.5%(2025)
	max.	-30%	(NMHC) -0.05%(2010) to -1.4%(2000)	-0.7%(2010) to -4%(2000)	-1%(2000) to -2%(2025)
Fuel Reid Vapor Pressure(RVP) (The RVP was increased from 6.5lb/in^2 to 11.5lb/in^2 for a number of calendar years between 1975 and 2050 with minimum and maximum temperatures 72°F and 92°F, respectively. Percent differences were determined relative to 7.5lb/in^2)	min.	6.5lb/in^2	-3%(1985) to -6%(2005)	0% (1975-2050)	approx. 0%
	max.	11.5lb/in^2	77%(2005) to 38%(1985)	101%(2050) to 2%(1975)	3%(2050) to -0.6%(1985)

Table A.2. All Vehicle Summary (Continued)

COMMAND	Change in Input		Change in Hydrocarbon emissions	Change in CO emissions	Change in Oxides of Nitrogen emissions
Mileage Accumulation(increase and decrease mileage accumulation relative to the MOBILE6 defaults)	min.	20% decrease	(NMHC) 3%(1980) 4%(2005) 3%(2015) 0.2%(2020)	–1.7%(1985) to -7.9%(2020)	3%(1990) to -12%(2020)
	max.	20% increase	(NMHC) 1%(1990) -1%(2000) 1%(2005) 3%(2020)	3%(1990) to 11%(2020)	-2%(1980) to 13%(2020)
Oxygenated Fuels (ether concentration from 1% to 2.7%; market share variations from 5% to 50%)	min.	5% mkt, 1%ether, 0% alcohol	(NMHC) approx. 0%	approx. 0%	0%
	max.	50% mkt, 0%ether, 2.7% alcohol	(NMHC) -2% (2000)to -3%(2020)	-5%(2000) to -3%(2020)	0%
Oxygenated Fuels (alcohol concentration from 0.7% to 3.5%; market share variations from 5% to 50%)	min.	50% mkt, 0%ether, 0.7% alcohol	(NMHC) approx. 1% (2000)to (2020)	<1% (2000) to (2020)	0%
	max.	50% mkt, 0%ether, 3.5% alcohol	(NMHC) -0.5% (2000)to -1%(2020)	-5%(2000) to -2%(2020)	0%
Registration Distribution(decrease newer vehicle fractions and increase older vehicle fractions)	min.	5% age shift	(NMHC) 5%(1985) to 31%(2015)	3%(1980) to 21%(2000)	1%(1985) to 12%(2020)
	max.	20% age shift	(NMHC) 13%(1975) to 74%(2015)	9%(1975) 47%(1995) 22%(2020)	1%(1980) to 38%(2020)
Speed VMT (Arterial; -3% - null low speed vehicle fractions 9% - equal vehicle fractions for all speeds 14% - increase low speed vehicle fraction by 10% 21% - increase low speed vehicle fraction by 20% 29% - increase low speed vehicle fraction by 30%)	min.	-3% (free-flow/ all day non-rush hour speeds)	(NMHC) -3%	approx. -1%	-3% to -0.5%
	max.	29%(congested traffic flow ;i.e., 30% of rush hour "free-flow" vehicles at the lower speeds)	(NMHC) 35%(1975) 33%(1985) 39%(2050)	21%(1975) 13%(2005) 15%(2020)	5%(1975) to 8%(2050)
Speed VMT (Freeway; reduce fraction of vehicles from high speeds to lower speeds)	min.	-50% (equal distribution of speeds)	(NMHC) 12%(1975) 10%(2020) 11%(2050)	+3%(1975) -1%(2000) 0%(2050)	0%(1975) -1%(1995) -2%(2005) 0%(2050)
	max.	10%(most vehicles at the higher speeds)	(NMHC) -4%(1975) -3%(1985) -4%(2050)	-3%(1975) -2%(1995) -1%(2020)	approx. -1%
Starts Per Day(change the number of starts per day from -50% to +50% in increments of 10% for each vehicle type)	min.	-50%	(NMHC) -17%(2025) to -13%(1975)	-16%(1975) to -13%(2025)	-10%(1975) to -7%(2025)
	max.	50%	(NMHC) 17%(2025) to 14%(1975)	14%(2025) to 15%(1975)	10%(1975) to 7%(2025)
Start Distribution	compare emissions with default hourly start fractions to a constant fraction of starts for each hour of the day		(NMHC) 0%(1975) to 3%(2025)	1%(1975) to 3%(2025)	2%(1975) to 1%(2025)

Table A.2. All Vehicle Summary (Continued)

COMMAND	Change in Input		Change in Hydrocarbon emissions	Change in CO emissions	Change in Oxides of Nitrogen emissions
Sulfur Content (calendar years 1999 and earlier)	min.	10%	(NMHC)-0.2% (1999) to 0%(1975)	-14%(1999) to 0%(1975)	3%(1999) to0%(1975
	max.	-90%	(NMHC)-4% (1999) to 0% (1975)	0.8%(1999) to 0% (1975)	0.3%(1999) to 0%(1975)
Temperature, Average Daily (standard temperature cycle and vary average daily temperature 12 to 107) F)	min.	12° F	17%(2025); 34%(1995) -6%(1975)	0%(1975) to 162%(2025)	41%(1975) to 22%(2025)
	max.	107° F	11%(2025) 26%(1995) 31%(1975	56%(1975) to 3%(2025)	-15%(1975) to7%(2025)
Temperature Cycles (keep average temperature a constant and vary the standard temperature cycle)	min.	constant temperature (-100%)	(NMHC) -3%(1975,42 °F) -2%(1975,102 °F) -8%(2000,82°F) 1%(2025,42 °F) 3%(2025,102°F)	-11%(1975, 102°F) -1%(1975,42 °F) 6%(2025,42 °F) -1%(2025,102 °F)	1%(1975,42°F) 4%(1975,102°F) -1%(2025,102°F)
	max.	34° F temperature range (+42%)	1%(1975,42 °F) 2%(1975,102 °F) 6%(2005,82 °F) 1%(2025,42 °F) 3%(2025,102 °F)	0%(1975,42 °F) 5%(1975,72 °F) 3%(1975,102 °F) -2%(2025,42°F) 0%(2025,102 °F)	1%(1975,82°F) to -1%(2025,72°F)
Temperature, Average Daily and Humidity [For each of a set of daily average temperatures (42, 72, 82, 92, 102, and 107) F) with a 24) F temperature range (the difference between the minimum and maximum temperatures is 24) F) variations of absolute humidity are made. Emissions results are determined and compared for each of these average daily temperatures with the absolute humidity set to 53.7, 75, 98.5, 107, and 149.5 grains/lb.]	min.	-28% (54grains/lb)	(NMHC) <0% and >-1%(all temperatures and all years)	<1% and >-1%(all temperatures and all years)	5%(2025) 3%(2005) 3%(2000) 5%(1975)
	max.	100% (150grains/lb)	(NMHC) >0% and <1% (all temperatures and all years)	<4% and >0%(all temperatures and all years)	-12%(2025) -7%(2005) -6%(2000) -12%(1975)

Table A.3. Affects of the relative proportion Heavy and Light Duty Trucks (VMT MIX command) on emissions from Heavy and Light Duty Vehicles

COMMAND	Change in Input		Change in Hydrocarbon emissions	Change in CO emissions	Change in Oxides of Nitrogen emissions
VMT Mix (Effects on Light-Duty Trucks Emissions Only) (The vehicle miles traveled fractions for light-duty trucks 2 were increased and decreased while holding the total proportion of vehicle miles traveled by all light-duty trucks constant and equal to the MOBILE6 default values for calendar years 1975, 2000, 2005, 2007, and 2020)	Min.	all LDT vehicle miles traveled fractions equal (approx. a 55% decrease in LDT2 fractions)	(NMHC) LDGT 8%(1975) 13%(2020) LDDT 0%(1975) -21%(2000) 0%(2020)	LDGT 5%(1975) 12%(2000) 5%(2020) LDDT 0%(1975) -19%(2000) 0%(2020)	LDGT 4%(1975) 5%(2000) 18%(2020) LDDT 0%(1975) 4%(2000) 0%(2020)
	Max.	increase vehicle miles traveled fractions for LDT2 by 20%	(NMHC) LDGT -5%(1975) -2%(2000) -3%(2020) LDDT 0%(1975) 8%(2000) 0%(2020)	LDGT -3%(1975) -1%(2020) LDDT 0%(1975) 8%(2000) 0%(2020)	LDGT -3%(1975) -1%(2000) -3%(2020) LDDT 0%(1975) 4%(2000) 0%(2020)
VMT Mix (Effects on Heavy-Duty Truck Emissions Only) (The vehicle miles traveled fractions for heavy-duty vehicles were increased and decreased while holding the total proportion of vehicle miles traveled by all heavy-duty vehicles constant and equal to the MOBILE6 default values for calendar years 1975, 2000, 2005, 2007, and 2020)	Min.	all HDV vehicle miles traveled fractions equal (approx. a 60% decrease in HD2B and HD8B fractions)	(NMHC) HDGV 15%(1975) 37%(2000) 31%(2020) HDDV -10%(1975) -20%(2000) -15%(2020)	HDGV 19%(1975) 49%(2000) 15%(2020) HDDV -8%(1975) -28%92000) -17%(2020)	HDGV 19%(1975) 11%(2020) HDDV -7%(1975) -26%(2000) -17%(2020)
	Max.	increase vehicle miles traveled fractions for HDV2B and HDV8B by 20%	(NMHC) HDGV 0%(1975) -6%(2000) -5%(2020) HDDV 0%(1975) 4%(2000) 3%(2020)	HDGV 0%(1975) -8%(2000) -2%(2020) HDDV 0%(1975) 6%(2000) 4%(2020)	HDGV 0%(1975) -2%(2020) HDDV 0%(1975) 5%(2000) 4%(2020)

Table A.4. Summary of LDGV results with input parameters which have minor (small) effects on emissions (changes which are less than 5%).

COMMAND	Change in Input		Change in Hydrocarbon emissions	Change in CO emissions	Change in Oxides of Nitrogen emissions
Absolute Humidity [Use high and low humidity values from August morning and afternoon average relative humidity values from Atlanta and Tucson (National Weather Service data).]	min.	-28% (54grains/lb)	(NMHC) ldgv running <-1% ldgv total:<0.5%	ldgv running -1.9%(2000) to -0.6%(2025)	Medium Level
	max.	100% (149grains/lb)	(NMHC) ldgv running:4% ldgv total:<0.5%	ldgv running 2.3%(2025) to 8.4%(2000)	Medium Level
Air Conditioning	Emissions Differences with Air Conditioning Correction Applied and Not Applied		2%(1975) 2%(2005) 0%(2025)	Medium Level	Medium Level
Average Daily Temperature and Humidity [For each of a set of daily average temperatures (42, 72, 82, 92, 102, and 107°F) with a 24°F temperature range (the difference between the minimum and maximum temperatures is 24°F) variations of absolute humidity are made. Emission results are determined and compared for each of these average daily temperatures with the absolute humidity set to 53.7, 75, 98.5, 107, and 149.5 grains/lb. for a range of calendar years.]	min.	-28% (54grains/lb)	(NMHC) –1% to 0% (all temperatures and all years)	–2% to 0% (all temperatures and all years)	Medium Level
	max.	100% (150grains/lb)	(NMHC) 0% to 1% (all temperatures and all years)	0% to 6% (all temperatures and all years)	Medium Level
Facility VMT [Add and subtract fraction of vehicles to/from freeways and arterials: New_freeway + new_ramp=(old_freeway + old_ramp) + x*old_arterial New ramp= 0.08*(new_ramp + new_freeway) new_freeway=(0.92/0.08) * new_ramp New_arterial=(1-x)*old_arterial]	min.	subtract 40% from arterials	(NMHC) -1%(1975) 0%(2000)	2%(1975) 4%(2000) 3%(2020)	1%(1975) 5%(2000) 2%(2020)
	max.	add 40% to arterials	(NMHC) 1%(1975) 0%(2007)	-1%(1975) -4%(2005) -3%(2020)	-1%(1975) -5%(2000) -2%(2020)
Fuel Program/Sulfur Content (calendar years 2000 and later; for default conventional eastern program reduce sulfur content by 10%, 20%, and 30%)	min.	-10%	(NMHC) -0.5% (2000) to 0%(2025)	-1.6%(2000) to -0.6%(2025)	-0.7%(2000) to 0%(2025)
	max.	-30%	(NMHC) -1.5%(2000) to -0.5%(2025)	-4.7%(2000) to -2%(2025)	-2.2%(2000) to -3.7%(2025)
Hourly Temperature (hourly temperatures using temperature cycle variations: The percent differences here are for a given hour of the day and model year. They are not results which have been averaged over an entire day. The daily averages tend to lessen the effects.)	min.	constant temperature (-100%)	(NMHC) 12% to -13% (102°F)	-35%((102°F) to 27%(92°F)	-24%(102°F) to 11%(92°F)
	max.	34°F temperature range (+42%)	(NMHC) -5%(102°F) to 3%(72°F)	-11%(92°F) to 7%(72°F)	-5%(92°F) to 4%(72°F)
Mileage Accumulation(increase and decrease mileage accumulation relative to the MOBILE6 defaults)	min.	20% decrease	(NMHC) 3%(1980) 5%(2005) 1%(2015) -2%(2020)	Medium Level	Medium Level
	max.	20% increase	(NMHC) 1%(1990) -2%(2000) -3%(2005) 2%(2020)	Medium Level	Medium Level

Table A.4. Summary of LDGV results with input parameters which have minor (small) effects on emissions (changes which are less than 5%). (Continued**)**

COMMAND	Change in Input		Change in Hydrocarbon emissions	Change in CO emissions	Change in Oxides of Nitrogen emissions
Oxygenated Fuels (ether concentration from 1% to 2.7%; market share variations from 5% to 50%)	min.	5% mkt, 1%ether, 0% alcohol	(NMHC) 0%(2005& 2020)	Approximately 0% (all years)	0%
	max.	50% mkt, 0%ether, 2.7% alcohol	(NMHC) -2% (2000) to -2%(2020)	-5%(2000) to -3%(2020)	0%
Oxygenated Fuels (alcohol concentration from 0.7% to 3.5%; market share variations from 5% to 50%)	min.	50% mkt, 0%ether, 0.7% alcohol	(NMHC) 1% (2000) to 2%(2020)	0.3%(2000) to 2%(2020)	0%
	max.	50% mkt, 0%ether, 3.5% alcohol	(NMHC) Approximately 0% (all years)	-5%(2000) to -2.5%(2020)	0%
Speed VMT (Arterial; -3% - null low speed vehicle fractions 9% - equal vehicle fractions for all speeds 14% - increase low speed vehicle fraction by 10% 21% - increase low speed vehicle fraction by 20% 29% - increase low speed vehicle fraction by 30%)	min.	-3% (free-flow/ all day non-rush hour speeds)	High Level	3% (all years)	-1% to 0% (all years)
	max.	29%(congested traffic flow,i.e., 30% more vehicles at the lower speeds)	High Level	-2%(2005) to +3%(1975)	5%(1975) to 8%(2050)
Speed VMT (Freeway; reduce fraction of vehicles from high speeds to lower speeds)	min.	-50% (equal distribution of speeds)	Medium Level	3%(1975) to -2%(2005)	-1.1%(2050) to -0.5%(1985)
	max.	10%(most vehicles at the higher speeds)	(NMHC)- 3.5%(1975) to -1%(2010)	< 0% and >-2%	+1.6%(1985) to 2%(2050)
Start Distribution	Compare emissions with default hourly start fractions to a constant fraction of starts for each hour of the day		(NMHC) 4.5%(1975) to 0.4%(2025)	3%(1975) to 0%(2025)	3%(1975) to 1%(2025)
Sulfur Content (calendar years 1999 and earlier)	min. (300ppm)	0%	(NMHC) 0% (1975) to -0.5%(1999)	0%(1975) to -1%(1999)	0%(1975) to -1%(1999)
	max. (30ppm)	-90%	(NMHC) 0% (1975) to -3.5% (1999)	0%(1975) to -1%(1999)	0%(1975) to -7%(1999)
Temperature Cycles (keep average daily temperature a constant and vary the standard temperature cycle)	min.	Constant temperature (-100%)	(NMHC) -3%(1975,102·F) -2%(1975,42·F) 14%(2025,102·F) -1%(2025,42·F) -8%(2005,82·F)	-11%(1975,102·F) -2%(1975,42·F) -0.5%(2025, 102·F) 5%(2025,42·F) 5%(2005,42·F)	5%(1975,102·F) 1%(1975,42·F) -1.4%(2025,102·F) 1%(2025,42·F) -8%(2025,75·F)
	max.	34·F temperature range (+42%)	(NMHC) 3%(1975,102·F) 2%(1975,42·F) 3%(2025,102·F) 2%(2025,42·F) 6%(2005,82·F)	4%(1975,102·F) 1%(1975,42·F) -0.3%(2025, 102·F) -2%(2025,42·F) -2%(2005,42·F)	-1%(1975,102·F) -1%(1975,42·F) -1%(2025,102·F) -1%(2025,42·F) 8%(2025,75·F)

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