

**Annual Average vs Monthly Average Values for
Selected Inputs to MOBILE6 – Effect on an Annual
Emissions Inventory**

Paper # 173

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ABSTRACT

In many urban areas, on-road vehicles are the biggest contributing source category of VOCs and NO_x. Based on a recently completed emission inventory study for three counties in Central Florida, the major source by far of anthropogenic VOCs and NO_x was on-road mobile sources, even though other sources (such as construction equipment, lawn and garden equipment, and various point sources) were also significant. Although there is specific guidance for conducting an ozone-season inventory for mobile sources, there is a lack of detailed guidance as to how to employ EPA's latest mobile source emission factor program, MOBILE6, for an annual inventory. Several of the MOBILE6 inputs that significantly influence emission factors (e.g., temperature) can vary widely throughout the year, and the annual average value may not be appropriate. Rather it may be better to utilize monthly values of these parameters. This paper investigates the sensitivity of the annual emission inventory results to using annual or monthly values of temperature, RVP of gasoline, and humidity.

INTRODUCTION

EPA's most recent mobile source model is MOBILE6.^{1,2} Most states were required to begin using MOBILE6.0 by the end of 2002 for SIP and conformity processes,³ and MOBILE 6.1/6.2 essentially duplicates MOBILE6.0 results for CO, VOCs, and NO_x, and extends its capabilities to PM and air toxics. Several authors have investigated the sensitivity of MOBILE6 to its input parameters. Gianelli, et al⁴ studied the sensitivity of MOBILE6 to 20 different inputs, and found that vehicle registrations, ambient temperature, and average speed all had major effects on the emission factors for all three pollutants. Also, major effects on VOCs and CO were reported for fuel RVP. Humidity was among the inputs that were reported to have intermediate effects on NO_x. Tang et al⁵ found that MOBILE6 results were most sensitive to speeds, and VMT distribution on roadway types, but that environmental factors such as temperature and humidity had important effects. Swisher and Hallmark⁶ tested the sensitivity of MOBILE6 to such inputs as min/max temperatures, average speed, vehicle age distribution, and starts per day.

There are at least two kinds of emission inventories: an ozone-season inventory, and an annual inventory. An ozone season inventory is useful for modeling of ozone

episodes and for identifying control measures that might be employed to reduce the risk of ozone exceedances, while annual inventories are required for state SIPs, and are used by EPA in preparing their annual national emissions report.⁷

For the ozone season inventory, the guidance is specific about how to obtain weather data – namely, to choose the 10 days with the past three years with the 10 highest ozone concentrations.⁸ The min/max temperatures and humidities that are input into MOBILE6 are based on those 10 highest ozone days. We were not able to find specific EPA guidance regarding these inputs for MOBILE6 for an annual inventory. Also, other authors have acknowledged that such guidance is missing.^{9,10} One approach that is followed is to simply use annual average values for each variable to cover the whole year.¹¹ However, another approach is to use monthly average values.¹²

For a regional emission inventory analysis using MOBILE6, it is not necessary to choose an average speed or to specify roadway types, because a distribution of speeds and roadway types is built into MOBILE6. In some areas (such as counties near national parks), vehicle mix may change substantially from season to season, and this may have a significant effect on emission factors.¹³ However, in every part of the country, ambient temperatures and/or humidity can change significantly from month to month; perhaps this variation should be modeled more closely in state SIPs.

MOBILE6 predicts that vehicle emission factors (EFs) exhibit minimums at certain temperature ranges. As an example, using typical central Florida inputs, MOBILE6 was run repeatedly to generate curves to display the variability of EFs with temperature and RVP. Minimums occur at around 60-80 °F for CO and NO_x, and around 30-50 °F for VOCs. Also, VOC and CO EFs increase by more than 100% and 50%, respectively, as RVP increase from 6.5 to 15 psi. Figures 1 and 2 display these data in the usual way (holding all other variables constant). It is possible that the annual average temperature of a region could be close to the temperature of minimum emissions, yet most (perhaps all) of the monthly EFs (reflecting the min/max temperatures of each month) could be higher than the average annual EF. Therefore, the choice of input values for these parameters might significantly affect the inventory.

BACKGROUND

An annual emission inventory was conducted for central Florida (3 counties): Orange, Seminole, and Osceola. According to the scope of this study, only VOCs and NO_x were considered, and only anthropogenic emissions were estimated. Biogenic emissions likely are substantial in these counties, but were excluded. On-road mobile sources were identified as the major contributors to emissions of both VOCs and NO_x. In performing the annual emission inventory, we followed available EPA guidance (EPA, 2001-EIIP), but it was not specific for on-road mobile sources. MOBILE6 was used, and monthly calculations were made to try to achieve higher accuracy because of the variability of temperature and humidity throughout the year (as discussed further in Methodology and Results in the following pages). A partial inventory (highlighting the largest sources) is shown in Tables 1 through 4.

Figure 1. Variability of MOBILE6 EFs with Min/Max Temperatures

Figure 1a. VOC and NOx Emission Factors (at constant RVP of 9.8 psi)

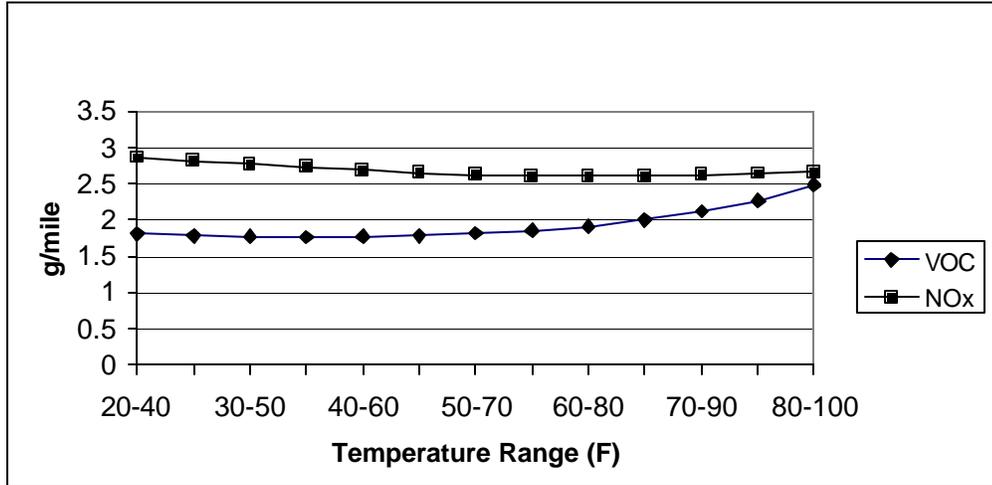


Figure 1b. CO Emission Factors (at constant RVP of 9.8 psi)

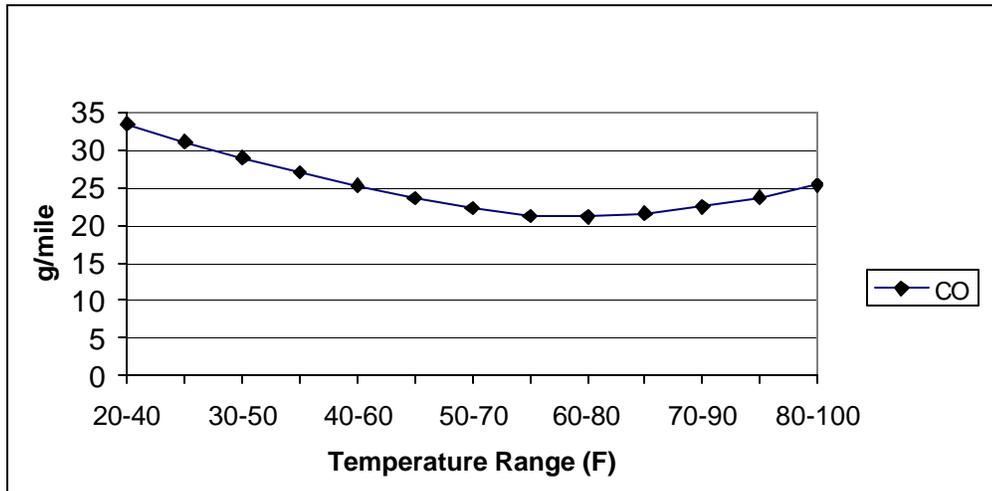


Figure 2. Variability of MOBILE6 EFs with gasoline RVP.

Figure 2a. VOC and NOx Emission Factors (at min/max T's of 62/82.6 °F)

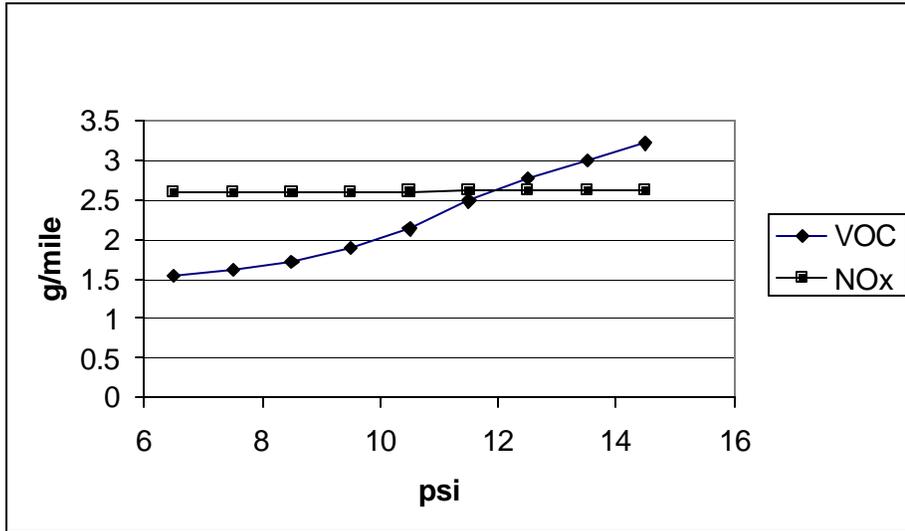


Figure 2b. CO Emission Factors (at min/max T's of 62/82.6 °F)

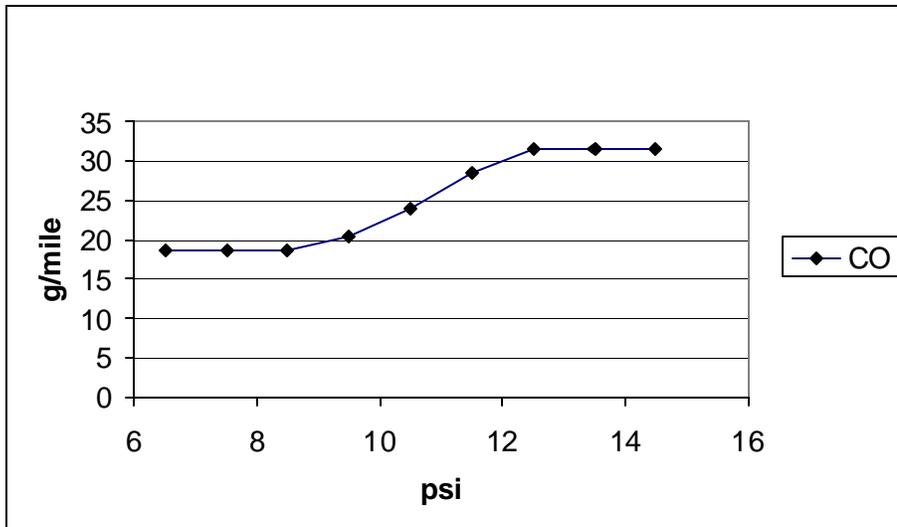


Table 1. VOC Emissions (tons/year) in Central Florida, 2002

	Orange	Osceola	Seminole	Total
Mobile sources*	33,766	7,605	10,306	51,677
Point sources	1,454	179	78	1,711
Area sources	17,412	8,474	5,312	31,198
Total (tons/year)	52,632	16,258	15,696	84,586

* includes on-road and non-road emissions

Table 2. Top sources of VOC emissions in Central Florida, 2002

Source	VOC (tons/year)	% of total emissions
On-road mobile sources	37,511	44.3 %
Non-road mobile sources, including:		
Commercial lawn & garden equipment	7,488	8.9 %
Construction/mining equipment	1,758	2.0 %
Residential lawn & garden equipment	1,088	1.3 %
Pleasure craft (motor boats, jet skis, etc)	1,434	1.7 %
All other non-road	2,399	2.8 %
Total non-road mobile sources	14,167	16.7 %
Consumer & commercial solvent use	6,004	7.1 %
Open burning and wildfires	5,192	6.1 %
Point Sources	1,711	2.0 %

Table 3. NO_x Emissions (tons/year) in Central Florida, 2002

	Orange	Osceola	Seminole	Total
Mobile sources*	44,739	9,495	13,456	67,690
Point sources	11,660	911	25	12,596
Area sources	35	59	9	103
Total (tons/year)	56,434	10,465	13,490	80,389

* includes on-road and non-road emissions

Table 4. Top sources of NO_x emissions in Central Florida, 2002

Source	NO _x (tons/year)	% of total emissions
On-road mobile sources	49,871	62.0 %
Non-road mobile sources, including:		
Construction & mining equipment	11,072	13.8 %
Commercial lawn & garden equipment	1,845	2.3 %
Aircraft	1,490	1.9 %
All other non-road	3,411	4.2 %
Total non-road mobile sources	17,818	22.2 %
Point sources *	12,596	15.7 %

* 82 % of all point source emissions of NO_x come from one large coal-fired power plant

METHODOLOGY and RESULTS

Historical meteorological data were gathered to obtain average monthly min/max temperatures, average humidities, and seasonal values of the RVP of gasoline in central Florida. These were input into MOBILE6 and month-specific EFs were obtained for VOCs and NO_x. In addition to evaluating the effects of monthly inputs for these three environmental factors, the effect of considering monthly vehicle miles traveled (VMT) was also investigated. Monthly VMTs were determined from the annual average daily traffic data obtained from the state DOT, and by using published FDOT weekly factors. Annual averages for the MOBILE6 input variables also were obtained. All these input data are shown in Table 5.

First, the emissions from on-road mobile sources were calculated using annual average values for all inputs. Next, the inventory was re-calculated using monthly inputs for the four sets of inputs that were being studied. The “big three” vehicle-related pollutants (VOCs, NO_x, and CO) were estimated for purposes of completeness in this paper. Table 6 shows the monthly emission factors and total emissions of each of the three pollutants. Note that with colder temperatures and higher RVPs, the CO emissions are highest in December through February. Also note that, despite the higher temperatures of summer, the VOC emissions decrease, and the CO emission factors decrease more than expected from looking at Figure 1. This somewhat counterintuitive result can be explained by the RVP effect, which is overshadowing the effect of temperature. For example, from February to March (and from May to June) there are big changes in emission factors with only small changes in temperature (see Tables 5 and 6).

Table 5. MOBILE6 Input Data – for each Month and for Annual Average

	Min Temp (F)	Max Temp (F)	Absolute Humidity (grains/lb)	RVP (psi)	VMT (mi/mo or mi/yr)
January	48.6	70.8	51	13.0	1,478,723,885
February	49.7	72.7	54	13.0	1,398,342,832*
March	55.2	78.0	65	9.2	1,553,798,824
April	59.4	83.0	78	9.2	1,513,722,547
May	65.9	87.8	95	9.2	1,519,126,676
June	71.8	90.5	117	7.8	1,429,387,729
July	73.1	91.5	123	7.8	1,457,844,404
August	73.4	91.5	124	7.8	1,467,127,445
September	72.4	89.7	120	9.2	1,365,613,627
October	65.8	84.6	95	9.2	1,450,322,392
November	57.5	78.5	72	9.2	1,401,929,203
December	51.3	72.9	55	13.0	1,451,303,280
Annual Avg.	62.0	82.6	87	9.8	17,487,242,844

* VMT is lower because there are only 28 days in February

Table 6. On-Road Mobile Source EFs and Emissions – based on Monthly Inputs and Annual Average Inputs

	VOC g/mi	NOx g/mi	CO g/mi	VOC tons/month	NOx tons/month	CO tons/month
January	2.398	2.799	26.775	3,910	4,563	43,653
February	2.456	2.776	26.728	3,786	4,280	41,207
March	1.797	2.701	19.210	3,078	4,627	32,909
April	1.846	2.650	19.198	3,081	4,423	32,040
May	1.890	2.560	19.544	3,166	4,288	32,734
June	1.727	2.481	18.651	2,722	3,910	29,393
July	1.746	2.465	18.925	2,806	3,962	30,419
August	1.746	2.462	18.955	2,824	3,982	30,661
September	1.938	2.475	19.978	2,918	3,726	30,080
October	1.834	2.549	18.940	2,933	4,076	30,286
November	1.674	2.505	17.917	2,587	3,872	27,694
December	2.312	2.601	25.623	3,699	4,162	41,000
Ann. Avg.	1.954	2.604	21.403	37,674	50,206	412,657

However, how does all this extra effort translate into the final annual inventory? Table 7 compares the final results for the mobile sources. As can be seen, the more accurate technique of using monthly input data resulted in slightly lower annual emissions, but the differences are not large (in fact the VOCs and NO_x were almost identical). The annual CO emissions were the most different at about 10,583 tons/year or about 2.6% of the total on-road emissions.

Table 7. Comparison of On-Road Mobile Source Inventories Using Monthly Average Input Data vs Annual Average Input Data

	VOC (tons/year)	NO _x (tons/year)	CO (tons/year)
Annual Average	37,674	50,206	412,657
Sum of Monthly Averages	37,511	49,871	402,074
Percent Difference	0.4 %	0.7 %	2.6 %

Interestingly, although the difference between the annual emissions estimate using annual average inputs or using monthly inputs is very small and not statistically significant, the monthly rates do vary significantly. Figure 3 compares the relative emission rates (RERs), defined as the ratio of each monthly emission rate to the annual average emission rate obtained from average annual inputs to MOBILE6, and demonstrates that, for central Florida, the relative emissions are higher in winter and lower in summer. A similar graph results from considering just the MOBILE6 EFs.

CONCLUSIONS

It is significantly more effort to gather and use monthly average data than to use annual average data for developing on-road mobile source emissions for an annual inventory. For Central Florida, there are only small differences in the results, which the authors conclude probably are not worth the extra effort. However, this study was of limited scope, and larger differences may occur in states that experience wider swings in temperature, and/or have significant differences in traffic in certain months. Indeed, because the EFs (especially for CO) increase nonlinearly with increasing temperature above 75 F and increase nonlinearly with decreasing temperature below 75 F, the authors expect that for areas with more extreme climates, the RERs would show more variation, and the total emissions based on monthly inputs will be greater than calculated by using a set of annual average inputs. However, in those cases, the development and use of RERs based on MOBILE6 EFs only would allow states and others to produce inventories using annual average inputs, and factor up as needed. The authors recommend that states and others should calculate the annual emissions inventory using annual average inputs, unless there are specific reasons to use monthly inputs.

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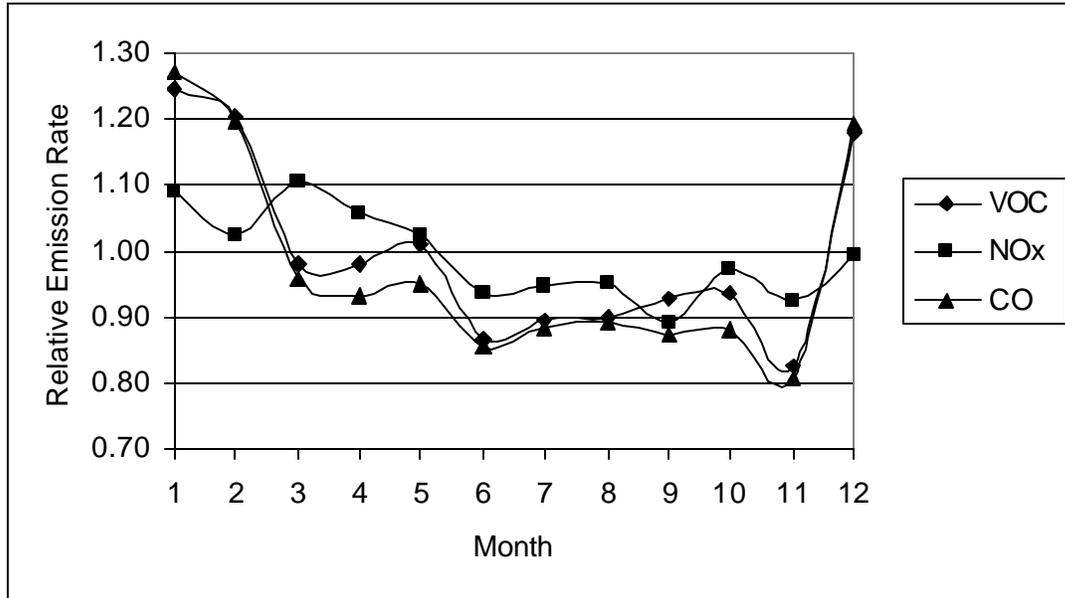


Figure 3. Relative emission rates (monthly emission rate/annual average) for mobile sources in central Florida, including monthly variations in VMT

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