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Statistical Analysis of the Phase 3 Emissions Data Collected in the EPAct/V2/E89 Program

January 7, 2010 – July 6, 2012

Richard F. Gunst
Southern Methodist University

NREL Technical Monitor: Matthew Thornton

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May 2013

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Executive Summary

Phase 3 of the EPAct/V2/E-89 Program investigated the effects of 27 program fuels and 15 program vehicles on exhaust emissions and fuel economy. In this phase of the EPAct/V2/E-89 Program, all vehicles were tested over the California Unified Driving Cycle (LA-92) at 75 °F. The program fuels differed on five fuel parameters: T_{50} (°F), T_{90} (°F), ethanol (vol. %), RVP (psi), and aromatics (vol. %). The vehicles were a selection of new, low-mileage 2008 model year Tier 2 vehicles. A total of 956 test runs were made on these 27 fuels and 15 vehicles between March 2009 and June 2010. Comprehensive statistical modeling and analyses were conducted on methane (g/mi), carbon dioxide g/mi), carbon monoxide (g/mi), fuel economy (mpg), non-methane hydrocarbons (g/mi), non-methane organic gases (g/mi), oxides of nitrogen (g/mi), particulate matter (mg/mi), and total hydrocarbons (g/mi).

In general, the model fits determined that emissions and fuel economy were complicated functions of the five fuel parameters. Fitted models were obtained for a Baseline Model that contained 17 linear, quadratic, and cross-product terms of the fuel parameters. Reduced models that deleted terms that were not statistically significant were also obtained. An extensive evaluation of alternative model fits produced a number of competing model fits from which the broad corpus of scientific, engineering, and emissions knowledge can be used to select for various intended uses. Many of these alternative fits produce similar estimates of mean emissions for the 27 program fuels but should be carefully evaluated for use with emerging fuels that have combinations of the fuel parameters that were not included in this program.

The strengths of the EPAct/V2/E-89 Program include a detailed database of information on each of the 27 program fuels on each of the 15 vehicles and, conversely, detailed information on each of the vehicles on each of the program fuels. Conclusions from the analysis of the Phase 3 data are germane to the 15 new, Tier 2 vehicles included in this project, the ranges of the five fuel properties tested in this phase of the EPAct/V2/E-89 Program, and the test conditions under which the testing was performed. Absent documented analyses of additional relevant data or other information that are not included in the Phase 3 data base, conclusions from analyses of the Phase 3 data should not be extrapolated to other vehicles or test conditions, including the in-use fleet, high emitting vehicles, other vehicle classes or technologies, testing at ambient temperatures other than 75°F, or engine operating conditions outside of the LA-92 test cycle (Unified Driving Cycle).

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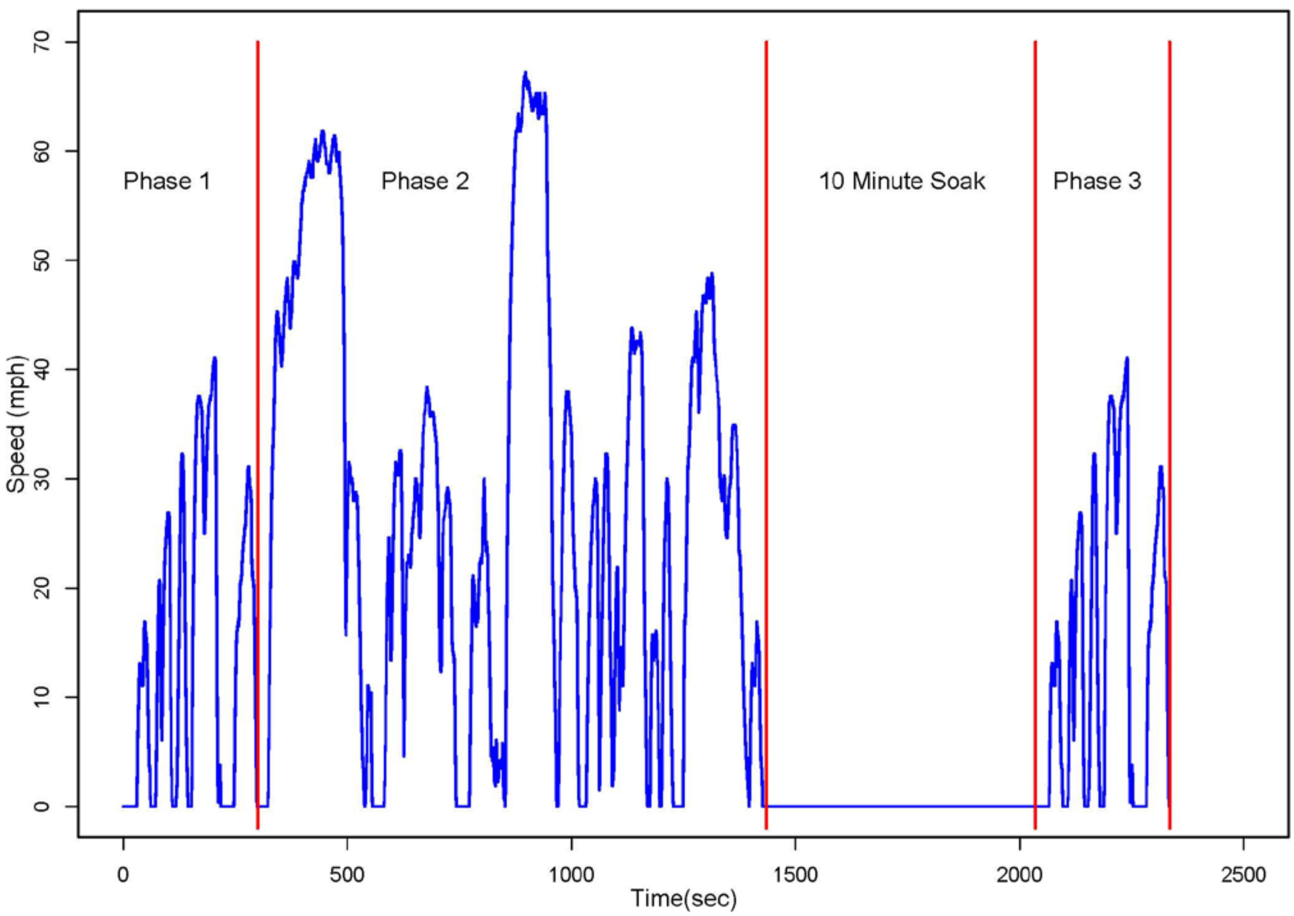
Statistical Analysis of the Phase 3 Emissions Data Collected in the EPAct/V2/E89 Program

I. Introduction

A. Overview

The primary goal of Phase 3 of the EPAct/V2/E-89 Program is to provide data needed to create statistical models that describe the effects of T_{50} (^oF), T_{90} (^oF), ethanol (EtOH, vol. %), RVP (psi), and aromatics (ARO, vol. %) content on exhaust emissions from a selection of 2008 model year Tier 2 vehicles. A total of 27 fuels were tested on 15 new, low-mileage, low-emitting vehicles at 75 ^oF over the LA92 test cycle between March 2009 and June 2010 (Whitney, 2010; Whitney, 2011). This report summarizes the results of the 956 test runs made on these 27 fuels and the 15 vehicles that were included in the test program. Emphasis in this report is on the statistical modeling and analysis of emissions and fuel economy (FE, mpg) over the LA-92 test cycle at 75 ^oF. Figure I.A.1 displays the time-speed trace for this driving cycle. The emissions analyzed in this report are methane (CH_4, g/mi), carbon dioxide (CO_2, g/mi), carbon monoxide (CO, g/mi), non-methane hydrocarbons (NMHC, g/mi), non-methane organic gases (NMOG, g/mi), oxides of nitrogen (NO_x, g/mi), particulate matter (PM, mg/mi), and total hydrocarbons (THC, g/mi).

Fig. I.A.1. LA92 Unified Cycle Time−Speed Trace



The Phase 3 statistical modeling and analyses are applicable only to emissions from new, low-emitting 2008 model year Tier 2 vehicles similar to those in the Phase 3 data file and might not apply to the on-road light-duty fleet, including high emitters, and vehicle operating conditions outside the LA-92 test cycle or for ambient operating conditions different from 75 ^{o}F. Effects of ambient temperatures (20 ^{o}F and 95 ^{o}F) on emissions from a limited sample of these same vehicles, as well as the effects on emissions from a sample of high-emitting vehicles, are being investigated in Phases 4 and 5 of the EPAct/V2/E-89 Program, respectively.

B. *Vehicles*

The vehicles chosen for this program are listed in Table I.B.1. These vehicles are all new 2008 model year Tier 2, low-mileage, low-emissions vehicles. All conclusions drawn on the basis of the analysis of Phase 3 data from this program are valid only for similar new 2008 model year Tier 2, low-mileage, low-emissions vehicles. Inferences based solely on the analyses of the Phase 3 data should not be made about makes, brands, or models not represented by the vehicles in Table I.B.1. In addition, conclusions drawn from the data about this fleet of vehicles are only representative of a fleet of vehicles with the same representation of makes, models, engine sizes, etc.

Table I.B.1 Phase 3 EPAct/V2/E89 Test Vehicles

Make	*Brand*	*Model*	*Engine*		*Bin*
GM	Chevrolet	Cobalt/HHR	2.4L	I4	5
GM	Chevrolet	Impala-FFV	3.5L	V6	5(CA)
GM	Saturn	Outlook	3.6L	V6	5(CA)
GM	Chevrolet	Silverado-FFV	5.3L	V8	5
Toyota	Toyota	Corolla	1.8L	I4	5(CA)
Toyota	Toyota	Camry	2.4L	I4	5(CA)
Toyota	Toyota	Sienna	3.3L	V6	5(CA)
Ford	Ford	Focus	2.0L	I4	4(CA)
Ford	Ford	Explorer	4.0L	V6	4
Ford	Ford	F150	5.4L	V6	8
Chrysler	Dodge	Caliber	2.4L	I4	5
Chrysler	Jeep	Liberty	3.7L	V6	5
Honda	Honda	Civic	1.8L	I4	5(CA)
Honda	Honda	Odyssey	3.5L	V6	5(CA)
Nissan	Nissan	Altima	2.5L	I4	5(CA

C. *Fuels*

The fuels included in this program were optimally selected using computer software that maximized the efficiency of the fuels in a specified statistical model to predict regulated emissions rates. Input to the computer software consisted of selected values of each of the five fuel properties: T_{50}, T_{90}, EtOH, RVP, and ARO. The software calculated efficiency values for all combinations of the fuel properties and identified the combinations of properties that produced the highest efficiency values relative to a specified fractional factorial experimental design based on the same fuel property combinations (Mason and Buckingham 2008).

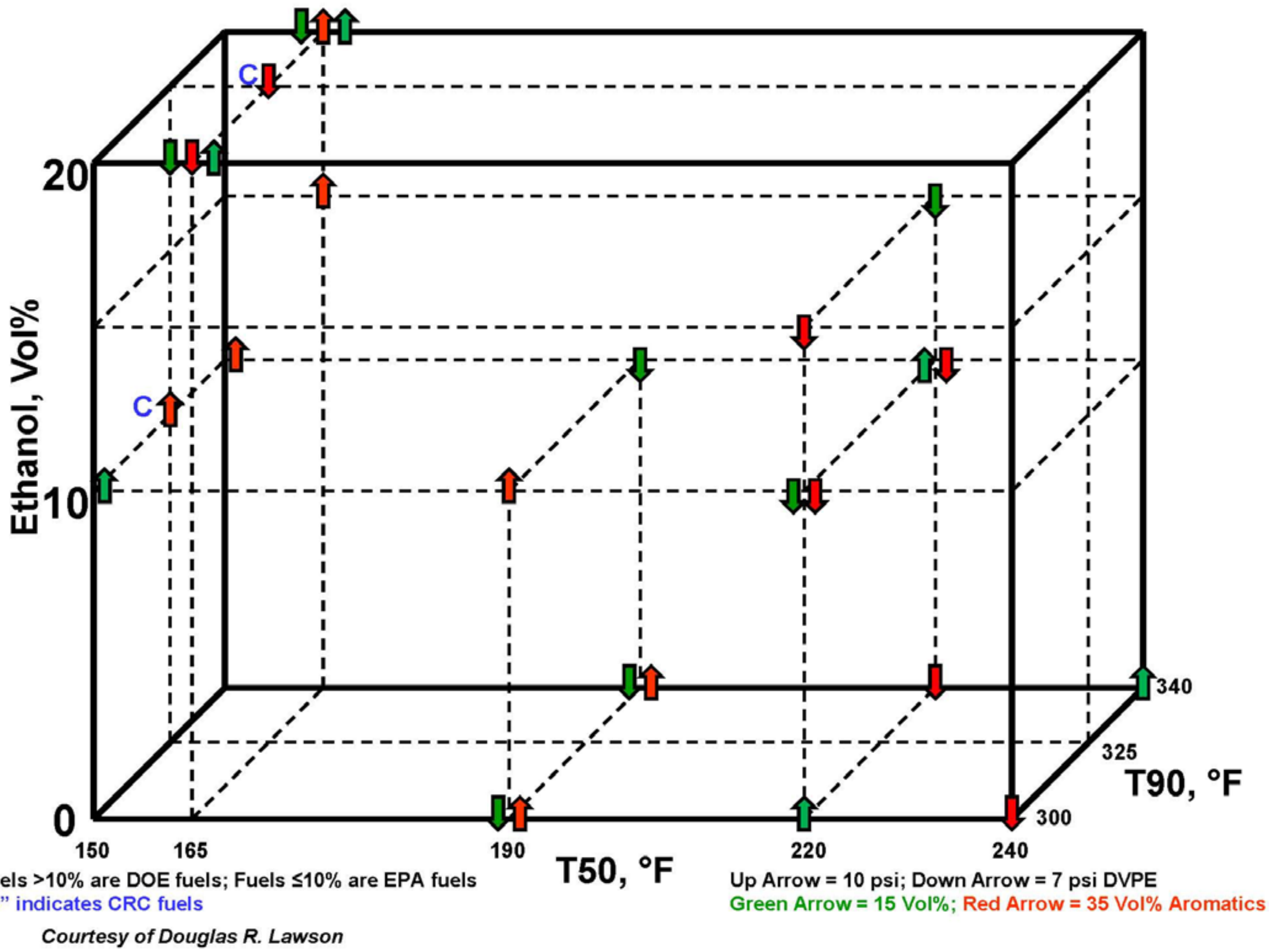
Several limiting factors restricted the fuels that could be included in the program (Mason and Buckingham 2008). First, some combinations of the fuel properties would not produce effective fuel blends for automobile engines. These combinations of fuel properties were eliminated from further consideration. Second, this test program could support the evaluation of only a limited number of fuels. Third, the fuel combinations chosen for consideration were selected to explore as wide a range on each fuel property as could be tested given the previous two constraints. Finally, the software used to select the combinations of fuel properties required that a prospective model be chosen that could be expected to satisfactorily model the emissions. Optimality was thus a function of the chosen model and subject to the conditions listed above. This important issue will be discussed further in Section II.B.1 (below).

Most of the fuels included in this test program are regarded as "extreme" because the combinations of fuel properties are at edges and corners of the region of permissible combinations of the fuel properties. These extreme combinations of the fuel properties were chosen for inclusion so that they would bound more typical properties that are the primary focus of predictive models. Thus, it is important to note that, like the limitations on conclusions that can be drawn relative to the vehicles included in this study, any conclusions drawn from the statistical modeling and analyses are restricted by the combined values and ranges of the fuel properties included in the program. One cannot, for example, draw conclusions about 20% EtOH without regard to the other fuel properties in the 20% EtOH blends, notably T_{50}, since all the fuels with 20% EtOH were blended with T_{50} at approximately 165 ^{o}F.

Early in Phase 3, it became clear that blended fuels did not exactly have the targeted fuel properties stipulated by the optimal design. In order to properly accommodate the actual properties of the 27 fuels, a blinded round-robin measurement experiment was conducted to determine the actual properties of the fuels being tested on the vehicles. The laboratory facilities that participated in the round-robin measurements of the fuel properties were BP, Chevron, Conoco Phillips, EPA, Exxon-Mobil, PAC, Marathon, and Shell. A scatterplot of the fuels as a function of T_{50}, T_{90}, and EtOH is shown in Figure I.C.1.

The calculated fuel properties (averages across the measurements provided by all participants) for each of the fuels are shown in Table I.C.1. These calculated fuel properties are used in all the statistical modeling and analyses that are included in this report.

Fig. I.C.1 Phase 3 EPAct/V2/E89 Fuel Properties (Does Not Include E85 Fuel).



D. Implications of Vehicle, Fuel, and Data Restrictions

The conditions on vehicle and fuel interpretations made above are not intended to detract from the relevance and importance of this program. They are necessary in order to ensure that the maximum benefit from the statistical analyses reported below can be obtained and that possible inadvertent misinterpretations of results and conclusions are minimized. As stated previously, the statistical modeling and analyses of the Phase 3 data are applicable only to emissions from new, low-emitting 2008 model year Tier 2 vehicles of similar makes, models, engine sizes, etc. and might not apply to the on-road light-duty fleet, including high emitters, and vehicle operating conditions outside the LA-92 test cycle or for ambient operating conditions different from 75 ^{o}F.

Table I.C.1 Phase 3 EPAct/V2/E89 Fuel Properties.

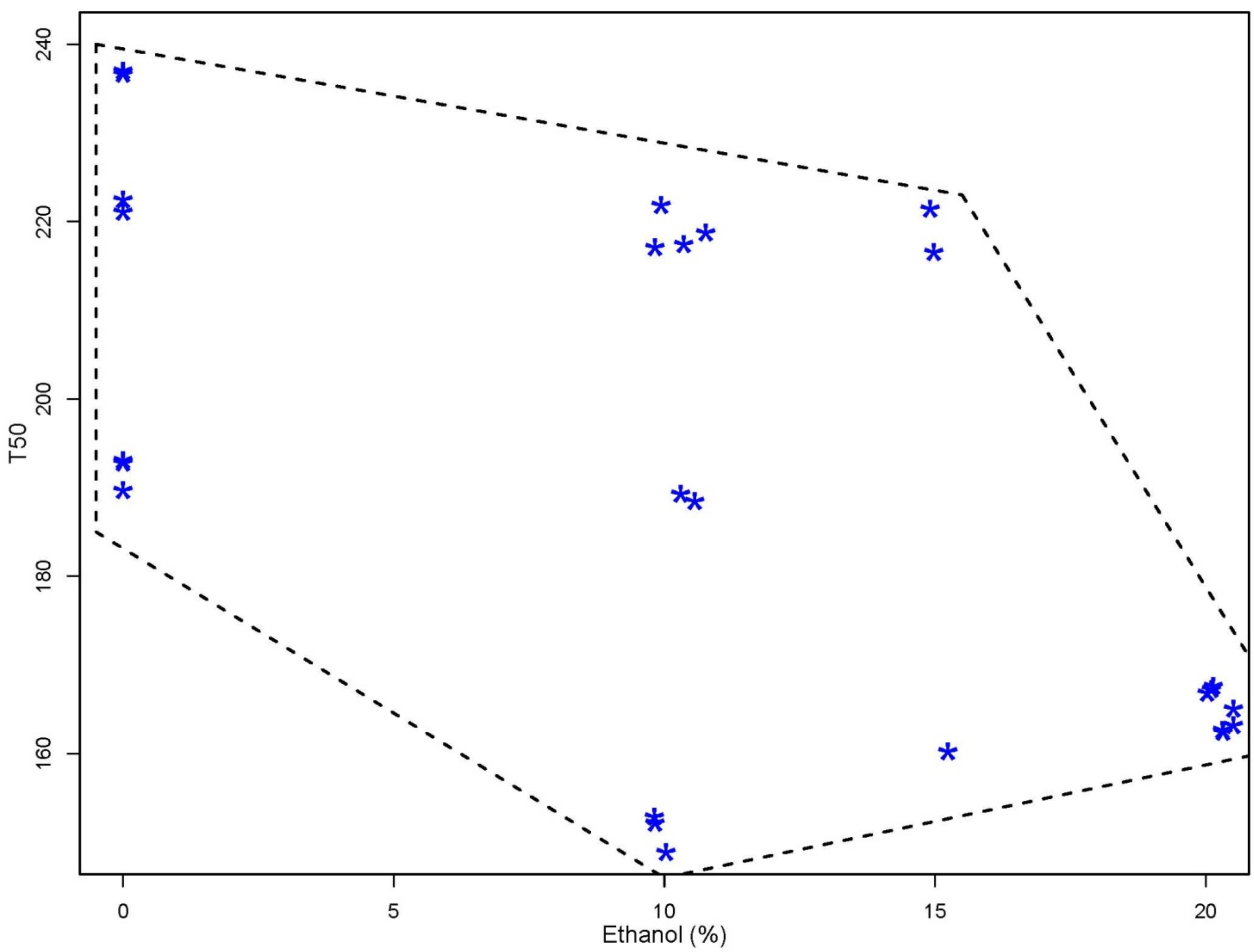
Fuel	*EtOH*	T_{50}	T_{90}	*RVP*	*ARO*
1	10.03	148.9	300.2	10.07	15.4
2	0	236.7	340.1	10.2	14.1
3	10.36	217.5	295.9	6.93	15
4	9.94	221.9	337.5	10.01	15.5
5	0	237	300	6.95	34.7
6	10.56	188.5	340.4	7.24	15
7	0	193.1	298.4	7.15	17
8	0	221.1	303.1	10.2	15.7
9	0	192.8	341.8	10.3	35.8
10	9.82	217.1	340.2	7.11	34
11	10.3	189.3	298.6	9.93	35
12	9.83	152.2	339.8	10.13	34.8
13	0	222.5	337.9	6.92	34.1
14	0	192.8	338.5	7.14	16.9
15	0	189.7	299.4	10.23	35.3
16	10.76	218.8	300.6	7.12	35.6
20	20.31	162.7	298.7	6.7	15.2
21	20.14	167.6	305	7.06	35.5
22	20.51	163.2	297.3	10.21	15
23	20.32	162.5	338.2	6.84	15.9
24	20.51	165.1	338.1	10.12	15.3
25	20.03	166.9	337.9	10.16	35.2
26	15.24	160.3	338.7	10.21	35.6
27	14.91	221.5	340.3	6.97	14.9
28	14.98	216.6	298.8	6.87	34.5
30	9.81	152.9	323.8	10.23	35.5
31	20.11	167.3	325.2	6.98	35.5

The fuels selected for this program also restrict the interpretations of the statistical results reported in subsequent sections of this report. Figure I.D.1 shows the combinations of the T_{50} and EtOH fuel parameters for the 27 fuels tested in Phase 3. Note that as the ethanol content of the fuels increases, T_{50} generally decreases. No inferences should be drawn from the statistical modeling and analysis for fuels with EtOH and T_{50} parameter values outside the region in Fig. I.D.1 indicated by the dashed lines and the accompanying T_{90}, ARO, and RVP parameter values for those fuels in Table I.C.1.

These restrictions on interpretations of the results of analyses of the Phase 3 data do not mandate that these results cannot, in conjunction with external studies and additional data, be used to provide a broader base of conclusions. No such mandate is stated or implied in this report.

Periodic concerns were raised about the accuracy of the PM measurements because of the large numbers of low and nondetectable measurements (see Table III.F.1) relative to background measurements. Caution should be exercised in interpreting the PM results until additional chemical analyses that are currently underway are completed.

Fig. I.D.1. Phase 3 EPAct/V2/E89 T50 and Ethanol fuel Properties.



II. Model Specification and Assumptions

A. *Statistical Model Error Assumptions*

Statistically optimal and computationally efficient modeling and analysis procedures are often achieved when measurements follow normal probability distributions and exhibit constant variability (e.g., the variability as measured by standard deviations is the same for all fuels and vehicles). Emissions and fuel economy measurements often violate these assumptions. Based on numerous previous emissions testing programs, the natural logarithms of emissions measured in the EPAct/V2/E89 Test Program were expected to exhibit constant variability and follow normal probability distributions with means that might differ for the fuels but with variability that is constant over repeat tests across fuels and vehicles. In addition, the inverse of fuel economy, fuel efficiency, has often been modeled rather than fuel economy itself. Analyses were conducted to investigate the reasonableness of these statistical modeling assumptions.

1. *Constant Variance Assumption*

The first analyses performed on the EPAct/V2/E89 concerned whether test-run-to-test-run variability was constant. If not, transformations of the measurements (logs of emissions, inverse FE) might better satisfy this assumption. One common and powerful graphical method used to assess whether the EPAct/V2/E89 data satisfied the assumption of constant variability was to graph standard deviations of repeat measurements versus the corresponding averages. These calculations and graphs were made and analyzed subject to the following stipulations.

- All valid nonzero data values were used in the calculations. No nonzero data values were deleted from the database. Additional analyses in which influential data values were deleted from the database confirmed the conclusions that were obtained from analyses of the complete database.

- Standard deviations were calculated only if two or more nonzero repeat measurements were available for a vehicle/fuel combination. If a vehicle/fuel had only one valid nonzero measurement, the standard deviation is identically zero and provides no information about measurement variability.

- Emissions that were reported to be identically 0 (non-detectable) were excluded from this analysis for the following reasons. If a vehicle\fuel combination had all repeats identically 0, both the average and the standard deviation are identically 0. If one of two repeats is exactly 0 and the other one has a nonzero value, say, x, the average is x/2 and the standard deviation is $x / \sqrt{2}$. When graphed, these averages and standard deviations would fall exactly on a straight line. This is an artifact of the 0 value and provides no information about the constant variability assumption. Very few composite Bag 1 emissions had 0 (non-detectable) measurements. Zero measurements occurred primarily for Bags 2 and 3 measurements on NMHC and NMOG, Bag 3 measurements on NO_x, and for PM measurements in all 3 bags and in the composite (weighted) measurements (see Section III.F).

Appendix I contains graphs of standard deviations vs. averages for each measurement, separately for composite (Figs. 1 – 9) and bag (Figs. 10 – 18 for Bag 1, Figs. 19 – 27 for Bag 2, Figs. 28 – 36 for Bag 3) measurements. The averages and standard deviations in each of the graphs are calculated across repeats for each vehicle/fuel combination. The upper two graphs in each figure are graphs of the standard deviations versus the corresponding averages for the raw measurements (a) and the transformed measurements (b).

Figures 1(a) and 1(b) illustrate how these graphs can be used to assess the assumption of constant variability for composite methane emissions. Figure 1(a) shows the typical wedge-shaped plot that indicates non-constant variability. All the standard deviations for small average CH_4 emissions are also small while for larger average CH_4 emissions many of the standard deviations increase. In contrast, Fig. 1(b) contains small and large standard deviations across the entire range of average logarithmically transformed CH_4 measurements. This is what is expected when variability is constant; i.e., there is no marked change in the magnitudes of standard deviations as the magnitudes of average log-transformed emissions increase. For composite CH_4 emissions, the log-transformed emissions better satisfy the constant variance assumption than the untransformed CH_4 emissions.

An examination of the figures in Appendix I lead to the following conclusions. The constant variance assumption appears to be better satisfied using log-transformed composite and bag emissions. For FE the constant variance assumption appears to be reasonable for the untransformed FE values. Thus the fuel economy measurements do not have to be transformed in order to reasonably satisfy the constant variance assumption.

In a few graphs it might appear that the log-transformation is not necessary (e.g., Bag 1 CO_2) but this is not true for any of the emissions across all bags and composite measurements. For consistency in the analyses, the assessment of the constant variance assumption leads to the conclusion that all emissions be log-transformed.

2. *Normal Probability Distributions for Errors*

The normal probability error assumption was examined using a model that does not require specification of the form of the fuel property effects. Fixed effects (see Section I.B.1 below) for the 27 fuels and random effects (see Section I.B.2 below) for the 15 vehicles were included. Specifically, the 27 fuel effects were included in the model as 27 fixed effects indicator variables (1 if a specific fuel, 0 otherwise). Vehicle effects were included as 15 random effects indicator variables. Fuel-by-vehicle indicator variables were also included as random effects indicator variables. This is not the model that will be used to determine the effects of the fuel properties. It was used because it allows the normal probability assumption to be investigated without reliance on correctly specifying the nature of the fuel effects. Alternative model specifications can be used and similar results will be obtained.

The graphs (c) and (d) in each figure in Appendix I provide assessments of the assumption that model errors are normally distributed. From the model fits, individual measurements were predicted for each fuel, vehicle, and repeat test. Residuals, differences between the actual measurements and the predicted measurements, were calculated; i.e., residual = actual measurement – model-predicted measurement. The residuals were ordered from smallest to largest and then graphed versus normal quantiles, values from a normal probability distribution. If the true model errors followed a normal probability distribution, the graphs of residuals vs. normal quantiles should approximate a straight line.

Figures 1(c) and 1(d) illustrate these normal quantile plots for methane composite emissions. Figure 1(c) is relatively linear in the middle but departs substantially from a straight line at the lower and upper ends of the graph. This departure is common when model errors do not follow a normal probability distribution. In contrast, the plotted values in Fig. 1(d) are much closer to a straight line over most of the range of the data. This indicates that logarithmically transformed CH_4 emissions have model errors that more closely follow a normal probability distribution than the untransformed CH_4 emissions.

An examination of the figures in Appendix I leads to the general conclusion that for composite and bag emissions the normality assumption appears to be better satisfied using log-transformed measurements. For FE the normality assumption appears to be reasonable for the untransformed FE values. Thus, the fuel economy measurements do not have to be transformed in order to reasonably satisfy the assumption that the model errors are normally distributed.

There are a few figures in which the log-transformed emissions are not closely linear but in those figures the graphs of the transformed emissions are more linear than those for the untransformed emissions. Moreover, in several of the graphs outliers in the untransformed emissions (generally very extreme values at the upper end of the graph) are not outliers in the log-transformed emissions (e.g., Fig. 7 for composite NO_x). In addition, analyses in which influential data values are deleted (all data values for which Studentized residuals exceed 3.5 in magnitude, see Section III.C) confirm the need to logarithmically transform emissions measurements. For these reasons, logarithmically transformed emissions will be modeled and analyzed.

B. *Model Specification*

Prior to statistical analyses of the data produced in Phase 3 of the EPAct/V2/E89 Program, careful consideration was given to the specification of the models that would be used to describe changes in emissions and fuel economy as a function of the controllable factors in the design of the program, namely the fuel effects and the vehicle effects. The validity of the statistical analyses can be critically dependent on the specification of the model.

Phase 3 of the EPAct/V2/E89 Program was designed to study the effects of fuel parameters on emissions measurements. Both fuels and vehicles contribute to changes in emissions but they do so in different ways. The nature of their influences on emissions must be assessed differently through the specification of their influences as either *fixed effects* or *random effects* in statistical models.

1. *Fuel Parameters: Fixed Effects*

The design of the fuels used in Phase 3 of this project was based on a specified EPA model involving the fuel parameters T_{50}, T_{90}, Ethanol, RVP, and Aromatics. The first 25 fuels in Table I.C.1 were selected to optimize the ability to estimate all the linear effects of the fuel parameters and select second-order (quadratic and interaction) effects of the fuel parameters. The model terms corresponding to these effects are statistically modeled as *fixed effects*. Fixed effect model terms are used when the effects are believed to change the mean emission or fuel economy. In other words, fuel parameter fixed effects produce systematic changes in the mean emission or fuel economy whereas both the vehicles chosen for the program and the repeat test runs produce random deviations around the mean.

The mean of a specified measurement (NO_x, THC, FE, etc.) for a particular fuel was modeled during the fuel design phase of this project as follows:

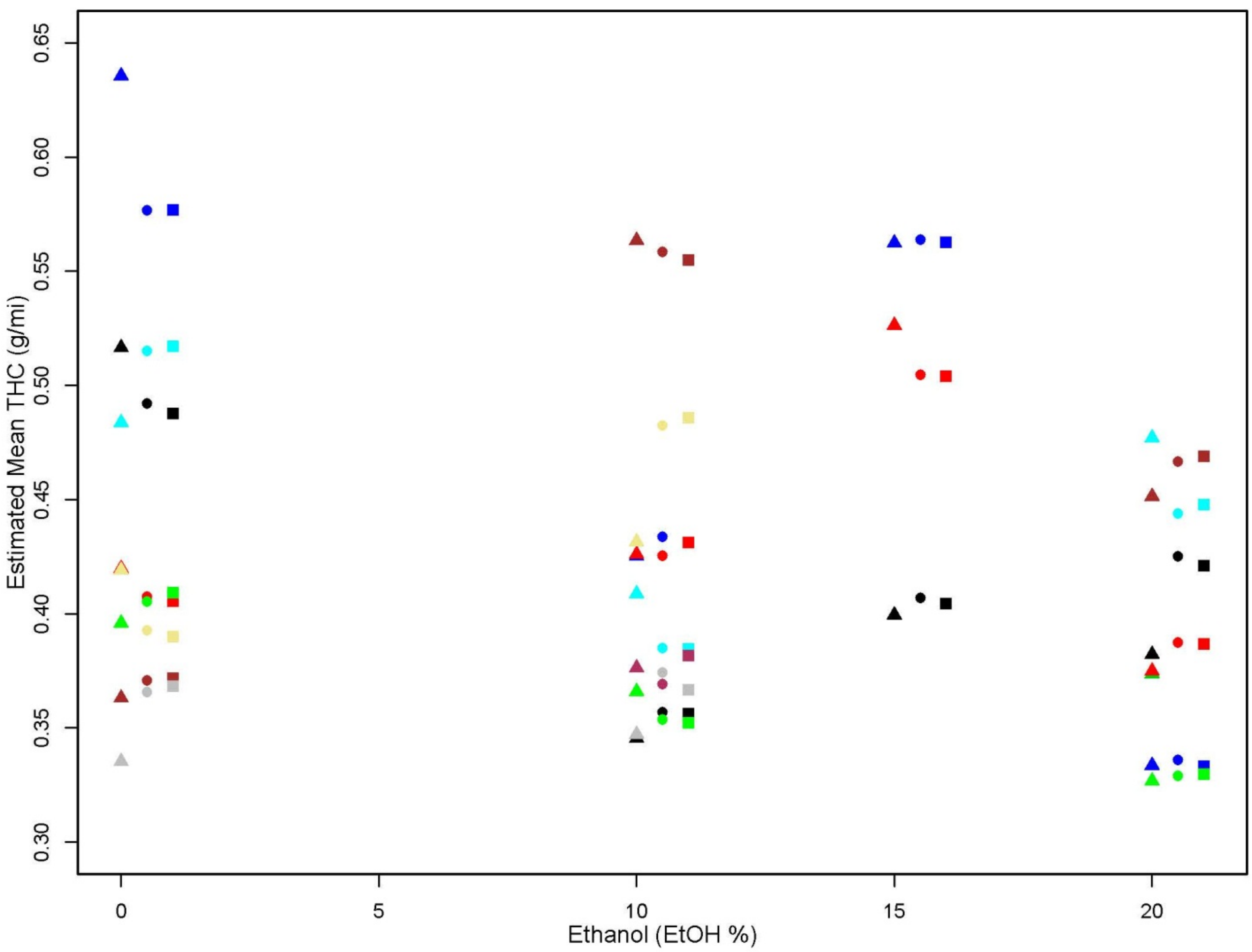
$$\text{Mean Measurement} = \beta_0 + \beta_1 T_{50} + \beta_2 T_{90} + \beta_3 \text{EtOH} + \beta_4 \text{RVP} + \beta_5 \text{ARO} + \beta_6 T_{50}{*}\text{EtOH} + \beta_7 T_{90}{*}\text{EtOH} + \beta_8 \text{RVP}{*}\text{EtOH} + \beta_9 \text{ARO}{*}\text{EtOH} + \beta_{10} T_{50}^2 + \beta_{11} \text{EtOH}^2.$$

The last two fuels in Table I.C.1, along with three additional fuels that are not being analyzed as part of the Phase 3 database, were included to permit the estimation of possible quadratic effects of T_{90} (Mason and Buckingham 2008). There are additional quadratic and interaction (cross-product) terms that could be added to the design model and can be fit using the data in the Phase 3 data base. Consequently, an expanded model that included additional interaction and quadratic terms was extensively investigated to assess whether terms not included in the EPA design model might aid in the prediction of the measured emissions and fuel economy. All interactions (cross-product terms) involving the five fuel properties that are not included in the EPA design model were initially added to form an expanded model. The T_{90}^2 term was also added. The squared terms RVP^2 and ARO^2 were not added to the design model because the design of the program included only two distinct values for each of these fuel properties.

There was concern raised over the inclusion of the T_{90}^2 term since only two of the original five fuels that were included in the design to estimate the effect of this term were ultimately included in the database. These two fuels have the lowest T_{50} and highest ARO parameter values. Inclusion of the T_{90}^2 term might detrimentally affect the prediction of emissions for the other fuels that do not have these extreme fuel parameter values and those for fuels that do not have extreme combinations of the fuel parameter values.

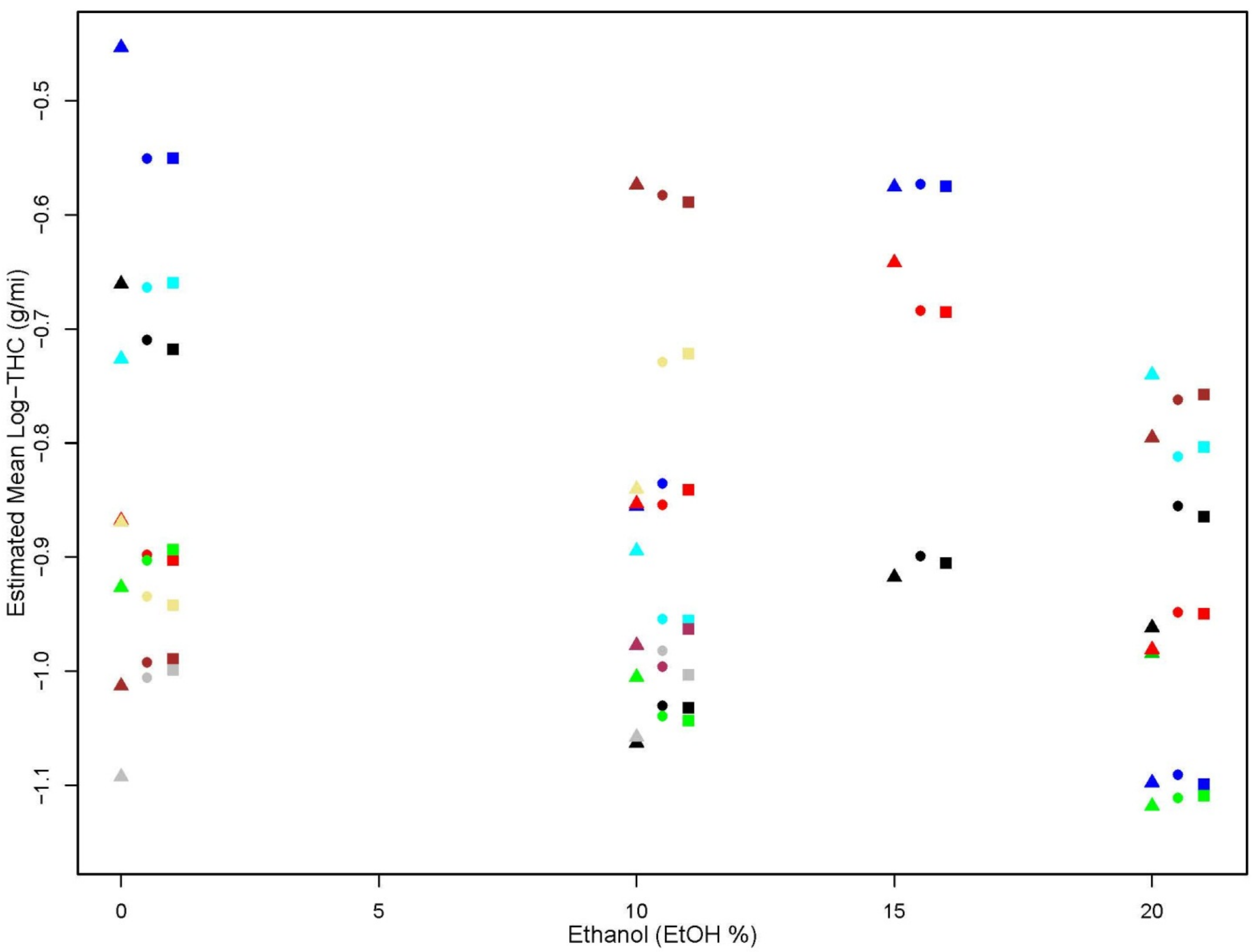
A number of analyses were performed to investigate the possible inclusion of the T_{90}^2 model term. Figures II.B.1 and II.B.2 provide a visual summary of the general conclusions reached in these investigations.

Fig. II.B.1 Model-Estimated Mean Bag 1 THC Emissions for the 27 Program Fuels. Exponentiated Log-transformed Data Averages (Triangles), Benchmark Model Estimates (Circles), Benchmark Model Estimates without the T_{90}^2 Term (Squares). Fuel Mean Estimates Color-Coded Separately for 0, 10%, 15%, and 20% Ethanol Content.



These figures display the exponentiated averages of the log-transformed Bag 1 THC emissions for each of the 27 fuels (Fig. II.B.1) and the averages of the log-transformed Bag 1 THC emissions (Fig. II.B.2), both indicated by the triangles. In each figure, model estimates of the mean emissions (Fig. II.B.1) and the mean log-emissions (Fig. II.B.2) for a model that includes all permissible quadratic terms, including the T_{90}^2 model term (circles), and the same model without the T_{90}^2 term (squares) are also displayed. In order to make comparisons easier, the 27 fuels are color-coded in the figures, separately for each of the fuels having the 4 targeted ethanol contents (0, 10%, 15%, 20%). The purpose of presenting these figures is not to compare estimated mean emissions for various fuels or to assess how well the model estimates agree with the averages calculated from the data. Rather, the purpose for displaying these figures is to compare the model predictions with and without the T_{90}^2 model term. Thus, the feature that is important in these figures is a comparison of the circles (estimates with the T_{90}^2 model term) and squares (estimates without the T_{90}^2 model term) that are of the same color.

Fig. II.B.2 Model-Estimated Mean Logarithmically Transformed Bag 1 THC Emissions for the 27 Program Fuels. Log-transformed Data Averages (Triangles), Benchmark Model Estimates (Circles), Benchmark Model Estimates without the T_{90}^2 Term (Squares). Fuel Mean Estimates Color-Coded Separately for 0, 10%, 15%, and 20% Ethanol Content.



For each of the 27 fuels, the estimated means for the models with and without the T_{90}^2 model term are very similar. Some fuels have means estimated from the model with the T_{90}^2 term slightly closer to the averages calculated from the data and for others the means estimated from the model without this term are slightly closer to the averages calculated from the data. There is no consistent preference for estimated mean emissions or mean log-emissions from either model fit. Quantitative assessments lead to the same conclusion. For completeness, all the model fits in this report are included for the Benchmark Model with and without the T_{90}^2 term.

After standardizing the polynomial terms and accommodating collinear terms (see Section III.B below), the following fixed-effects portion of an expanded model includes all permissible (see Section III.B) quadratic and interaction terms for the statistical modeling and analysis of logarithmically transformed emissions and untransformed fuel economy:

$$\begin{aligned}\text{Mean Measurement} = {} & \beta_0 + \beta_1 T_{50} + \beta_2 T_{90} + \beta_3 EtOH + \beta_4 RVP + \beta_5 ARO \\ & + \beta_6 T_{50}^2 + \beta_7 EtOH^2 + \beta_8 T_{90}^2 + \beta_9 T_{50}{*}T_{90} + \beta_{10} T_{50}{*}EtOH + \beta_{11} T_{50}{*}ARO \\ & + \beta_{12} T_{90}{*}EtOH + \beta_{13} T_{90}{*}RVP + \beta_{14} T_{90}{*}ARO + \beta_{15} EtOH{*}RVP + \beta_{16} EtOH{*}ARO \\ & + \beta_{17} RVP{*}ARO.\end{aligned}$$

2. *Vehicles and Model Errors: Random Effects*

Statistical models include random effects for two reasons: (1) the effects represent influences on measurements from factors whose levels or values represent only a small sample of possible levels or values, or (2) the effects represent uncontrolled variation from various sources; e.g., measurement error, test-run-to-test-run variability, equipment or operational variability, etc. Both of these sources of random effects are present in the data from the EPAct/V2/E89 Program.

The 15 vehicles chosen for inclusion in this program represent a very small selection of low-mileage, low-emitting Tier 2 vehicles. As such, they represent a random sample from a larger fleet of similar vehicles (not necessarily all possible Tier 2 vehicles). Due to the known large vehicle-to-vehicle variability in emissions, even for vehicles of the same model type, the effects of vehicles on emissions are not systematic but random. Similarly, repeat-test variation is random due to the numerous small but consequential variations in the testing and measurement processes.

Vehicle effects are modeled as random changes in the overall level of emissions, changes that are due to the individual vehicles being tested. To model these random vehicle effects, a random intercept term b_v is added to the constant overall mean effect β_0; i.e., the model intercept term β_0 is replaced by $\beta_0 + b_v$, where b_v represents the random change attributable to vehicle v from the overall mean emission level β_0. The test-run variability is specified by an additive random error, e. Inclusion of these random effects in the expanded fixed effects model defined above results in the following model for a measurement on a single test run for a specified vehicle and fuel:

$$\begin{aligned}\text{Measured Value} = {} & \beta_0 + b_v + \beta_1 T_{50} + \beta_2 T_{90} + \beta_3 EtOH + \beta_4 RVP + \beta_5 ARO \\ & + \beta_6 T_{50}^2 + \beta_7 EtOH^2 + \beta_8 T_{90}^2 + \beta_9 T_{50}{*}T_{90} + \beta_{10} T_{50}{*}EtOH + \beta_{11} T_{50}{*}ARO \\ & + \beta_{12} T_{90}{*}EtOH + \beta_{13} T_{90}{*}RVP + \beta_{14} T_{90}{*}ARO + \beta_{15} EtOH{*}RVP + \beta_{16} EtOH{*}ARO \\ & + \beta_{17} RVP{*}ARO + e.\end{aligned}$$

This model is referred to in this report as the *Benchmark Model*. Both the Benchmark Model and the expanded model without the T_{90}^2 model term are fit and discussed in subsequent sections of this report.

III. Additional Modeling Issues

A. Collinearity Detection

In its simplest form, a collinearity occurs when two polynomial terms in a model are highly correlated. An example is a model that includes x and x^2 when x takes on only positive values. This type of collinearity is easily detected by examining correlations among all pairs of terms in a model. In order to minimize this common occurrence of collinearities with polynomial models, all the fuel properties in this 27-fuel database were standardized before polynomial terms were calculated. Standardization replaces values of a fuel property x (e.g., T_{50}) by $(x - mean_x)/std_x$, where $mean_x$ is the average of all the values of x and std_x is the standard deviation of the values of x. Standardization for this project was based on the averages and standard deviations of the 27 values for each of the five fuel properties. All modeling and analysis of model fits use this standardization for the five fuel properties.

Collinearities are not restricted to only two quantitative variables. It is common that interaction terms like x_1*x_2, x_1*x_3, and x_2*x_3 will not have large correlations with each other but will be highly collinear due to the presence of all three terms and their constituents x_1, x_2, and x_3 in a model, even if the individual terms x_j have been standardized. Collinearities like these might not be detectable through an examination of correlations.

Variance inflation factors (VIF) can detect whether a model term is collinear with any number of other model terms. VIF values can be expressed as

$$VIF = \frac{1}{1 - R^2}$$

where R^2 is the proportion of the variability in a specified model term that can be explained by the other terms in the model (R^2 is the coefficient of determination when the specified model term is regressed on the other model terms). A VIF > 10 is regarded as indicating a serious collinearity problem involving the specified model term.

B. Collinearities in the Benchmark Model

As will be described below, it is computationally efficient to investigate subset models, models in which terms that are not statistically significant are deleted from the Benchmark Model, by using regression algorithms like Proc Reg in SAS. Proc Reg models only fixed effects but it contains several highly efficient computing routines for examining alternative subset models. Computations for collinearity assessments are also highly efficient using this algorithm. In order to use Proc Reg, however, random effects in the Benchmark Model must be replaced by fixed effects.

Use of a fixed effects algorithm can be justified only if the results are essentially the same as one would obtain using a less efficient but more appropriate algorithm that can model random effects; e.g., Proc Mixed in SAS. Replacing the one fixed effects intercept term (β_0) and 15 random vehicle intercept terms (b_v) in the Benchmark Model with 15 individual fixed-effects intercepts (β_v), one for each vehicle, enables Proc Reg to be used for collinearity assessments.

Initial calculation of correlations and VIF values for the expanded model that contains the 15 fixed-effects vehicle terms, all the fuel property terms, interactions (cross-products) of the fuel properties, and the quadratic terms for T_{50}, T_{90}, and EtOH resulted in large collinearity diagnostic values. This occurred even after the individual fuel property terms were standardized as described in the previous section. Consideration was given to deleting various terms from the Benchmark Model in order to eliminate the collinearities. This option was not considered desirable since several terms would need to be deleted. In addition, some of the terms that would need to be deleted would be terms that were included in the EPA design model that was used to select the fuel properties.

After investigating several alternatives, a simple expedient was found to all but eliminate the problem: standardize the cross-product and squared model terms. Consequently, all analyses included in this report are based on the following standardization steps:

Step 1: Calculate the averages and standard deviations of the five fuel properties across the 27 fuels.

Step 2: Standardize the linear fuel properties T_{50}, T_{90}, EtOH, RVP, and ARO.

Step 3: Form the cross-product and squared terms from the standardized linear terms.

Step 4: Calculate the averages and standard deviations of the cross-product and squared terms across the 27 fuels.

Step 5: Standardize the cross-product and squared terms.

After standardizing all the model terms in the expanded model, all the VIF values were less than 6 except for the T_{50}*RVP and T_{50}*EtOH terms, which had VIF values that exceeded 10. Accommodation of collinearities generally requires that one of the collinear model terms be deleted. This is required because the terms are redundant – they are repeating information and can lead to coefficient estimates (estimated β_j values in the model) that have incorrect signs and/or unacceptably large magnitudes. Since the fuel properties were selected using the EPA design model, a model that contains the T50*EtOH term, the T_{50}*RVP interaction was deleted from the expanded model. This resulted in the Benchmark Model shown in Section II.B.2.

C. *Influential Data Values*

A small number of extreme data values can result in substantial and often deleterious changes to estimates of fixed effects relative to a database that does not contain the extreme data values. Consequently, extreme data values, termed *influential* values if they substantially change model fits, must be identified and their influence on fuel parameter effects must be assessed.

A very powerful statistic that is often used to detect influential data values is a *Studentized residual*, defined as

$$t = \frac{\text{Actual Measurement} - \text{Predicted Measurement}}{\text{Standard Error}}$$

As indicated by this formula, Studentized residuals (t) are calculated for each measurement value. A predicted measurement value is calculated from a fit to the fixed and random effects with a very critical condition: the measurement value itself is not used in the fit and hence cannot affect its own prediction. The calculated (externally standardized) standard error in the formula is a scale factor that quantifies the variability of the difference between a measurement value and its predicted value. A Studentized residual greater than 3.5 in magnitude identifies a possible influential measurement value. Subsequent analyses are needed to confirm whether the identified values are indeed influential.

Appendix II lists the individual measurements values that were initially identified as influential. It is important to note that for any specified measure the composite (weighted) and bag emissions model fits identify very few of the 956 measurement values that are possibly influential data values.

Any data value corresponding to a Studentized residual greater than 3.5 in magnitude was further evaluated by EPA staff. If a conclusion was drawn that such a value was an aberration, that data value was removed from the database and model fitting was performed using the remaining data values. If no such reason for removal of a data value was found, the data value remained in the database. Only 3 PM values, one for each of Bags 1-3, were ultimately removed from the analyses: Bag 1, Run 6247; Bag 2, Run 5324; and Bag 3, Run 6281. Because these bag measurements were considered aberrant data values, their corresponding composite values were also removed.

D. *Measurement Drift*

Measurement values are sometimes affected by any of a variety of sources of drift. Vehicle wear, instrument calibration, and fuel property changes over time are but a few of the possible contributors to measurement drift. To ensure that drift did not affect the comparisons among the fuels in Phase 3 of the EPAct/V2/E89 Program, several fuels were selected for repeat measurements on one or more vehicles. All 15 vehicles were tested on one fuel at the beginning of the program, the middle of the program, and the end of the program. Various statistical analyses of drift were conducted, including graphical assessment of possible drift, modeling measurements as a function of odometer reading, and modeling measurements as a function of the time of test (beginning, middle, and end). Random vehicle effects were included in all the modeling.

No consistent drift in time-of-test measurements was found. No adjustment for measurement drift is warranted by the analyses performed.

E. *Carryover Effects*

Approximately midway through the test program it was discovered that up to five of the 15 test vehicles did not have sufficient drainage of the fuel tanks, leading to concern that carryover effects from one fuel to the next might mitigate the ability to properly determine the effects of the individual fuel properties on emissions. Beginning in August 2009, an additional fuel drain-and-fill sequence was added to the two sequences that had previously been in place for the test program.

Following completion of the program a variety of statistical comparisons were made on the suspect vehicles by EPA staff. Analyses included comparing emissions results between the suspect vehicles and the remaining vehicles, comparing fuel-change effects among the suspect vehicles pre- and post-August 2009, and assessments of fitted models with respect to various scenarios involving the percentage of fuel property carryover that might remain after incomplete drainage.

None of the analyses performed provided conclusive evidence of substantive carryover effects. Consequently, no accommodation of possible carryover effects was made in the models or analyses included in this report.

F. *Zero (Nondetectable) Emissions Measurements*

Measurements on some of these low-emitting Tier 2 vehicles resulted in vehicle measured values that did not exceed background measured values for a particular species. When this occurred, the values reported in the data files were set to zero. Table III.F.1 lists the number of recorded zero values for each emission and bag.

Table III.F.1 Number of Recorded Zero Values.

	Bag 1	Bag 2	Bag 3	Composite
CH_4	0	0	0	0
CO	0	0	0	0
CO_2	0	0	0	0
NMHC	0	44	128	0
NMOG	0	44	119	0
NO_x	2	4	25	0
PM	45	47	82	8
THC	0	3	2	0

The presence of zero values in the data results in an important modeling issue. Since logarithmic transformations are modeled for all the emissions, SAS sets the log-transformed values to "missing." These values are then automatically eliminated from the modeling and analysis.

Alternative accommodation of zero values so that they are not ignored in the modeling and analysis has often been accomplished by assigning small but nonzero values to the nondetectable measurements; e.g., ½ of the minimum value that is measured. This can be criticized as being arbitrary and but one of many assignments that could be made. A careful investigation of the consequences of replacing zero values with either the minimum value or a fraction of the minimum value for the respective emissions was undertaken. Also undertaken was the investigation of an alternative estimation method.

There is a widely accepted statistical alternative to the replacement of zero values by small fixed quantities. In the statistical literature on survival modeling, this problem is one of censored data. Survival modeling does not assign (impute) values for the nondetectable measurements nor does it ignore them. Rather, survival modeling estimates the probability of obtaining nondetectable measurements and includes those estimated probabilities in a maximum likelihood estimation procedure for the fixed model effects.
A number of investigations of these alternatives were performed both as part of this contract and separately by EPA staff. A consensus agreement was reached on the accommodation of zero values.

- *Five or Fewer Zero Values*
  If an emission/bag (e.g., Bag 2 NOx) has five or fewer zero values, the values are replaced by the minimum measured value for that emission and bag.

- *More than Five Zero Values*
  If an emission/bag has more than five zero values, censored data modeling using Proc LifeReg in SAS is used to fit and evaluate models.

Proc LifeReg does not permit the modeling of random vehicle effects. The inclusion of fixed intercept parameters, as was done with Proc Reg in the collinearity assessment in Section III.B and is done with the fitting of reduced models in Section V, results in correct estimates of the fixed fuel parameter effects but seemingly does not provide a means for estimating the common intercept β_0 for the Benchmark and reduced models. A common intercept is available: the average of the 15 individual vehicle intercept estimates. This intercept estimate is used in all the models fit by Proc LifeReg.

IV. Procedures for Selecting Reduced Model Fits

A. The Challenge of Selecting a Single "Best" Reduced Model Fit

The complete Benchmark Model likely has terms that do not improve the accuracy of emissions predictions. Retaining terms that do not improve the accuracy of predictions can increase the uncertainty in the predictions because any nonzero model terms change the predictions even if the terms are not required for an adequate fit. Usually such changes are small relative to the changes in predicted values attributable to the statistically significant model terms. Nevertheless, it is generally desirable to delete unnecessary model terms.

The process for deleting unnecessary model terms is called *variable selection*. There are many statistical procedures that can be used to reduce the number of model terms by deleting ones that do not contribute to the prediction of the modeled emissions; none are universally accepted as the best procedure to use for all modeling situations and for all types of data. Similarly, the notion that any statistical procedure can provide a single "best" reduced model is not substantiated in the statistical literature. A "best" reduced model is only best once a variable selection procedure is selected and a criterion for "best" according to that procedure has been selected. These decisions can be highly subjective.

Experience with a variety of variable selection procedures suggests the following important considerations when fitting reduced models to emissions.

- When properly applied, different variable selection methods usually produce similar, although not necessarily identical, reduced model fits.
- Variable selection methods generally identify a number of well-fitting reduced model fits. One should not expect any variable selection method to identify a single "best" model fit from among the $2^{17} = 131{,}072$ possible reduced model fits from the Benchmark Model.
- Although, the criterion for "best" with a particular variable selection method can enable the selection of one of the better-fitting reduced model fits, it is far preferable to use scientific or engineering knowledge to select from among the better fitting models one or more model fits that are consistent with accepted knowledge about fuel parameter effects on emissions.

B. *Variable Selection Methods: Measurements and Bags with Five or Fewer Zero Values*

1. *Initial Screening of Model Terms*

Proc Reg in SAS includes a wide variety of variable selection algorithms that are widely used, highly efficient, and highly effective for selecting terms that can be deleted from regression models. Fuel parameter terms that should be deleted are those in the Benchmark Model that do not contribute substantively to the prediction of regulated emissions or fuel economy values. Proc Mixed in SAS, the algorithm that is used to fit most of the final models, does not permit the use of these fast, effective algorithms. Using Proc Mixed, reduced model fits must be obtained one by one in separate SAS computer runs. With Proc Reg, statistical criteria for evaluating hundreds of alternative model fits can be obtained very rapidly with a single SAS run.

As mentioned in Section III.B., an issue with the use of Proc Reg instead of Proc Mixed is that vehicles are random effects and Proc Reg fits only fixed effects models. All the fuel parameter terms are fixed effects. However, since all vehicles are to be included in the fitted models and variable selection is to be performed only on the fixed effect fuel properties, Proc Reg can be used for the initial screening of the fuel parameter model terms. To do so, individual intercepts for each vehicle are added to the other fixed effects terms of the model, the overall intercept is deleted, and no random effects other than the error term are included. All the vehicle intercepts are retained in each reduced model fit, which is an option in Proc Reg. This is actually what occurs with Proc Mixed and calculations using both methods are essentially identical for the fixed-effects fuel parameter model terms.

In this initial screening of terms, not only are the vehicle intercepts required to be in each model fit, the *principle of hierarchy* must be maintained. This principle states that interaction terms (products) and powers of fuel properties can be properly assessed only if the constituent linear terms are also in the model. Only subset models that adhere to this principle are considered candidates for final reduced model fits.

The option in Proc Reg that is used to screen terms from the Benchmark Model is the *Best Subset* algorithm. This algorithm efficiently searches all the possible subsets of model terms and calculates various statistics that can be used to select better reduced (subset) model fits, model fits with some of the original model terms deleted. A widely used statistic for selecting better reduced model fits is Mallow's C_p statistic. Small values of C_p, values near the number of terms in the reduced model, are regarded as identifying the better reduced model fits. Alternatively, information criteria can be used to select better reduced models. Often Mallows' C_p and information criteria assessments lead to the same subset model but they need not do so.

Two fundamental and important considerations need to be understood with the use of variable selection methods to select reduced models. First, the goal of variable selection methods is to select reduced models that eliminate model terms that do not contribute substantially to model predictions. Consequently, it must be verified that reduced model fits predict with strong fidelity to complete model fits. Thus, if only the Phase 3 data are used to identify the better reduced model fits, as is the case for this report, the complete model fits provide the relevant comparisons against which reduced models must be assessed. As mentioned above, if other scientific or engineering data or knowledge are available, that additional information can and should inform the selection of reduced models.

Second, the "best" model should not be selected solely on the basis of the smallest value of a variable selection criterion (e.g., C_p, Bayes Information Criterion). Often, the subset model with the smallest value of a criterion is within tenths or hundredths of a percentage point of several other subset models that have criterion values that are extremely close to the minimum. This point is being emphasized because some of the reduced model fits that provide criterion values near the minimum might be preferable to the fit that produces the minimum criterion value because of external scientific or engineering reasons.

2. *Final Model Fits*

Since only the Phase 3 data are available for this report, reduced models for the various emissions and bags are selected using the minimum C_p criterion. Once the terms for a reduced model are selected using the C_p criterion, Proc Mixed is used to fit the reduced model and determine whether all the remaining terms in the model are statistically significant. Occasionally, a term in the selected reduced model is not significant. When this occurs, additional hierarchical model fits with the next smaller C_p values are examined until a reduced model fit with hierarchical model terms that are all statistically significant is identified.

It is widely recognized that often too small a p-value cutoff for statistical significance is used for subset model selection. With any variable selection technique when there are a number of model terms, the more serious statistical hypothesis testing error generally is not the Type I error (falsely concluding a term is needed when it is not). The more serious error is generally the Type II error (falsely concluding a term is not needed when it is needed). Standard practice is to choose a p-value cutoff that is larger than the usual one, $\alpha = 0.05$. The significance level used in this report to determine statistical significance is $\alpha = 0.10$. Consequently, absent any scientific or engineering knowledge of fuel parameter effect on emissions that would enable the selection of one of the better reduced models, the three criteria for selecting a preferred model fit are:

- Select from among model fits adhering to the hierarchy principle,
- Select the model fit having the smallest C_p value, and
- Select reduced models that have all model terms, subject to the hierarch principle, that have estimated coefficients that are statistically significant (p-value < 0.10).

C. *Variable Selection Methods: Measurements and Bags with More than Five Zero Values*

When a measurement/bag data set contains more than five zero values Proc LifeReg, a censored data statistical model fitting method, is used to fit candidate models. Proc LifeReg fits only a single model in one SAS run. It does not have the efficient best subset algorithm that is available in Proc Reg. When Proc LifeReg is used, variable selection is conducted using *Backward Elimination*. Backward Elimination deletes terms that are not statistically significant from the Benchmark Model one-by-one until only statistically significant terms remain. Likelihood ratio statistics are calculated and model terms are deleted until all the computed p-values in a hierarchical reduced model fit are less than 0.10.

In Section V, tables are presented with alternative reduced models that are similar to the tables for reduced model fits using Proc Reg and C_p statistics when there are five or fewer zero values. When there are more than five zero values, however, the reduced model fits eliminate the zero values. Consequently, these reduced model fits might differ from those that would be obtained if Proc LifeReg model fits could be obtained from all possible reduced models. Such an exhaustive model fitting calculation is beyond the scope of this work. The reduced model fits presented in Section V are given to provide some sense of the alternative model fits that would be appropriate had there been no zero data values. Further comments on this are made in Section V.

V. *Model Fits: Results*

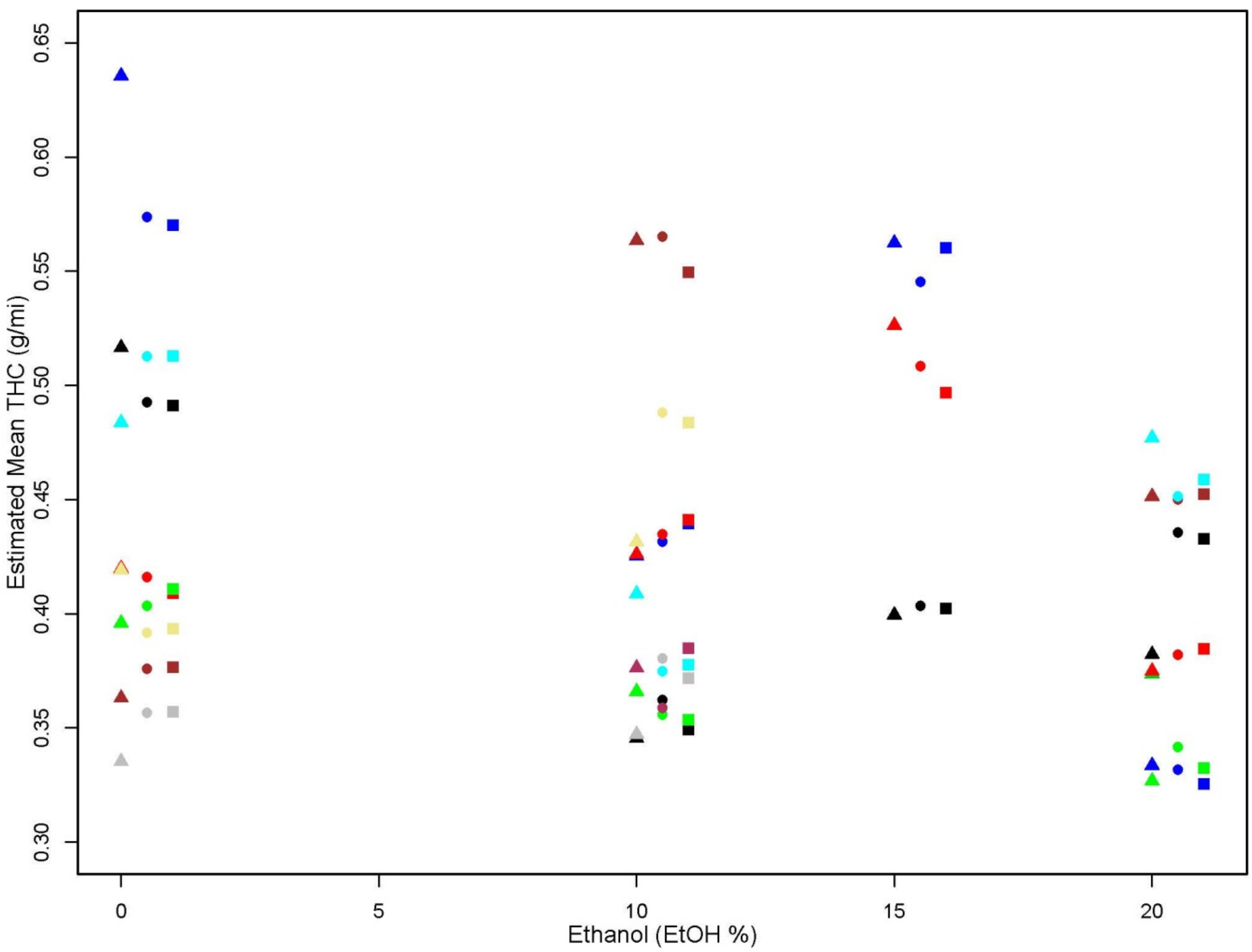
A. *Benchmark Model Fits*

Appendix III contains tables of Benchmark Model fits in which all the 17candidate fuel parameter model terms are included in the fitted model. Separate tables are provided for composite emissions and for each bag. Each table includes all the emissions and fuel economy model fits. Appendix IV contains similar tables of model fits for the Benchmark Model fits that exclude the T_{90}^2 model term. As demonstrated in Figs. II.B.1 and II.B.2 for Bag 1 THC emissions, these complete model fits produce very similar estimated mean emissions for the 27 program fuels.

B. *Reduced Model Fits*

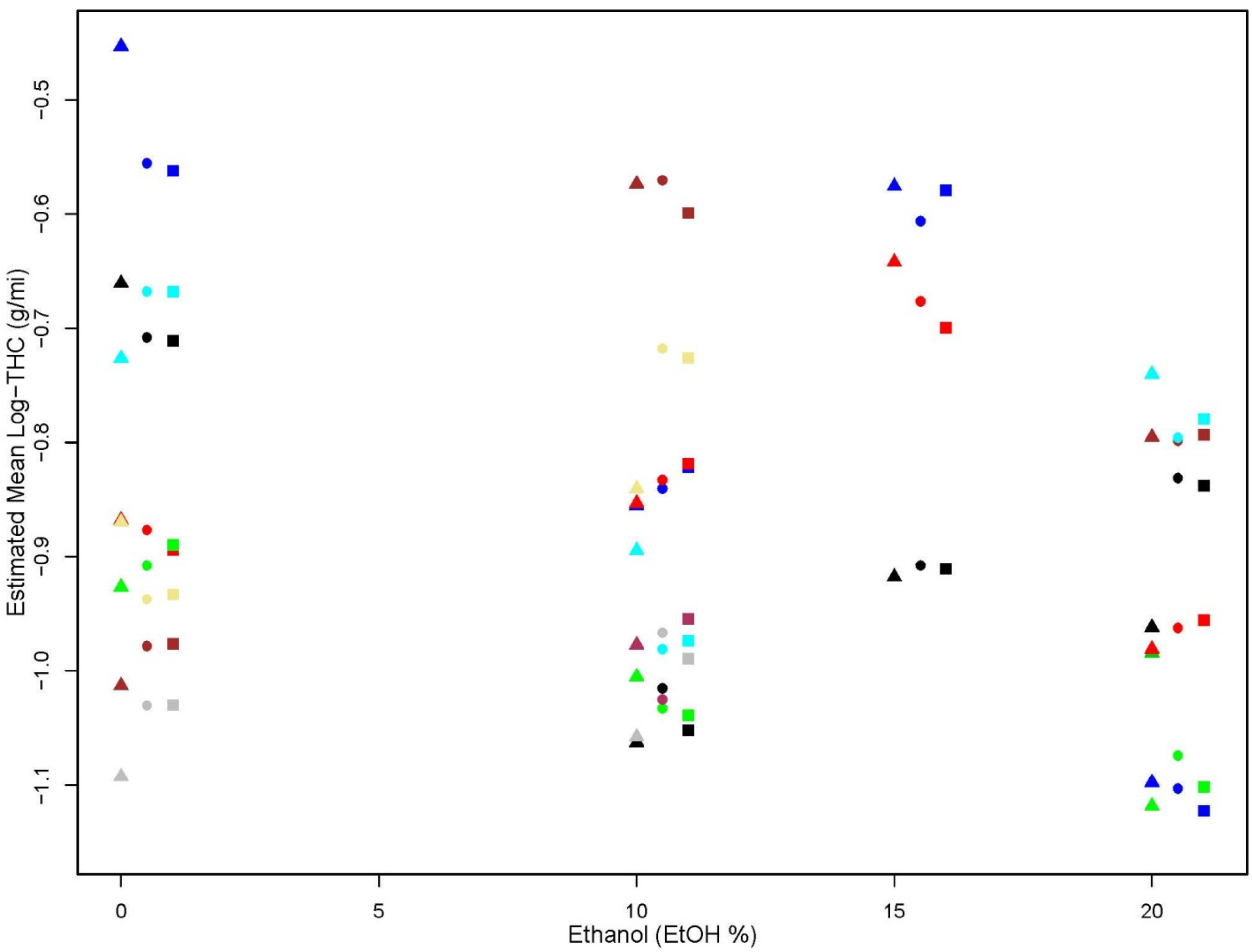
Appendix V contains tables of the reduced Benchmark Model fits that resulted from the variable selection procedures detailed in Sections IV.B and IV.C. The corresponding reduced model fits using the Benchmark Model without the T_{90}^2 term are included in Appendix VI. Examination of the reduced model fits in Appendices V and VI reveals that the only differences in the reduced models selected using Benchmark Models with and without the T_{90}^2 model term are for FE (composite and all three bags), PM (composite and Bags 1 and 2), and THC (Bag 1).

Fig. V.B.1 Model-Estimated Mean Bag 1 THC Emissions for the 27 Program Fuels. Exponentiated Log-transformed Data Averages (Triangles), Reduced Benchmark Model Estimates (Circles), Reduced Benchmark Model Estimates without the T_{90}^2 Term (Squares). Fuel Mean Estimates Color-Coded Separately for 0, 10%, 15%, and 20% Ethanol Content.



As with the complete Benchmark Model fits in Figs. II.B.1 and II.B.2, the reduced model fits with and without the T_{90}^2 model term provide comparable estimates of the 27 fuel mean emissions and mean log-emissions. For some of the 27 fuels, each of these model fits predicts the mean emissions slightly better than the other model fit. Neither of the two model fits results in estimated means that are consistently closer to the exponentiated averages of the log-emissions (Fig. V.B.1) or the averages of the log-emissions (Fig. V.B.2).

Fig. V.B.2 Model-Estimated Mean Logarithmically Transformed Bag 1 THC Emissions for the 27 Program Fuels. Log-transformed Data Averages (Triangles), Reduced Benchmark Model Estimates (Circles), Reduced Benchmark Model Estimates without the T_{90}^2 Term (Squares). Fuel Mean Estimates Color-Coded Separately for 0, 10%, 15%, and 20% Ethanol Content.



C. Alternative Reduced Model Fits

In Section IV.A (above) emphasis was placed on the difficulty of uniquely identifying a single best model fit for data sets and models as complex as the polynomial ones on which this project is based. In order to document and illustrate the importance of this principle, Appendixes VII through X provide alternative reduced models for composite and bag emissions, respectively. These model fits are from among the 200 model fits for each emission that (a) adhere to the hierarch principle, (b) have the smallest C_p values, and (c) contain only terms that are statistically significant ($p < 0.10$). Up to 25 alternative model fits are tabled. If fewer than 25 alternative models are shown, there were fewer than 25 among the 200 model fits with the smallest C_p values that adhere to the hierarchy principle and have all model terms statistically significant.

The reduced model fit for Bag 1 THC with the T_{90}^2 model term and the fit without the T_{90}^2 model term are among the first 5 "best" model fits but neither one is the first one listed. This is because the first one listed has a model term that is not statistically significant. The fit that includes the T_{90}^2 term is the second "best" model fit and the one without the T_{90}^2 model term is the 5th "best" model fit. However, as demonstrated in the previous section, both of these two model fits are comparable in estimating the 27 fuel means for THC.

The alternative model fits given in Appendices VII through X can be examined to determine if there are specific model fits that contain model terms that are preferable to the reduced model fits given in Appendices V and VI. A basis for preferring one or more of the alternative model fits can be based on well-accepted scientific or engineering principles that relate the model terms to known effects on emissions. Caution should be exercised in assessing any of the alternative models that are selected for any of the models that were fit using Proc LifeReg because of large numbers of zero (nondetectable) measurements. There is no algorithm that accompanies Proc LifeReg that permits the determination of alternative "best" reduced models. In order to provide some indication of the nature of possible alternative model fits, Proc Reg was used to identify the better subsets. This requires that all zero and missing values be deleted from the assessment of alternative reduced model fits since logarithmically transformed emissions are fit. These alternative model fits should be investigated further to determine whether they do provide alternative, equally effective, model fits.

VI. Discussion and Recommendations

A. Program Strengths and Limitations

Phase 3 of the EPAct/V2/E89 Program achieved the goal of creating an extensive database of emissions across the 27 program fuels and the 15 program vehicles that were included in the test program. The goals of this project focused on fuels with varying amounts of ethanol and the accompanying four fuel parameters. The variety of fuels evaluated is one of the strengths of this program.

Evaluations of alternative model specifications, the inclusion or exclusion of specific fuels, and the inclusion or exclusion of specific vehicles can be performed. For example, estimated model means for fuels not included in the database can be calculated and compared to program fuel results. The sensitivity of model estimates can be assessed with respect to individual fuel properties and the inclusion or exclusion of individual model terms. The database can be used to investigate fuel property effects on individual vehicles or groups of new, low-emitting Tier 2 vehicles. Conversely, the effects on fuel mean estimates can be assessed relative to the inclusion or exclusion of individual vehicles or groups of vehicles.

The strengths of the program also induce limitations on the conclusions that can be drawn from the statistical modeling and analysis. A major limitation involves the selected vehicles. It is not clear that the Tier 2 vehicles selected for this program were intended to represent a well-defined fleet of vehicles. To the extent that such a fleet can be defined and these vehicles are representative of that fleet, inferences can be appropriate to the fleet. Absent the definition of a fleet for inferential purposes and substantive documentation that these vehicles are representative of the defined fleet, the conclusions drawn from the statistical modeling and analyses of the program data are relevant only to these 15 vehicles. Moreover, there is substantial statistical evidence that several of the vehicles in this project highly influence the modeling results. This is understandable and expected since the few vehicles in this study are so different in size (e.g., compact cars, trucks, SUVs), engines (e.g., 1.8L I4 to 5.3L V8), technology classes (e.g., all Tier 2 but Bins 4 to 8), etc. Since only one vehicle of each selected model is included in the database, it cannot be determined whether any influence of the individual vehicles on the modeling results is due to the individual vehicles or to the model types that they represent.

B. Recommendations

1. Benchmark vs. Reduced Model Fits

A great deal of effort was expended by all the program participants to evaluate reduced models in which the model terms that do not contribute to the overall predictive ability of the fitted models are eliminated. The benefit of doing so is that there is the possibility that reduced models would be simpler to interpret and the effects of individual fuel parameters would be more easily discerned. Appendices V and VI document that these goals are not achieved. Many of the reduced model fits require a large number of terms and model fits show little consistency (apart from that induced by the hierarchy principle) in the terms remaining in the model fits. Finally, with today's computing power there is no major computational advantage to fitting reduced models over fitting the complete Benchmark Model.

Appendix XI contains graphical comparisons of the estimated mean emissions and fuel economy for the 27 program fuels using the Benchmark Model fits (Appendix III) and reduced model fits having the smallest C_p values (Appendix V). Graphs are included for each of the modeled emissions and fuel economy for each phase of the LA-92 Unified test cycle. Also included are graphs for the composite (weighted bag) emissions.

In each graph in Appendix XI the averages emissions and fuel economy values are shown as solid green triangles. The averages for the emissions measurements are obtained by exponentiating the averages of the logarithmically transformed emissions. Fuel economy was not transformed; hence, ordinary averages for fuel economy are calculated and graphed. The solid black circles are estimates of the mean emissions for the 27 fuels, estimates obtained from the Benchmark Model fits. The solid blue squares are estimates of the mean emissions for the 27 fuels that are obtained from the respective reduced model fits.

In all of the graphs the estimates from the Benchmark Model fits and from the respective reduced model fits are very similar. This is what one would expect if the reduced models were retaining the predictive ability of the full model. In order to give a clearer sense of the similarity of the estimated means from the model fits, quadratic curves were fit to the estimated means as a function of the ethanol content, separately for estimated means from the Benchmark Model and those from the respective reduced model fits. In most of the graphs the two curves completely overlap. In the few figures where the curves do not completely overlap, the differences are minor.

It is recommended that the fitted Benchmark Models be used for prediction purposes rather than the various reduced model fits. The Benchmark Model fits all contain any of the model terms that are useful in prediction. Unlike the reduced model fits, the benchmark Model fits do not require individual judgment about which variable selection procedure to use, what criteria to impose on the variable selection procedures, and how decisions regarding competing reduced models are to be made. Using the fitted Benchmark Models also allows consistency in methods across emissions types and bags. This is especially valuable for the censored data model fits using Proc LifeReg, where the computational ability to fit reduced models is severely limited.

The graphs in Appendix XI illustrate only one of many possible summaries of the data and the model fits. Overall trends can be evaluated with respect to changes of the fuel parameters – within the constraints of the limits illustrated in Figures I.C.1 and I.D.1.

2. *Additional Issues*

To the extent that the prevalence of nondetectable emissions are likely to be present in future studies, alternative statistical modeling methods should be investigated. Censored data modeling, as was used in this project, is but one of a number of alternatives that might be needed to satisfactorily model emissions for future generations of vehicles that are expected to have even lower emissions levels than the vehicles included in this project. An investigation of possible alternative modeling methods was beyond the scope of this effort.

Finally, the statistical modeling performed on the emissions in this database clearly indicates that future designs of similar studies should be based on a full quadratic model in the fuel parameters. The results of the modeling performed on this project, whether using the complete Benchmark Model fits or the various reduced model fits, benefitted from combinations of virtually all the model terms that were able to be included in the statistical models. This knowledge is an additional benefit of this project.

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The author gratefully acknowledges the financial support from the U.S. Department of Energy Office of Vehicle Technologies through the National Renewable Energy Laboratory under NREL subcontract number LGC-0-40441-01. The formulation of estimation strategies and accommodations of influential data and zero (nondetectable) measurements benefitted greatly from discussions with EPA staff, notably George Hoffman, Rafal Sobotowski, Aron Butler, and James Warila. Additional input from scientists and engineers who are members of the Coordinating Research Council E-89 Panel is greatly appreciated. Kevin Whitney, Southwest Research Institute provided valuable insight into testing procedures, including the LA-92 time trace data used in Fig. I.A.1. Finally, none of this work would have been possible without the guidance and support of Doug Lawson, National Renewable Energy Laboratory.

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K. Whitney, “EPAct Fuel Blending,” Final Report, NREL Subcontract ACI-8-88612-01 and EPA Contract EP-C-07-028, Southwest Research Institute, September 2010.

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APPENDICES

I. Constant Variance and Normal Probability Assessments

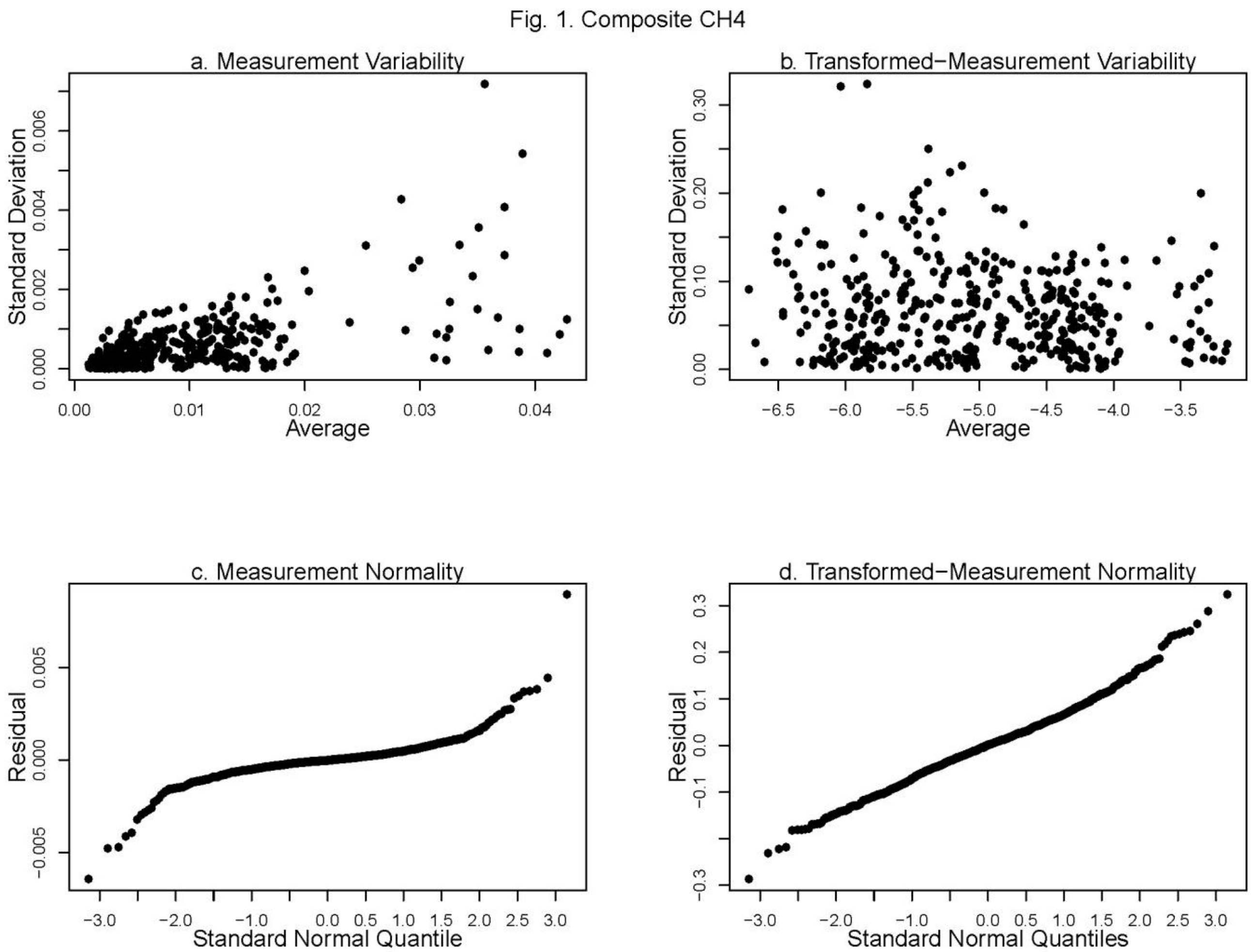


Fig. 2. Composite CO

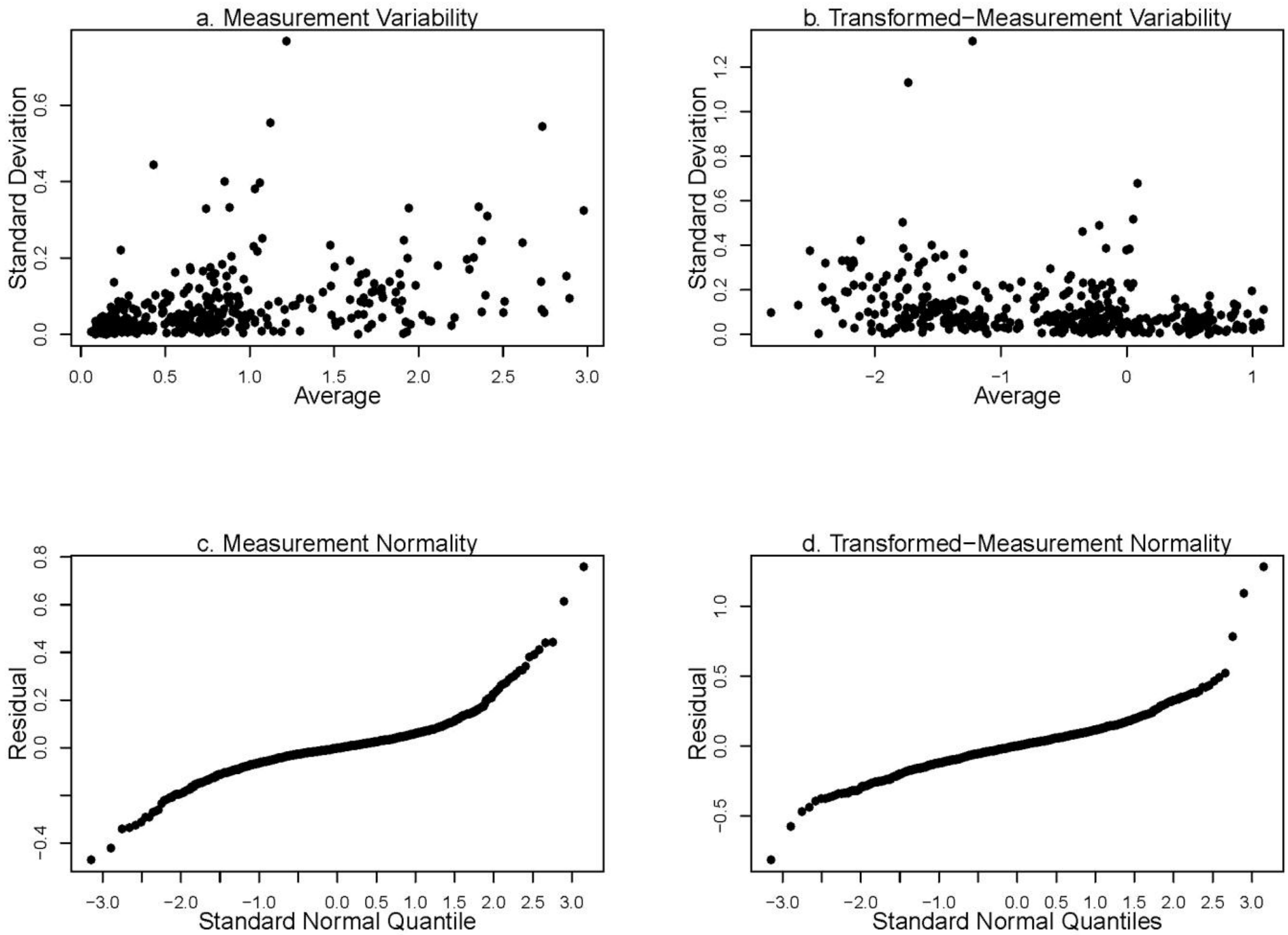


Fig. 3. Composite CO_2

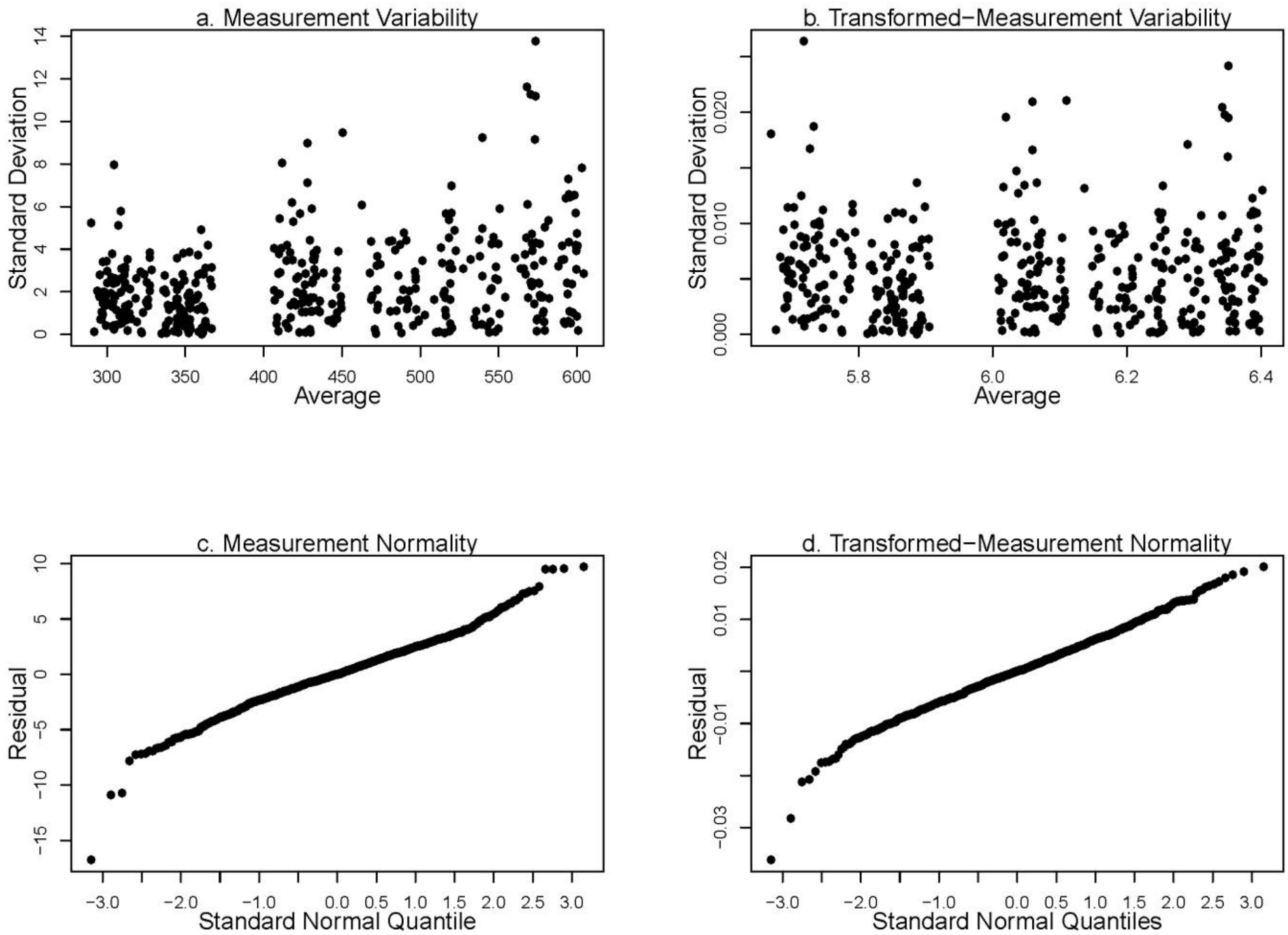


Fig. 4. Composite FE

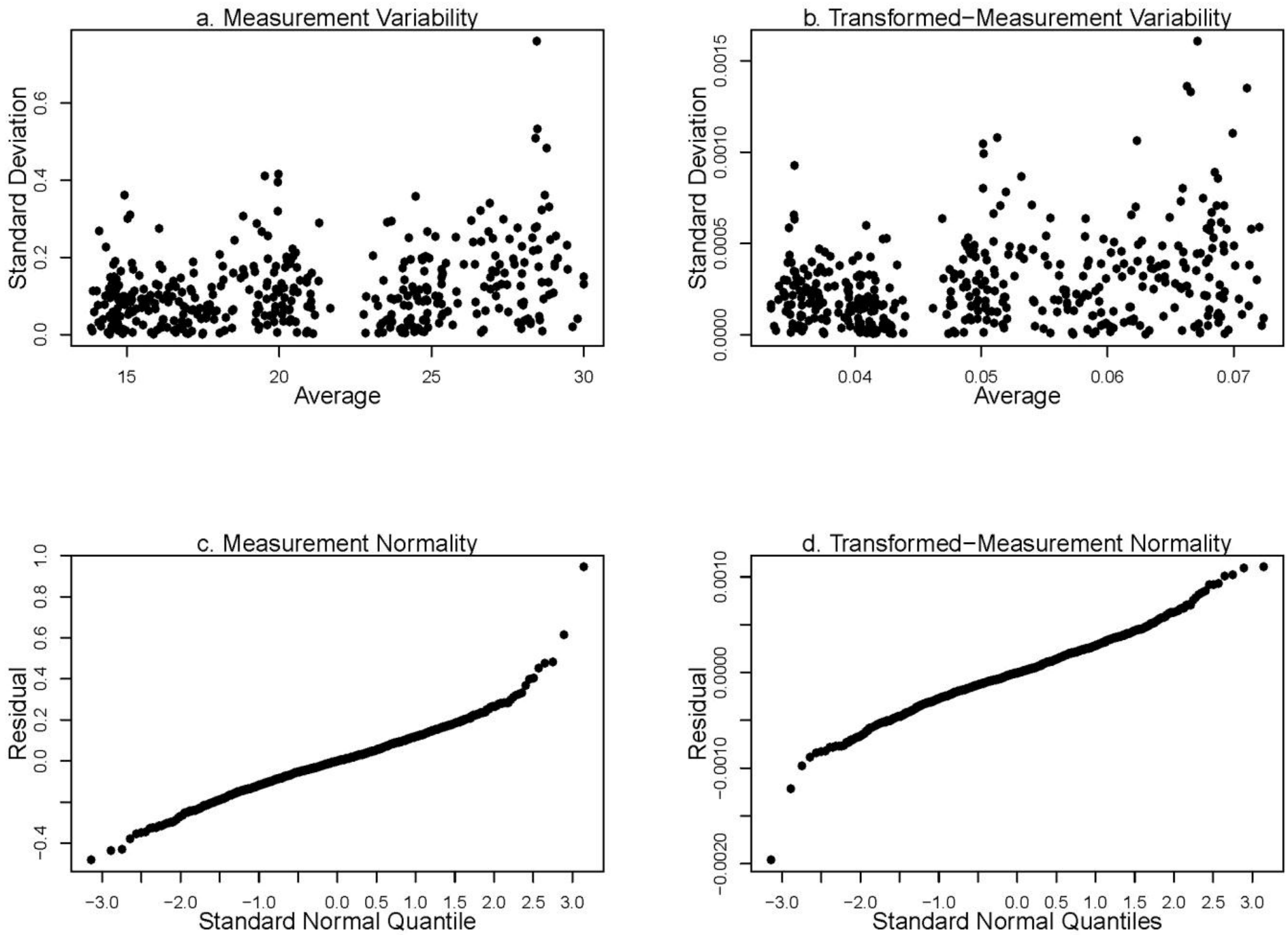


Fig. 5. Composite NMHC

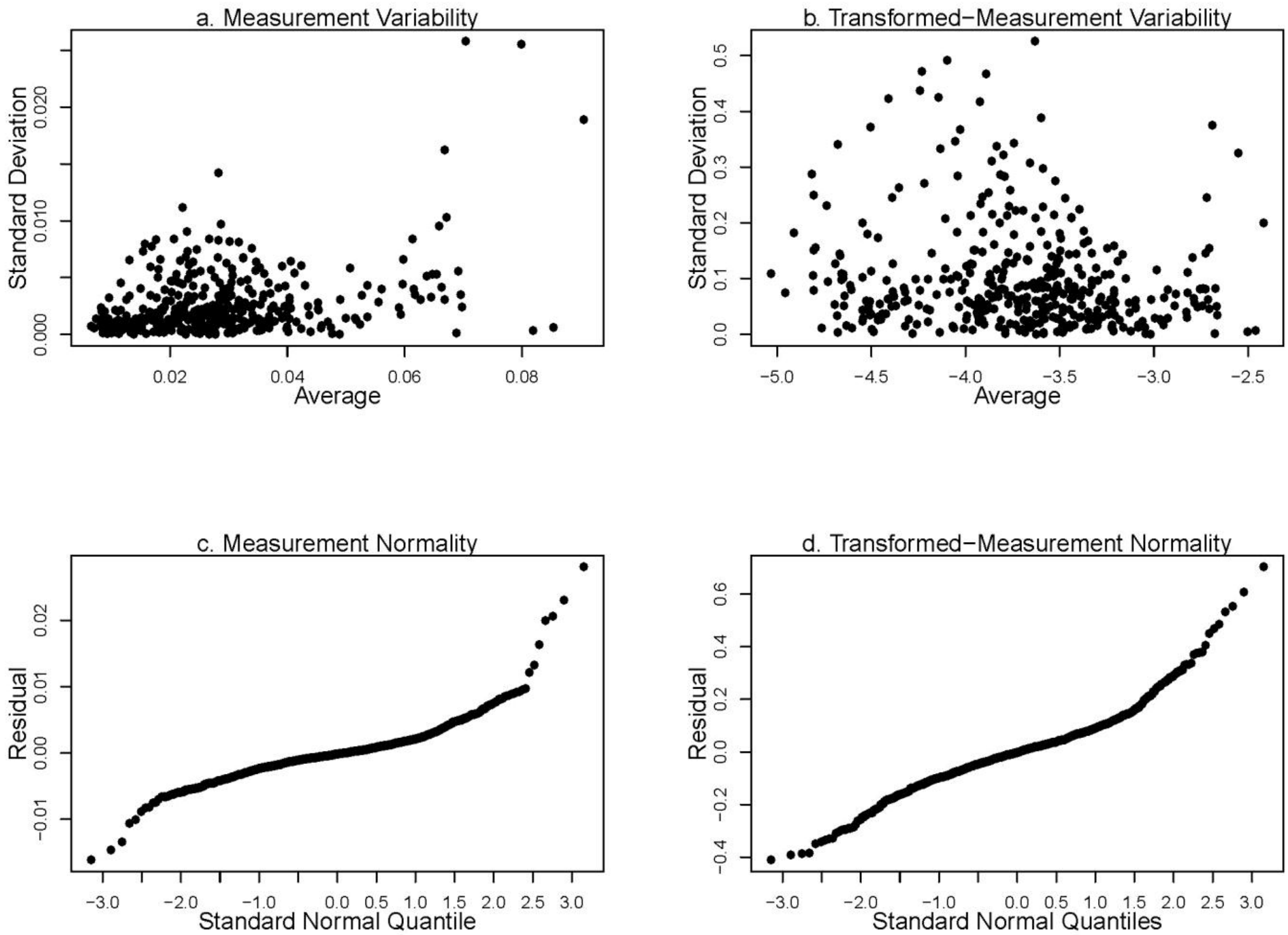


Fig. 6. Composite NMOG

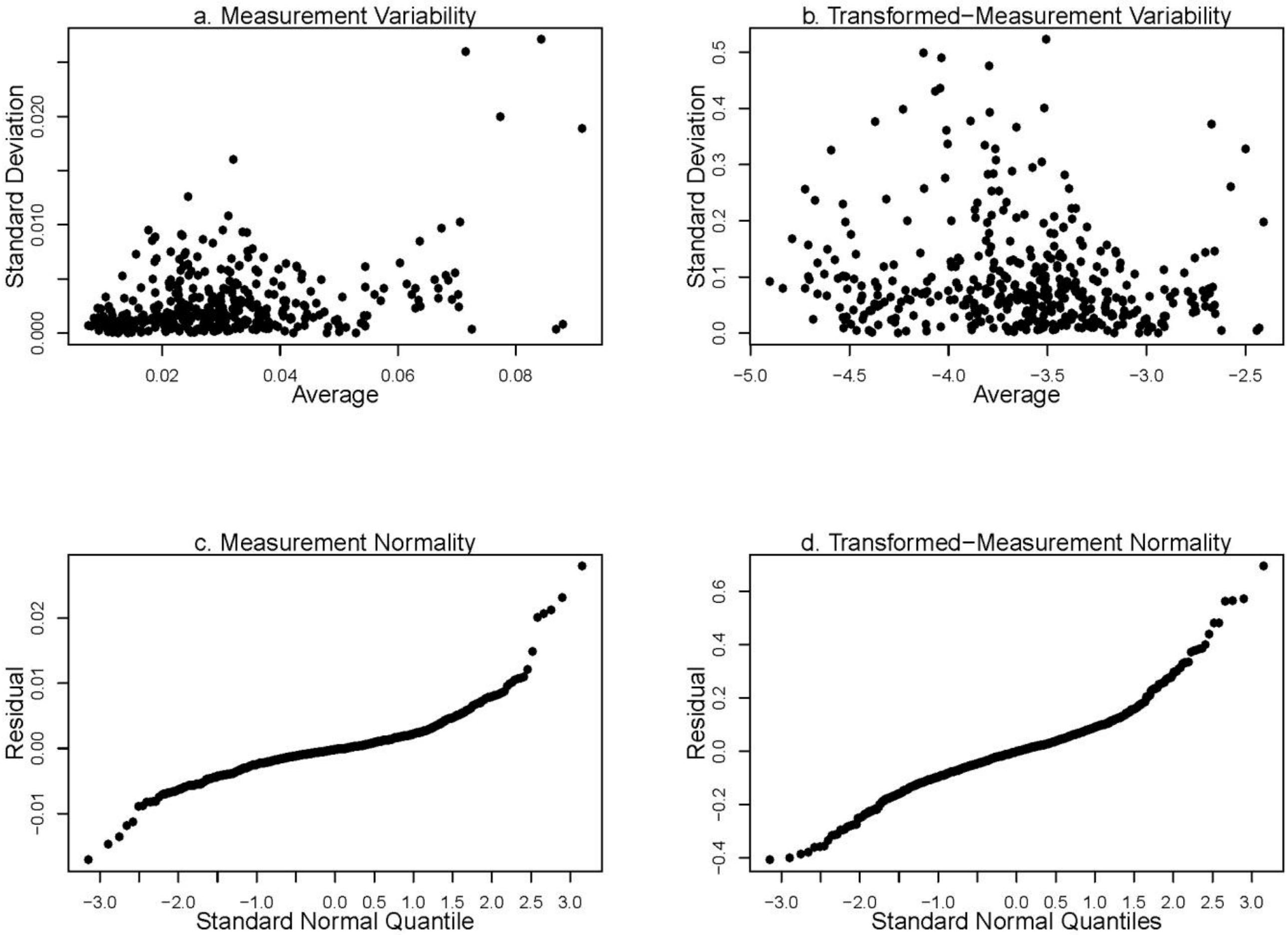


Fig. 7. Composite NOx

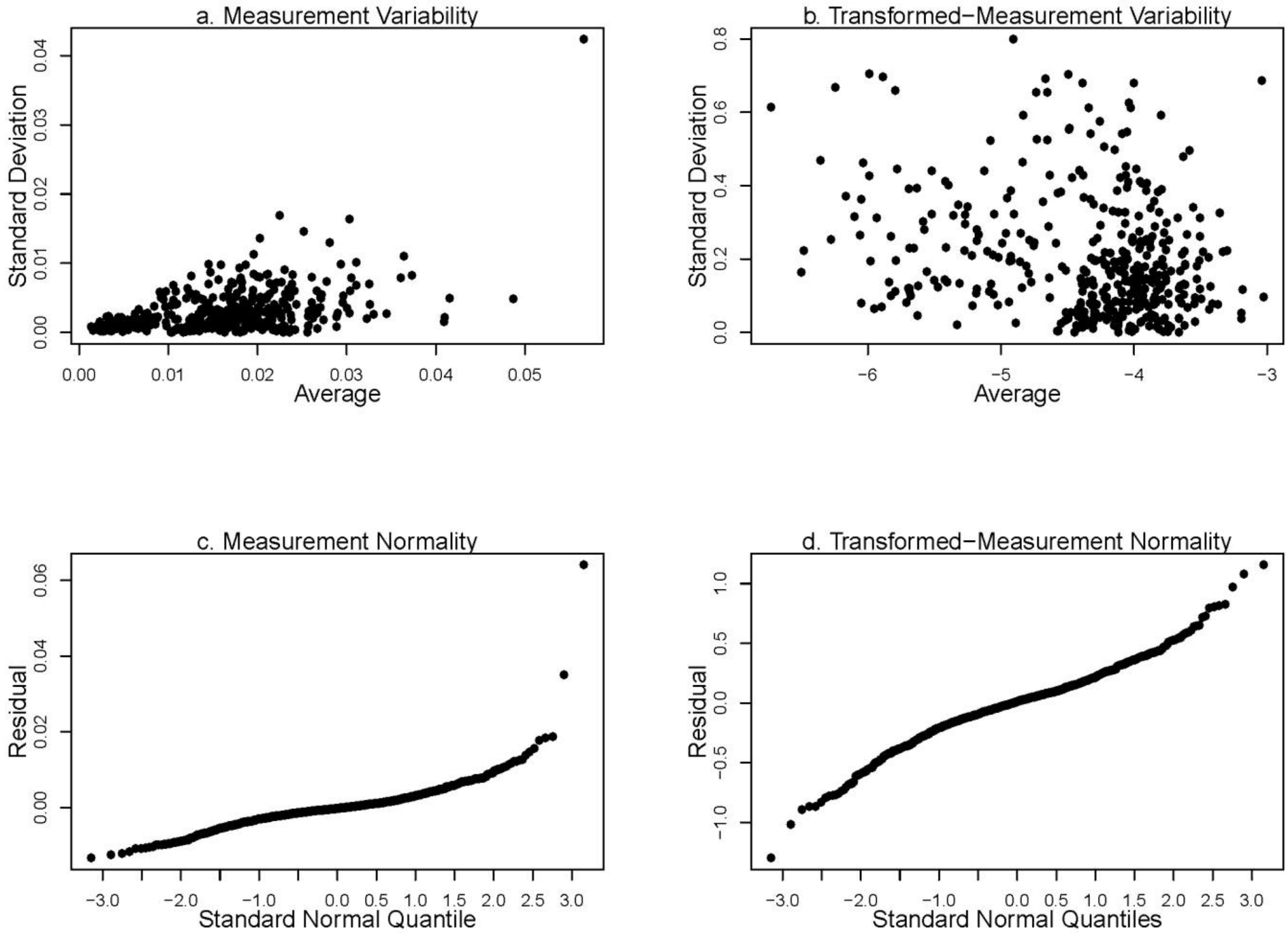


Fig. 8. Composite PM

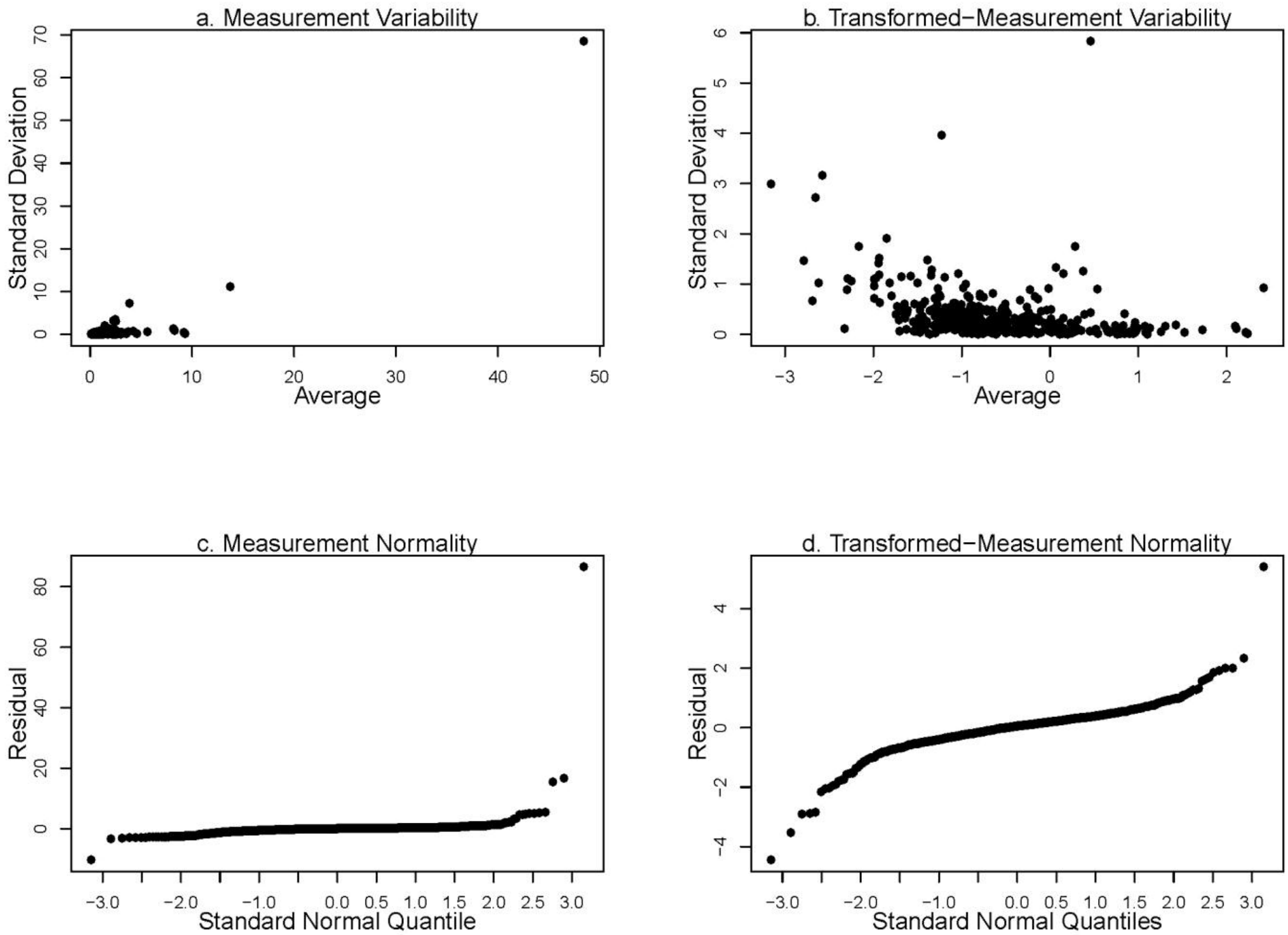


Fig. 9. Composite THC

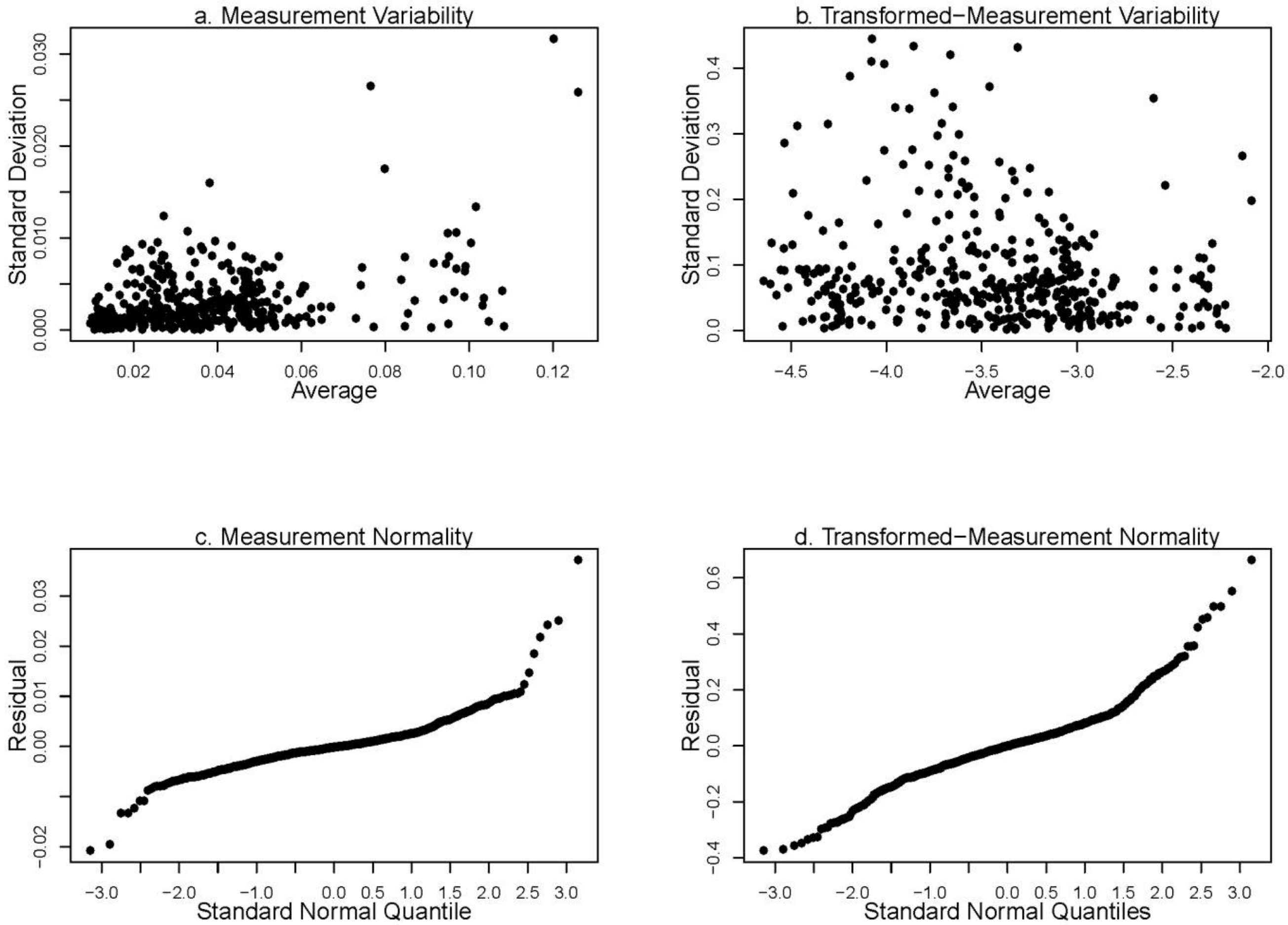


Fig. 10. Bag 1 CH_4

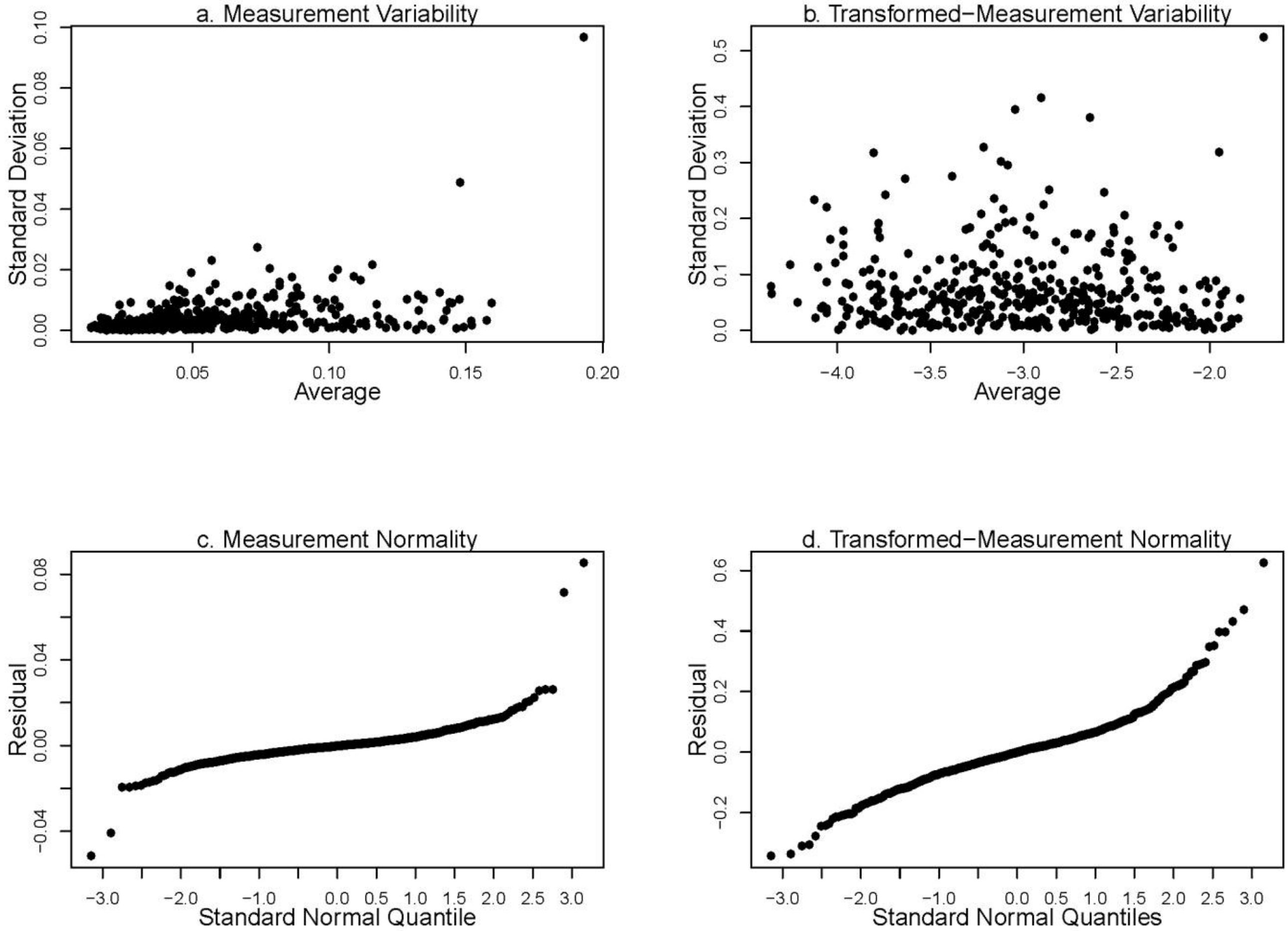


Fig. 11. Bag 1 CO

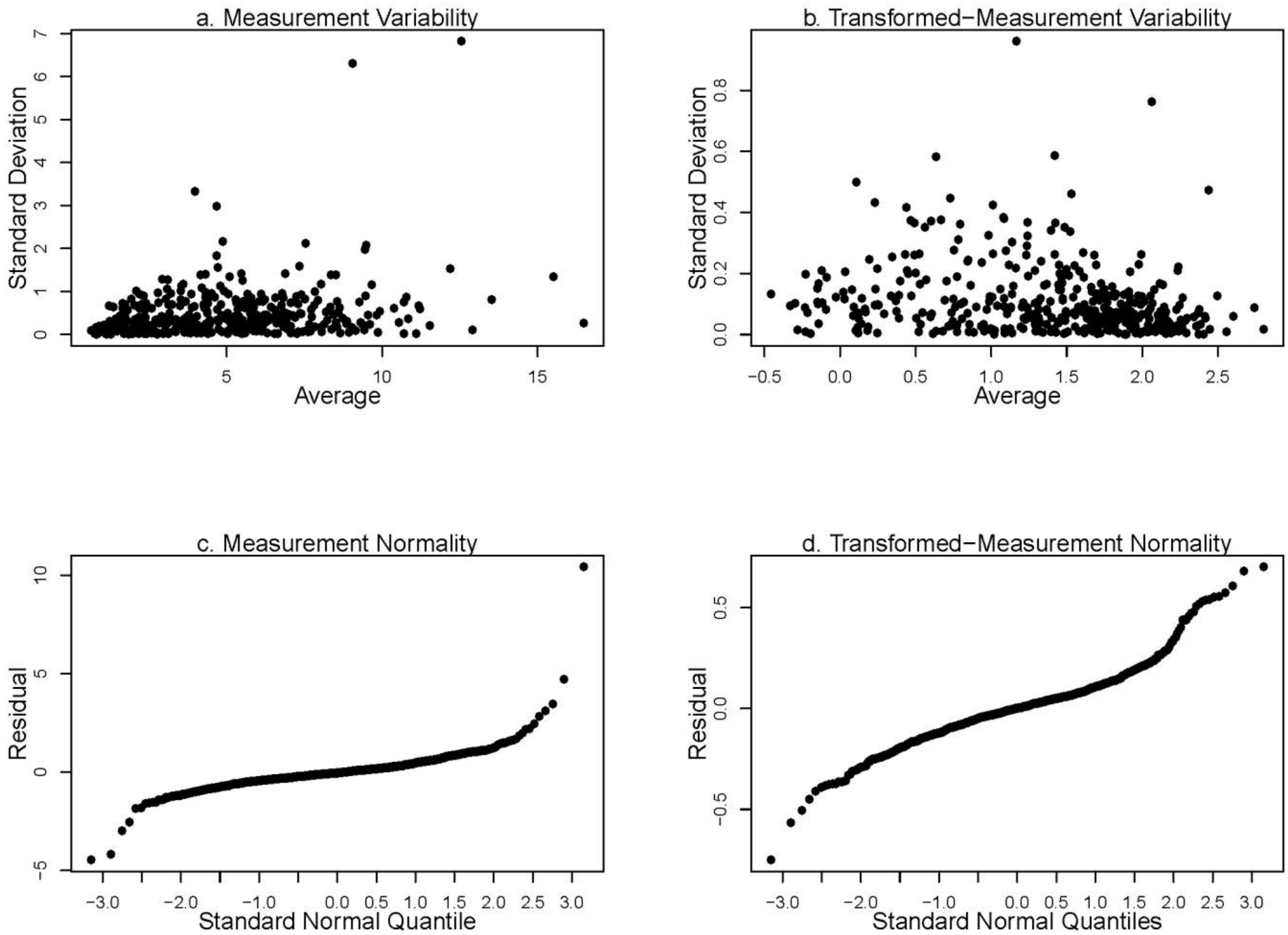


Fig. 12. Bag 1 CO2

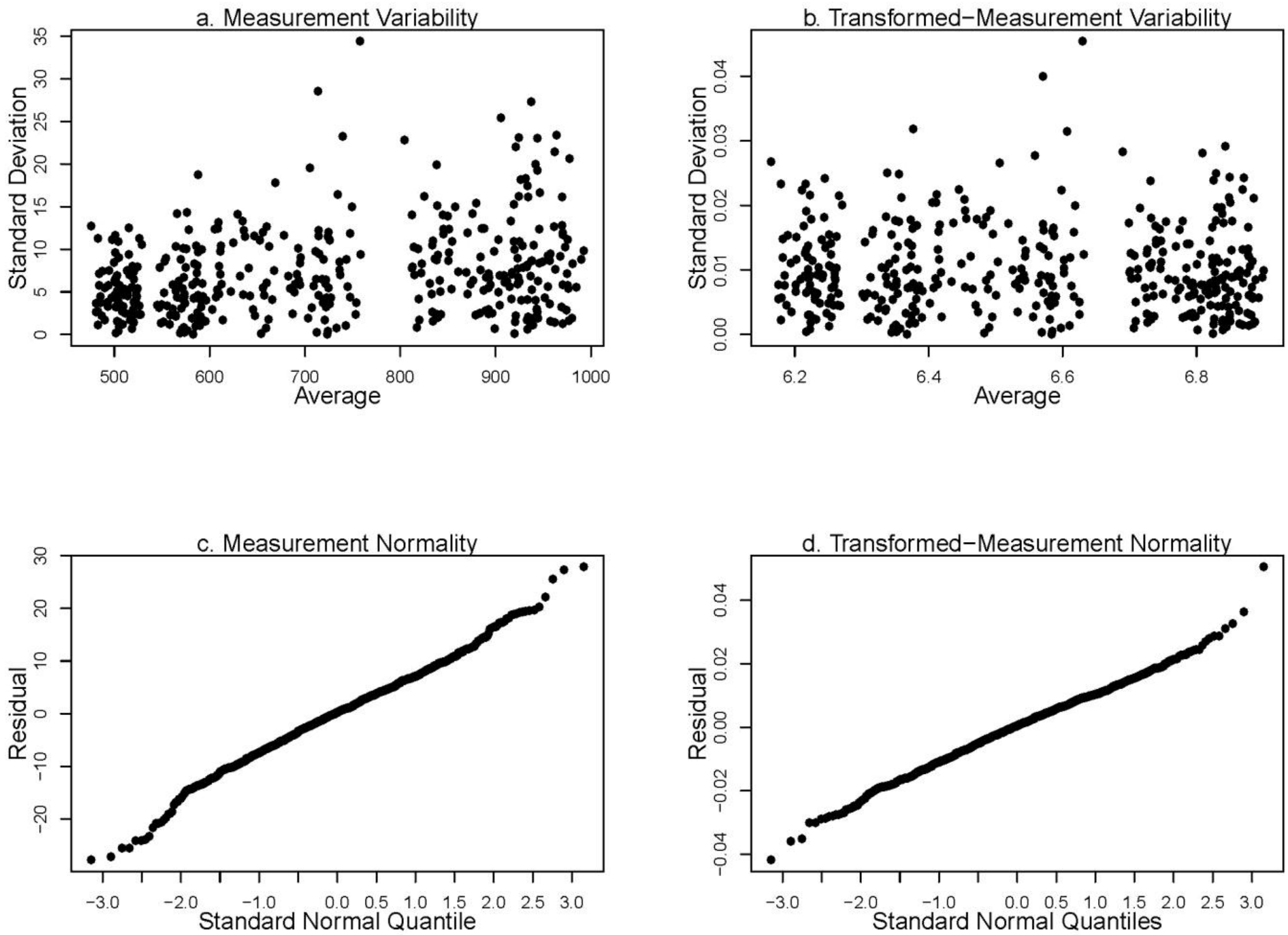


Fig. 13. Bag 1 FE

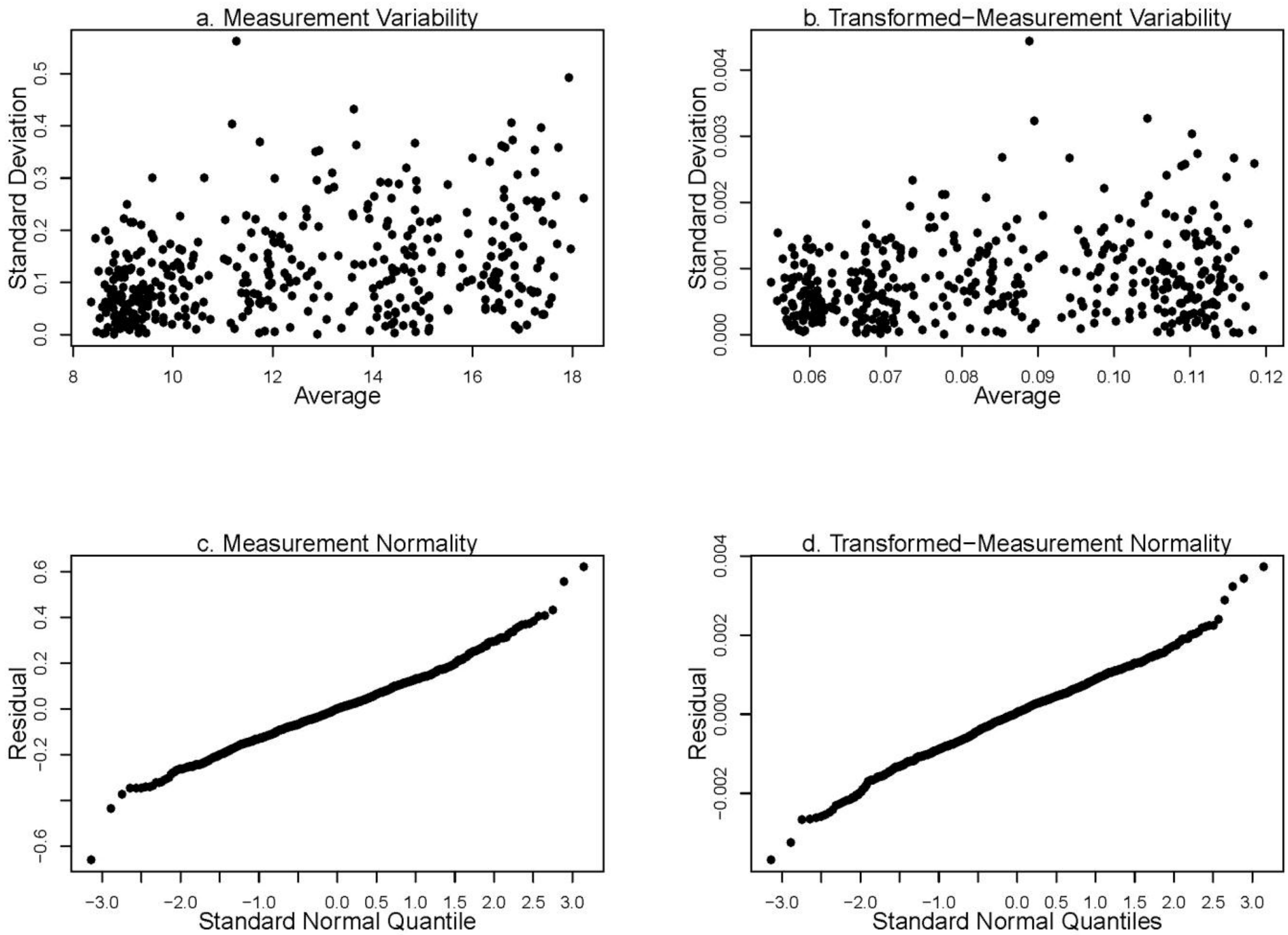


Fig. 14. Bag 1 NMHC

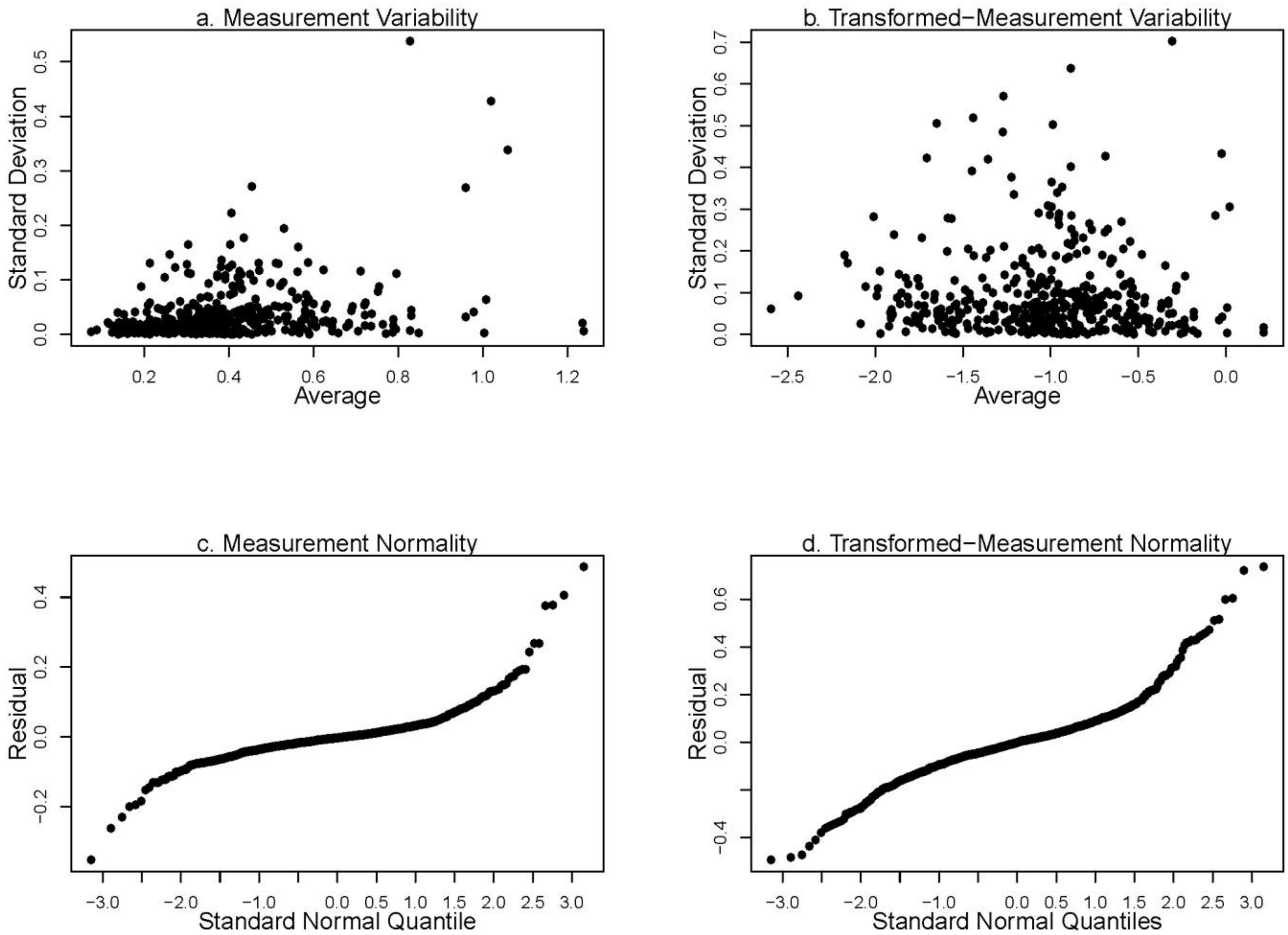


Fig. 15. Bag 1 NMOG

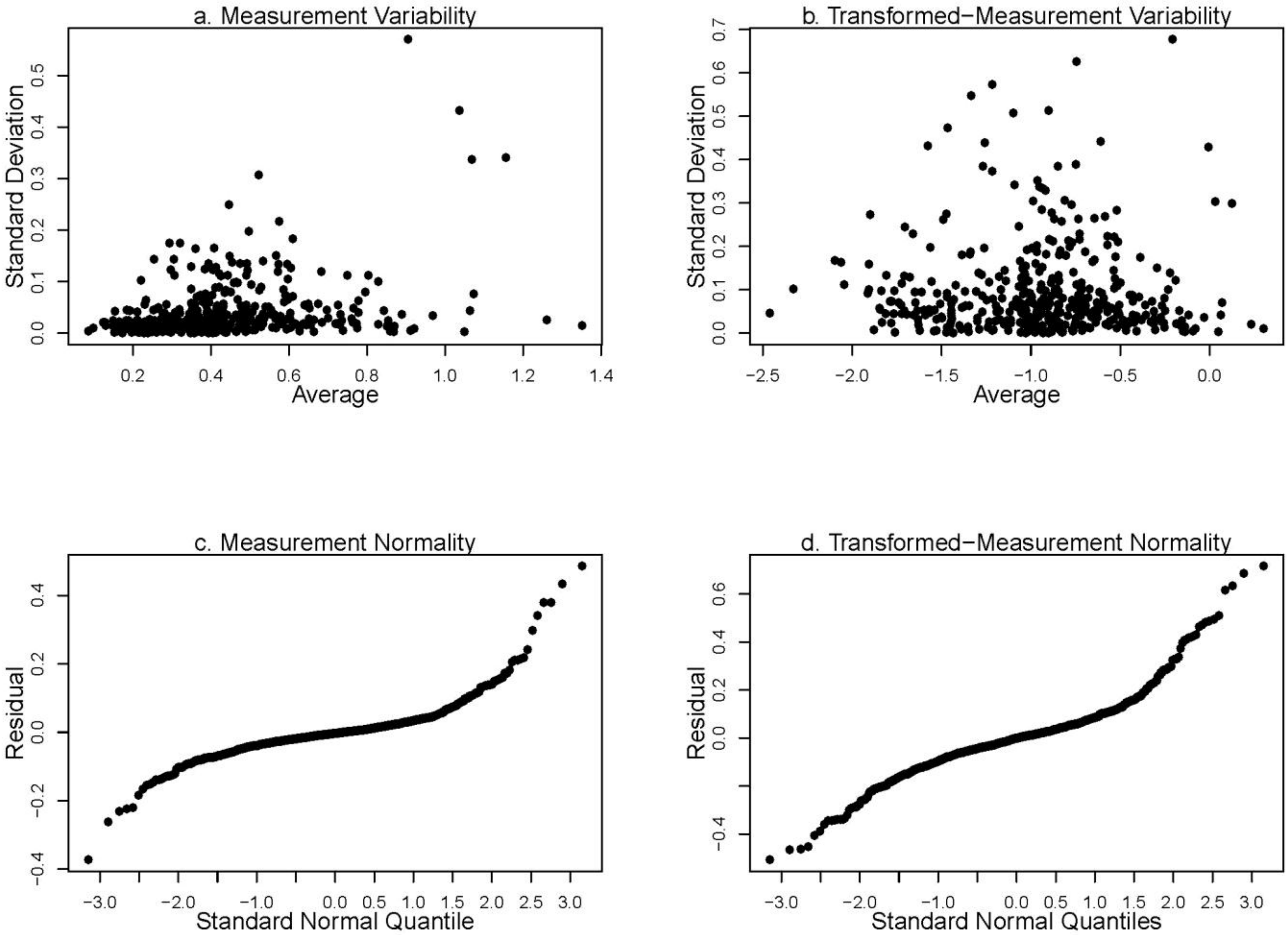


Fig. 16. Bag 1 NOx

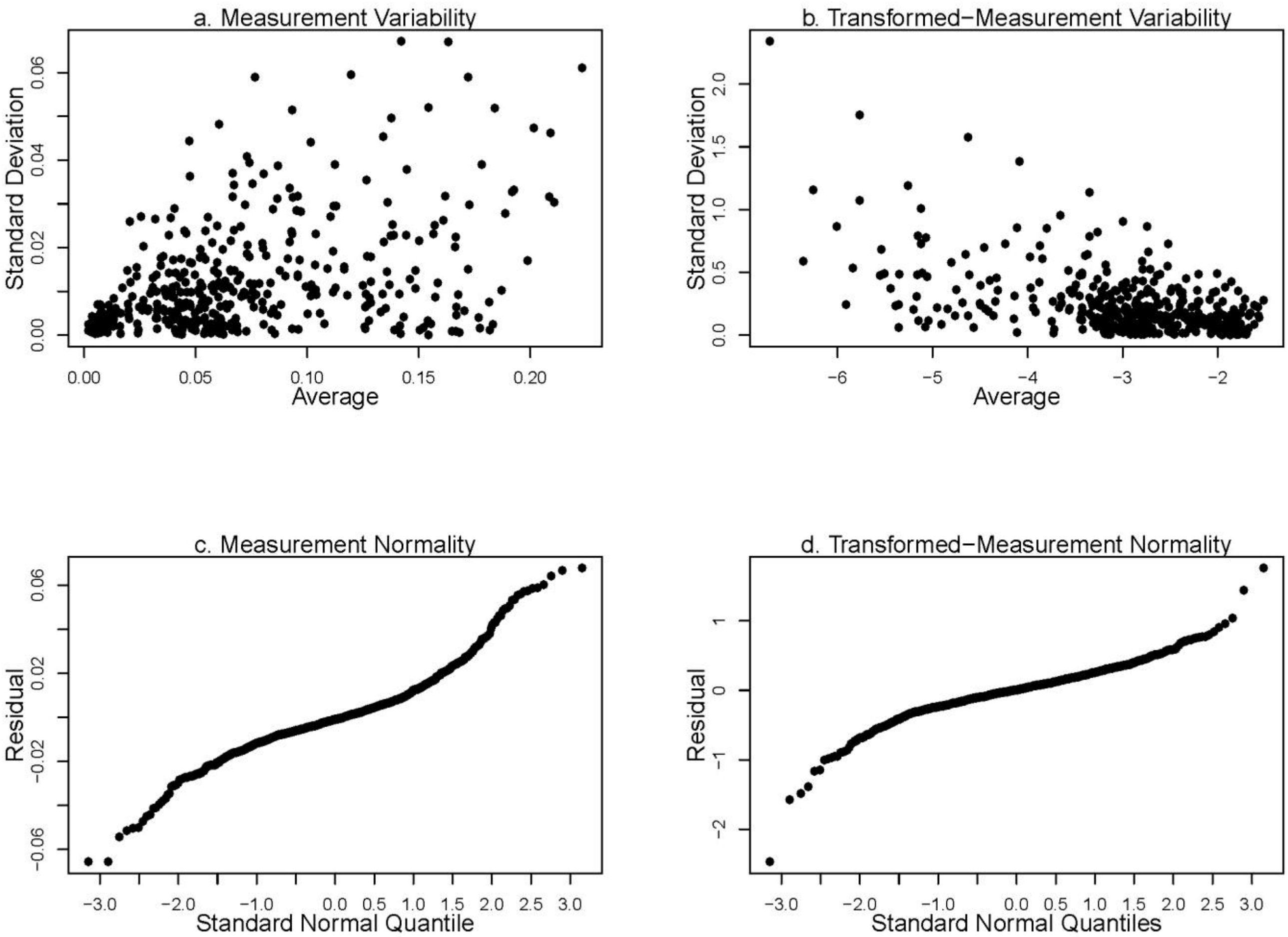


Fig. 17. Bag 1 PM

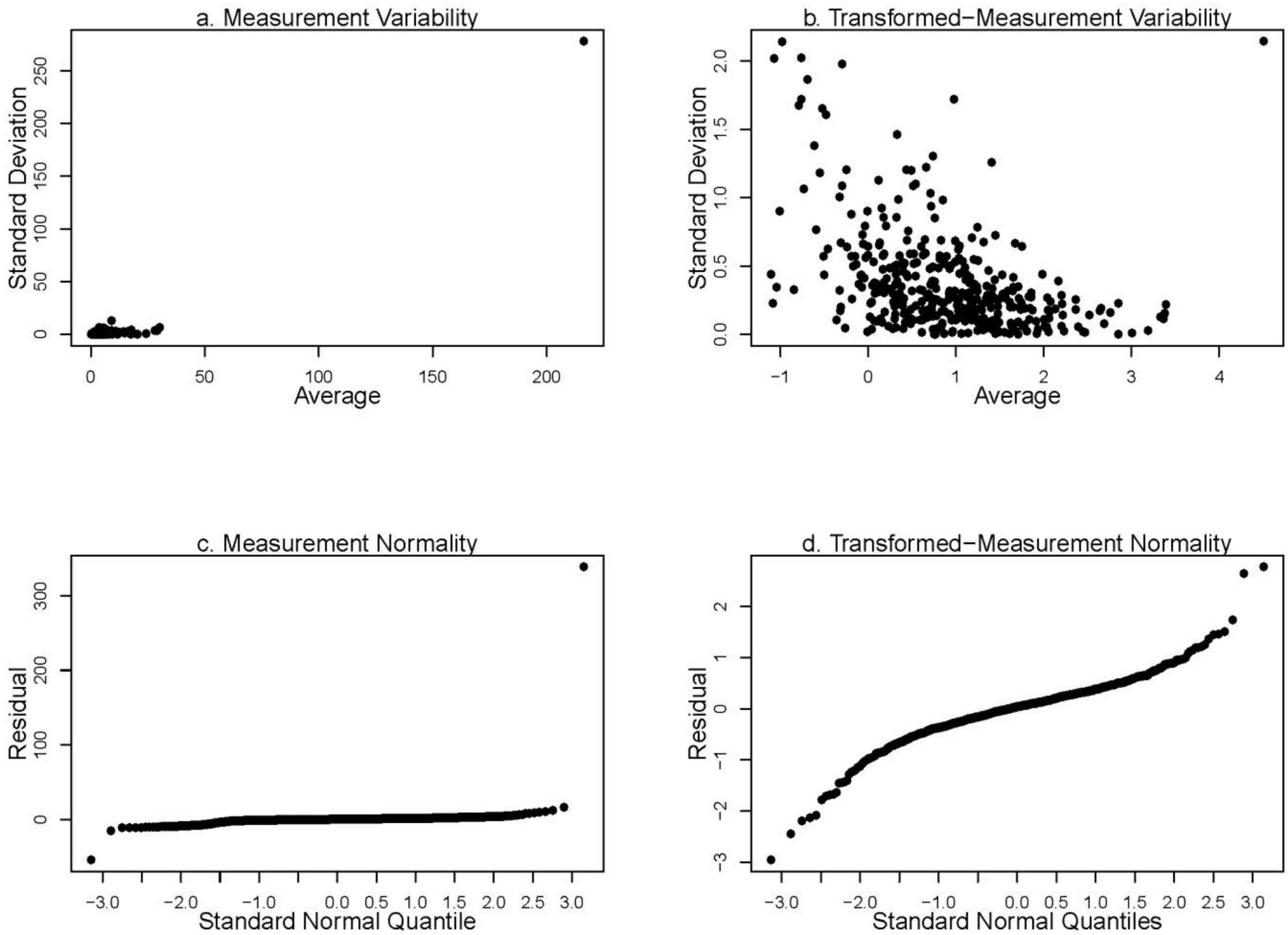


Fig. 18. Bag 1 THC

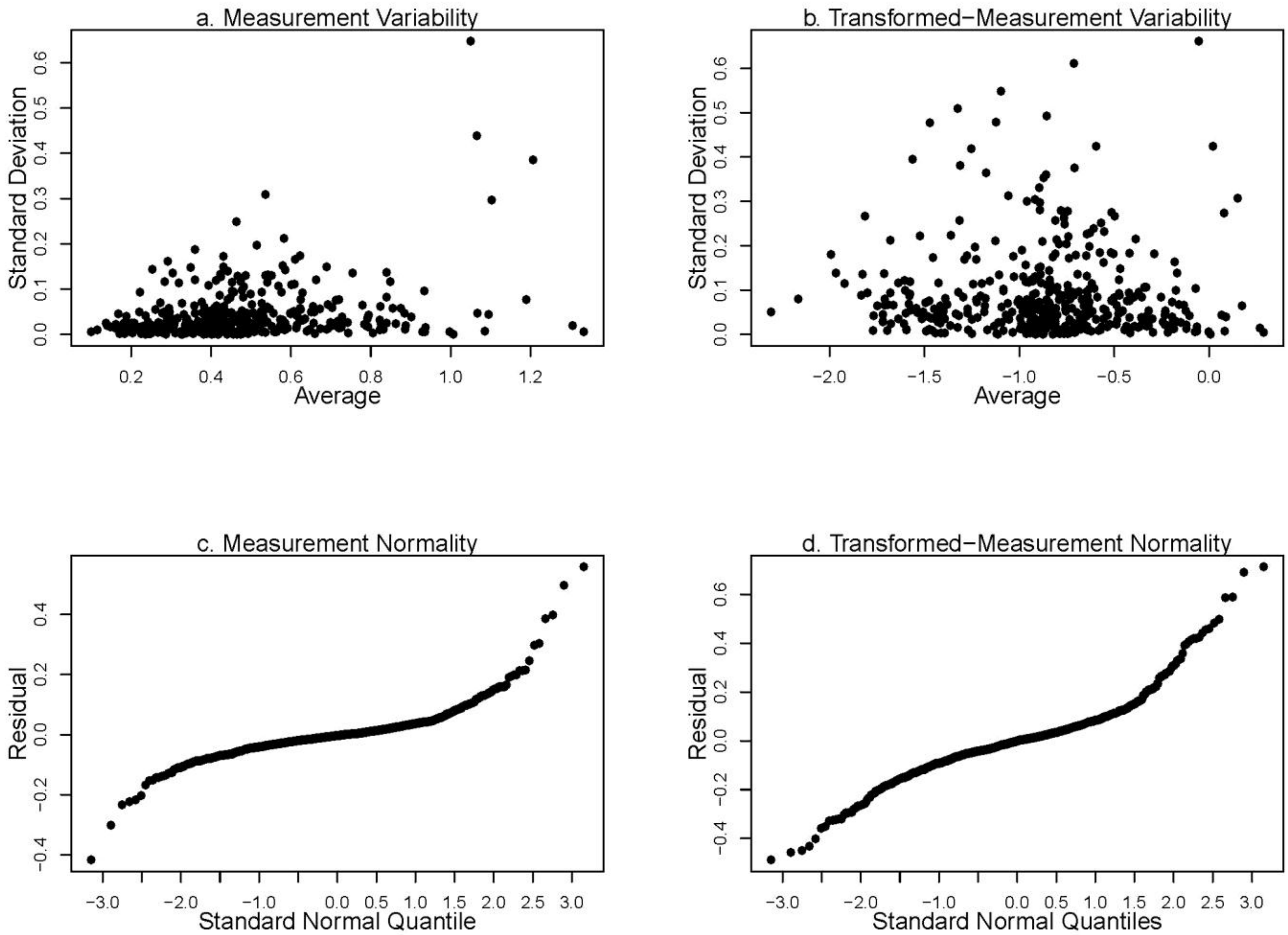


Fig. 19. Bag 2 CH_4

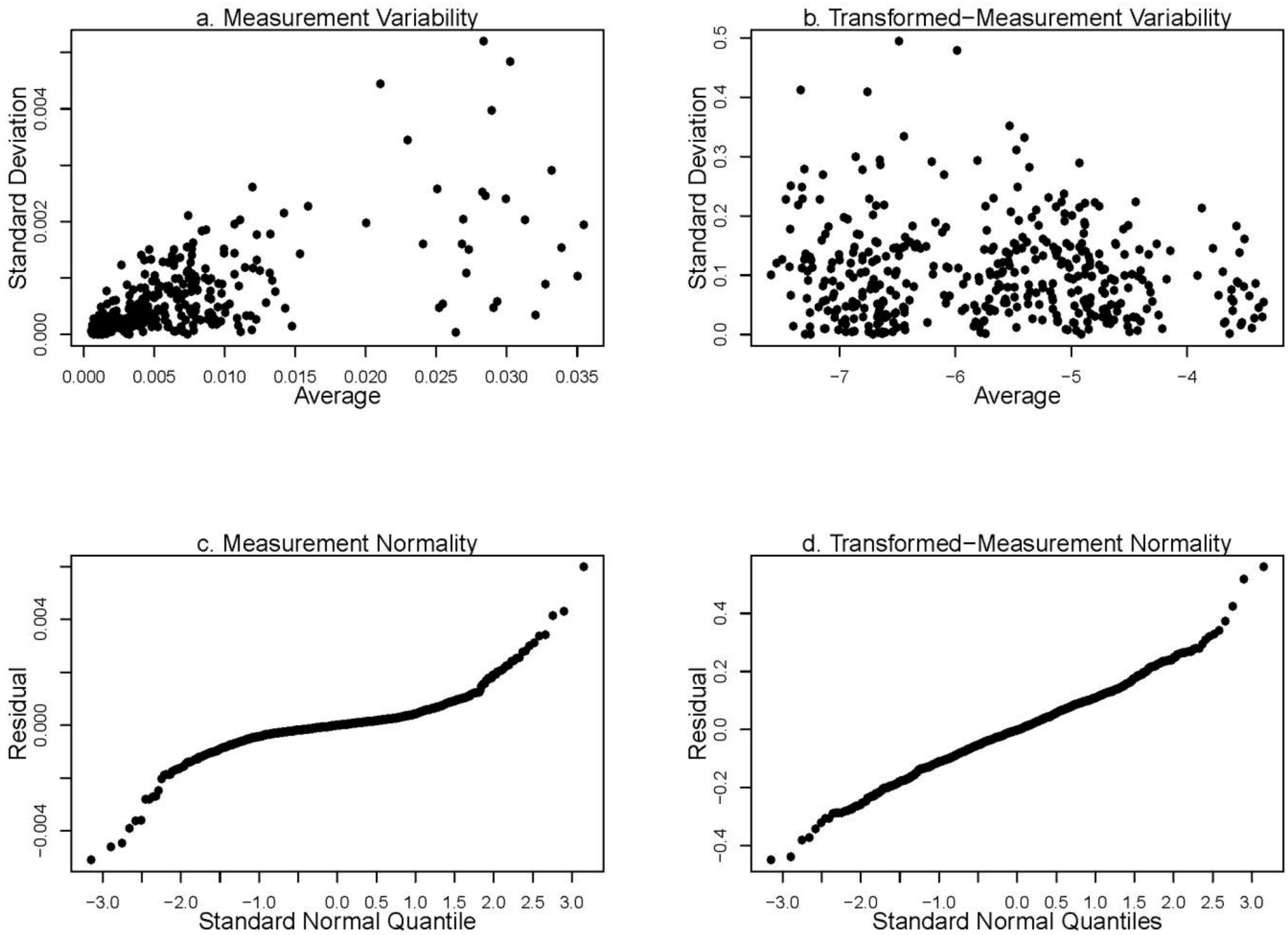


Fig. 20. Bag 2 CO

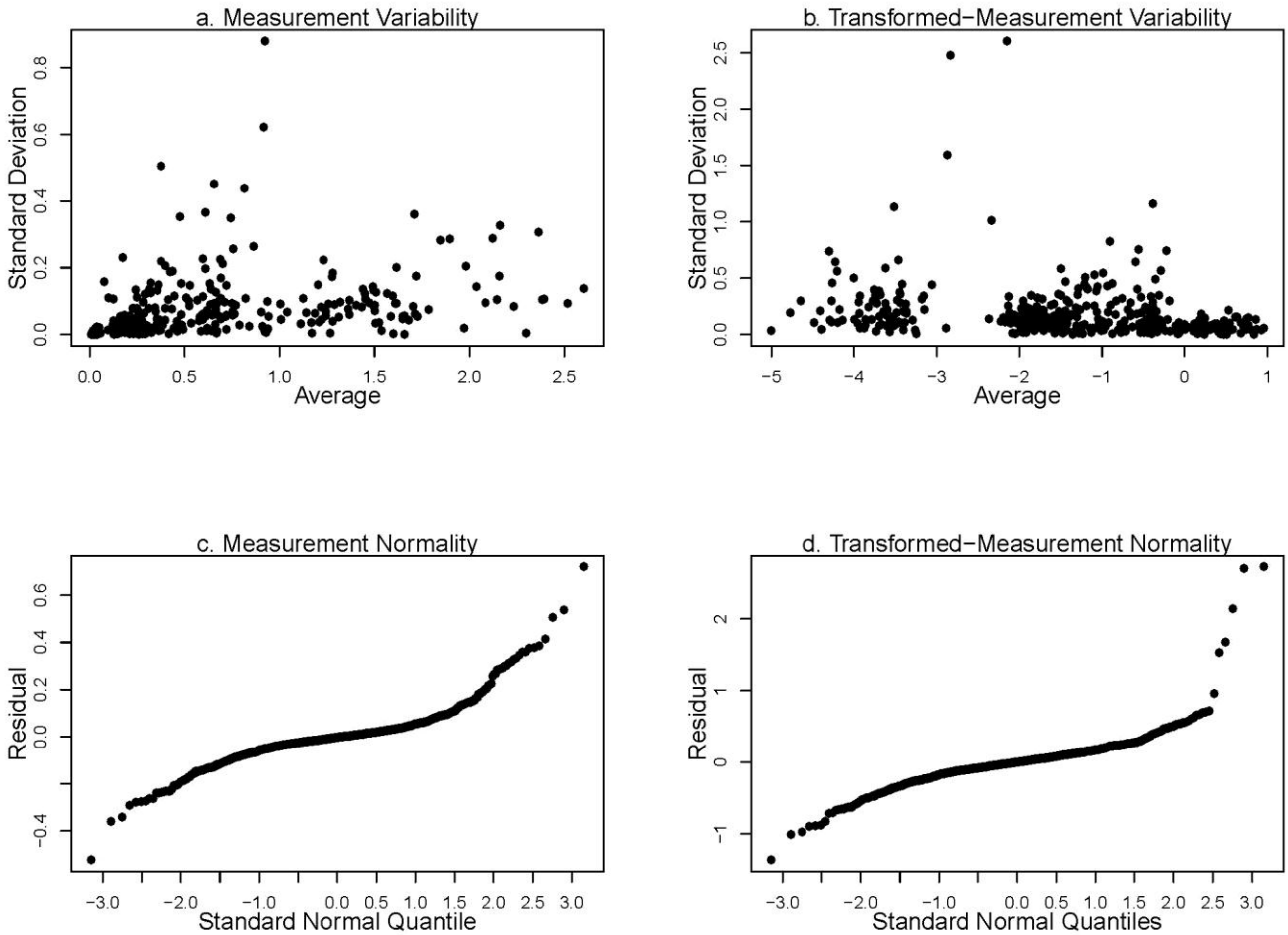


Fig. 21. Bag 2 CO2

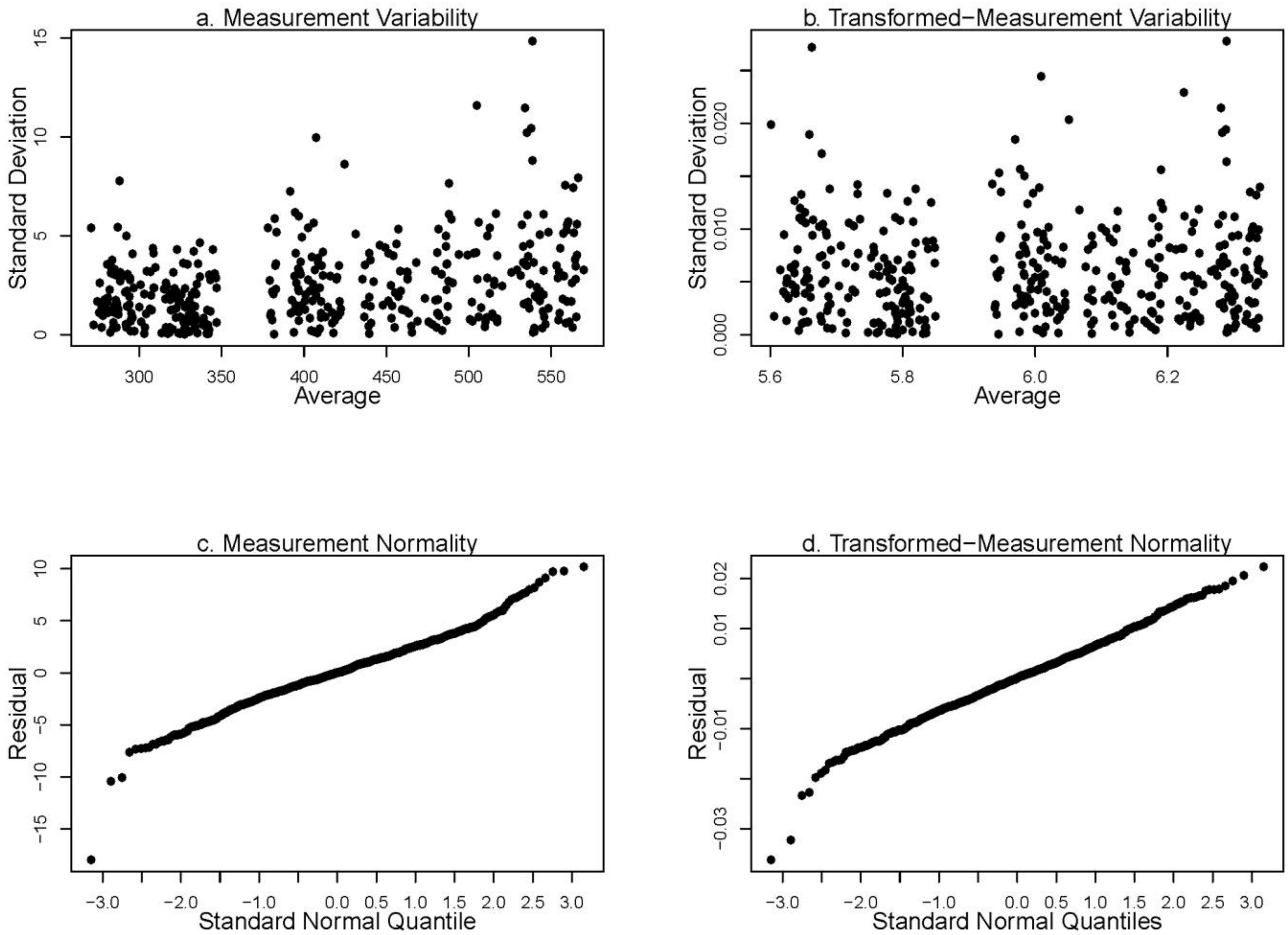


Fig. 22. Bag 2 FE

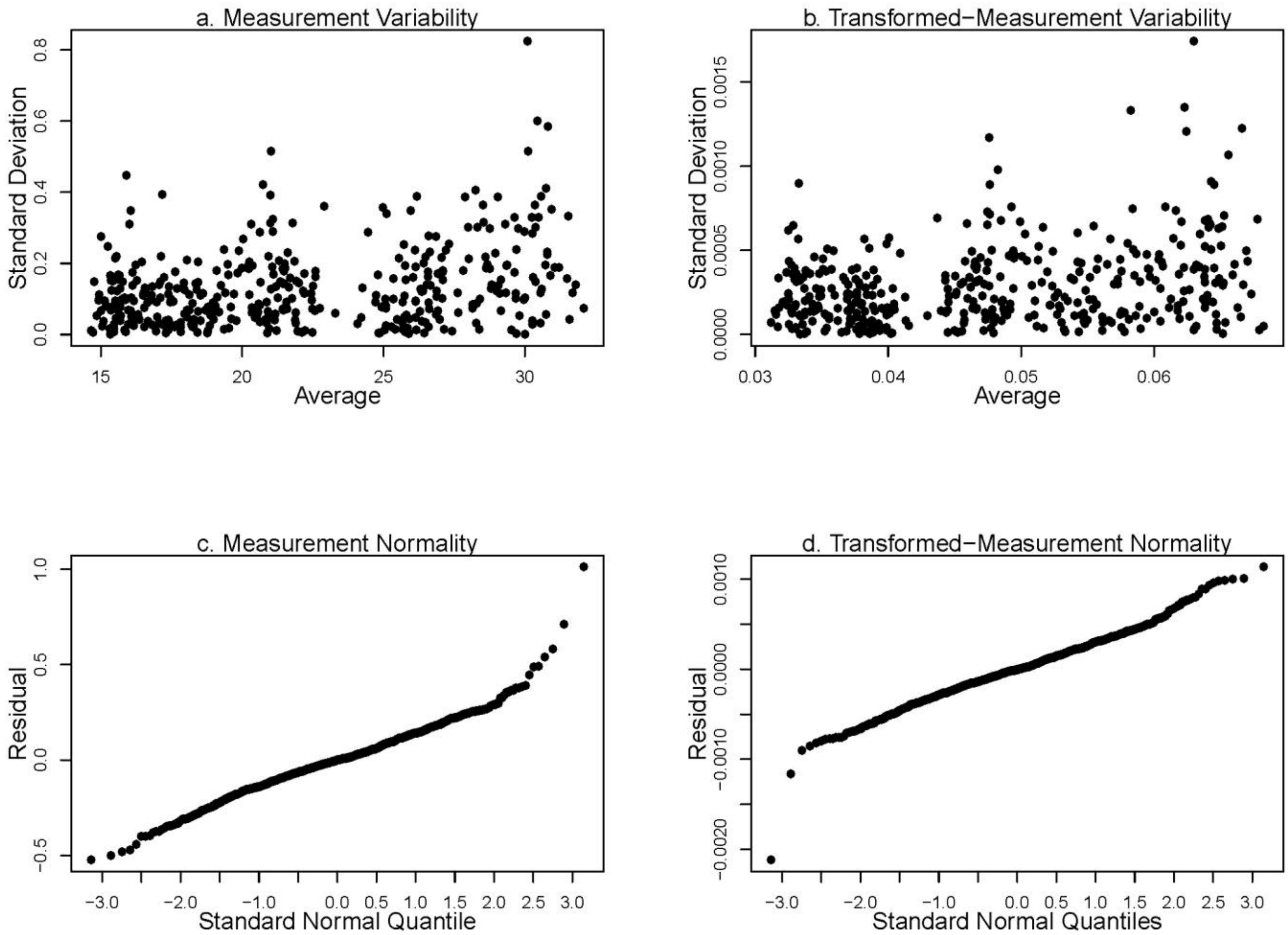


Fig. 23. Bag 2 NMHC

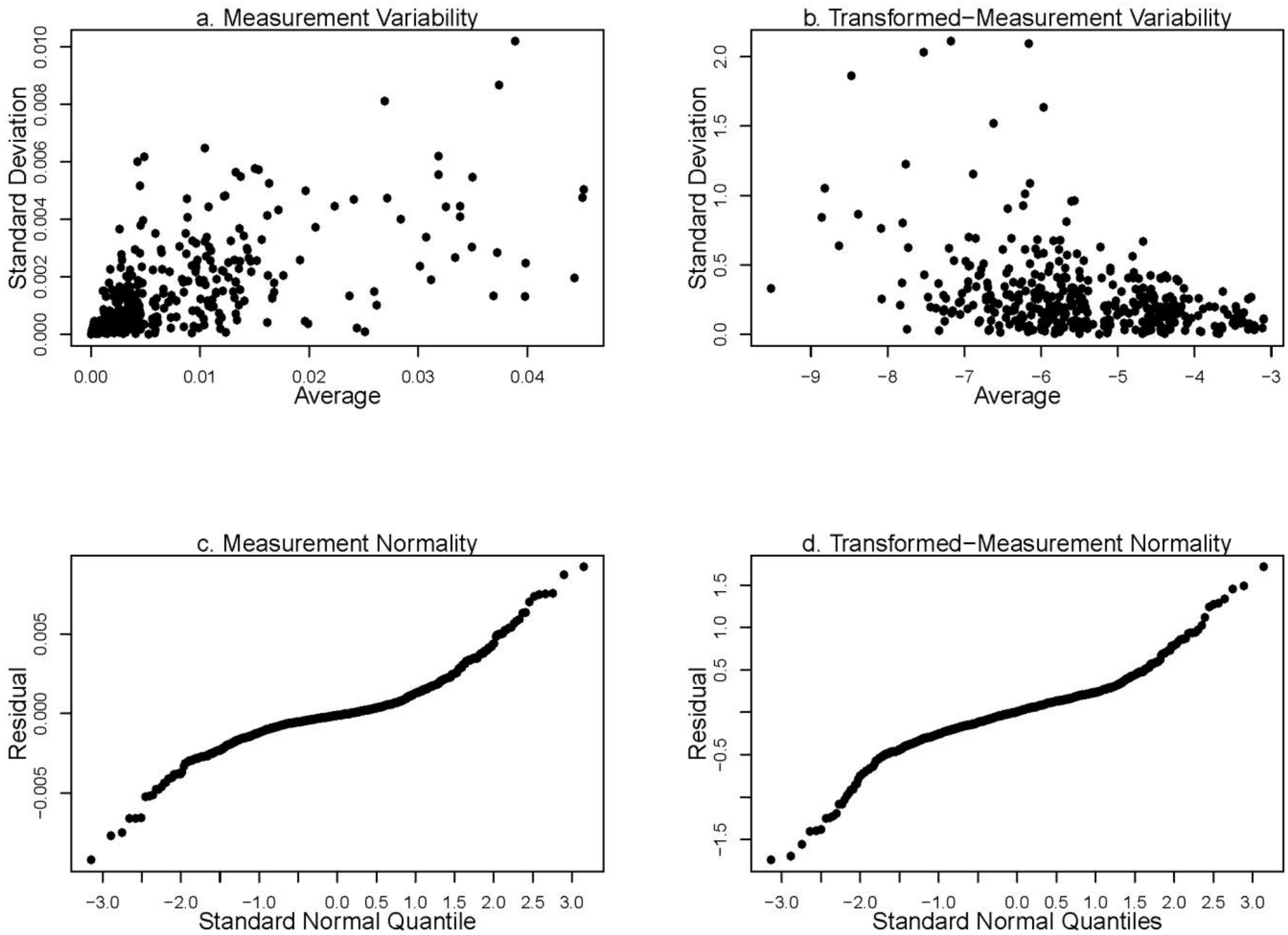


Fig. 24. Bag 2 NMOG

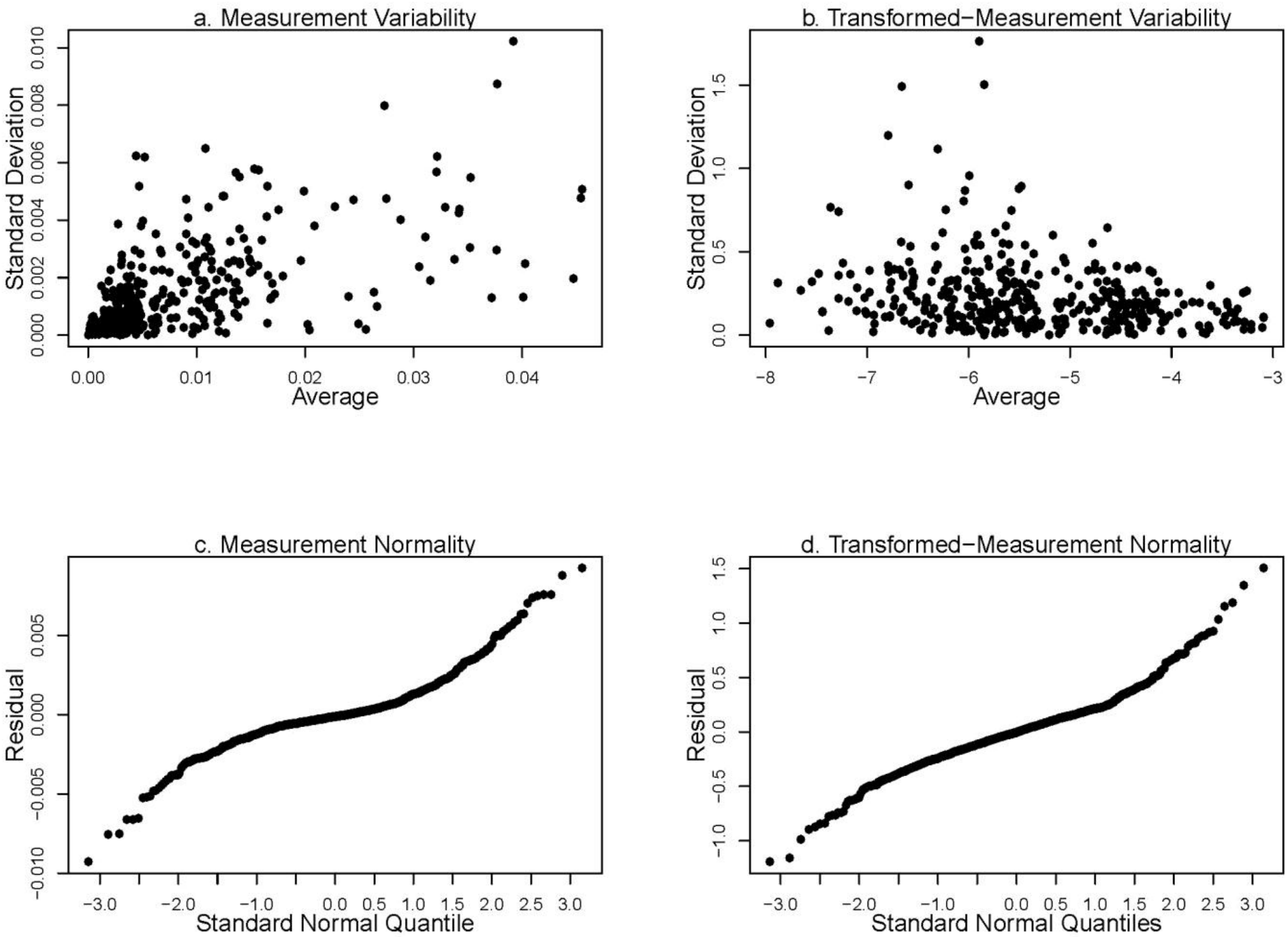


Fig. 25. Bag 2 NOx

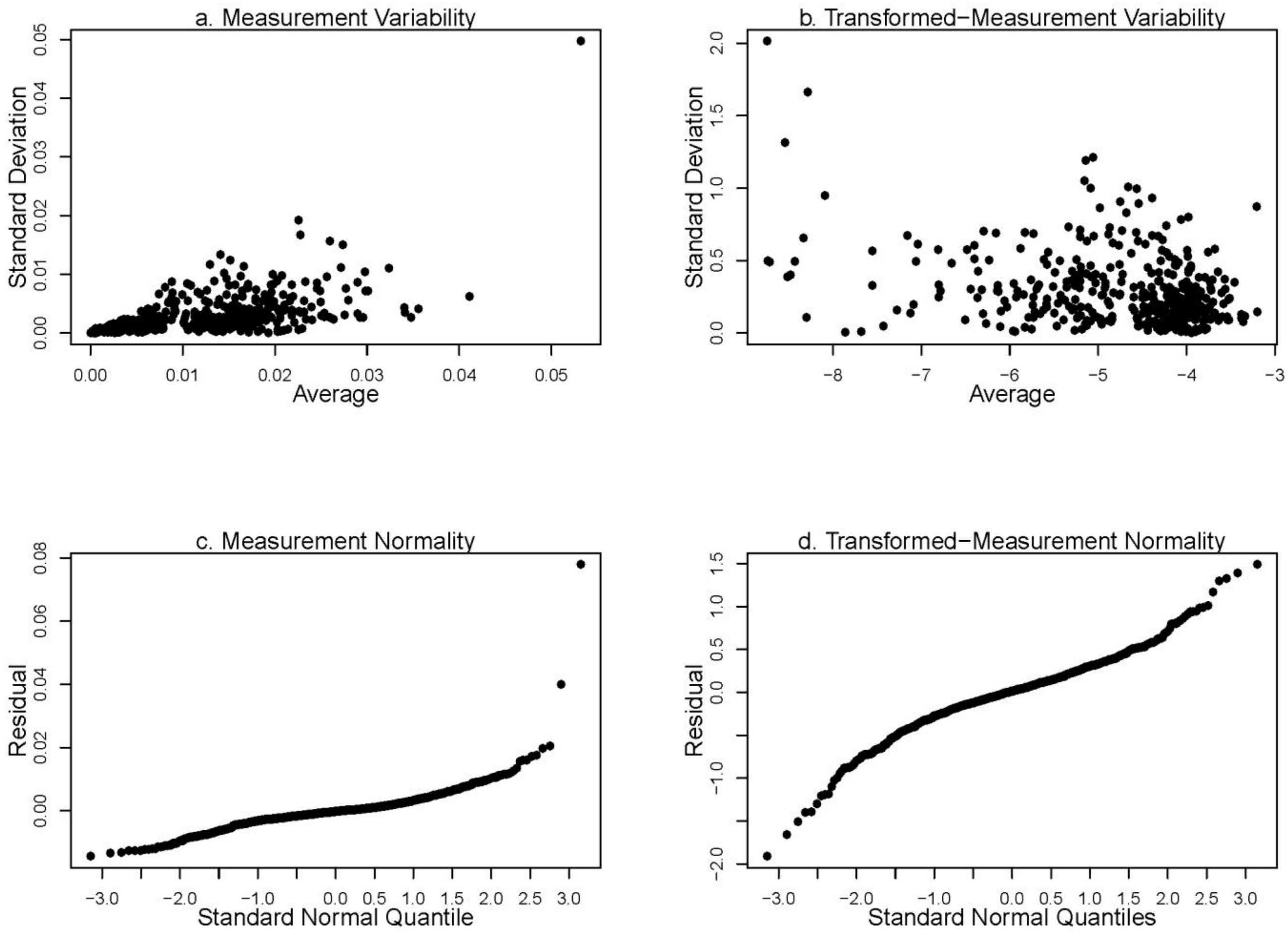


Fig. 26. Bag 2 PM

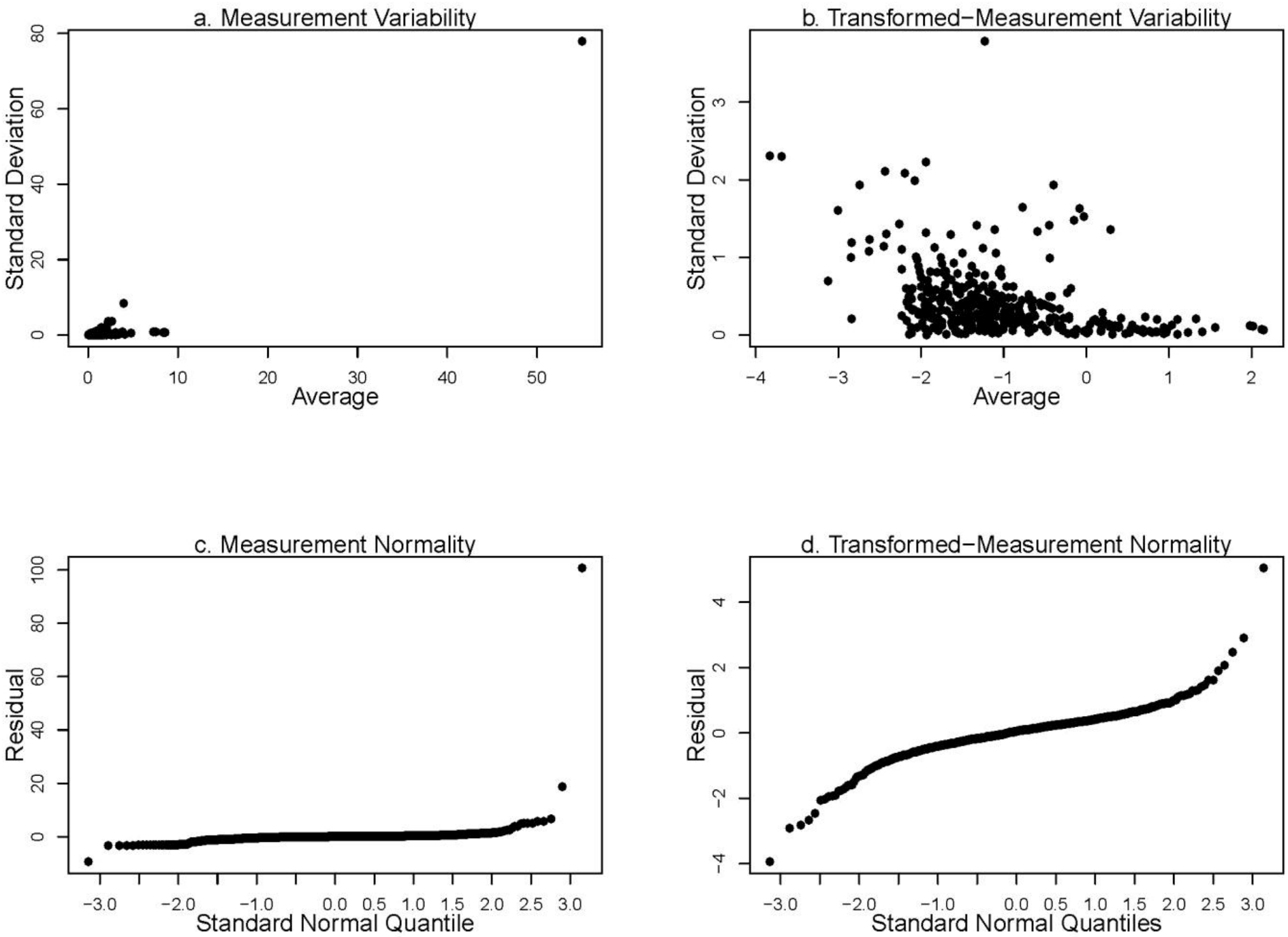


Fig. 27. Bag 2 THC

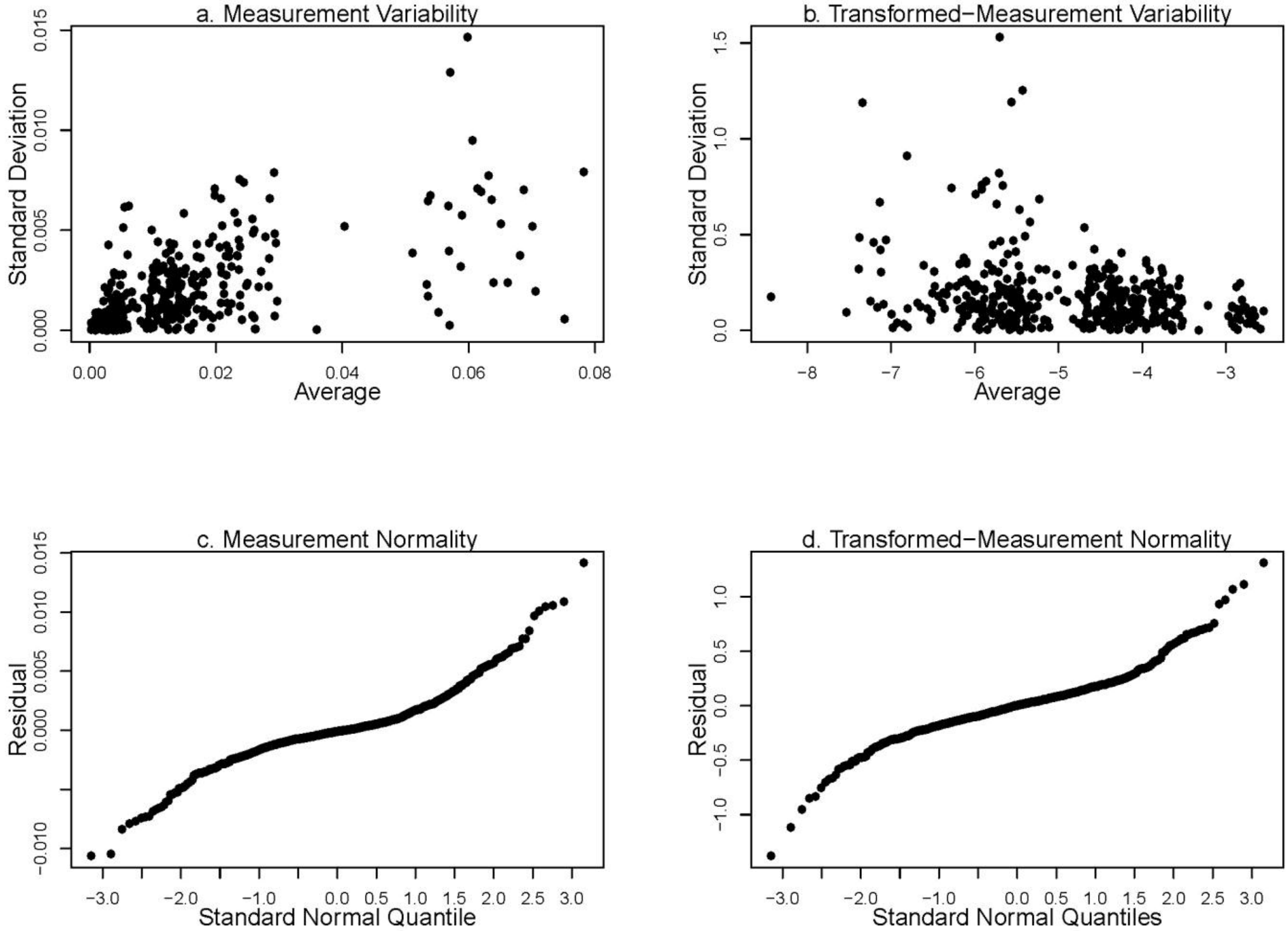


Fig. 28. Bag 3 CH4

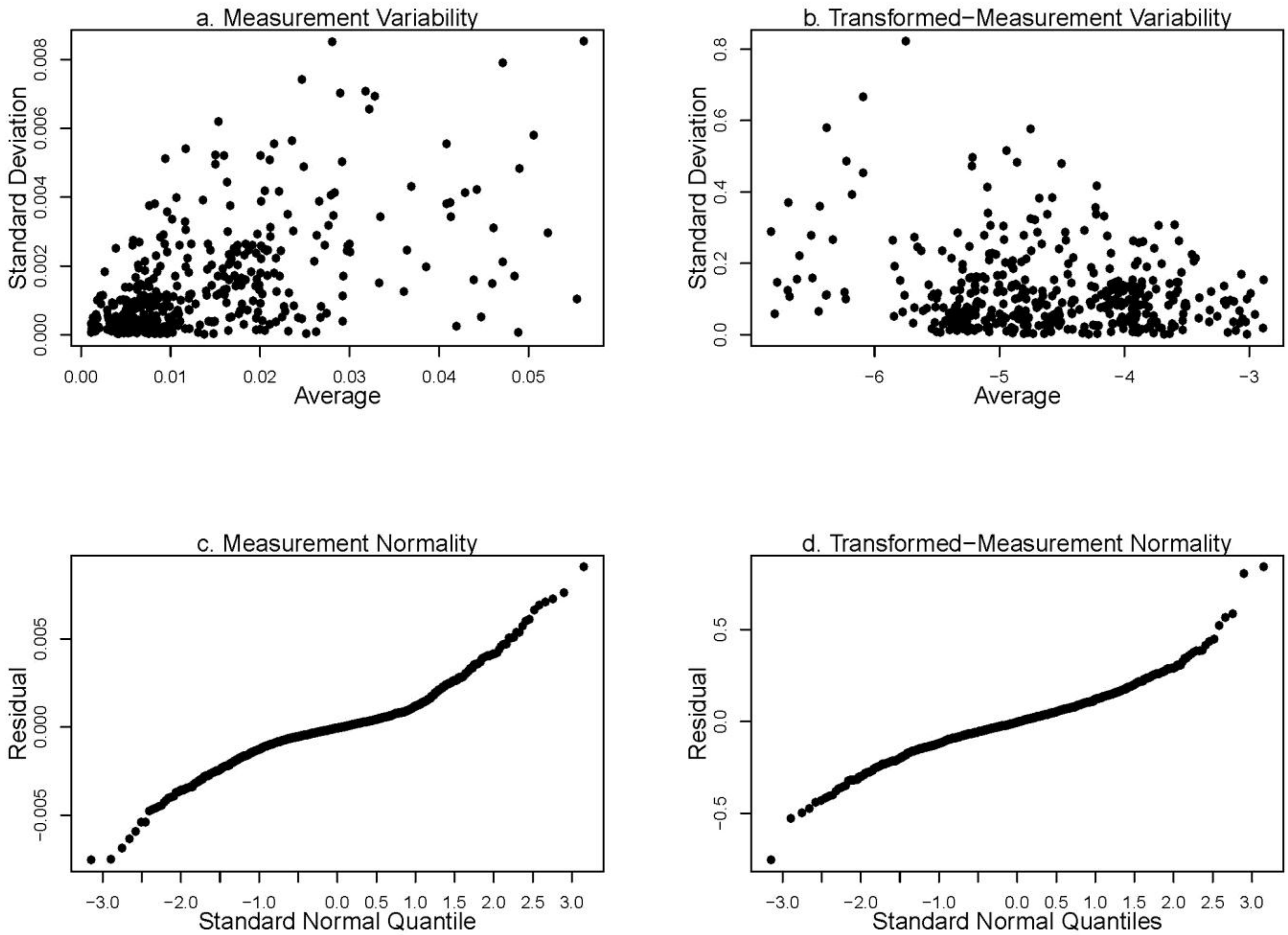


Fig. 29. Bag 3 CO

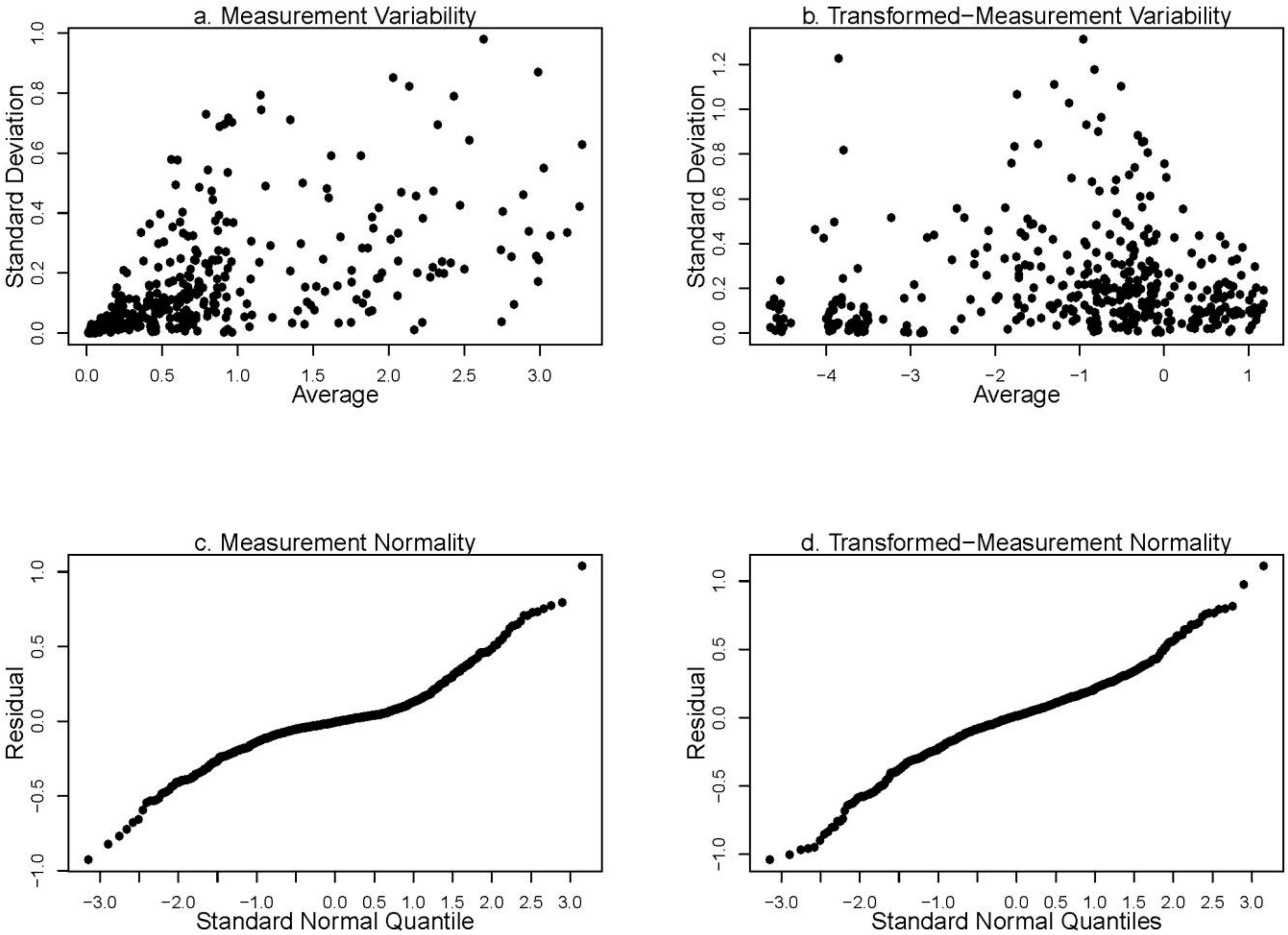


Fig. 30. Bag 3 CO2

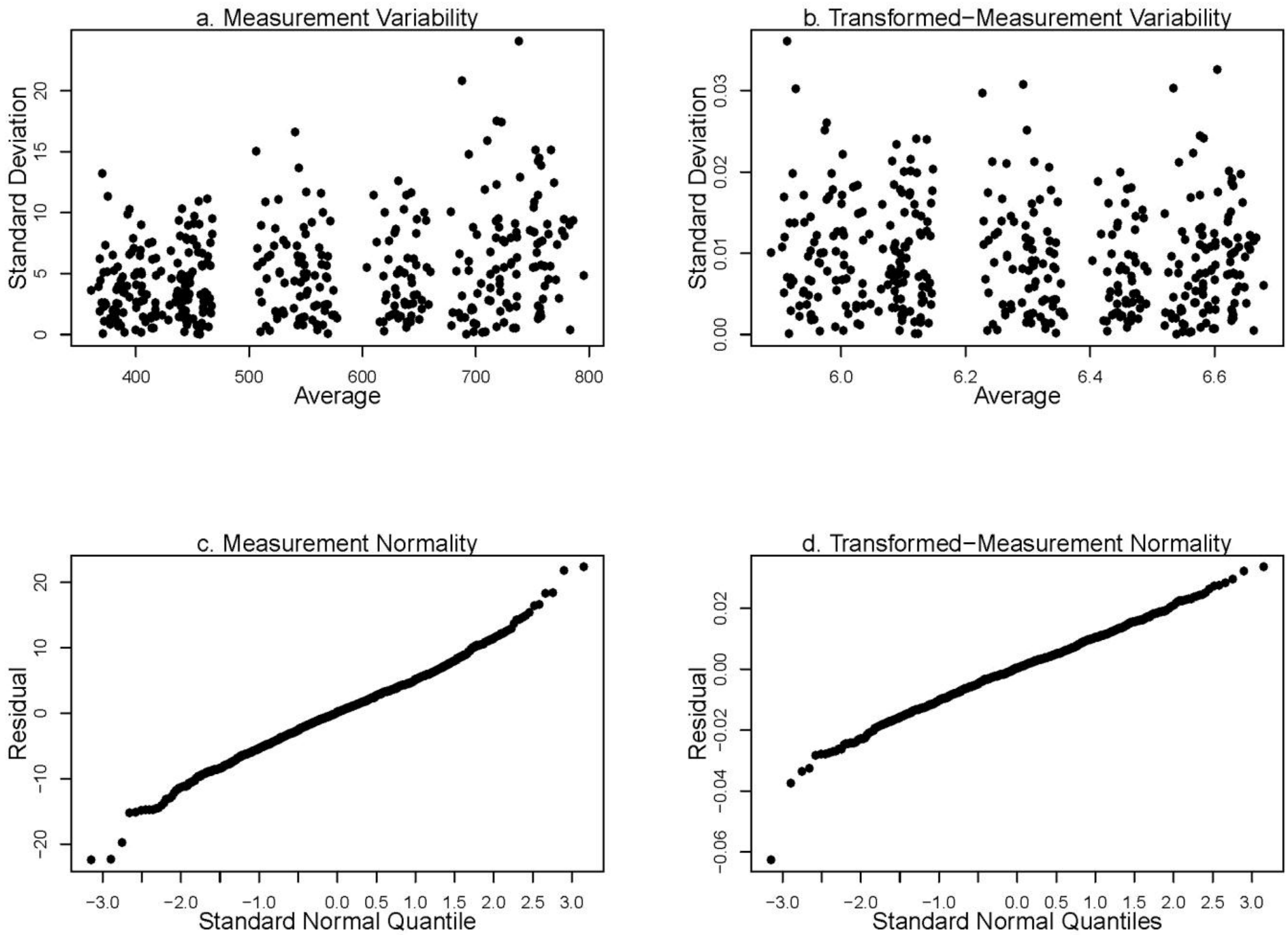


Fig. 31. Bag 3 FE

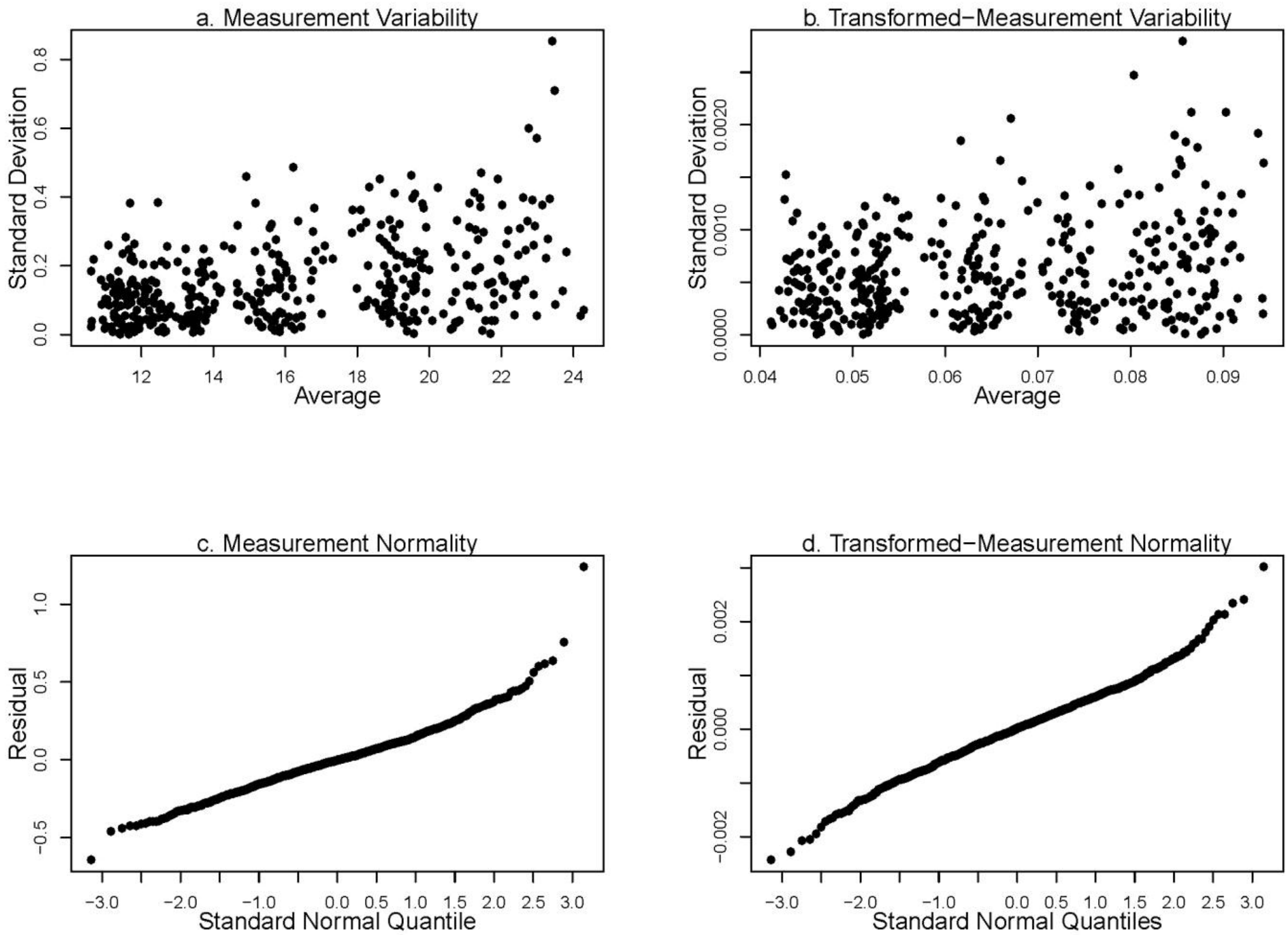


Fig. 32. Bag 3 NMHC

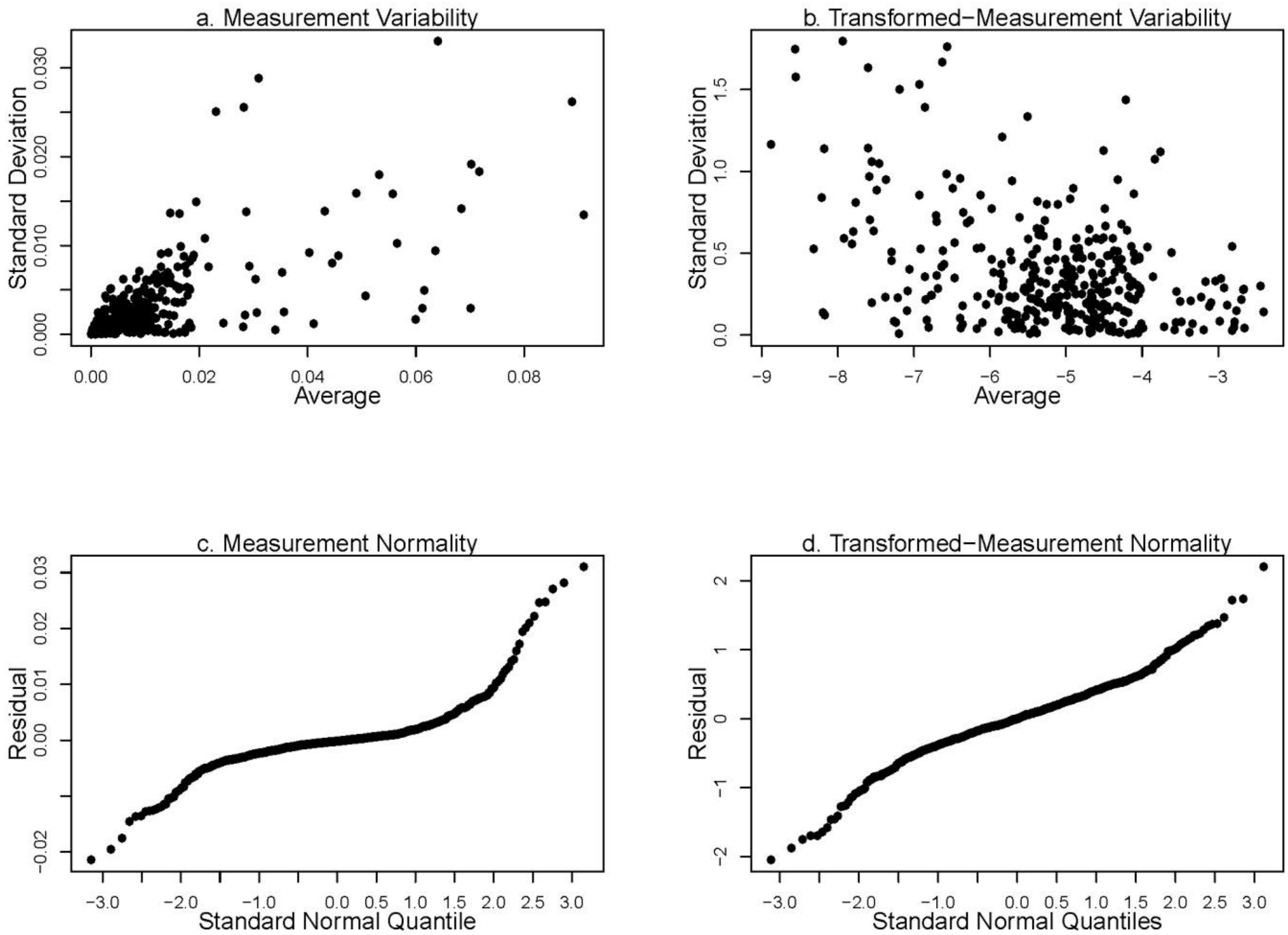


Fig. 33. Bag 3 NMOG

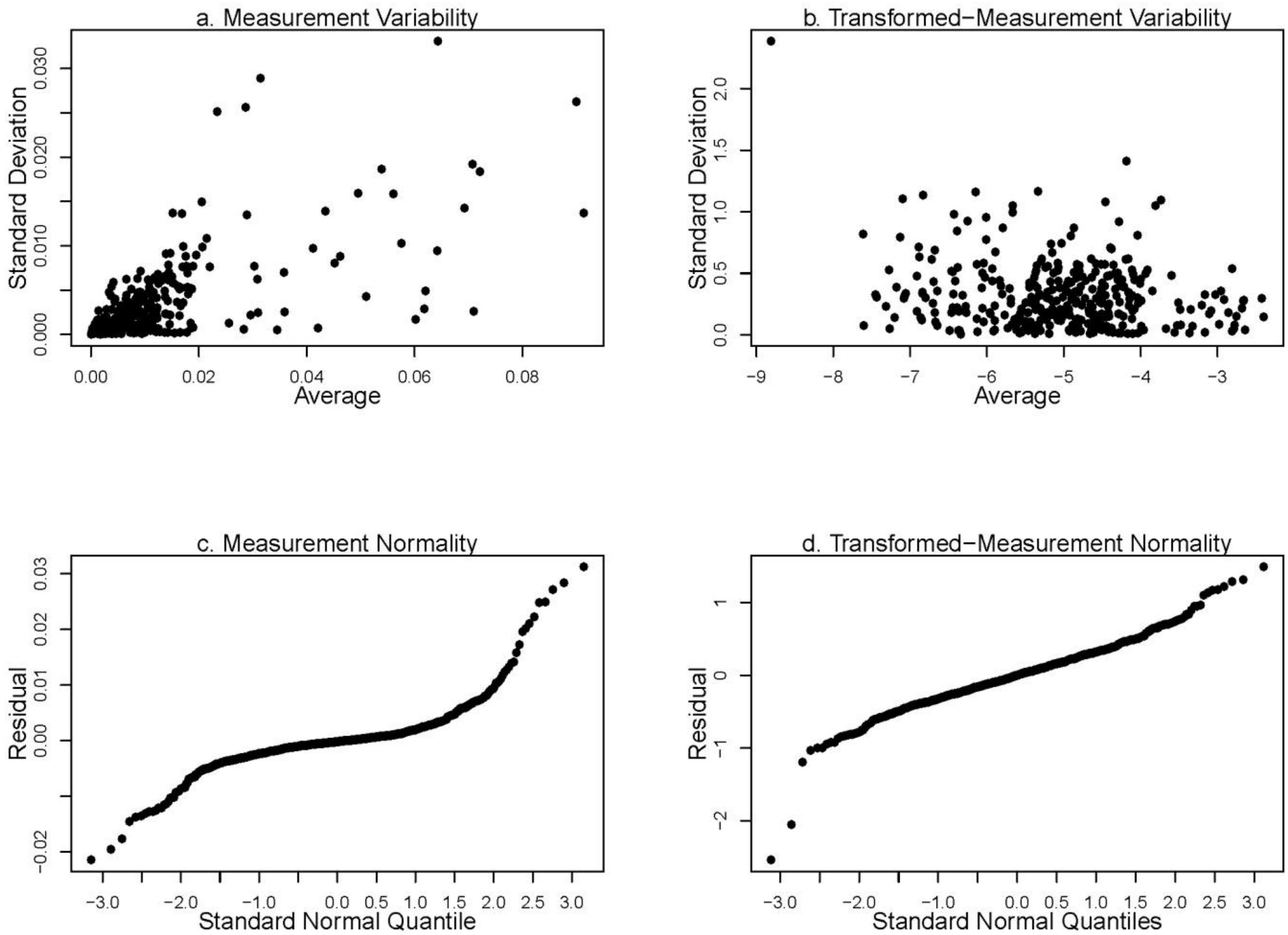


Fig. 34. Bag 3 NOx

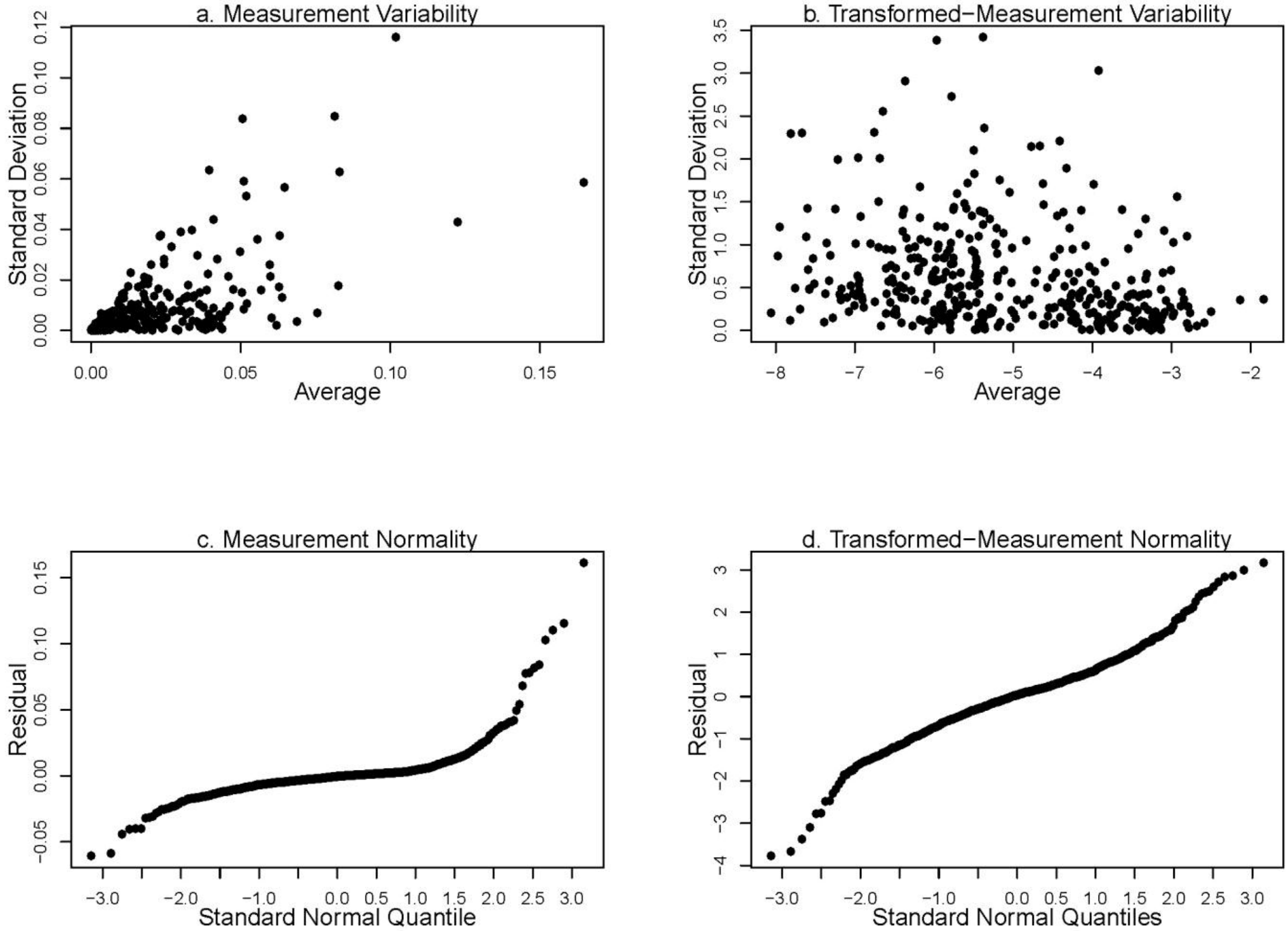


Fig. 35. Bag 3 PM

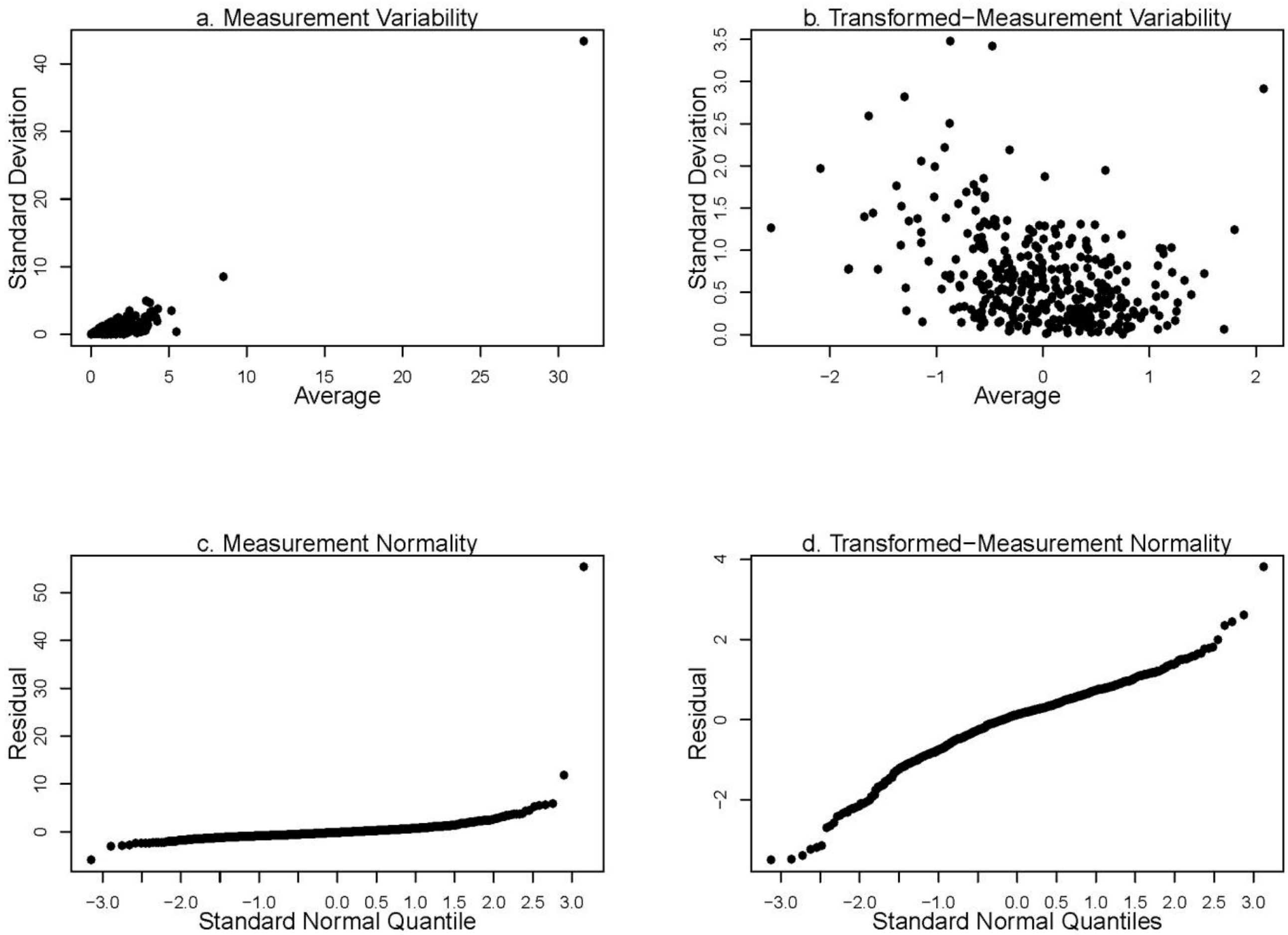
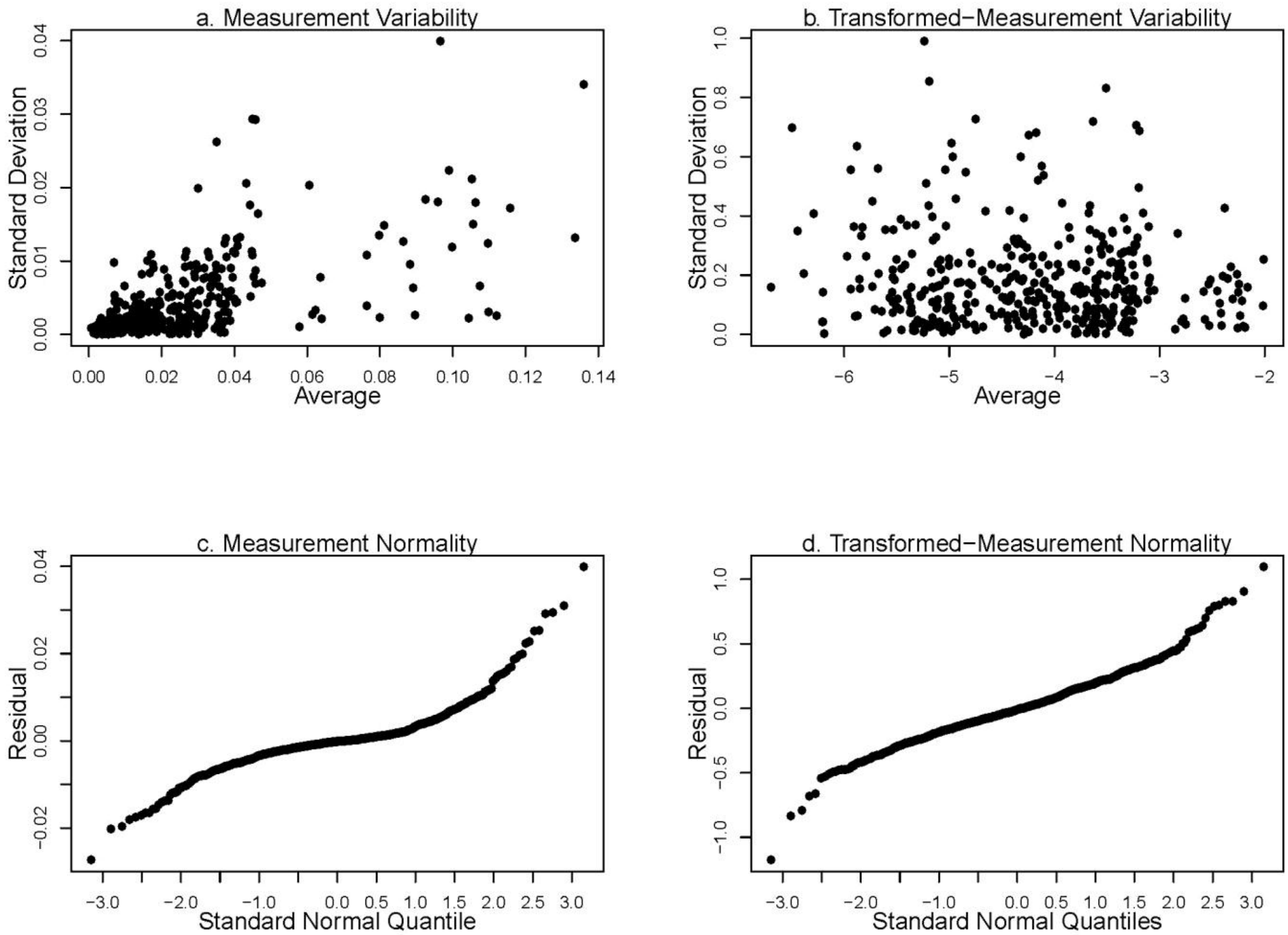


Fig. 36. Bag 3 THC



II. *Identification of Influential Data Values*

TestNumb	Measure	Bag	Fuel	VehCode	Run	Value	lnvalue	RStudent
EPA-FFOC-P3-14EP-T1	NOx	Bag 1	14	FFOC	8002	0.000	-8.3681	-4.9631
EPA-FFOC-P3-22-T2	NOx	Bag 1	22	FFOC	7343	0.000	-8.3681	-5.0226
EPA-FFOC-P3-28-T1	NOx	Bag 1	28	FFOC	6533	0.001	-7.0728	-4.0383
EPA-FFOC-P3-30-T2	NOx	Bag 1	30	FFOC	6751	0.000	-8.3681	-5.2339
EPA-TSIE-P3-22-T1	NOx	Bag 1	22	TSIE	6277	0.001	-7.0099	-3.6305
EPA-CIMP-P3-22-T3	PM	Bag 1	22	CIMP	8205	0.034	-3.3854	-4.4472
EPA-FFOC-P3-11-T3	PM	Bag 1	11	FFOC	7584	0.058	-2.8415	-4.4757
EPA-JLIB-P3-16-T1	PM	Bag 1	16	JLIB	6247	412.589	6.0225	6.3501
EPA-TCOR-P3-11-T1	PM	Bag 1	11	TCOR	8103	0.086	-2.4592	-3.9674
EPA-TCOR-P3-13-T2	PM	Bag 1	13	TCOR	7309	0.199	-1.6164	-3.5452
EPA-TCOR-P3-28-T2	PM	Bag 1	28	TCOR	8059	0.083	-2.4915	-4.2513
EPA-CCOB-P3-2-T2	NOx	Bag 2	02	CCOB	4487	0.000	-9.0654	-3.5848
EPA-CCOB-P3-3-T1	NOx	Bag 2	03	CCOB	6068	0.000	-10.1693	-4.5424
EPA-CCOB-P3-9-T1	NOx	Bag 2	09	CCOB	5599	0.000	-9.4720	-3.8958
EPA-CCOB-P3-11-T2	NOx	Bag 2	11	CCOB	5323	0.000	-9.0886	-3.7228
EPA-CCOB-P3-15-T3	NOx	Bag 2	15	CCOB	7249	0.000	-9.0789	-3.6720
EPA-CCOB-P3-20-T1	NOx	Bag 2	20	CCOB	6591	0.000	-10.1693	-4.5969
EPA-CCOB-P3-20-T2	NOx	Bag 2	20	CCOB	6599	0.000	-10.1693	-4.5969
EPA-CCOB-P3-24-T2	NOx	Bag 2	24	CCOB	6215	0.000	-9.4605	-4.0116
EPA-CCOB-P3-25-T1	NOx	Bag 2	25	CCOB	5797	0.000	-10.1693	-4.8033
EPA-CCOB-P3-26-T1	NOx	Bag 2	26	CCOB	5222	0.000	-10.1693	-4.6923
EPA-CCOB-P3-28-T2	NOx	Bag 2	28	CCOB	6114	0.000	-8.7848	-3.5057
EPA-CCOB-P3-7-T1	PM	Bag 2	07	CCOB	4801	0.004	-5.4612	-3.9928
EPA-FEXP-P3-27-T2	PM	Bag 2	27	FEXP	5324	110.019	4.7007	5.7181
EPA-JLIB-P3-2MP-T1	PM	Bag 2	02	JLIB	5735	21.127	3.0506	4.2356
EPA-TSIE-P3-14-T1	PM	Bag 2	14	TSIE	6936	0.005	-5.3128	-3.8110

TestNumb	Measure	Bag	Fuel	VehCode	Run	Value	lnvalue	RStudent
EPA-TCOR-P3-27-T2	NMOG	Bag 3	27	TCOR	7472	0.000	-10.4987	-4.6589
EPA-TCOR-P3-31-T2	NMOG	Bag 3	31	TCOR	7026	0.000	-10.2435	-4.4175
EPA-FEXP-P3-10-T1	PM	Bag 3	10	FEXP	6281	62.231	4.1309	4.5104
EPA-HCIV-P3-13-T1	PM	Bag 3	13	HCIV	5819	0.032	-3.4498	-4.0248
EPA-JLIB-P3-9-T1	PM	Bag 3	09	JLIB	4762	0.037	-3.2942	-3.6165
EPA-JLIB-P3-15-T2	PM	Bag 3	15	JLIB	4730	0.036	-3.3263	-3.7380
EPA-NALT-P3-22-T1	PM	Bag 3	22	NALT	5853	0.031	-3.4666	-3.8219
EPA-TCAM-P3-14-T2	PM	Bag 3	14	TCAM	5605	0.031	-3.4827	-3.7435
EPA-TCAM-P3-30-T1	PM	Bag 3	30	TCAM	6138	0.031	-3.4864	-4.0290
EPA-FFOC-P3-7-T2	NOx	Composite	07	FFOC	6507	0.001	-7.1622	-3.6919
EPA-FFOC-P3-21-T2	NOx	Composite	21	FFOC	6873	0.001	-6.8407	-3.5229
EPA-FEXP-P3-27-T2	PM	Composite	27	FEXP	5324	96.813	4.5728	6.0752
EPA-JLIB-P3-2MP-T1	PM	Composite	02	JLIB	5735	18.561	2.9210	4.1800
EPA-JLIB-P3-16-T1	PM	Composite	16	JLIB	6247	21.588	3.0722	4.1733
EPA-JLIB-P3-28-T3	PM	Composite	28	JLIB	5363	0.018	-4.0306	-3.8410
EPA-TCOR-P3-13-T2	PM	Composite	13	TCOR	7309	0.010	-4.5749	-4.7448
EPA-TCOR-P3-20-T1	PM	Composite	20	TCOR	8156	0.018	-4.0092	-3.5089
EPA-TCOR-P3-28-T2	PM	Composite	28	TCOR	8059	0.008	-4.8085	-4.6425
EPA-TSIE-P3-24-T1	PM	Composite	24	TSIE	5491	0.005	-5.2755	-4.9787

III. Benchmark Model Fits

				Composite					
	CH_4	CO_2	CO	FE	NMHC	NMOG	NO_x	PM	THC
Intercept	-5.03540	6.04550	-0.64560	20.81240	-3.72380	-3.64930	-4.35490	-0.70961	-3.44440
T_{50}	0.08344	0.00072	0.03311	0.11710	0.14370	0.14050	0.01621	-0.03520	0.13040
T_{90}	0.01802	0.00042	-0.04190	0.03955	0.04088	0.03560	0.00584	0.16110	0.03799
EtOH	0.07912	0.00192	-0.02842	-0.35430	0.05102	0.09173	0.06761	0.08360	0.07273
RVP	-0.01460	-0.00070	0.02456	-0.02939	-0.04424	-0.04453	0.02697	-0.08490	-0.03975
ARO	-0.09512	0.01784	0.05817	0.26750	0.09832	0.09348	0.06656	0.26630	0.05734
T_{50}^2	0.03815	-0.00062	0.04222	0.00403	0.08038	0.08048	0.02209	-0.00820	0.07234
$EtOH^2$	0.02056	0.00049	0.05984	0.01870	0.04028	0.03918	0.00517	-0.08320	0.03598
T_{90}^2	-0.00662	0.00061	0.00743	0.07931	0.01119	0.01110	-0.00627	0.11840	0.00992
$T_{50}*T_{90}$	0.01549	-0.00042	0.02533	0.02521	0.04490	0.04613	0.02014	0.10230	0.03991
$T_{50}*EtOH$	0.01609	-0.00015	0.05990	0.00052	0.03433	0.03440	0.00780	-0.12470	0.02972
$T_{50}*ARO$	0.02377	-0.00014	0.03226	-0.01418	0.01819	0.01693	0.06477	-0.03960	0.01778
$T_{90}*EtOH$	0.01054	-0.00024	0.02322	0.03997	0.04108	0.03776	0.01798	0.10390	0.03558
$T_{90}*RVP$	-0.00483	0.00015	0.01302	-0.00422	-0.01313	-0.01306	0.00326	-0.03080	-0.01092
$T_{90}*ARO$	0.01705	-0.00073	0.01892	0.01512	0.01940	0.01917	-0.01671	0.07630	0.01952
EtOH*RVP	-0.00236	-0.00054	-0.00143	0.02143	-0.00039	-0.00004	-0.00152	-0.03260	-0.00095
EtOH*ARO	0.03087	0.00036	0.03843	0.05595	0.04110	0.03691	0.02980	0.07010	0.03647
RVP*ARO	0.02407	-0.00084	0.02615	-0.02246	0.03108	0.02973	0.03497	-0.04180	0.02591

				Bag 1					
	CH_4	CO_2	CO	FE	NMHC	NMOG	NO_x	PM	THC
Intercept	-3.00660	6.55020	1.34730	12.46640	-1.03050	-0.95100	-3.01760	0.65359	-0.86550
T_{50}	0.10350	0.00071	0.00518	0.07436	0.15860	0.15580	-0.03431	0.00470	0.15090
T_{90}	0.00916	0.00285	-0.14010	0.01159	0.02476	0.01880	0.04186	0.34940	0.02218
EtOH	0.09007	0.00254	-0.07493	-0.20910	0.05323	0.10150	0.01796	0.15120	0.07684
RVP	-0.02666	-0.00134	0.00877	-0.00163	-0.04329	-0.04388	-0.04116	-0.06190	-0.04180
ARO	-0.09546	0.01763	-0.00142	0.16460	0.11900	0.11260	0.14510	0.43550	0.09095
T_{50}^2	0.06186	-0.00066	0.07169	-0.00638	0.08998	0.09071	-0.06488	0.07900	0.08763
$EtOH^2$	0.03495	-0.00038	0.08439	0.01187	0.05323	0.05233	-0.06955	-0.02130	0.05087
T_{90}^2	0.00622	0.00028	0.02124	0.04858	0.01962	0.01861	0.04167	0.11760	0.01877
$T_{50}*T_{90}$	0.02086	0.00046	0.01428	0.00459	0.04877	0.05079	0.00627	0.03890	0.04683
$T_{50}*EtOH$	0.03083	-0.00061	0.10830	-0.00878	0.04154	0.04144	-0.10640	-0.04520	0.03988
$T_{50}*ARO$	0.01919	-0.00076	0.04355	-0.00117	0.00899	0.00895	-0.03170	-0.03400	0.01024
$T_{90}*EtOH$	0.02494	0.00035	0.01787	0.01454	0.04874	0.04499	0.04282	0.10180	0.04543
$T_{90}*RVP$	-0.00623	0.00092	-0.00063	-0.01220	-0.01403	-0.01393	0.04624	-0.05580	-0.01332
$T_{90}*ARO$	0.02957	-0.00035	0.03690	0.00132	0.01753	0.01753	-0.04948	0.05510	0.01955
EtOH*RVP	0.00523	-0.00037	0.00414	0.00943	0.00652	0.00626	-0.01820	0.01190	0.00614
EtOH*ARO	0.03902	0.00018	0.05942	0.03064	0.04111	0.03650	-0.04301	0.06820	0.03854
RVP*ARO	0.02601	-0.00122	0.04181	-0.00741	0.03405	0.03322	-0.04170	-0.06020	0.03198

				Bag 2					
	CH_4	CO_2	CO	FE	NMHC	NMOG	NO_x	PM	THC
Intercept	-5.70760	5.98250	-1.38940	22.18230	-5.71266	-5.51674	-4.78630	-1.30852	-4.90990
T_{50}	0.07009	0.00063	0.05910	0.12620	0.09240	0.07900	0.01117	-0.18650	0.06874
T_{90}	0.02128	0.00019	0.04389	0.04410	0.15790	0.11470	0.00249	0.15660	0.07708
EtOH	0.07266	0.00173	0.04056	-0.37580	0.07730	0.07510	0.05538	0.00190	0.06497
RVP	-0.00512	-0.00067	0.04841	-0.03338	-0.06540	-0.05240	-0.00340	-0.15880	-0.04241
ARO	-0.09712	0.01792	0.10280	0.28340	0.03750	0.03910	0.04139	0.25220	-0.02502
$T_{50}{}^2$	0.01620	-0.00064	0.01988	0.00592	0.03570	0.05070	0.04231	-0.03150	0.02535
$EtOH^2$	0.00285	0.00054	0.04538	0.01950	-0.05190	-0.02730	0.04067	-0.15900	-0.01860
$T_{90}{}^2$	-0.01878	0.00072	0.00299	0.08296	0.01680	0.01140	-0.00454	0.15190	0.00942
$T_{50}*T_{90}$	0.01128	-0.00051	0.01511	0.02847	0.03620	0.02450	0.02191	0.16000	0.00981
$T_{50}*EtOH$	-0.00263	-0.00015	0.02892	0.00205	0.00540	0.01880	0.04910	-0.14210	-0.00939
$T_{50}*ARO$	0.02798	-0.00016	0.01856	-0.01549	0.08910	0.06250	0.03479	-0.11570	0.03548
$T_{90}*EtOH$	-0.00595	-0.00033	-0.01040	0.04429	0.01150	0.00290	0.01662	0.10970	-0.01142
$T_{90}*RVP$	-0.01029	0.00005	-0.00943	-0.00263	-0.00460	-0.01020	-0.03421	-0.01180	-0.01529
$T_{90}*ARO$	0.00836	-0.00073	0.00294	0.01685	0.04580	0.03430	-0.00433	0.03460	0.02007
EtOH*RVP	-0.00824	-0.00058	0.00428	0.02384	-0.03600	-0.03140	0.02423	-0.02490	-0.02370
EtOH*ARO	0.02356	0.00044	0.02524	0.05840	0.09300	0.06910	0.05087	-0.00780	0.04125
RVP*ARO	0.02280	-0.00084	0.02011	-0.02456	-0.03340	-0.01400	0.01298	-0.10590	-0.01247

				Bag 3					
	CH_4	CO_2	CO	FE	NMHC	NMOG	NO_x	PM	THC
Intercept	-4.59680	6.29480	-1.14010	16.25390	-5.98367	-5.84969	-5.25399	-0.35602	-4.22870
T_{50}	0.04566	0.00118	0.04185	0.08507	0.06590	-0.00890	-0.01040	-0.03110	0.05592
T_{90}	0.01368	0.00048	0.05095	0.02869	0.15750	0.15500	0.08130	0.00310	0.04391
EtOH	0.04658	0.00287	-0.06092	-0.28790	-0.10720	-0.01720	0.08070	-0.04340	0.01983
RVP	0.01558	-0.00079	0.04303	-0.01968	-0.06320	-0.09920	0.19650	-0.13950	-0.00457
ARO	-0.10510	0.01758	0.07019	0.21280	0.00530	-0.00460	0.05030	-0.00240	-0.05995
$T_{50}{}^2$	0.01783	-0.00033	0.00462	0.00144	-0.02420	-0.04920	0.05230	-0.10230	0.02588
$EtOH^2$	0.00595	0.00093	-0.00347	0.01482	-0.03870	-0.01120	-0.02340	-0.07510	-0.00134
$T_{90}{}^2$	-0.01882	0.00008	-0.02190	0.06897	0.01610	0.03970	-0.05460	-0.02190	-0.01066
$T_{50}*T_{90}$	-0.00247	-0.00018	0.00129	0.01942	0.00970	0.02510	0.02340	-0.02410	0.00504
$T_{50}*EtOH$	-0.01293	0.00031	-0.02114	-0.00100	-0.05140	-0.08240	0.06850	-0.15120	-0.03099
$T_{50}*ARO$	0.02923	0.00042	0.02674	-0.01146	-0.03220	-0.06600	0.19310	-0.01070	0.02090
$T_{90}*EtOH$	0.00093	0.00023	0.00556	0.02858	0.00860	0.01950	0.03610	0.03990	0.00495
$T_{90}*RVP$	-0.00080	0.00037	0.00290	-0.00456	0.03060	0.04690	0.03770	0.00020	-0.00808
$T_{90}*ARO$	0.00506	-0.00106	0.01004	0.01722	-0.02780	-0.03520	-0.03780	0.08920	0.00036
EtOH*RVP	-0.00024	-0.00038	-0.00064	0.01357	0.07610	0.07850	-0.04870	-0.07420	0.01621
EtOH*ARO	0.02639	-0.00039	0.02470	0.05933	-0.02390	-0.03360	0.05140	0.05440	0.01739
RVP*ARO	0.03270	-0.00078	0.03390	-0.01406	-0.05230	-0.08320	0.05670	-0.16310	0.03543

IV. Benchmark Model Fits Without the T_{90}^2 Model Term

	Composite								
	CH_4	CO_2	CO	FE	NMHC	NMOG	NO_x	PM	THC
Intercept	-5.03540	6.04550	-0.64550	20.81320	-3.72370	-3.64910	-4.35490	-0.70825	-3.44430
T_{50}	0.07854	0.00117	0.03861	0.17630	0.15200	0.14870	0.01157	0.05250	0.13770
T_{90}	0.02037	0.00020	-0.04454	0.01138	0.03690	0.03165	0.00807	0.11890	0.03446
EtOH	0.07774	0.00205	-0.02687	-0.33760	0.05335	0.09404	0.06630	0.10840	0.07480
RVP	-0.01736	-0.00044	0.02766	0.00384	-0.03957	-0.03990	0.02435	-0.03540	-0.03561
ARO	-0.09321	0.01767	0.05603	0.24450	0.09510	0.09028	0.06837	0.23220	0.05448
T_{50}^2	0.03852	-0.00065	0.04181	-0.00021	0.07976	0.07986	0.02244	-0.01470	0.07179
$EtOH^2$	0.02073	0.00047	0.05966	0.01693	0.04000	0.03890	0.00533	-0.08610	0.03574
$T_{50}*T_{90}$	0.01541	-0.00041	0.02543	0.02662	0.04505	0.04628	0.02006	0.10370	0.04004
$T_{50}*EtOH$	0.01572	-0.00012	0.06032	0.00498	0.03497	0.03503	0.00744	-0.11800	0.03028
$T_{50}*ARO$	0.02004	0.00020	0.03644	0.03100	0.02447	0.02316	0.06125	0.02700	0.02336
$T_{90}*EtOH$	0.01179	-0.00036	0.02181	0.02521	0.03897	0.03566	0.01917	0.08150	0.03371
$T_{90}*RVP$	-0.00577	0.00024	0.01407	0.00707	-0.01154	-0.01148	0.00237	-0.01400	-0.00951
$T_{90}*ARO$	0.01624	-0.00066	0.01983	0.02500	0.02076	0.02052	-0.01748	0.09060	0.02073
EtOH*RVP	-0.00272	-0.00051	-0.00103	0.02552	0.00022	0.00056	-0.00186	-0.02610	-0.00041
EtOH*ARO	0.03043	0.00040	0.03893	0.06176	0.04185	0.03766	0.02938	0.07820	0.03713
RVP*ARO	0.02028	-0.00049	0.03041	0.02342	0.03750	0.03609	0.03138	0.02610	0.03160

	Bag 1								
	CH_4	CO_2	CO	FE	NMHC	NMOG	NO_x	PM	THC
Intercept	-3.00650	6.55020	1.34760	12.46690	-1.03030	-0.95080	-3.01710	0.65501	-0.86530
T_{50}	0.10810	0.00091	0.02091	0.11070	0.17310	0.16950	-0.00344	0.09190	0.16480
T_{90}	0.00695	0.00275	-0.14770	-0.00566	0.01778	0.01218	0.02703	0.30760	0.01550
EtOH	0.09137	0.00260	-0.07050	-0.19880	0.05733	0.10540	0.02666	0.17590	0.08076
RVP	-0.02406	-0.00122	0.01763	0.01872	-0.03511	-0.03611	-0.02377	-0.01270	-0.03396
ARO	-0.09725	0.01755	-0.00755	0.15050	0.11340	0.10720	0.13310	0.40170	0.08553
T_{50}^2	0.06151	-0.00068	0.07052	-0.00897	0.08889	0.08968	-0.06719	0.07250	0.08659
$EtOH^2$	0.03479	-0.00039	0.08386	0.01079	0.05274	0.05186	-0.07060	-0.02420	0.05040
$T_{50}*T_{90}$	0.02094	0.00046	0.01456	0.00546	0.04903	0.05103	0.00683	0.04040	0.04708
$T_{50}*EtOH$	0.03119	-0.00060	0.10950	-0.00606	0.04265	0.04250	-0.10400	-0.03850	0.04095
$T_{50}*ARO$	0.02268	-0.00061	0.05549	0.02650	0.02001	0.01941	-0.00828	0.03230	0.02079
$T_{90}*EtOH$	0.02376	0.00030	0.01386	0.00551	0.04504	0.04147	0.03496	0.07960	0.04189
$T_{90}*RVP$	-0.00535	0.00096	0.00238	-0.00528	-0.01125	-0.01130	0.05214	-0.03920	-0.01066
$T_{90}*ARO$	0.03032	-0.00032	0.03949	0.00737	0.01992	0.01980	-0.04440	0.06950	0.02184
EtOH*RVP	0.00557	-0.00036	0.00529	0.01194	0.00758	0.00727	-0.01594	0.01820	0.00715
EtOH*ARO	0.03944	0.00020	0.06085	0.03420	0.04243	0.03775	-0.04021	0.07630	0.03980
RVP*ARO	0.02957	-0.00106	0.05398	0.02069	0.04529	0.04389	-0.01782	0.00740	0.04274

	CH_4	CO_2	CO	FE	NMHC	NMOG	NO_x	PM	THC
				Bag 2					
Intercept	-5.70790	5.98250	-1.38940	22.18310	-5.71247	-5.51659	-4.78630	-1.30679	-4.90980
T_{50}	0.05617	0.00116	0.06132	0.18820	0.10490	0.08750	0.00781	-0.07400	0.07571
T_{90}	0.02797	-0.00007	0.04283	0.01463	0.15190	0.11060	0.00410	0.10260	0.07373
EtOH	0.06874	0.00188	0.04119	-0.35820	0.08080	0.07750	0.05443	0.03370	0.06694
RVP	-0.01296	-0.00037	0.04966	0.00138	-0.05840	-0.04760	-0.00529	-0.09530	-0.03848
ARO	-0.09170	0.01771	0.10200	0.25930	0.03260	0.03580	0.04270	0.20850	-0.02773
T_{50}^2	0.01724	-0.00068	0.01971	0.00149	0.03470	0.05000	0.04256	-0.03990	0.02482
$EtOH^2$	0.00332	0.00052	0.04531	0.01765	-0.05230	-0.02760	0.04078	-0.16280	-0.01884
$T_{50}*T_{90}$	0.01103	-0.00050	0.01515	0.02995	0.03640	0.02470	0.02185	0.16190	0.00994
$T_{50}*EtOH$	-0.00370	-0.00011	0.02909	0.00671	0.00630	0.01950	0.04885	-0.13350	-0.00885
$T_{50}*ARO$	0.01743	0.00024	0.02024	0.03176	0.09860	0.06900	0.03224	-0.03020	0.04078
$T_{90}*EtOH$	-0.00240	-0.00047	-0.01096	0.02885	0.00830	0.00080	0.01748	0.08110	-0.01320
$T_{90}*RVP$	-0.01295	0.00015	-0.00901	0.00919	-0.00220	-0.00860	-0.03485	0.00980	-0.01396
$T_{90}*ARO$	0.00607	-0.00065	0.00331	0.02719	0.04790	0.03570	-0.00488	0.05320	0.02122
EtOH*RVP	-0.00926	-0.00054	0.00444	0.02812	-0.03510	-0.03080	0.02398	-0.01670	-0.02319
EtOH*ARO	0.02229	0.00049	0.02545	0.06447	0.09420	0.06990	0.05056	0.00260	0.04188
RVP*ARO	0.01203	-0.00043	0.02182	0.02343	-0.02370	-0.00750	0.01038	-0.01880	-0.00707

	CH_4	CO_2	CO	FE	NMHC	NMOG	NO_x	PM	THC
				Bag 3					
Intercept	-4.59700	6.29480	-1.14030	16.25450	-5.98349	-5.84929	-5.25460	-0.35629	-4.22880
T_{50}	0.03173	0.00123	0.02563	0.13660	0.07790	0.02050	-0.05080	-0.04730	0.04803
T_{90}	0.02037	0.00046	0.05874	0.00419	0.15170	0.14090	0.10070	0.01090	0.04770
EtOH	0.04265	0.00288	-0.06549	-0.27340	-0.10380	-0.00880	0.06930	-0.04800	0.01761
RVP	0.00773	-0.00076	0.03389	0.00922	-0.05640	-0.08260	0.17370	-0.14870	-0.00902
ARO	-0.09965	0.01756	0.07651	0.19280	0.00070	-0.01610	0.06610	0.00390	-0.05688
T_{50}^2	0.01888	-0.00033	0.00583	-0.00224	-0.02510	-0.05130	0.05530	-0.10110	0.02647
$EtOH^2$	0.00642	0.00093	-0.00292	0.01328	-0.03910	-0.01230	-0.02200	-0.07460	-0.00108
$T_{50}*T_{90}$	-0.00272	-0.00018	0.00100	0.02065	0.00990	0.02570	0.02260	-0.02440	0.00490
$T_{50}*EtOH$	-0.01400	0.00031	-0.02239	0.00287	-0.05050	-0.08030	0.06540	-0.15240	-0.03160
$T_{50}*ARO$	0.01866	0.00046	0.01443	0.02782	-0.02310	-0.04360	0.16240	-0.02300	0.01491
$T_{90}*EtOH$	0.00448	0.00022	0.00969	0.01575	0.00550	0.01190	0.04640	0.04400	0.00696
$T_{90}*RVP$	-0.00347	0.00038	-0.00020	0.00527	0.03290	0.05250	0.03000	-0.00290	-0.00959
$T_{90}*ARO$	0.00276	-0.00106	0.00737	0.02582	-0.02580	-0.03040	-0.04440	0.08660	-0.00094
EtOH*RVP	-0.00126	-0.00037	-0.00183	0.01713	0.07690	0.08060	-0.05160	-0.07540	0.01564
EtOH*ARO	0.02512	-0.00038	0.02323	0.06438	-0.02280	-0.03080	0.04770	0.05290	0.01668
RVP*ARO	0.02191	-0.00074	0.02135	0.02584	-0.04300	-0.06030	0.02540	-0.17560	0.02932

V. Reduced Benchmark Model Fits

				Composite					
	CH_4	CO_2	CO	FE	NMHC	NMOG	NO_x	PM	THC
Intercept	-5.03540	6.04560	-0.64540	20.81260	-3.72370	-3.64920	-4.35540	-0.70765	-3.44430
T_{50}	0.07343	0.00141	0.04458	0.13790	0.14710	0.14390	-0.00464	0.00030	0.13370
T_{90}	0.01883	0.00004	-0.04511	0.03232	0.03719	0.03203		0.14450	0.03454
EtOH	0.07141	0.00227	-0.02066	-0.34500	0.04829	0.08899	0.05197	0.09750	0.07065
RVP	-0.01973	-0.00053	0.03009	-0.01736	-0.04162	-0.04191		-0.05980	-0.03735
ARO	-0.09298	0.01790	0.05713	0.26350	0.09426	0.08941	0.06226	0.25900	0.05384
T_{50}^2	0.02915		0.04815		0.07459	0.07470			0.06756
$EtOH^2$	0.00795	0.00076	0.06553	0.01924	0.03534	0.03418		-0.07280	0.03203
T_{90}^2				0.06368				0.08310	
$T_{50}*T_{90}$	0.02010		0.01831	0.02936	0.05099	0.05214		0.12360	0.04504
$T_{50}*EtOH$			0.06442		0.03170	0.03173		-0.11320	0.02768
$T_{50}*ARO$	0.01729		0.03584		0.02461	0.02349	0.02282		0.02313
$T_{90}*EtOH$	0.01427		0.01598	0.03699	0.04369	0.04039		0.10270	0.03753
$T_{90}*RVP$									
$T_{90}*ARO$	0.01445	-0.00069	0.02102	0.01614	0.01968	0.01950		0.07160	0.01974
EtOH*RVP				0.02380					
EtOH*ARO	0.02741		0.04131	0.06244	0.03975	0.03565		0.08670	0.03526
RVP*ARO	0.01956		0.03435		0.03428	0.03287			0.02896

				Bag 1					
	CH_4	CO_2	CO	FE	NMHC	NMOG	NO_x	PM	THC
Intercept	-3.00670	6.55020	1.34720	12.46650	-1.03080	-0.95130	-3.01640	0.65357	-0.86600
T_{50}	0.10590	0.00235	0.02159	0.08231	0.15730	0.15410	0.01026	0.02850	0.12570
T_{90}	0.00858	0.00267	-0.14690	0.00663	0.01683	0.01124	0.02389	0.33560	0.03021
EtOH	0.08877	0.00371	-0.06967	-0.20290	0.04439	0.09272	0.03802	0.17220	0.05959
RVP	-0.02456		0.02063	0.00317	-0.04766	-0.04834	-0.01417	-0.03160	-0.05415
ARO	-0.09816	0.01761	-0.01156	0.16290	0.11120	0.10510	0.13360	0.42020	0.09038
T_{50}^2	0.05882		0.07222		0.07769	0.07866	-0.05701	0.12470	0.07506
$EtOH^2$	0.03133		0.08535	0.02017	0.04274	0.04204	-0.05981		0.04171
T_{90}^2				0.04281				0.10110	0.02856
$T_{50}*T_{90}$	0.02280				0.05224	0.05437			0.04939
$T_{50}*EtOH$	0.02883		0.11170		0.03580	0.03576	-0.09774		0.03766
$T_{50}*ARO$	0.02585		0.05859						
$T_{90}*EtOH$	0.02655				0.05123	0.04763	0.02544	0.06110	0.05489
$T_{90}*RVP$				-0.01610			0.04562	-0.07080	
$T_{90}*ARO$	0.03072		0.03861		0.02069	0.02049	-0.04769		0.01949
EtOH*RVP				0.01315					
EtOH*ARO	0.03977	0.00087	0.06244	0.03191	0.02594	0.02171	-0.03038	0.09300	0.02825
RVP*ARO	0.02791		0.05370		0.02820	0.02723			

				Bag 2					
	CH_4	**CO_2**	**CO**	**FE**	**NMHC**	**NMOG**	**NO_x**	**PM**	**THC**
Intercept	-5.70760	5.98250	-1.38950	22.18250	-5.71157	-5.51664	-4.78820	-1.31205	-4.90920
T_{50}	0.04477	0.00166	0.02484	0.14960	0.09700	0.08590		-0.00370	0.07154
T_{90}	0.02445	-0.00027	0.04177	0.03626	0.13590	0.10910	-0.00046	0.09530	0.06681
EtOH	0.06076	0.00231		-0.36530	0.07930	0.07300	0.04112	0.11580	0.06814
RVP	-0.02082		0.02839	-0.01978	-0.05330	-0.04630	-0.01464		-0.03953
ARO	-0.09211	0.01793	0.09800	0.27910	0.03730	0.03550	0.03534	0.19880	-0.02281
T_{50}^2	0.01398	-0.00053			0.04160	0.04120			0.03054
$EtOH^2$		0.00080		0.01903	-0.04890	-0.04240			
T_{90}^2				0.06595					
T_{50}*T_{90}	0.01374		0.02177	0.03204	0.04700	0.02930		0.10590	0.02886
T_{50}*EtOH									
T_{50}*ARO					0.09200	0.07380			0.03386
T_{90}*EtOH				0.04033					
T_{90}*RVP	-0.00992						-0.04014		
T_{90}*ARO		-0.00064		0.01820		0.03270			
EtOH*RVP				0.02631		-0.03130			
EtOH*ARO	0.01047	0.00050		0.06572	0.09640	0.07180	0.02739		0.04028
RVP*ARO									

				Bag 3					
	CH_4	**CO_2**	**CO**	**FE**	**NMHC**	**NMOG**	**NO_x**	**PM**	**THC**
Intercept	-4.59780	6.29480	-1.14090	16.25400	-5.98276	-5.84707	-5.25543	-0.35375	-4.23000
T_{50}	0.01886	0.00188		0.09820	0.13560	0.07830	-0.02240	-0.04110	0.03595
T_{90}	0.01856	0.00027	0.05783	0.02466	0.15460	0.14700	0.08500		0.04904
EtOH	0.03187	0.00340	-0.08151	-0.28220	-0.05810	0.03410	0.08840	-0.02120	0.00788
RVP			0.02394	-0.01161	-0.03130	-0.05730	0.16920	-0.12750	-0.01423
ARO	-0.10040	0.01776	0.07193	0.21000			0.06670	0.01860	-0.06120
T_{50}^2									
$EtOH^2$		0.00094		0.01580					
T_{90}^2				0.05867					
T_{50}*T_{90}				0.02268					
T_{50}*EtOH	-0.02007					-0.07290	0.06370	-0.08240	-0.03125
T_{50}*ARO		0.00086					0.08940		
T_{90}*EtOH				0.02737					
T_{90}*RVP									
T_{90}*ARO		-0.00118		0.01788					
EtOH*RVP				0.01449	0.07730	0.07090			0.01666
EtOH*ARO				0.06443				0.08490	
RVP*ARO								-0.10620	

VI. Reduced Benchmark Model Fits Without the T_{90}^2 Model Term

				Composite					
	CH_4	CO_2	CO	FE	NMHC	NMOG	NO_x	PM	THC
Intercept	-5.03540	6.04560	-0.64540	20.81330	-3.72370	-3.64920	-4.35540	-0.70724	-3.44430
T_{50}	0.07343	0.00141	0.04458	0.17810	0.14710	0.14390	-0.00464	0.03440	0.13370
T_{90}	0.01883	0.00004	-0.04511	0.01078	0.03719	0.03203		0.11460	0.03454
EtOH	0.07141	0.00227	-0.02066	-0.33630	0.04829	0.08899	0.05197	0.09990	0.07065
RVP	-0.01973	-0.00053	0.03009	0.00469	-0.04162	-0.04191		-0.04960	-0.03735
ARO	-0.09298	0.01790	0.05713	0.24520	0.09426	0.08941	0.06226	0.23220	0.05384
T_{50}^2	0.02915		0.04815		0.07459	0.07470			0.06756
$EtOH^2$	0.00795	0.00076	0.06553	0.01450	0.03534	0.03418		-0.06570	0.03203
T_{90}^2									
$T_{50}*T_{90}$	0.02010		0.01831	0.02357	0.05099	0.05214		0.10890	0.04504
$T_{50}*EtOH$			0.06442		0.03170	0.03173		-0.08840	0.02768
$T_{50}*ARO$	0.01729		0.03584	0.03066	0.02461	0.02349	0.02282		0.02313
$T_{90}*EtOH$	0.01427		0.01598	0.02252	0.04369	0.04039		0.08460	0.03753
$T_{90}*RVP$									
$T_{90}*ARO$	0.01445	-0.00069	0.02102	0.02527	0.01968	0.01950		0.08660	0.01974
EtOH*RVP				0.02552					
EtOH*ARO	0.02741		0.04131	0.06264	0.03975	0.03565		0.05940	0.03526
RVP*ARO	0.01956		0.03435	0.02608	0.03428	0.03287			0.02896

				Bag 1					
	CH_4	CO_2	CO	FE	NMHC	NMOG	NO_x	PM	THC
Intercept	-3.00670	6.55020	1.34720	12.46630	-1.03080	-0.95130	-3.01640	0.65289	-0.86580
T_{50}	0.10590	0.00235	0.02159	0.10840	0.15730	0.15410	0.01026	0.10040	0.14900
T_{90}	0.00858	0.00267	-0.14690		0.01683	0.01124	0.02389	0.30340	0.01435
EtOH	0.08877	0.00371	-0.06967	-0.19930	0.04439	0.09272	0.03802	0.18070	0.06793
RVP	-0.02456		0.02063	0.02178	-0.04766	-0.04834	-0.01417		-0.04669
ARO	-0.09816	0.01761	-0.01156	0.14780	0.11120	0.10510	0.13360	0.37920	0.08343
T_{50}^2	0.05882		0.07222		0.07769	0.07866	-0.05701	0.08060	0.07555
$EtOH^2$	0.03133		0.08535	0.01462	0.04274	0.04204	-0.05981		0.04065
T_{90}^2									
$T_{50}*T_{90}$	0.02280				0.05224	0.05437			0.05003
$T_{50}*EtOH$	0.02883		0.11170		0.03580	0.03576	-0.09774		0.03426
$T_{50}*ARO$	0.02585		0.05859	0.03946					
$T_{90}*EtOH$	0.02655				0.05123	0.04763	0.02544	0.06470	0.04782
$T_{90}*RVP$							0.04562		
$T_{90}*ARO$	0.03072		0.03861		0.02069	0.02049	-0.04769	0.06650	0.02260
EtOH*RVP									
EtOH*ARO	0.03977	0.00087	0.06244	0.04073	0.02594	0.02171	-0.03038		0.02297
RVP*ARO	0.02791		0.05370	0.02439	0.02820	0.02723			0.02552

				Bag 2					
	CH_4	CO_2	CO	FE	NMHC	NMOG	NO_x	PM	THC
Intercept	-5.70760	5.98250	-1.38950	22.18360	-5.71157	-5.51664	-4.78820	-1.30747	-4.90920
T_{50}	0.04477	0.00166	0.02484	0.16750	0.09700	0.08590		-0.07520	0.07154
T_{90}	0.02445	-0.00027	0.04177	0.01110	0.13590	0.10910	-0.00046	0.09460	0.06681
EtOH	0.06076	0.00231		-0.37410	0.07930	0.07300	0.04112	0.04030	0.06814
RVP	-0.02082		0.02839	-0.01562	-0.05330	-0.04630	-0.01464	-0.07030	-0.03953
ARO	-0.09211	0.01793	0.09800	0.25810	0.03730	0.03550	0.03534	0.19830	-0.02281
T_{50}^2	0.01398	-0.00053			0.04160	0.04120			0.03054
$EtOH^2$		0.00080			-0.04890	-0.04240		-0.13480	
T_{90}^2									
$T_{50}*T_{90}$	0.01374		0.02177	0.02279	0.04700	0.02930		0.11550	0.02886
$T_{50}*EtOH$								-0.10250	
$T_{50}*ARO$					0.09200	0.07380			0.03386
$T_{90}*EtOH$				0.02651					
$T_{90}*RVP$	-0.00992						-0.04014		
$T_{90}*ARO$		-0.00064		0.02795		0.03270			
EtOH*RVP				0.03030		-0.03130			
EtOH*ARO	0.01047	0.00050		0.04230	0.09640	0.07180	0.02739		0.04028
RVP*ARO									

				Bag 3					
	CH_4	CO_2	CO	FE	NMHC	NMOG	NO_x	PM	THC
Intercept	-4.59780	6.29480	-1.14090	16.25490	-5.98276	-5.84707	-5.25543	-0.35375	-4.23000
T_{50}	0.01886	0.00188		0.13190	0.13560	0.07830	-0.02240	-0.04110	0.03595
T_{90}	0.01856	0.00027	0.05783	0.00467	0.15460	0.14700	0.08500		0.04904
EtOH	0.03187	0.00340	-0.08151	-0.27900	-0.05810	0.03410	0.08840	-0.02120	0.00788
RVP			0.02394	0.00963	-0.03130	-0.05730	0.16920	-0.12750	-0.01423
ARO	-0.10040	0.01776	0.07193	0.18630			0.06670	0.01860	-0.06120
T_{50}^2									
$EtOH^2$		0.00094							
T_{90}^2									
$T_{50}*T_{90}$									
$T_{50}*EtOH$	-0.02007					-0.07290	0.06370	-0.08240	-0.03125
$T_{50}*ARO$		0.00086		0.02797			0.08940		
$T_{90}*EtOH$									
$T_{90}*RVP$									
$T_{90}*ARO$		-0.00118		0.02440					
EtOH*RVP				0.01449	0.07730	0.07090			0.01666
EtOH*ARO				0.06304				0.08490	
RVP*ARO				0.02284				-0.10620	

VII. Composite Reduced Hierarchical Model Fit Terms

CH_4

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	28.2383	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	EA	RA			
2	28.8717	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9E	T9A	EA	RA				
3	29.0245	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9R	T9A	EA	RA		
4	29.0455	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA	RA		
5	29.8225	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9E	T9A	EA	RA					
6	29.8553	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	ER	EA	RA		
7	29.9398	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5A	T9E	T9A	EA	RA			
8	30.2011	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9E	T9R	T9A	EA	RA			
9	30.2471	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9R	T9A	EA	RA	
10	30.3129	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9E	T9A	ER	EA	RA			
11	30.6076	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T5A	T9E	T9A	EA	RA				
12	30.6940	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9R	T9A	ER	EA	RA	
13	30.7799	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	ER	EA	RA	
14	30.9186	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9E	T9A	ER	EA	RA				
15	31.2487	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9R	T9A	EA	RA			
16	31.3395	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9A	EA							
17	31.3769	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9R	T9A	EA	RA		
18	31.4999	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5A	T9E	T9A	ER	EA	RA		
19	31.5508	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5A	T9E	T9R	T9A	EA	RA		
20	31.5552	T50	T90	ETOH	RVP	ARO	T502	T59	T5E	T5A	T9E	T9A	EA	RA				
21	31.6042	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T9E	T9A	EA	RA					
22	31.6066	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	EA					
23	31.6083	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	EA	RA				
24	31.6233	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9E	T9R	T9A	EA	RA				
25	31.6737	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9E	T9R	T9A	ER	EA	RA		

CO_2

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	23.2801	T50	T90	ETOH	ARO	T502	EtOH2	T9A	EA									
2	23.2943	T50	T90	ETOH	RVP	ARO	EtOH2	T9A	EA									
3	23.3760	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T9A	ER	EA							
4	23.4640	T50	T90	ETOH	RVP	ARO	EtOH2	T9A	ER	EA								
5	23.4698	T50	T90	ETOH	RVP	ARO	T502	T5E	T9R	T9A	ER	RA						
6	23.5333	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T9A	EA								
7	23.5484	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T9R	T9A	ER	RA						
8	23.5601	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T9A	EA								
9	23.6007	T50	T90	ETOH	RVP	ARO	EtOH2	T9A	ER									
10	23.6068	T50	T90	ETOH	ARO	T502	EtOH2	T9E	T9A	EA								
11	23.6799	T50	T90	ETOH	RVP	ARO	EtOH2	T9A										

NO_x

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	16.3931	T50	ETOH	ARO	T5A													
2	16.6166	ETOH	ARO															
3	17.4336	T50	ETOH	RVP	ARO	T5A												
4	17.6403	T50	ETOH	ARO	T502	T5A												
5	17.6647	T50	T90	ETOH	ARO	T5A	T9A											
6	17.7712	ETOH	ARO	EA														
7	18.0163	T50	T90	ETOH	ARO	T5A												
8	18.0177	T50	T90	ETOH	ARO	T5A	T9E											
9	18.0277	T50	ETOH	ARO	EtOH2	T5A												

CO

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	28.3254	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9R	T9A	EA	RA		
2	28.7466	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	EA	RA			
3	29.0381	T50	T90	ETOH	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA					
4	29.4118	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5E	T5A	T9A	EA	RA					
5	30.0170	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA	RA		
6	30.0322	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9R	T9A	EA	RA	
7	30.0997	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA				
8	30.1535	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9A	EA	RA				
9	30.3086	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9R	T9A	ER	EA	RA	
10	30.3628	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA			
11	30.4810	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5E	T5A	T9E	T9A	EA	RA				
12	30.7422	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	ER	EA	RA		
13	30.9759	T50	T90	ETOH	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA				
14	31.1716	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9R	T9A	EA		
15	31.2573	T50	T90	ETOH	ARO	T502	EtOH2	T902	T5E	T9E	T9A	EA						
16	31.2747	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5E	T5A	T9R	T9A	EA	RA				
17	31.3256	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T5E	T5A	T9A	EA	RA				
18	31.3946	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5E	T5A	T9A	ER	EA	RA				
19	31.4655	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA			
20	31.5569	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA	RA			
21	31.5877	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T5E	T9E	T9A	EA					
22	31.6473	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9R	T9A	EA	RA			
23	31.9944	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	ER	EA	RA	
24	32.0000	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9R	T9A	ER	EA	RA
25	32.0236	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9R	T9A	EA			

FE

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	24.9008	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T9E	T9A	ER	EA					
2	24.9151	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T9E	T9A	ER	EA	RA				
3	25.6905	T50	T90	ETOH	RVP	ARO	T902	T59	T5E	T9E	T9A	ER	EA					
4	26.1064	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	T9A	ER	EA				
5	26.1804	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T9E	ER	EA						
6	26.1847	T50	T90	ETOH	RVP	ARO	T902	T59	T5E	T9E	ER	EA						
7	26.2208	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T9E	ER	EA	RA					
8	26.2358	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5A	T9E	T9A	ER	EA	RA			
9	26.3029	T50	T90	ETOH	RVP	ARO	T902	T59	T5E	T9E	T9A	ER	EA	RA				
10	26.4475	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5E	T9E	T9A	ER	EA				
11	26.7250	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	T9A	ER	EA	RA			
12	26.7896	T50	T90	ETOH	RVP	ARO	T902	T59	T9E	T9A	ER	EA	RA					
13	26.7999	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5A	T9E	T9A	ER	EA				
14	26.8470	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5E	T9E	T9A	ER	EA	RA			
15	26.8496	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T9E	T9R	T9A	ER	EA				
16	26.8952	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T9E	T9R	T9A	ER	EA	RA			
17	26.9153	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	ER	EA					
18	26.9730	T50	T90	ETOH	RVP	ARO	T902	T59	T5E	T9E	ER	EA	RA					
19	27.0935	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5A	T9E	ER	EA	RA				
20	27.2743	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5E	T9E	ER	EA					
21	27.6143	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T5E	T9E	T9A	ER	EA				
22	27.6238	T50	T90	ETOH	RVP	ARO	T902	T59	T5E	T9E	T9R	T9A	ER	EA				
23	27.6397	T50	T90	ETOH	RVP	ARO	T902	T59	T5E	T5A	T9E	T9A	ER	EA				
24	27.7414	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	ER	EA	RA				
25	27.7797	T50	T90	ETOH	RVP	ARO	T902	T59	T5E	T5A	T9E	T9A	ER	EA	RA			

NMHC

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	27.9010	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	EA	RA			
2	28.5676	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9R	T9A	EA	RA		
3	28.6069	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	EA	RA				
4	28.8763	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9A	EA	RA						
5	28.9672	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA				
6	29.0490	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA	RA			
7	29.0776	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA	RA		
8	29.1190	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9E	T9A	EA	RA					
9	29.2717	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9R	T9A	EA	RA			
10	29.4968	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9E	T9A	EA	RA				
11	29.5118	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9E	T9A	EA						
12	29.6095	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9E	T9A	EA	RA					
13	29.6562	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA	RA		
14	29.6709	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T9E	T9A	EA	RA					
15	29.7113	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA			
16	29.9005	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	ER	EA	RA		
17	30.0019	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9R	T9A	EA	RA	
18	30.0126	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	EA					
19	30.0257	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	T9A	EA	RA				
20	30.3521	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	ER	EA	RA			
21	30.4842	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9A	EA							
22	30.5165	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9R	T9A	EA	RA					
23	30.5670	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9R	T9A	ER	EA	RA	
24	30.7391	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	T9A	EA					
25	30.8145	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9E	T9R	T9A	EA	RA			

NMOG

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	27.9154	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	EA	RA			
2	28.4287	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	EA	RA				
3	28.5424	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9A	EA	RA						
4	28.5728	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9R	T9A	EA	RA		
5	28.7373	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA				
6	28.9061	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9E	T9A	EA	RA					
7	28.9363	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA	RA			
8	28.9671	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA	RA		
9	29.0844	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9R	T9A	EA	RA			
10	29.1722	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9E	T9A	EA						
11	29.2980	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9E	T9A	EA	RA					
12	29.4652	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA			
13	29.5823	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T9E	T9A	EA	RA					
14	29.5864	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9E	T9A	EA	RA				
15	29.6404	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	EA					
16	29.6669	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA	RA		
17	29.9151	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	ER	EA	RA		
18	30.0000	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9R	T9A	EA	RA	
19	30.0030	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	T9A	EA	RA				
20	30.0945	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9A	EA							
21	30.1525	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9R	T9A	EA	RA					
22	30.1556	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	ER	EA	RA			
23	30.5083	T50	T90	ETOH	RVP	ARO	T502	T59	T5E	T9E	T9A	EA	RA					
24	30.5120	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9A	ER	EA	RA					
25	30.5687	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9R	T9A	ER	EA	RA	

PM: Zeros Deleted

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	21.7039	T50	T90	ETOH	RVP	ARO	EtOH2	T59	T5E	T9E	T9A	EA						
2	23.0847	T50	T90	ETOH	RVP	ARO	EtOH2	T59	T5E	T9E	T9A	ER	EA					
3	23.2776	T50	T90	ETOH	ARO	EtOH2	T59	T5E	T9E	T9A	EA							
4	23.3369	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5E	T9E	T9A	EA					
5	23.4011	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	EA					
6	23.5737	T50	T90	ETOH	RVP	ARO	EtOH2	T59	T5E	T9E	T9R	T9A	EA					
7	23.6459	T50	T90	ETOH	RVP	ARO	EtOH2	T59	T5E	T9E	T9A	EA	RA					
8	23.6834	T50	T90	ETOH	RVP	ARO	EtOH2	T59	T5E	T5A	T9E	T9A	EA					
9	24.5445	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5E	T9E	T9A	ER	EA				
10	24.7155	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	ER	EA				
11	24.7513	T50	T90	ETOH	ARO	EtOH2	T59	T5E	T5A	T9E	T9A	EA						
12	24.7779	T50	T90	ETOH	ARO	T502	EtOH2	T59	T5E	T9E	T9A	EA						
13	24.9240	T50	T90	ETOH	RVP	ARO	EtOH2	T59	T5E	T9E	T9R	T9A	ER	EA				
14	25.0479	T50	T90	ETOH	RVP	ARO	EtOH2	T59	T5E	T5A	T9E	T9A	ER	EA				
15	25.0658	T50	T90	ETOH	RVP	ARO	T59	T5E	T9E	T9A	EA							
16	25.0815	T50	T90	ETOH	RVP	ARO	EtOH2	T59	T5E	T9E	T9A	ER	EA	RA				
17	25.1150	T50	T90	ETOH	ARO	T59	T5E	T9E	T9A	EA								
18	25.1187	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA				
19	25.1452	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA				
20	25.1841	T50	T90	ETOH	ARO	EtOH2	T902	T59	T5E	T9E	T9A	EA						
21	25.2633	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA				
22	25.2995	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9A	EA							
23	25.3354	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5E	T9E	T9A	EA	RA				
24	25.3600	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9R	T9A	EA				
25	25.3632	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	EA				

THC

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	27.6831	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	EA	RA			
2	28.2890	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA				
3	28.5555	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9R	T9A	EA	RA		
4	28.6452	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	EA	RA				
5	28.8087	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9E	T9A	EA						
6	28.9472	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9A	EA	RA						
7	28.9841	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA	RA			
8	29.0060	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9E	T9A	EA	RA					
9	29.0753	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9E	T9A	EA	RA				
10	29.1211	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA			
11	29.2177	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	EA					
12	29.2490	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA	RA		
13	29.4350	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA	RA		
14	29.4966	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T9E	T9A	EA	RA					
15	29.5019	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9A	EA							
16	29.5160	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9R	T9A	EA	RA			
17	29.6234	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9E	T9A	EA	RA					
18	29.6740	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	ER	EA	RA		
19	29.6892	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	T9A	EA					
20	29.7485	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	T9A	EA	RA				
21	30.0142	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9R	T9A	EA	RA	
22	30.2419	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	ER	EA			
23	30.2853	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA			
24	30.4340	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	ER	EA	RA			
25	30.5169	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9E	T9A	ER	EA					

VIII. Bag 1 Reduced Hierarchical Model Fit Terms

CH_4

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	27.5786	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	EA	RA			
2	28.8785	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	ER	EA	RA		
3	29.0834	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9R	T9A	EA	RA		
4	29.3359	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA	RA		
5	29.8799	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA				
6	30.3338	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9R	T9A	ER	EA	RA	
7	30.6559	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9R	T9A	EA	RA	
8	30.6629	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA	RA			
9	30.7075	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	ER	EA	RA	
10	30.8549	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	ER	EA	RA			
11	31.2130	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	ER	EA	RA		
12	31.2204	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9E	T9A	EA	RA				
13	31.2567	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA			
14	31.2585	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	ER	EA			
15	31.2723	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	EA	RA				
16	31.3824	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9E	T9A	EA	RA					
17	31.6348	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA			
18	31.6360	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA	RA		
19	32.0000	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9R	T9A	ER	EA	RA
20	32.0470	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	EA					
21	32.1990	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	ER	EA	RA	
22	32.2704	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9R	T9A	ER	EA	RA		
23	32.4279	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9E	T9A	EA						
24	32.7000	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5E	T5A	T9E	T9R	T9A	EA	RA			
25	32.7109	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	ER	EA		

CO_2

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	16.4670	T50	T90	ETOH	ARO	EA												
2	16.6309	T50	T90	ETOH	RVP	ARO	EA											
3	16.7138	T50	T90	ETOH	RVP	ARO	T5A	RA										
4	16.8887	T50	T90	ETOH	RVP	ARO	T5A	T9R	RA									
5	17.0677	T50	T90	ETOH	RVP	ARO	T9R	EA										
6	17.3938	T50	T90	ETOH	ARO	EtOH2	EA											
7	17.5859	T50	T90	ETOH	RVP	ARO	T9R	EA	RA									
8	17.5964	T50	T90	ETOH	RVP	ARO	EA	RA										
9	17.7166	T50	T90	ETOH	RVP	ARO	ER	EA										
10	17.7376	T50	T90	ETOH	RVP	ARO	T5E	EA										
11	17.7468	T50	T90	ETOH	RVP	ARO	EtOH2	EA										
12	17.8306	T50	T90	ETOH	ARO	T5E	EA											
13	17.9423	T50	T90	ETOH	RVP	ARO	T9R	RA										
14	18.0882	T50	T90	ETOH	RVP	ARO	T502	T5A	T9R	RA								
15	18.1076	T50	T90	ETOH	ARO	T9A	EA											
16	18.1319	T50	T90	ETOH	RVP	ARO	T9R	ER	EA									
17	18.1321	T50	T90	ETOH	ARO	T9E	EA											
18	18.1384	T50	T90	ETOH	RVP	ARO	T902	T9R										
19	18.1428	T50	T90	ETOH	ARO	T902	EA											
20	18.1565	T50	T90	ETOH	RVP	ARO	T9R	ER	EA	RA								
21	18.1767	T50	T90	ETOH	RVP	ARO	T9R	ER	RA									
22	18.1816	T50	T90	ETOH	RVP	ARO	T5A	ER	RA									
23	18.1861	T50	T90	ETOH	RVP	ARO	T5A	T9R	ER	RA								
24	18.2492	T50	T90	ETOH	RVP	ARO	T59	T9R	EA									
25	18.2852	T50	T90	ETOH	RVP	ARO	ER	EA	RA									

CO

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	25.7012	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5E	T5A	T9A	EA	RA					
2	26.9336	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T5E	T5A	T9A	EA	RA				
3	27.0540	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5E	T5A	T9E	T9A	EA	RA				
4	27.4055	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5E	T5A	T9A	ER	EA	RA				
5	27.4902	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9A	EA	RA				
6	27.5427	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T5E	T5A	T9E	T9A	EA	RA			
7	27.5520	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5E	T5A	T9R	T9A	EA	RA				
8	27.9537	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	EA	RA			
9	28.1728	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA	RA		
10	28.5162	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T5E	T5A	T9R	T9A	EA	RA			
11	28.5295	T50	T90	ETOH	ARO	T502	EtOH2	T902	T5E	T5A	T9E	T9A	EA					
12	28.6664	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T5E	T5A	T9A	ER	EA	RA			

NO_x

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	25.8471	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5E	T9E	T9R	T9A	EA					
2	26.7494	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5E	T9R	T9A	EA						
3	26.8198	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5E	T9E	T9R	T9A	ER	EA				

FE

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	21.1315	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T9E	T9R	ER	EA						
2	21.2959	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T9R	ER	EA							
3	22.1469	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T9E	T9R	EA							
4	22.5756	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T9E	T9R	EA	RA						
5	22.6215	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T9E	T9R	ER	EA	RA					
6	22.8798	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T5E	T9E	T9R	ER	EA					
7	22.9105	T50	T90	ETOH	ARO	EtOH2	T902	T5A	T9E	EA								
8	22.9273	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T9E	T9R	ER	EA					
9	22.9409	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T5A	T9E	T9R	ER	EA					
10	22.9507	T50	T90	ETOH	ARO	EtOH2	T902	T9E	EA									
11	22.9610	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T5A	T9E	T9R	EA						
12	22.9818	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T9R	ER	EA						
13	23.0717	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T9E	T9R	T9A	ER	EA					
14	23.1187	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T9E	T9R	ER	EA					
15	23.1780	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T5E	T9R	ER	EA						
16	23.2088	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T5A	T9R	ER	EA						

NMHC

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	28.3075	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA	RA			
2	28.6953	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	EA	RA				
3	28.7304	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	EA	RA			
4	28.7646	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA	RA		
5	28.9563	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA				
6	29.0626	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	EA	RA				
7	29.4553	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	ER	EA	RA			
8	29.6316	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	T9A	EA	RA				
9	29.7192	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	ER	EA	RA		
10	29.7758	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA	RA		
11	29.7861	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	EA	RA					
12	29.7986	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	EA	RA			
13	29.8070	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9R	T9A	EA	RA			
14	29.8433	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9R	T9A	EA	RA		
15	29.8719	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	EA					
16	30.1167	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA			
17	30.1337	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T9E	T9A	EA	RA					
18	30.1470	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	ER	EA	RA			
19	30.1864	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	ER	EA	RA	
20	30.2365	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	ER	EA	RA		
21	30.4036	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9R	T9A	EA	RA	
22	30.4839	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9R	T9A	ER	EA	RA		
23	30.5377	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA			
24	30.5454	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9A	EA	RA						
25	30.6387	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9E	T9A	EA	RA				

NMOG

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	28.2764	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA	RA			
2	28.4653	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	EA	RA				
3	28.6012	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	EA	RA			
4	28.7333	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA	RA		
5	28.7990	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA				
6	29.0584	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	EA	RA				
7	29.3052	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	ER	EA	RA			
8	29.5543	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9R	T9A	EA	RA			
9	29.6404	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	T9A	EA	RA				
10	29.6914	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9R	T9A	EA	RA		
11	29.7205	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	ER	EA	RA		
12	29.7384	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	EA					
13	29.7509	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA	RA		
14	29.7955	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	EA	RA			
15	29.8153	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	EA	RA					
16	29.9394	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T9E	T9A	EA	RA					
17	29.9458	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA			
18	30.1435	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	ER	EA	RA		
19	30.1737	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9A	EA	RA						
20	30.1813	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	ER	EA	RA			
21	30.1871	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	ER	EA	RA	
22	30.3128	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9R	T9A	ER	EA	RA		
23	30.3774	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9R	T9A	EA	RA	
24	30.4121	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA			
25	30.4723	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9E	T9A	EA	RA					

PM: Zeros Deleted

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	24.6881	T50	T90	ETOH	RVP	ARO	EtOH2	T5E	T9E	T9A	ER	EA						
2	24.7475	T50	T90	ETOH	RVP	ARO	T502	T9E	T9A	ER	EA							
3	24.8349	T50	T90	ETOH	RVP	ARO	T502	T5E	T9E	T9A	ER	EA						
4	25.3069	T50	T90	ETOH	RVP	ARO	EtOH2	T59	T5E	T9E	T9A	ER	EA					
5	25.4082	T50	T90	ETOH	RVP	ARO	T502	T902	T5E	T9E	T9A	ER	EA					
6	25.7259	T50	T90	ETOH	RVP	ARO	T502	T902	T5E	T9E	T9R	T9A	ER	EA				
7	25.7468	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5E	T9E	T9A	ER	EA					
8	25.8498	T50	T90	ETOH	RVP	ARO	T502	T59	T5E	T9E	T9A	ER	EA					
9	25.8552	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9A	ER	EA						
10	25.8584	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T5E	T9E	T9A	ER	EA					
11	25.8868	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T5E	T9E	T9A	ER	EA				
12	25.9505	T50	T90	ETOH	RVP	ARO	T502	T9E	T9R	T9A	ER	EA						
13	25.9640	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5E	T9E	T9A	ER	EA				
14	25.9984	T50	T90	ETOH	RVP	ARO	T502	T5E	T9E	T9R	T9A	ER	EA					
15	26.0108	T50	T90	ETOH	RVP	ARO	T502	T902	T9E	T9A	ER	EA						
16	26.1271	T50	T90	ETOH	RVP	ARO	T502	T5A	T9E	T9A	ER	EA						
17	26.3602	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T9E	T9A	ER	EA						
18	26.4217	T50	T90	ETOH	RVP	ARO	EtOH2	T5E	T9E	T9R	T9A	ER	EA					
19	26.4389	T50	T90	ETOH	RVP	ARO	EtOH2	T5E	T5A	T9E	T9A	ER	EA					
20	26.4582	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T5E	T9E	T9A	ER	EA				
21	26.5044	T50	T90	ETOH	RVP	ARO	T502	T5E	T5A	T9E	T9A	ER	EA					
22	26.5430	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	ER	EA				
23	26.5684	T50	T90	ETOH	RVP	ARO	T502	T5E	T9E	T9A	ER	EA	RA					
24	26.6552	T50	T90	ETOH	RVP	ARO	T502	T902	T9E	T9R	T9A	ER	EA					
25	26.6686	T50	T90	ETOH	RVP	ARO	EtOH2	T5E	T9E	T9A	ER	EA	RA					

THC

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	28.4415	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA	RA			
2	28.7327	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	EA				
3	28.7453	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	EA	RA			
4	28.8715	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA	RA		
5	29.0256	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	EA	RA				
6	29.7177	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9A	ER	EA	RA			
7	29.7719	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA	RA		
8	29.8206	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	T9A	EA	RA				
9	29.8290	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	ER	EA	RA		
10	29.8337	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	EA			
11	29.8594	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9R	T9A	EA	RA		
12	30.1383	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9R	T9A	EA	RA			
13	30.2392	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	EA	RA				
14	30.2581	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9E	T9A	ER	EA	RA		
15	30.2694	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9R	T9A	ER	EA	RA	
16	30.3964	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9R	T9A	EA	RA	
17	30.4794	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T5A	T9E	T9A	EA			
18	30.5245	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T9E	T9A	EA	RA					
19	30.6663	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	T9A	ER	EA			
20	30.7060	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T5E	T9E	EA					
21	30.7453	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T9E	T9R	T9A	ER	EA	RA		
22	30.7584	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9E	T9A	EA	RA				
23	30.8415	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9E	T9A	EA						
24	30.8637	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9E	T9A	EA	RA					
25	30.8953	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9A	EA	RA						

IX. Bag 2 Reduced Hierarchical Model Fit Terms

CH_4

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	25.9507	T50	T90	ETOH	RVP	ARO	T502	T59	T9R	EA								
2	26.4633	T50	T90	ETOH	RVP	ARO	T502	T902	T59									
3	26.6994	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T5A	EA	RA						
4	26.7082	T50	T90	ETOH	RVP	ARO	T502	T59	T9R	ER	EA							
5	26.8555	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T5A	T9A	ER	EA	RA				
6	26.8574	T50	T90	ETOH	RVP	ARO	T502	T59	EA									
7	26.9471	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T5A	ER	EA	RA					
8	27.0157	T50	T90	ETOH	RVP	ARO	T502	T59	T9R	T9A	EA							
9	27.0287	T50	T90	ETOH	RVP	ARO	T502	T59	T5E	T9R	EA							
10	27.0996	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9A								
11	27.1125	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T5A	T9A	EA	RA					
12	27.1632	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9R	ER	EA						
13	27.1742	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T9R	EA							
14	27.2340	T50	T90	ETOH	RVP	ARO	T502	T902	T59	EA								
15	27.3329	T50	T90	ETOH	RVP	ARO	T902	T59	T9A									
16	27.3366	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9R	EA							
17	27.3422	T50	T90	ETOH	RVP	ARO	T902	T59										
18	27.3478	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9R								
19	27.3576	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T5A	T9R	T9A	ER	EA	RA			
20	27.3880	T50	T90	ETOH	RVP	ARO	T502	T59	T9R	T9A	ER	EA						
21	27.4600	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9R	EA							
22	27.6337	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T5A	T9R	EA	RA					
23	27.6388	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9R	T9A							
24	27.6680	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	ER	EA							
25	27.6894	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9R	T9A	ER	EA					

CO_2

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	22.8792	T50	T90	ETOH	ARO	T502	EtOH2	T9A	EA									
2	23.0357	T50	T90	ETOH	ARO	T502	EtOH2	T9E	T9A	EA								
3	23.0445	T50	ETOH	RVP	ARO	T502	EtOH2	ER	RA									
4	23.2388	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T9A	ER	EA							
5	23.2681	T50	ETOH	RVP	ARO	T502	EtOH2	ER	EA									
6	23.3017	T50	ETOH	ARO	T502	EtOH2	EA											
7	23.4052	T90	ETOH	RVP	ARO	EtOH2	T902	T9A	ER	EA	RA							
8	23.4598	T50	ETOH	RVP	ARO	T502	T5E	ER	RA									
9	23.5398	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T9A	EA								
10	23.5629	T50	ETOH	RVP	ARO	T502	EtOH2	ER	EA	RA								
11	23.5861	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T9A	EA								
12	23.5900	T50	T90	ETOH	ARO	T502	EtOH2	T59	T9E	T9A	EA							
13	23.6892	T50	T90	ETOH	ARO	T502	EtOH2	T9A										
14	23.6949	T50	ETOH	RVP	ARO	T502	EtOH2	ER										
15	23.7367	T50	ETOH	RVP	ARO	EtOH2	ER	EA										
16	23.7428	T50	T90	ETOH	RVP	ARO	EtOH2	T9A	EA									
17	23.8076	T50	ETOH	RVP	ARO	T502	ER	RA										
18	23.8254	T50	ETOH	RVP	ARO	T502	EtOH2	EA										
19	23.8451	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T9A	ER	EA							
20	23.8475	T50	T90	ETOH	RVP	ARO	EtOH2	T9A	ER	EA								

NO_x

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	17.1524	T90	ETOH	RVP	ARO	T9R	ER	EA										
2	17.7111	T90	ETOH	RVP	ARO	T9R	EA											

CO

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	14.0533	T50	T90	RVP	ARO	T59												
2	15.0314	T50	T90	RVP	ARO													
3	15.2662	T50	T90	ETOH	RVP	ARO	T59											
4	15.3346	T50	T90	ETOH	RVP	ARO	EtOH2	T59										
5	15.9672	T50	T90	RVP	ARO	T502	T59											
6	15.9695	T50	T90	RVP	ARO	T902	T59											
7	16.0017	T50	T90	RVP	ARO	T59	T9R											
8	16.0225	T50	T90	RVP	ARO	T59	RA											
9	16.0424	T50	T90	RVP	ARO	T59	T9A											
10	16.0529	T50	T90	RVP	ARO	T59	T5A											
11	16.1445	T50	T90	ETOH	RVP	ARO	EtOH2											
12	16.2884	T50	T90	ETOH	RVP	ARO												
13	16.5404	T50	T90	ETOH	RVP	ARO	EtOH2	T9E										
14	16.5894	T50	T90	ETOH	RVP	ARO	T9E											
15	16.6823	T50	T90	ETOH	RVP	ARO	EtOH2	T59	T5E									
16	16.7256	T50	T90	RVP	ARO	RA												
17	16.9503	T50	T90	RVP	ARO	T9R												
18	16.9590	T50	T90	ETOH	RVP	ARO	EtOH2	T59	EA									
19	16.9635	T50	T90	RVP	ARO	T502												
20	16.9649	T50	T90	RVP	ARO	T902												
21	16.9937	T50	T90	RVP	ARO	T9A												
22	17.0120	T50	T90	RVP	ARO	T5A												
23	17.0213	T50	T90	ETOH	RVP	ARO	T59	EA										
24	17.0642	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59									
25	17.0863	T50	T90	ETOH	RVP	ARO	T502	T59										

FE

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	24.9257	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T9E	T9A	ER	EA					
2	24.9710	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T9E	T9A	ER	EA	RA				
3	25.3374	T50	T90	ETOH	RVP	ARO	T902	T59	T5E	T9E	T9A	ER	EA					
4	25.8883	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	T9A	ER	EA				
5	25.9441	T50	T90	ETOH	RVP	ARO	T902	T59	T9E	T9A	ER	EA	RA					
6	25.9505	T50	T90	ETOH	RVP	ARO	T902	T59	T5E	T9E	T9A	ER	EA	RA				
7	25.9725	T50	T90	ETOH	RVP	ARO	T902	T59	T5E	T9E	ER	EA						
8	26.2099	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5A	T9E	T9A	ER	EA	RA			
9	26.3059	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T9E	ER	EA						
10	26.3776	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T9E	ER	EA	RA					
11	26.4627	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5E	T9E	T9A	ER	EA				
12	26.6400	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	T9A	ER	EA	RA			
13	26.7321	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T59	T9E	ER	EA					
14	26.7661	T50	T90	ETOH	RVP	ARO	T902	T59	T5E	T9E	ER	EA	RA					
15	26.8504	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5A	T9E	T9A	ER	EA				
16	26.8971	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5E	T9E	T9A	ER	EA	RA			
17	26.9256	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T9E	T9R	T9A	ER	EA				
18	26.9628	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T9E	T9R	T9A	ER	EA	RA			
19	27.1382	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T59	T5A	T9E	ER	EA	RA				
20	27.1461	T50	T90	ETOH	RVP	ARO	T902	T59	T9E	T9A	ER	EA						
21	27.2264	T50	T90	ETOH	RVP	ARO	T902	T59	T5A	T9E	T9A	ER	EA	RA				
22	27.3049	T50	T90	ETOH	RVP	ARO	T902	T59	T5E	T5A	T9E	T9A	ER	EA				
23	27.3364	T50	T90	ETOH	RVP	ARO	T902	T59	T5E	T9E	T9R	T9A	ER	EA				
24	27.3364	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T5E	T9E	T9A	ER	EA				
25	27.3377	T50	T90	ETOH	RVP	ARO	T902	T59	T5E	T5A	T9E	T9A	ER	EA	RA			

NMHC: Zeros Deleted

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	21.9559	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5A	T9A	ER	EA						
2	22.1020	T50	T90	ETOH	RVP	ARO	T502	T5E	T5A	T9A	ER	EA						
3	22.3290	T50	T90	ETOH	RVP	ARO	T502	T5A	T9A	ER	EA							
4	22.7652	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9A	ER	EA					
5	22.8738	T50	T90	ETOH	RVP	ARO	T502	T5E	T5A	T9R	T9A	ER	EA					
6	22.9228	T50	T90	ETOH	RVP	ARO	T502	T5A	T9R	T9A	ER	EA						
7	22.9681	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5A	T9R	T9A	ER	EA					
8	23.0711	T50	T90	ETOH	RVP	ARO	T502	T59	T5E	T5A	T9A	ER	EA					
9	23.1727	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9A	ER	EA						
10	23.3769	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9A	EA							
11	23.5078	T50	T90	ETOH	RVP	ARO	T502	T5A	T9A	EA								
12	23.5280	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9A	EA						
13	23.5382	T50	T90	ETOH	RVP	ARO	T502	T59	T5E	T5A	T9A	EA						
14	23.5612	T50	T90	ETOH	RVP	ARO	T502	T5E	T5A	T9A	EA							
15	23.7601	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5A	ER	EA							
16	23.8151	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5A	T9A	EA							
17	23.8247	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5E	T5A	T9A	ER	EA					
18	23.8856	T50	T90	ETOH	RVP	ARO	T502	T5A	T9R	T9A	EA							
19	23.8980	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5A	T9A	ER	EA	RA					
20	23.9211	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5A	T9E	T9A	ER	EA					
21	23.9516	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	EA								
22	23.9556	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T5A	T9A	ER	EA					
23	24.0373	T50	T90	ETOH	RVP	ARO	T502	T5A	ER	EA								
24	24.0661	T50	T90	ETOH	RVP	ARO	T502	T5E	T5A	T9E	T9A	ER	EA					
25	24.0698	T50	T90	ETOH	RVP	ARO	T502	T5E	T5A	T9A	ER	EA	RA					

NMOG: Zeros Deleted

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	22.5079	T50	T90	ETOH	RVP	ARO	T502	T5E	T5A	T9A	ER	EA						
2	22.8665	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5A	T9A	ER	EA						
3	23.0350	T50	T90	ETOH	RVP	ARO	T502	T5E	T5A	T9R	T9A	ER	EA					
4	23.1281	T50	T90	ETOH	RVP	ARO	T502	T59	T5E	T5A	T9A	ER	EA					
5	23.2341	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9A	ER	EA					
6	23.7124	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5A	T9R	T9A	ER	EA					
7	24.3019	T50	T90	ETOH	RVP	ARO	T502	T5E	T5A	T9E	T9A	ER	EA					
8	24.3170	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5E	T5A	T9A	ER	EA					
9	24.3300	T50	T90	ETOH	RVP	ARO	T502	T59	T5E	T5A	T9R	T9A	ER	EA				
10	24.4346	T50	T90	ETOH	RVP	ARO	T502	T59	T5E	T5A	T9A	EA						
11	24.4974	T50	T90	ETOH	RVP	ARO	T502	T5E	T5A	T9A	ER	EA	RA					
12	24.5013	T50	T90	ETOH	RVP	ARO	T502	T902	T5E	T5A	T9A	ER	EA					
13	24.6395	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	ER	EA						
14	24.6649	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5A	T9E	T9A	ER	EA					
15	24.6710	T50	T90	ETOH	RVP	ARO	T502	T5E	T5A	T9E	T9R	T9A	ER	EA				
16	24.7058	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5A	ER	EA							
17	24.7162	T50	T90	ETOH	RVP	ARO	T502	T5E	T5A	ER	EA							
18	24.7315	T50	T90	ETOH	RVP	ARO	T502	T5A	T9A	ER	EA							
19	24.7339	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9R	T9A	ER	EA				
20	24.7812	T50	T90	ETOH	RVP	ARO	T502	T902	T5E	T5A	T9R	T9A	ER	EA				
21	24.8409	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5E	T5A	T9A	ER	EA				
22	24.8487	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5A	T9A	ER	EA	RA					
23	24.8543	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T902	T5A	T9A	ER	EA					
24	24.9003	T50	T90	ETOH	RVP	ARO	T502	T59	T5E	T5A	ER	EA						
25	24.9456	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9A	EA						

PM: Zeros Deleted

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	17.5056	T50	T90	ETOH	ARO	T59	T9E	T9A	EA									
2	18.8699	T50	T90	ETOH	ARO	T502	T59	T9E	T9A	EA								
3	19.1181	T50	T90	ETOH	RVP	ARO	T59	T9E	T9A	EA								
4	19.2033	T50	T90	ETOH	ARO	T59	T5A	T9E	T9A	EA								
5	19.2736	T50	T90	ETOH	ARO	T59	T5E	T9E	T9A	EA								
6	19.3382	T50	T90	ETOH	ARO	EtOH2	T59	T9E	T9A	EA								
7	19.3714	T50	T90	ETOH	ARO	T902	T59	T9E	T9A	EA								
8	20.1544	T50	T90	ETOH	ARO	EtOH2	T59	T5E	T9E	T9A	EA							
9	20.1832	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9A	EA							
10	20.2219	T50	T90	ETOH	ARO	T59	T9A	EA										
11	20.2442	T50	T90	ETOH	RVP	ARO	T59	T9E	T9A	EA	RA							
12	20.3697	T50	T90	ETOH	RVP	ARO	T59	T9E	T9R	T9A	EA							
13	20.4889	T50	T90	ETOH	ARO	T502	T59	T5A	T9E	T9A	EA							
14	20.7677	T50	T90	ETOH	ARO	T502	EtOH2	T59	T9E	T9A	EA							
15	20.8221	T50	T90	ETOH	RVP	ARO	T59	T5E	T9E	T9A	EA							
16	20.8462	T50	T90	ETOH	ARO	T502	T59	T5E	T9E	T9A	EA							
17	20.8488	T50	T90	ETOH	ARO	T502	T902	T59	T9E	T9A	EA							
18	20.8863	T50	T90	ETOH	ARO	T59	T9E	EA										
19	20.9035	T50	T90	ETOH	RVP	ARO	EtOH2	T59	T9E	T9A	EA							
20	20.9233	T50	T90	ETOH	ARO	T59	T9E	T9A										
21	20.9572	T50	T90	ETOH	RVP	ARO	T502	T59	T9E	T9R	T9A	EA						
22	20.9817	T50	T90	ETOH	ARO	EtOH2	T59	T5A	T9E	T9A	EA							
23	21.0162	T50	T90	ETOH	ARO	T59	T5E	T5A	T9E	T9A	EA							
24	21.0254	T50	T90	ETOH	RVP	ARO	T59	T5A	T9E	T9A	EA							
25	21.0257	T50	T90	ETOH	RVP	ARO	T902	T59	T9E	T9A	EA							

THC

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	22.9157	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9A	ER	EA						
2	23.2944	T50	T90	ETOH	RVP	ARO	T502	T5A	T9E	T9R	T9A	ER	EA					
3	23.6089	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	ER	EA							
4	23.6850	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	EA								
5	23.7357	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9A	EA							
6	23.8603	T50	T90	ETOH	RVP	ARO	T502	T5A	T9E	T9A	ER	EA						
7	23.8918	T50	T90	ETOH	RVP	ARO	T502	T5A	T9E	T9R	ER	EA						
8	23.9209	T50	T90	ETOH	RVP	ARO	T502	T5A	T9E	ER	EA							
9	23.9254	T50	T90	ETOH	RVP	ARO	T502	T5A	T9R	T9A	ER	EA						
10	23.9300	T50	T90	ETOH	RVP	ARO	T502	T5A	T9A	ER	EA							
11	23.9370	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	T9A	ER	EA					
12	23.9587	T50	T90	ETOH	RVP	ARO	T502	T5A	T9E	T9R	EA							
13	24.0551	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9R	T9A	ER	EA					
14	24.1535	T50	T90	ETOH	RVP	ARO	T502	T5A	T9E	T9R	T9A	EA						
15	24.3964	T50	T90	ETOH	RVP	ARO	T502	T5A	T9E	EA								
16	24.5585	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9E	T9A	ER	EA					
17	24.5921	T50	T90	ETOH	RVP	ARO	EtOH2	T9A	ER	RA								
18	24.6349	T50	T90	ETOH	RVP	ARO	T502	T59	T5E	T5A	T9A	ER	EA					
19	24.6658	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9E	EA							
20	24.6894	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T59	T5A	ER	EA						
21	24.6978	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T5A	T9E	T9R	T9A	ER	EA				
22	24.7551	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9E	ER	EA						
23	24.8489	T50	T90	ETOH	RVP	ARO	T502	T59	T5A	T9A	ER	EA	RA					
24	24.8495	T50	T90	ETOH	RVP	ARO	T502	T9E	T9R	EA								
25	24.8613	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T5A	T9A	ER	EA					

X. Bag 3 Reduced Hierarchical Model Fit Terms

CH_4

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	16.4670	T50	T90	ETOH	ARO	EA												
2	16.6309	T50	T90	ETOH	RVP	ARO	EA											
3	16.7138	T50	T90	ETOH	RVP	ARO	T5A	RA										
4	16.8887	T50	T90	ETOH	RVP	ARO	T5A	T9R	RA									
5	17.0677	T50	T90	ETOH	RVP	ARO	T9R	EA										
6	17.3938	T50	T90	ETOH	ARO	EtOH2	EA											
7	17.5859	T50	T90	ETOH	RVP	ARO	T9R	EA	RA									
8	17.5964	T50	T90	ETOH	RVP	ARO	EA	RA										
9	17.7166	T50	T90	ETOH	RVP	ARO	ER	EA										
10	17.7376	T50	T90	ETOH	RVP	ARO	T5E	EA										
11	17.7468	T50	T90	ETOH	RVP	ARO	EtOH2	EA										
12	17.8306	T50	T90	ETOH	ARO	T5E	EA											
13	17.9423	T50	T90	ETOH	RVP	ARO	T9R	RA										
14	18.0882	T50	T90	ETOH	RVP	ARO	T502	T5A	T9R	RA								
15	18.1076	T50	T90	ETOH	ARO	T9A	EA											
16	18.1319	T50	T90	ETOH	RVP	ARO	T9R	ER	EA									
17	18.1321	T50	T90	ETOH	ARO	T9E	EA											
18	18.1384	T50	T90	ETOH	RVP	ARO	T902	T9R										
19	18.1428	T50	T90	ETOH	ARO	T902	EA											
20	18.1565	T50	T90	ETOH	RVP	ARO	T9R	ER	EA	RA								
21	18.1767	T50	T90	ETOH	RVP	ARO	T9R	ER	RA									
22	18.1816	T50	T90	ETOH	RVP	ARO	T5A	ER	RA									
23	18.1861	T50	T90	ETOH	RVP	ARO	T5A	T9R	ER	RA								
24	18.2492	T50	T90	ETOH	RVP	ARO	T59	T9R	EA									
25	18.2852	T50	T90	ETOH	RVP	ARO	ER	EA	RA									

CO_2

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	16.4670	T50	T90	ETOH	ARO	EA												
2	16.6309	T50	T90	ETOH	RVP	ARO	EA											
3	16.7138	T50	T90	ETOH	RVP	ARO	T5A	RA										
4	16.8887	T50	T90	ETOH	RVP	ARO	T5A	T9R	RA									
5	17.0677	T50	T90	ETOH	RVP	ARO	T9R	EA										
6	17.3938	T50	T90	ETOH	ARO	EtOH2	EA											
7	17.5859	T50	T90	ETOH	RVP	ARO	T9R	EA	RA									
8	17.5964	T50	T90	ETOH	RVP	ARO	EA	RA										
9	17.7166	T50	T90	ETOH	RVP	ARO	ER	EA										
10	17.7376	T50	T90	ETOH	RVP	ARO	T5E	EA										
11	17.7468	T50	T90	ETOH	RVP	ARO	EtOH2	EA										
12	17.8306	T50	T90	ETOH	ARO	T5E	EA											
13	17.9423	T50	T90	ETOH	RVP	ARO	T9R	RA										
14	18.0882	T50	T90	ETOH	RVP	ARO	T502	T5A	T9R	RA								
15	18.1076	T50	T90	ETOH	ARO	T9A	EA											
16	18.1319	T50	T90	ETOH	RVP	ARO	T9R	ER	EA									
17	18.1321	T50	T90	ETOH	ARO	T9E	EA											
18	18.1384	T50	T90	ETOH	RVP	ARO	T902	T9R										
19	18.1428	T50	T90	ETOH	ARO	T902	EA											
20	18.1565	T50	T90	ETOH	RVP	ARO	T9R	ER	EA	RA								
21	18.1767	T50	T90	ETOH	RVP	ARO	T9R	ER	RA									
22	18.1816	T50	T90	ETOH	RVP	ARO	T5A	ER	RA									
23	18.1861	T50	T90	ETOH	RVP	ARO	T5A	T9R	ER	RA								
24	18.2492	T50	T90	ETOH	RVP	ARO	T59	T9R	EA									
25	18.2852	T50	T90	ETOH	RVP	ARO	ER	EA	RA									

CO

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	16.4670	T50	T90	ETOH	ARO	EA												
2	16.6309	T50	T90	ETOH	RVP	ARO	EA											
3	16.7138	T50	T90	ETOH	RVP	ARO	T5A	RA										
4	16.8887	T50	T90	ETOH	RVP	ARO	T5A	T9R	RA									
5	17.0677	T50	T90	ETOH	RVP	ARO	T9R	EA										
6	17.3938	T50	T90	ETOH	ARO	EtOH2	EA											
7	17.5859	T50	T90	ETOH	RVP	ARO	T9R	EA	RA									
8	17.5964	T50	T90	ETOH	RVP	ARO	EA	RA										
9	17.7166	T50	T90	ETOH	RVP	ARO	ER	EA										
10	17.7376	T50	T90	ETOH	RVP	ARO	T5E	EA										
11	17.7468	T50	T90	ETOH	RVP	ARO	EtOH2	EA										
12	17.8306	T50	T90	ETOH	ARO	T5E	EA											
13	17.9423	T50	T90	ETOH	RVP	ARO	T9R	RA										
14	18.0882	T50	T90	ETOH	RVP	ARO	T502	T5A	T9R	RA								
15	18.1076	T50	T90	ETOH	ARO	T9A	EA											
16	18.1319	T50	T90	ETOH	RVP	ARO	T9R	ER	EA									
17	18.1321	T50	T90	ETOH	ARO	T9E	EA											
18	18.1384	T50	T90	ETOH	RVP	ARO	T902	T9R										
19	18.1428	T50	T90	ETOH	ARO	T902	EA											
20	18.1565	T50	T90	ETOH	RVP	ARO	T9R	ER	EA	RA								
21	18.1767	T50	T90	ETOH	RVP	ARO	T9R	ER	RA									
22	18.1816	T50	T90	ETOH	RVP	ARO	T5A	ER	RA									
23	18.1861	T50	T90	ETOH	RVP	ARO	T5A	T9R	ER	RA								
24	18.2492	T50	T90	ETOH	RVP	ARO	T59	T9R	EA									
25	18.2852	T50	T90	ETOH	RVP	ARO	ER	EA	RA									

FE

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	16.4670	T50	T90	ETOH	ARO	EA												
2	16.6309	T50	T90	ETOH	RVP	ARO	EA											
3	16.7138	T50	T90	ETOH	RVP	ARO	T5A	RA										
4	16.8887	T50	T90	ETOH	RVP	ARO	T5A	T9R	RA									
5	17.0677	T50	T90	ETOH	RVP	ARO	T9R	EA										
6	17.3938	T50	T90	ETOH	ARO	EtOH2	EA											
7	17.5859	T50	T90	ETOH	RVP	ARO	T9R	EA	RA									
8	17.5964	T50	T90	ETOH	RVP	ARO	EA	RA										
9	17.7166	T50	T90	ETOH	RVP	ARO	ER	EA										
10	17.7376	T50	T90	ETOH	RVP	ARO	T5E	EA										
11	17.7468	T50	T90	ETOH	RVP	ARO	EtOH2	EA										
12	17.8306	T50	T90	ETOH	ARO	T5E	EA											
13	17.9423	T50	T90	ETOH	RVP	ARO	T9R	RA										
14	18.0882	T50	T90	ETOH	RVP	ARO	T502	T5A	T9R	RA								
15	18.1076	T50	T90	ETOH	ARO	T9A	EA											
16	18.1319	T50	T90	ETOH	RVP	ARO	T9R	ER	EA									
17	18.1321	T50	T90	ETOH	ARO	T9E	EA											
18	18.1384	T50	T90	ETOH	RVP	ARO	T902	T9R										
19	18.1428	T50	T90	ETOH	ARO	T902	EA											
20	18.1565	T50	T90	ETOH	RVP	ARO	T9R	ER	EA	RA								
21	18.1767	T50	T90	ETOH	RVP	ARO	T9R	ER	RA									
22	18.1816	T50	T90	ETOH	RVP	ARO	T5A	ER	RA									
23	18.1861	T50	T90	ETOH	RVP	ARO	T5A	T9R	ER	RA								
24	18.2492	T50	T90	ETOH	RVP	ARO	T59	T9R	EA									
25	18.2852	T50	T90	ETOH	RVP	ARO	ER	EA	RA									

NO_x: Zeros Deleted

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	18.4442	T50	T90	ETOH	RVP	ARO	T5A											
2	18.6377	T50	T90	ETOH	RVP	ARO	T5A	T9A										
3	18.6694	T90	ETOH	RVP	ARO	EA												
4	18.8605	T50	T90	ETOH	RVP	ARO	T5E	T5A										
5	19.0192	ETOH	RVP	ARO	EA													
6	19.2799	T50	T90	ETOH	RVP	ARO	EtOH2	T5A										
7	19.2862	T50	T90	ETOH	RVP	ARO	T5A	T9E										
8	19.3238	T50	T90	ETOH	RVP	ARO	T5E	T5A	T9A									
9	19.3277	T50	T90	ETOH	RVP	ARO	T5A	RA										
10	19.3377	T50	T90	ETOH	RVP	ARO	T502	T5E	T5A									
11	19.4545	T50	T90	ETOH	RVP	ARO	EtOH2	T5A	T9A									
12	19.4752	T50	T90	ETOH	RVP	ARO	T5A	T9A	RA									
13	19.5250	T90	ETOH	RVP	ARO	T9A	EA											
14	19.5438	T90	ETOH	RVP	ARO													

PM: Zeros Deleted

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	17.9004	T90	ETOH	ARO	T902	T9A	EA											
2	18.9160	T50	T90	ETOH	ARO	T902	T9A	EA										

NMHC: Zeros Deleted

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	16.4747	T50	T90	ETOH	RVP	ARO	T502	T9R										
2	17.1075	T50	T90	ETOH	RVP	ARO	T5E	T9R										
3	17.1122	T50	T90	ETOH	RVP	ARO	T502	T9E	T9R									
4	17.1780	T50	T90	ETOH	RVP	ARO	T502	T59	T9R									
5	17.2314	T50	T90	ETOH	RVP	ARO	T502	T5E	T9R									
6	17.4329	T50	T90	ETOH	RVP	ARO	EtOH2	T5E	T9R									
7	17.4869	T50	T90	ETOH	RVP	ARO	T502	T902	T9R									
8	17.6616	T50	T90	ETOH	RVP	ARO	T5E	T9E	T9R									
9	17.7916	T50	T90	ETOH	RVP	ARO	T502	T5E	T9E	T9R								
10	17.8919	T50	T90	ETOH	RVP	ARO	T902	T5E	T9R									
11	17.9280	T50	T90	ETOH	RVP	ARO	T502	T59	T5E	T9R								
12	18.0122	T50	T90	ETOH	RVP	ARO	EtOH2	T5E	T9E	T9R								
13	18.0729	T50	T90	ETOH	RVP	ARO	T502	EtOH2	T9R									
14	18.0871	T50	T90	ETOH	RVP	ARO	T59	T5E	T9R									
15	18.0908	T50	T90	ETOH	RVP	ARO	T902	T9R										
16	18.1693	T50	T90	ETOH	RVP	ARO	T502	T9R	T9A									
17	18.3060	T50	T90	ETOH	RVP	ARO	T502	T902	T59	T9R								
18	18.3264	T50	T90	ETOH	RVP	ARO	T502	T9R	ER									
19	18.4050	T50	T90	ETOH	ARO	T902	T5A											
20	18.4259	T50	T90	ETOH	RVP	ARO	T502	T9R	RA									
21	18.4538	T50	T90	ETOH	RVP	ARO	EtOH2	T902	T5E	T9R								
22	18.4581	T50	T90	ETOH	RVP	ARO	T502	T9R	EA									
23	18.4731	T50	T90	ETOH	RVP	ARO	T502	T5A	T9R									
24	18.4889	T50	T90	ETOH	RVP	ARO	T502	T902	T9E	T9R								
25	18.5660	T50	T90	ETOH	RVP	ARO	EtOH2	T59	T5E	T9R								

NMOG: Zeros Deleted

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	16.4670	T50	T90	ETOH	ARO	EA												
2	16.6309	T50	T90	ETOH	RVP	ARO	EA											
3	16.7138	T50	T90	ETOH	RVP	ARO	T5A	RA										
4	16.8887	T50	T90	ETOH	RVP	ARO	T5A	T9R	RA									
5	17.0677	T50	T90	ETOH	RVP	ARO	T9R	EA										
6	17.3938	T50	T90	ETOH	ARO	EtOH2	EA											
7	17.5859	T50	T90	ETOH	RVP	ARO	T9R	EA	RA									
8	17.5964	T50	T90	ETOH	RVP	ARO	EA	RA										
9	17.7166	T50	T90	ETOH	RVP	ARO	ER	EA										
10	17.7376	T50	T90	ETOH	RVP	ARO	T5E	EA										
11	17.7468	T50	T90	ETOH	RVP	ARO	EtOH2	EA										
12	17.8306	T50	T90	ETOH	ARO	T5E	EA											
13	17.9423	T50	T90	ETOH	RVP	ARO	T9R	RA										
14	18.0882	T50	T90	ETOH	RVP	ARO	T502	T5A	T9R	RA								
15	18.1076	T50	T90	ETOH	ARO	T9A	EA											
16	18.1319	T50	T90	ETOH	RVP	ARO	T9R	ER	EA									
17	18.1321	T50	T90	ETOH	ARO	T9E	EA											
18	18.1384	T50	T90	ETOH	RVP	ARO	T902	T9R										
19	18.1428	T50	T90	ETOH	ARO	T902	EA											
20	18.1565	T50	T90	ETOH	RVP	ARO	T9R	ER	EA	RA								
21	18.1767	T50	T90	ETOH	RVP	ARO	T9R	ER	RA									
22	18.1816	T50	T90	ETOH	RVP	ARO	T5A	ER	RA									
23	18.1861	T50	T90	ETOH	RVP	ARO	T5A	T9R	ER	RA								
24	18.2492	T50	T90	ETOH	RVP	ARO	T59	T9R	EA									
25	18.2852	T50	T90	ETOH	RVP	ARO	ER	EA	RA									

THC

Obs	Cp	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	16.4670	T50	T90	ETOH	ARO	EA												
2	16.6309	T50	T90	ETOH	RVP	ARO	EA											
3	16.7138	T50	T90	ETOH	RVP	ARO	T5A	RA										
4	16.8887	T50	T90	ETOH	RVP	ARO	T5A	T9R	RA									
5	17.0677	T50	T90	ETOH	RVP	ARO	T9R	EA										
6	17.3938	T50	T90	ETOH	ARO	EtOH2	EA											
7	17.5859	T50	T90	ETOH	RVP	ARO	T9R	EA	RA									
8	17.5964	T50	T90	ETOH	RVP	ARO	EA	RA										
9	17.7166	T50	T90	ETOH	RVP	ARO	ER	EA										
10	17.7376	T50	T90	ETOH	RVP	ARO	T5E	EA										
11	17.7468	T50	T90	ETOH	RVP	ARO	EtOH2	EA										
12	17.8306	T50	T90	ETOH	ARO	T5E	EA											
13	17.9423	T50	T90	ETOH	RVP	ARO	T9R	RA										
14	18.0882	T50	T90	ETOH	RVP	ARO	T502	T5A	T9R	RA								
15	18.1076	T50	T90	ETOH	ARO	T9A	EA											
16	18.1319	T50	T90	ETOH	RVP	ARO	T9R	ER	EA									
17	18.1321	T50	T90	ETOH	ARO	T9E	EA											
18	18.1384	T50	T90	ETOH	RVP	ARO	T902	T9R										
19	18.1428	T50	T90	ETOH	ARO	T902	EA											
20	18.1565	T50	T90	ETOH	RVP	ARO	T9R	ER	EA	RA								
21	18.1767	T50	T90	ETOH	RVP	ARO	T9R	ER	RA									
22	18.1816	T50	T90	ETOH	RVP	ARO	T5A	ER	RA									
23	18.1861	T50	T90	ETOH	RVP	ARO	T5A	T9R	ER	RA								
24	18.2492	T50	T90	ETOH	RVP	ARO	T59	T9R	EA									
25	18.2852	T50	T90	ETOH	RVP	ARO	ER	EA	RA									

XI. Benchmark and Reduced Model Fit Estimates of Mean Emissions for the Program Fuels

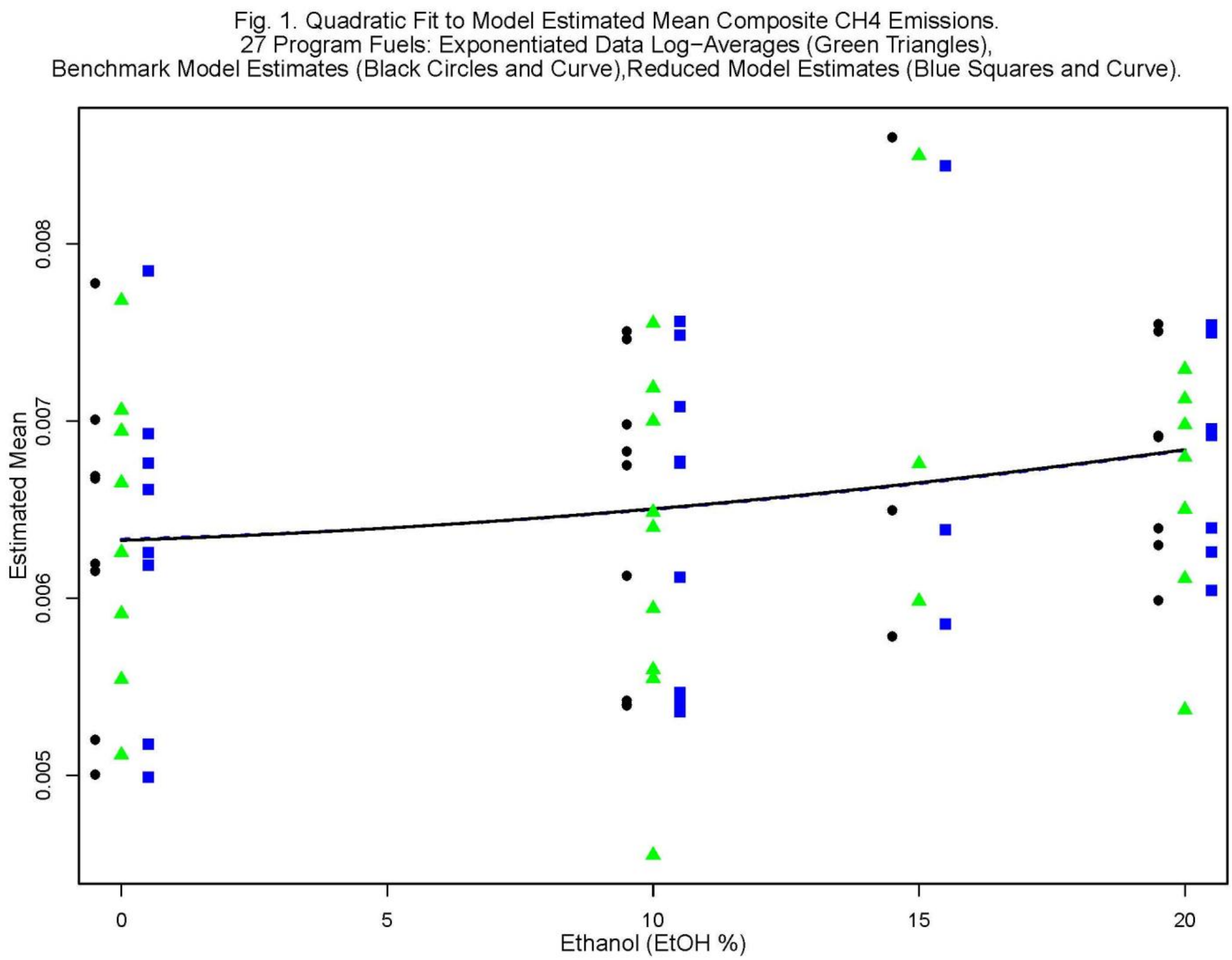


Fig. 2. Quadratic Fit to Model Estimated Mean Composite CO Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

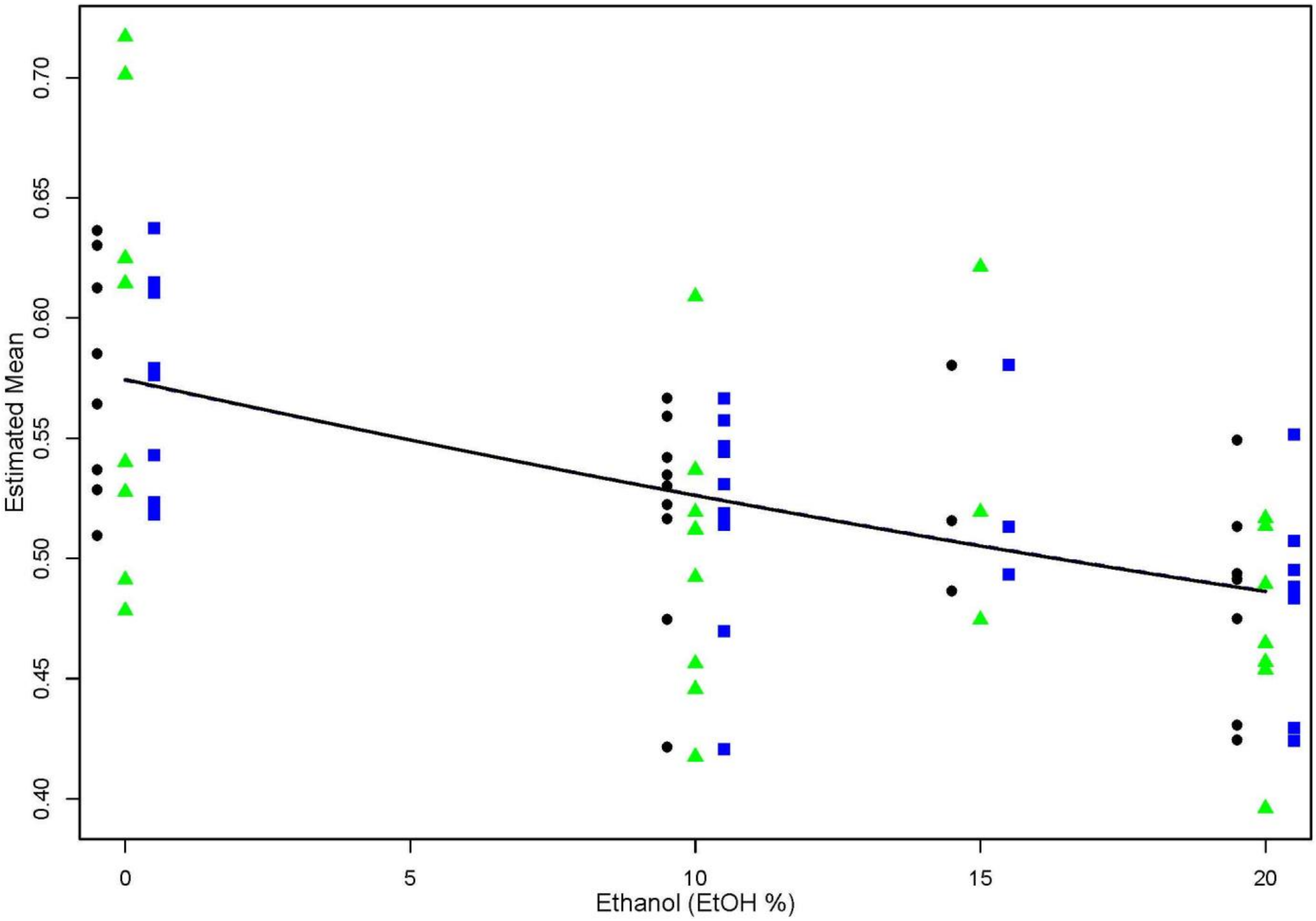


Fig. 3. Quadratic Fit to Model Estimated Mean Composite CO2 Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

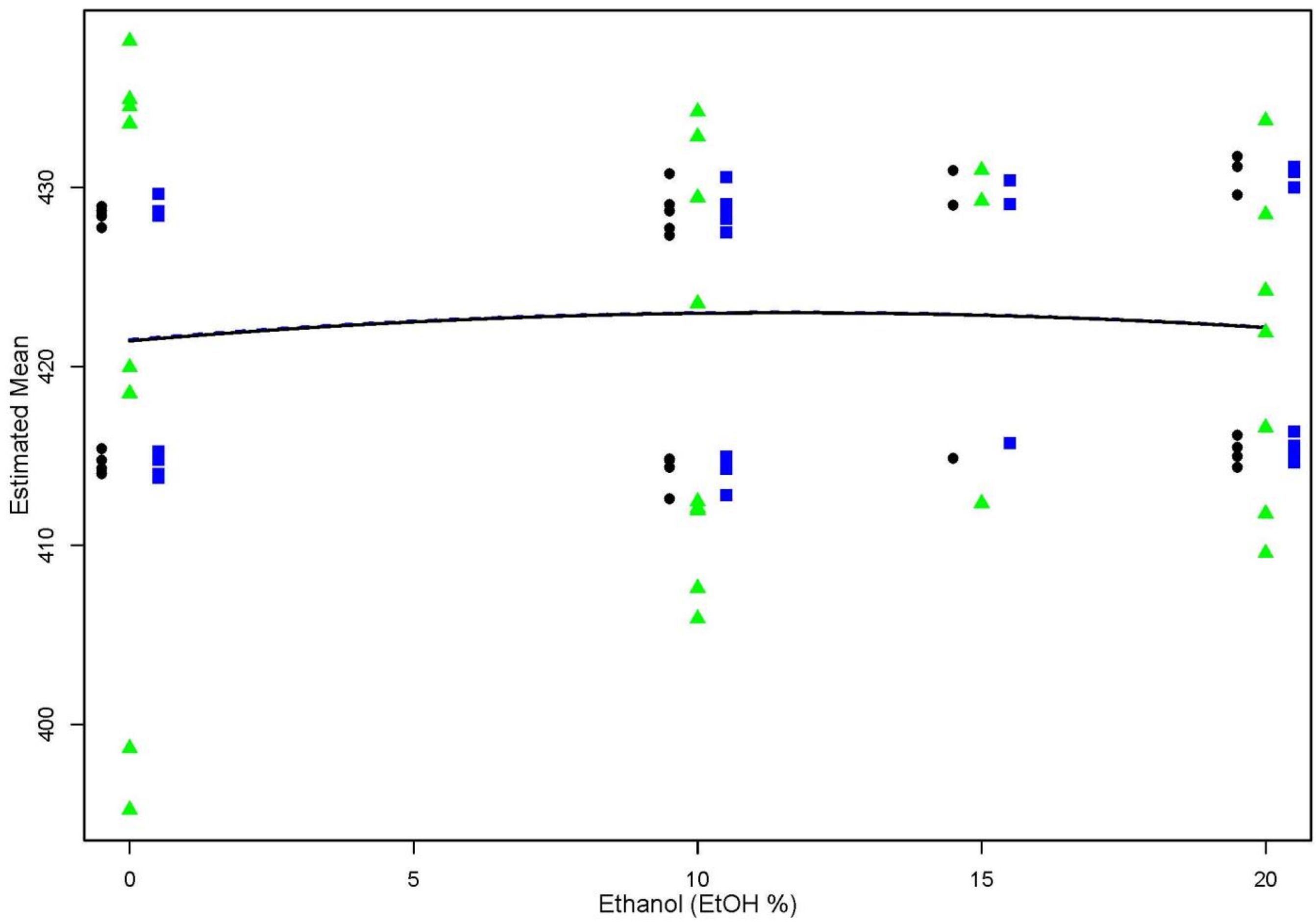


Fig. 4. Quadratic Fit to Model Estimated Mean Composite FE Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

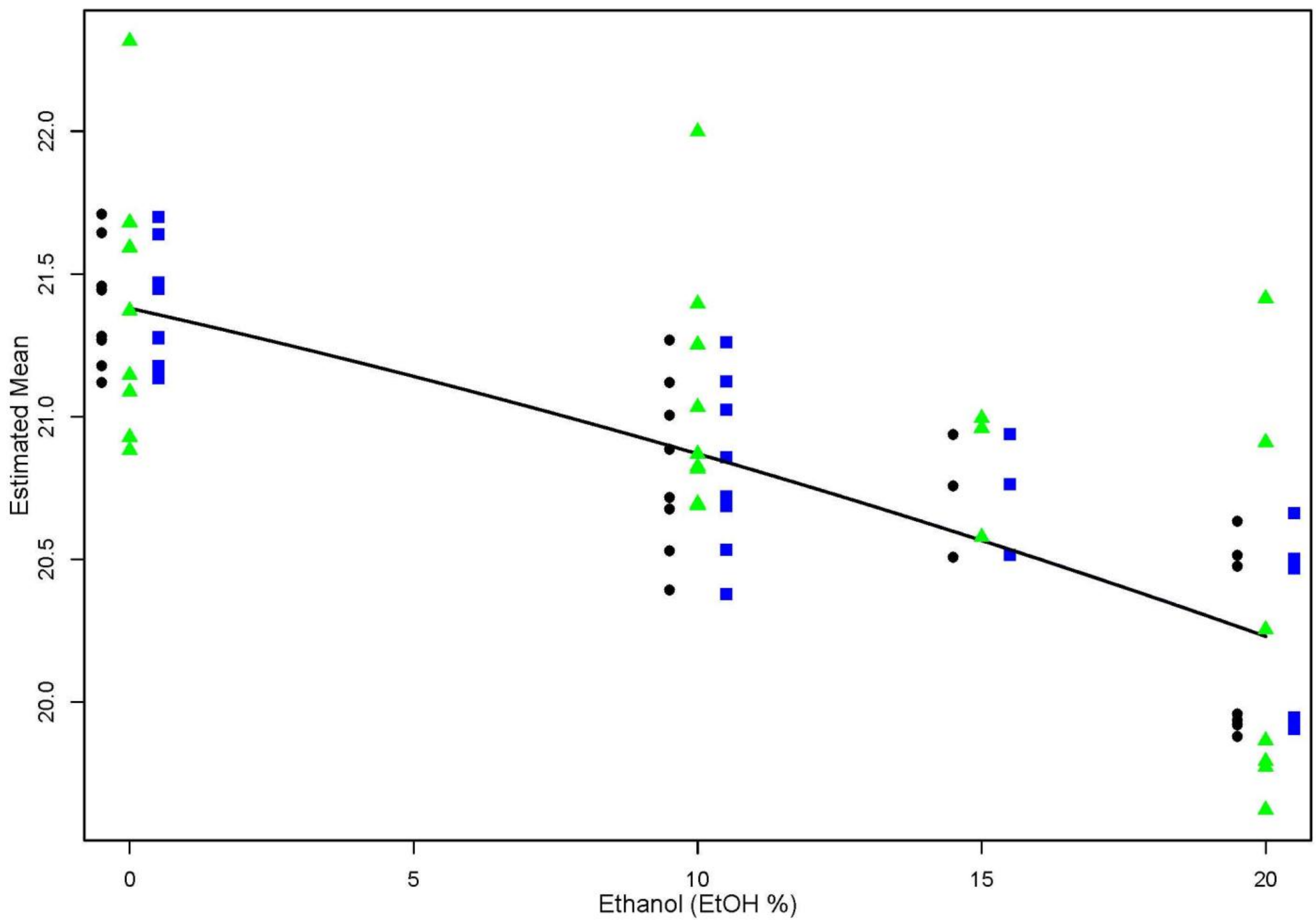


Fig. 5. Quadratic Fit to Model Estimated Mean Composite NOx Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

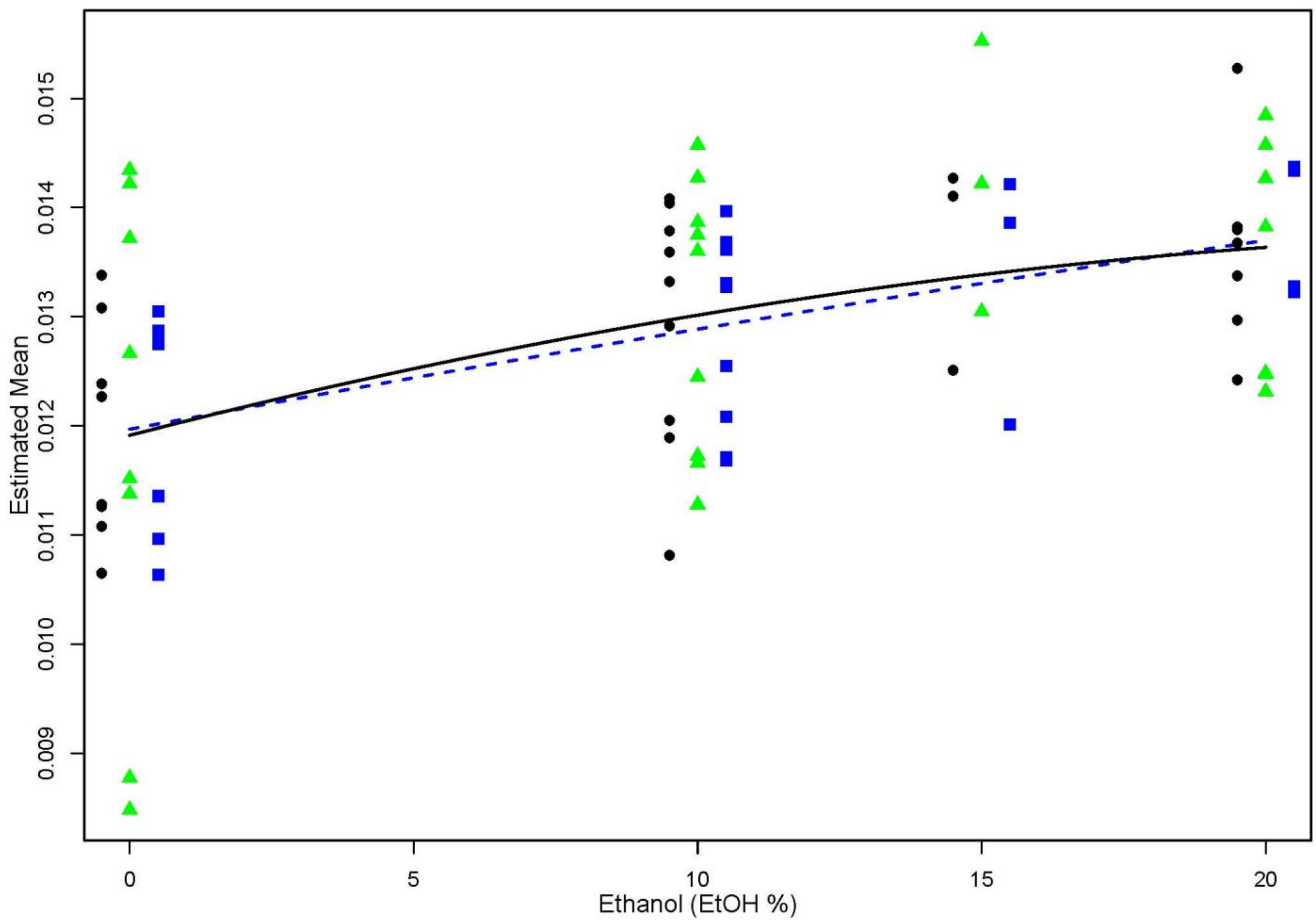


Fig. 6. Quadratic Fit to Model Estimated Mean Composite PM Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

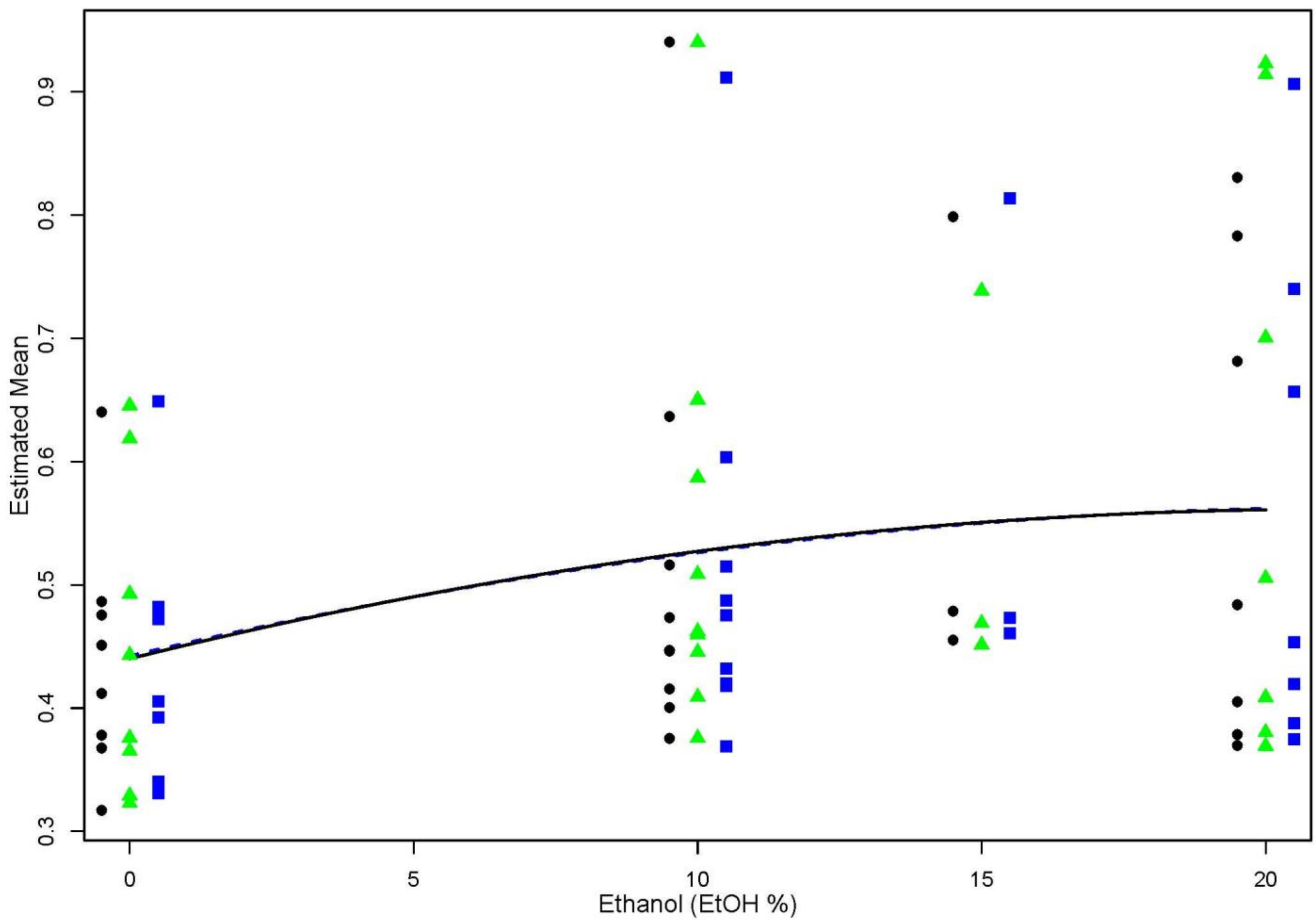


Fig. 7. Quadratic Fit to Model Estimated Mean Composite THC Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

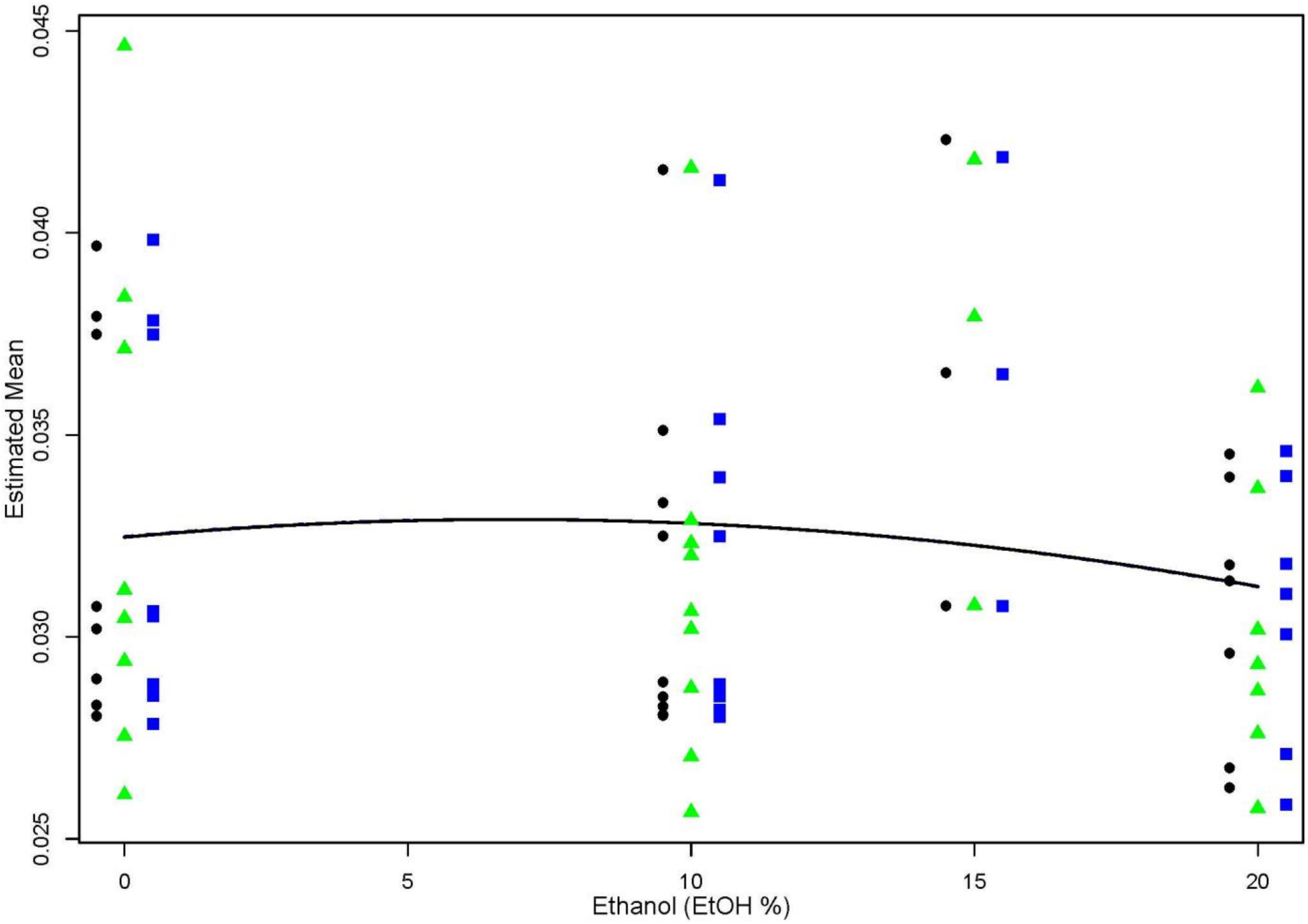


Fig. 8. Quadratic Fit to Model Estimated Mean Composite NMHC Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

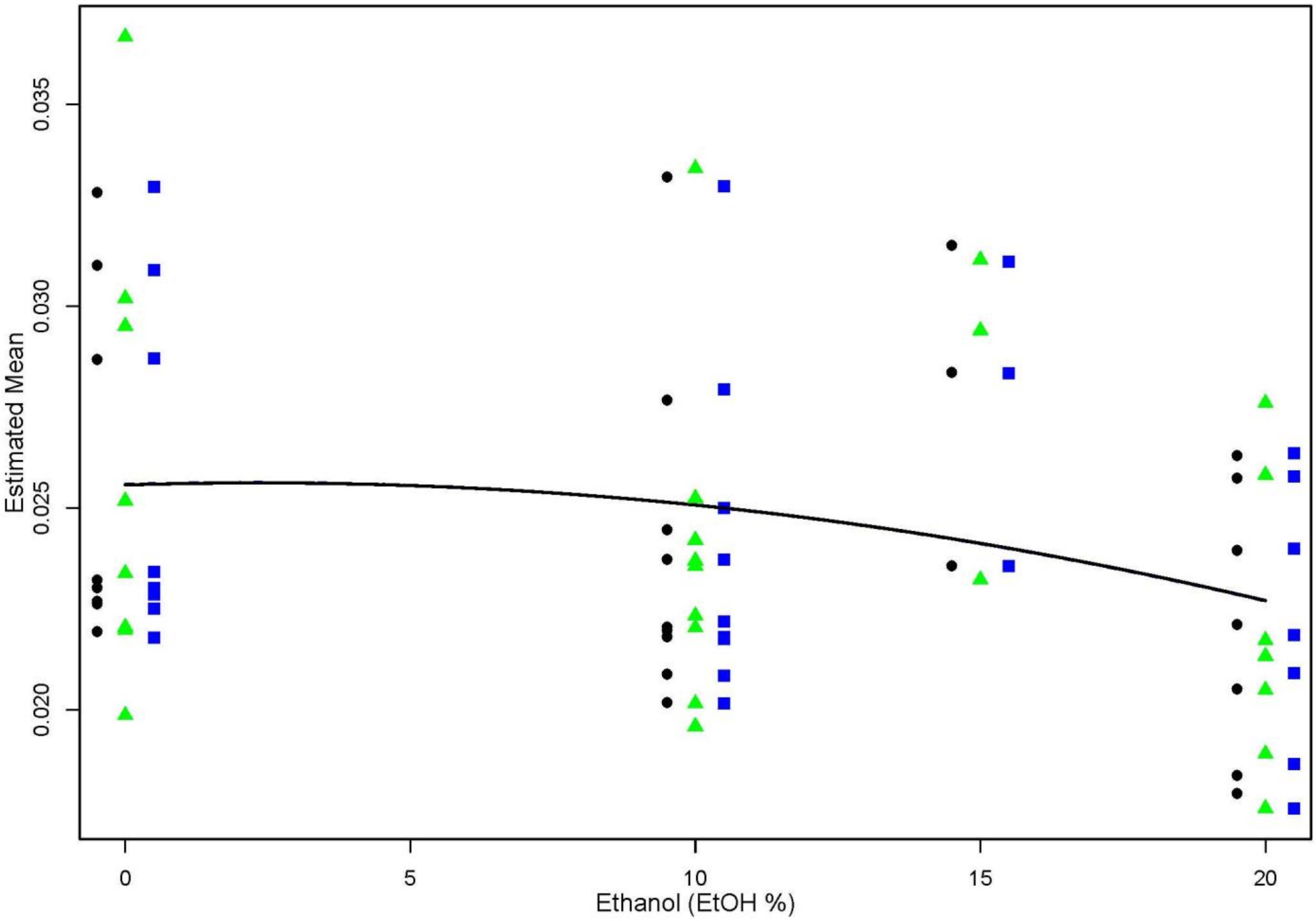
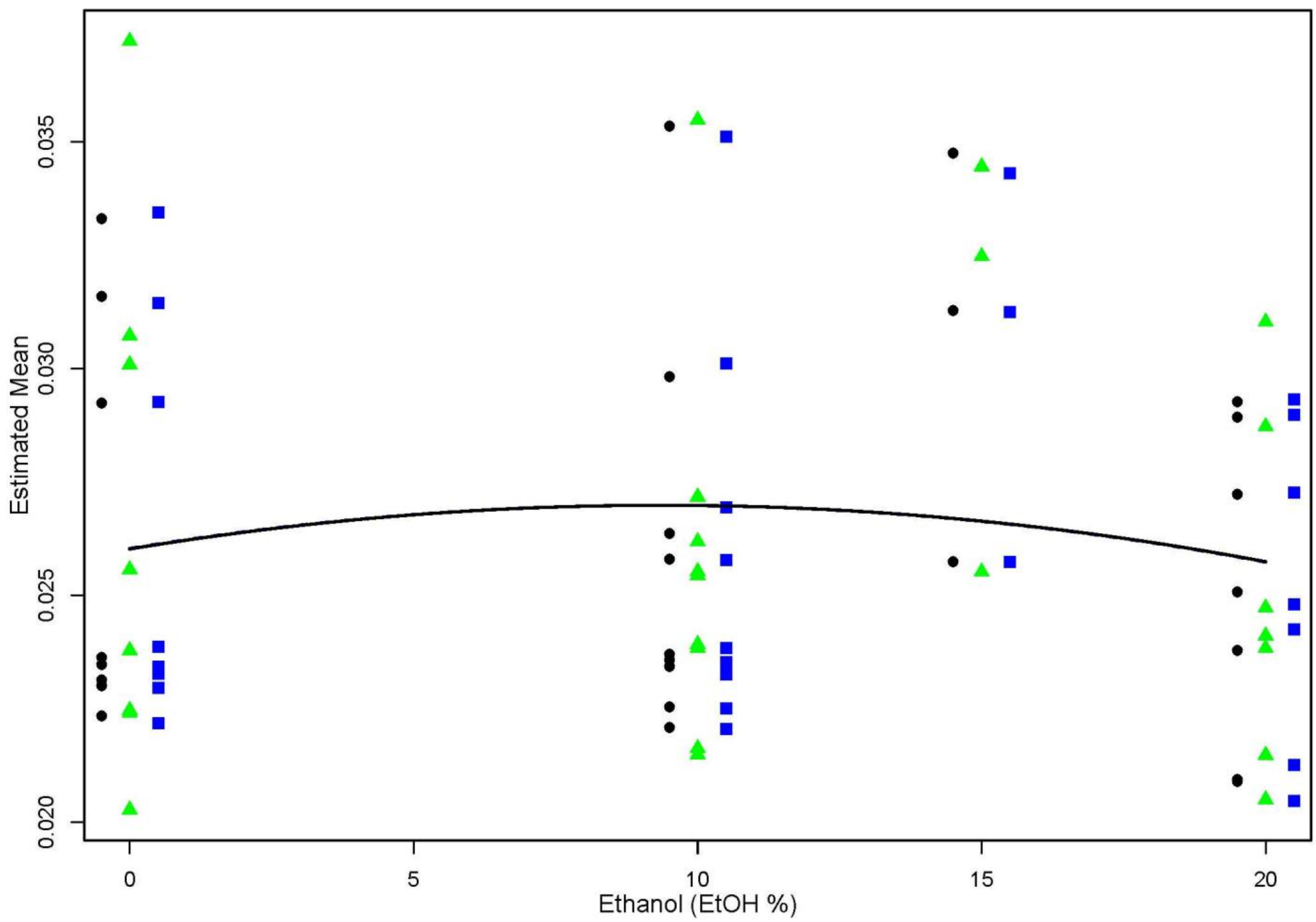


Fig. 9. Quadratic Fit to Model Estimated Mean Composite NMOG Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).



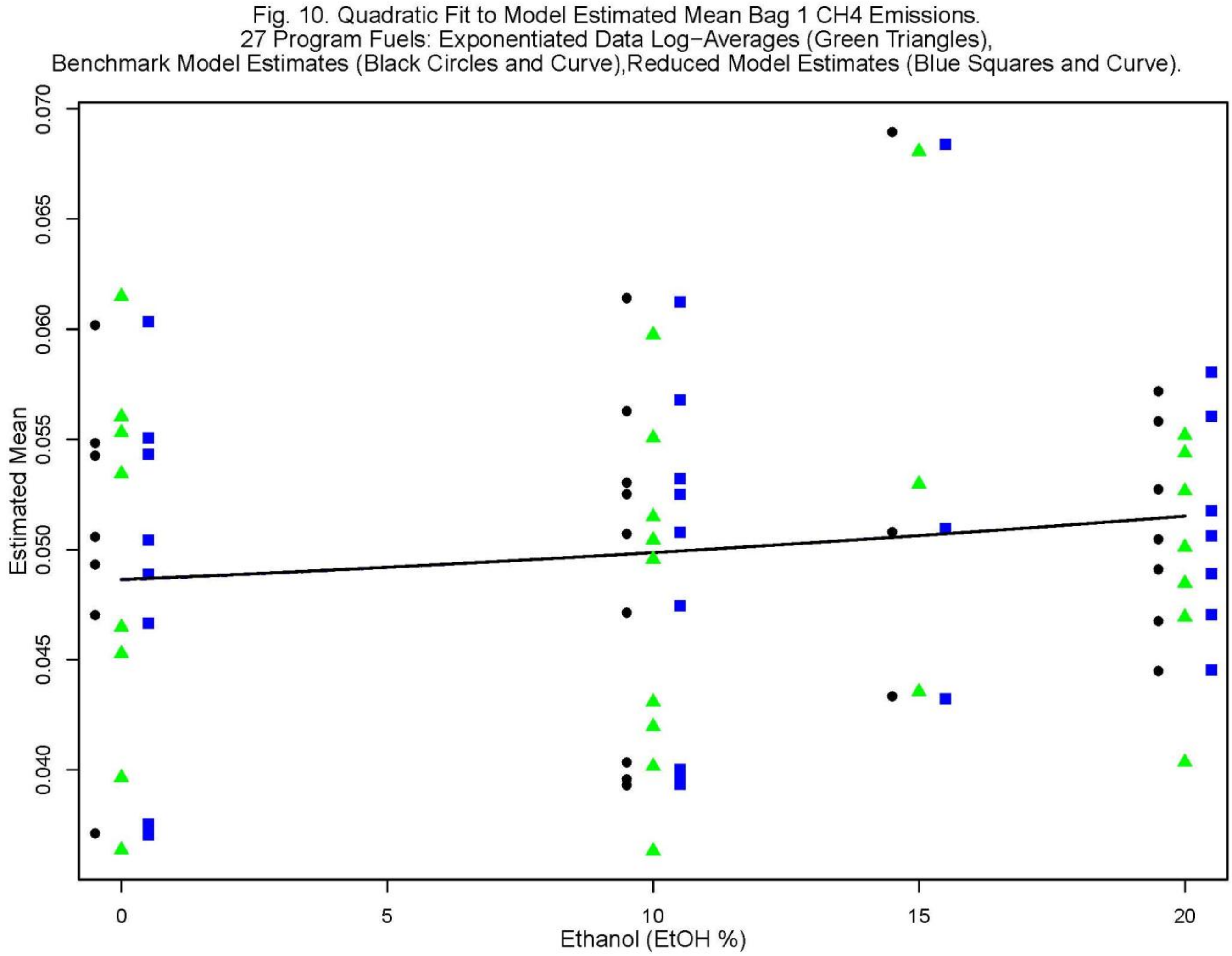


Fig. 10. Quadratic Fit to Model Estimated Mean Bag 1 CH4 Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).
Estimated Mean
0.040
0.045
0.050
0.055
0.060
0.065
0.070
0
5
10
15
20
Ethanol (EtOH %)

Fig. 11. Quadratic Fit to Model Estimated Mean Bag 1 CO Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

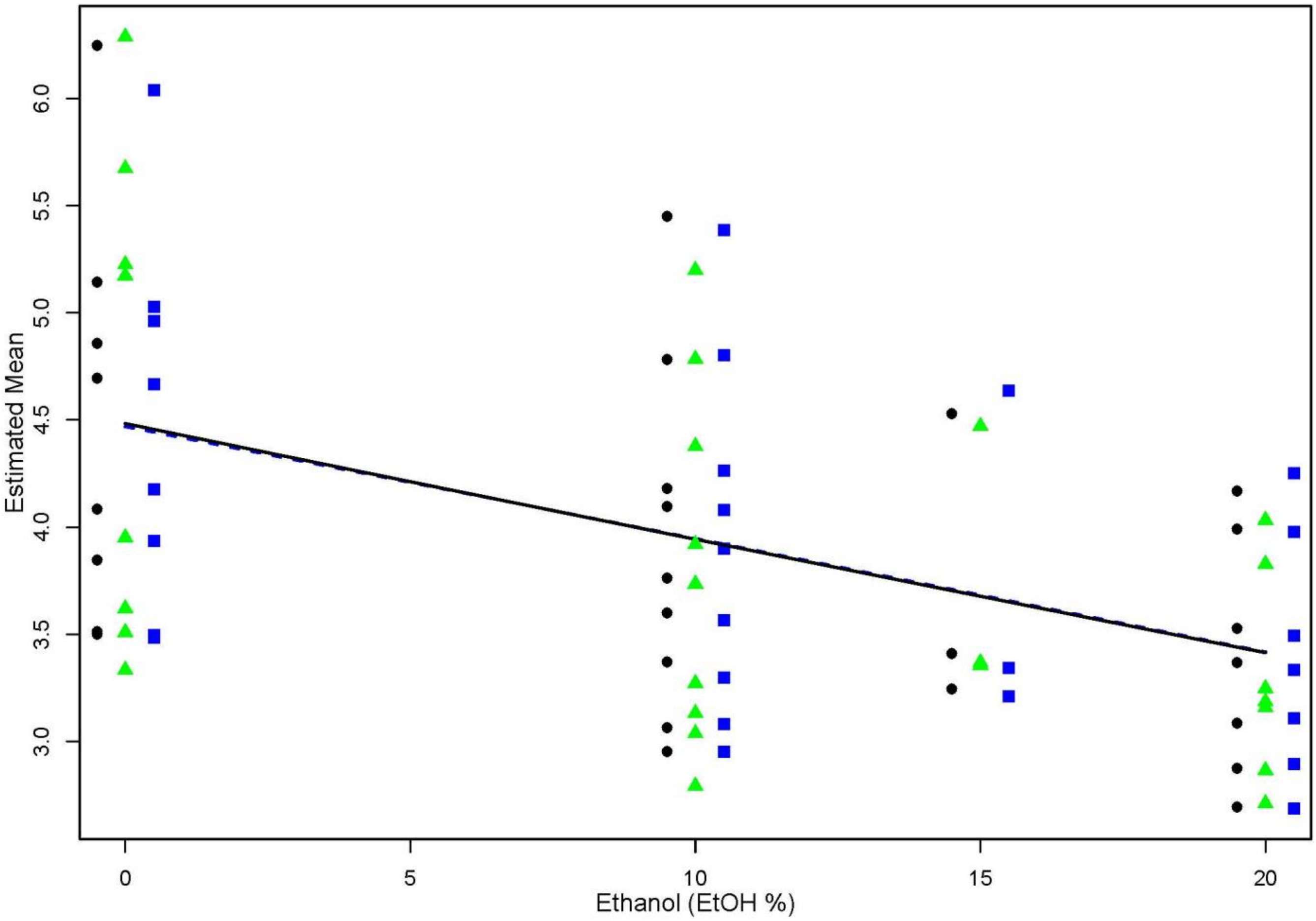


Fig. 12. Quadratic Fit to Model Estimated Mean Bag 1 CO2 Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

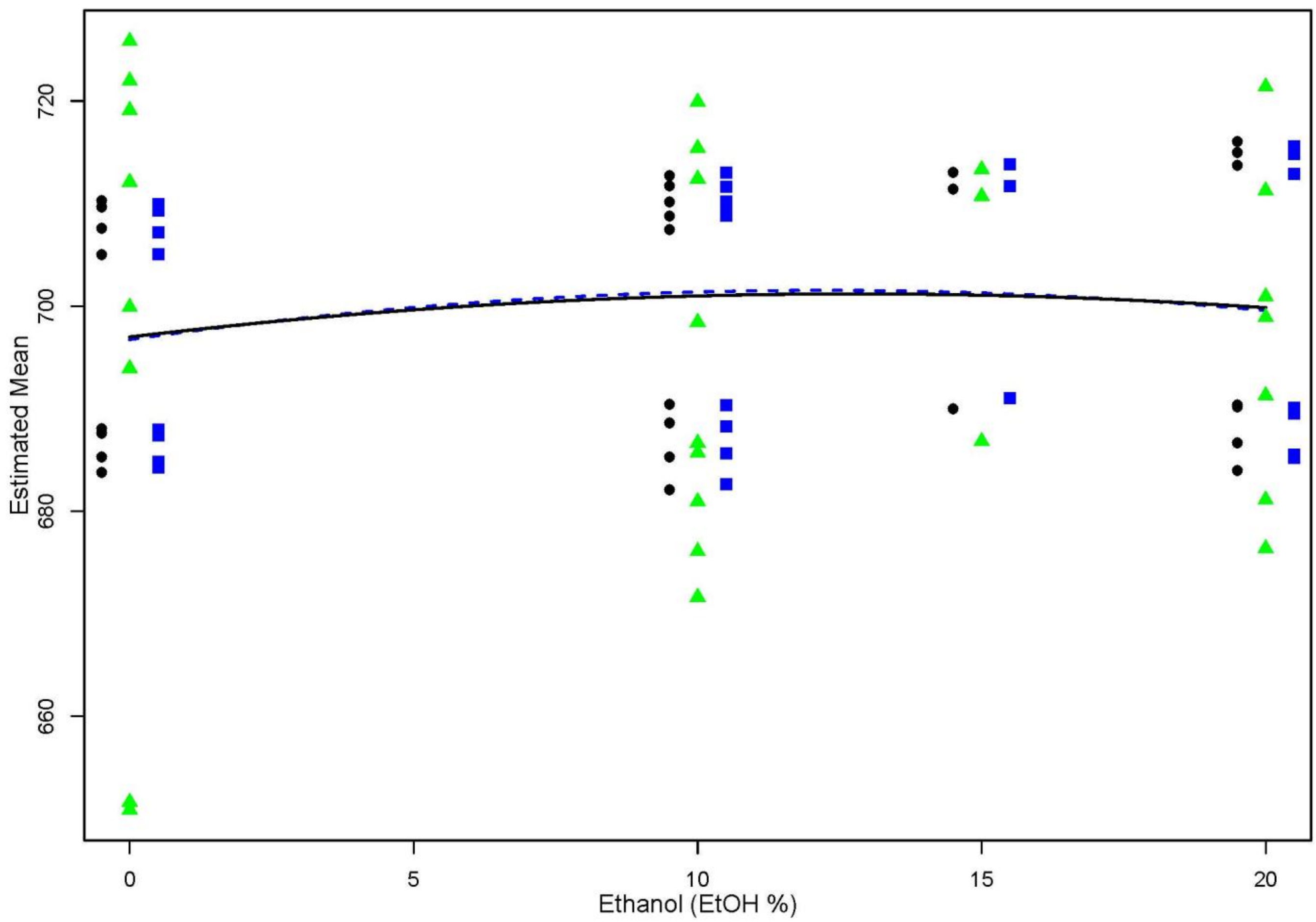


Fig. 13. Quadratic Fit to Model Estimated Mean Bag 1 FE Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

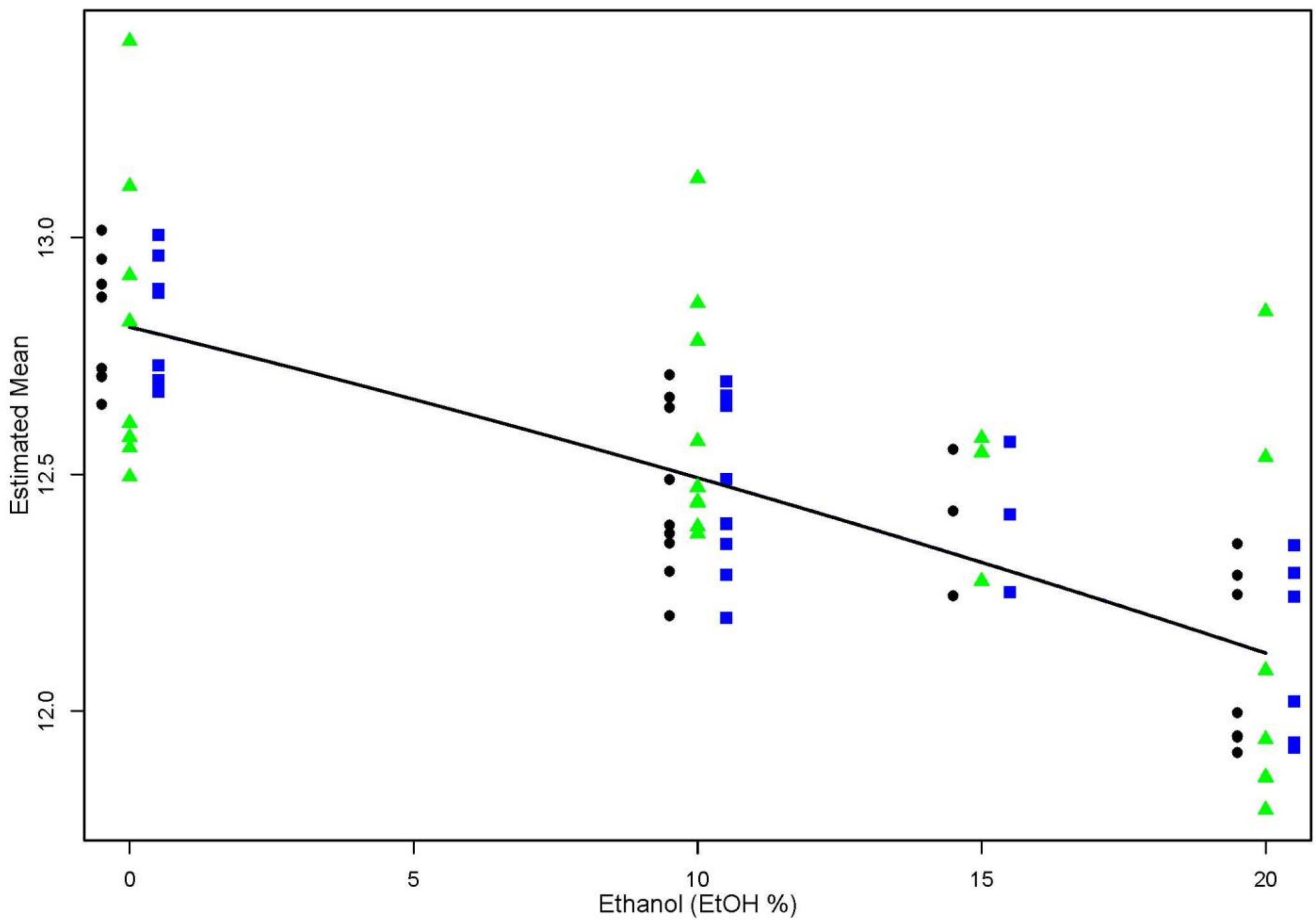


Fig. 14. Quadratic Fit to Model Estimated Mean Bag 1 NOx Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

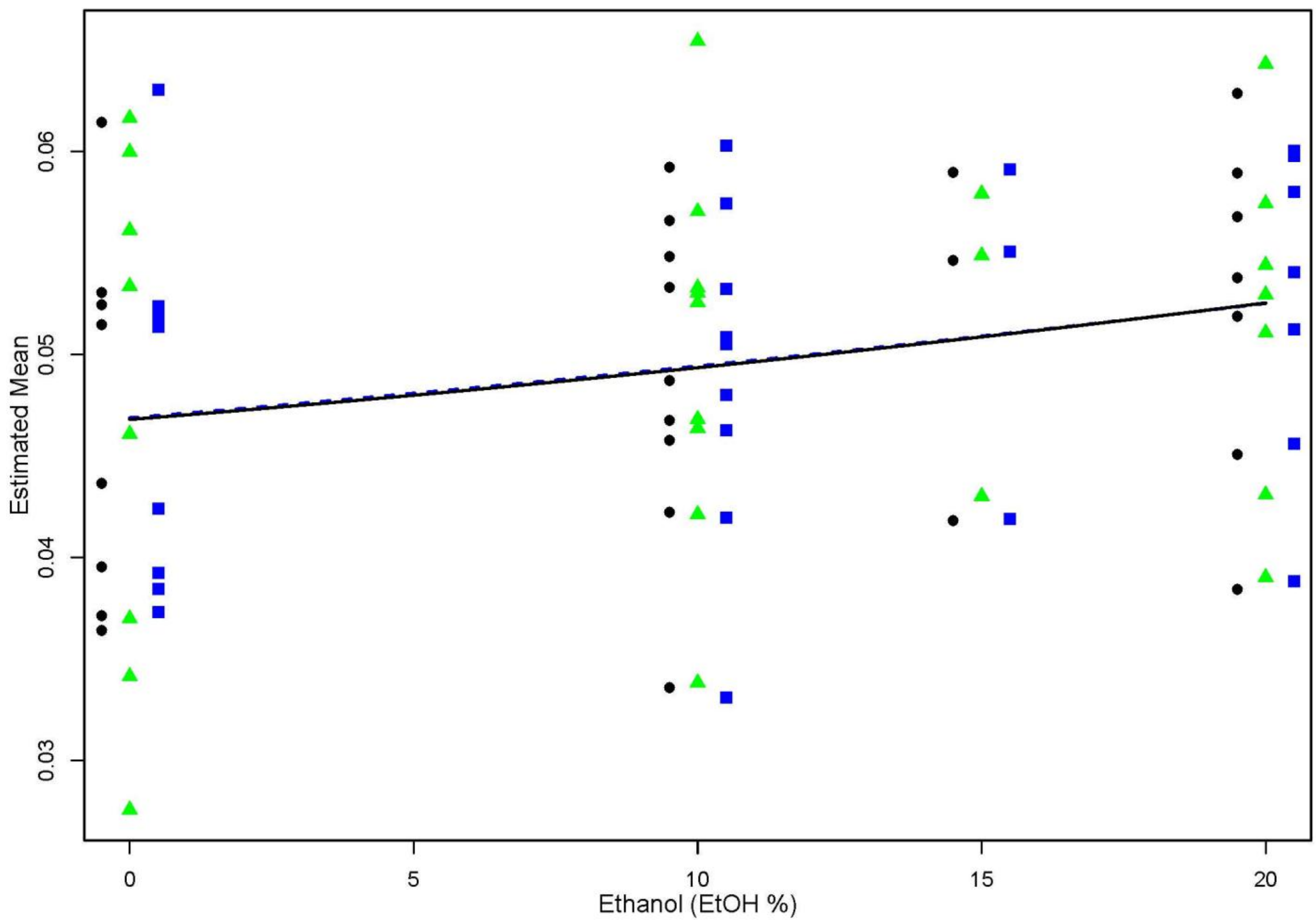


Fig. 15. Quadratic Fit to Model Estimated Mean Bag 1 PM Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

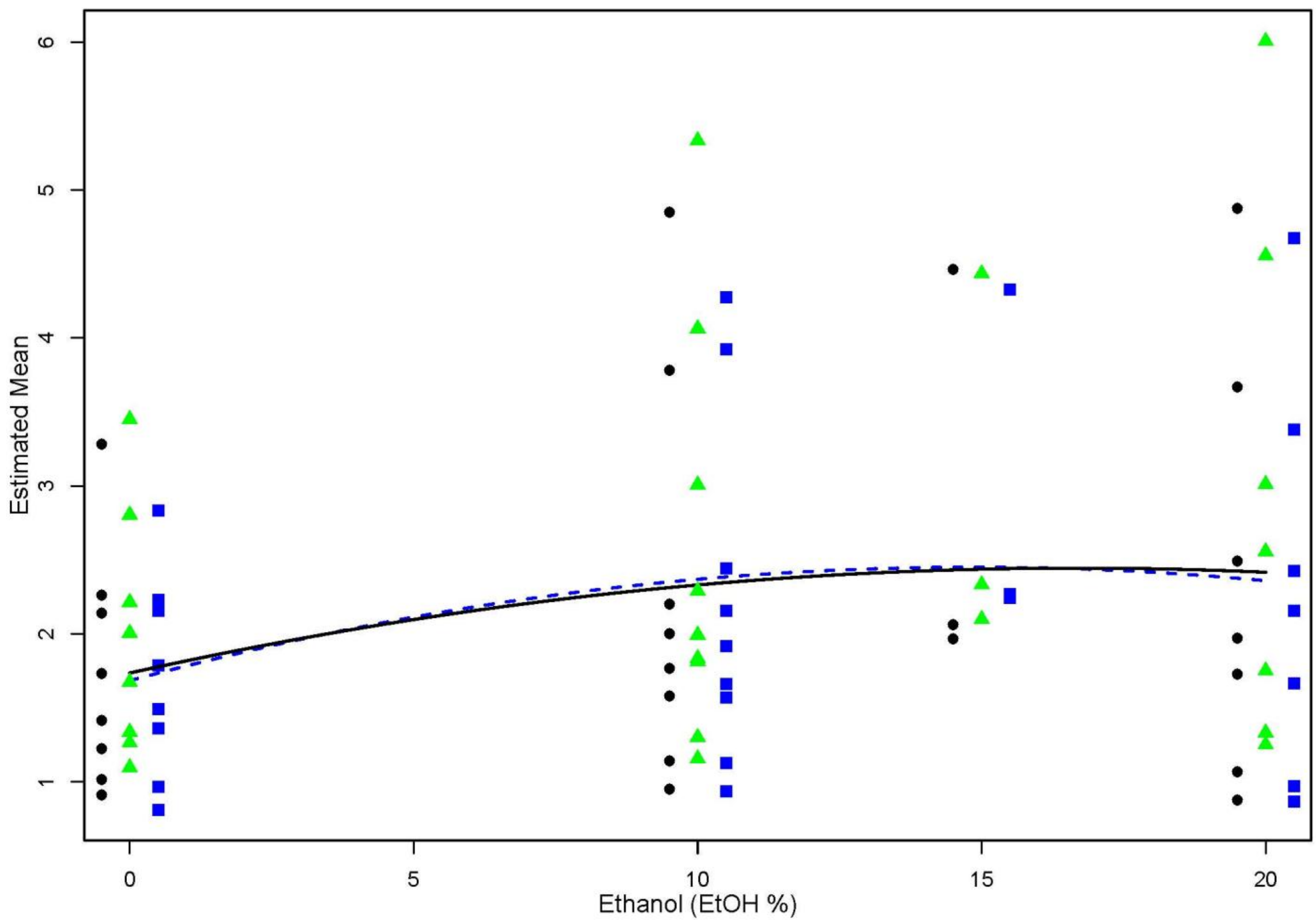


Fig. 16. Quadratic Fit to Model Estimated Mean Bag 1 THC Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

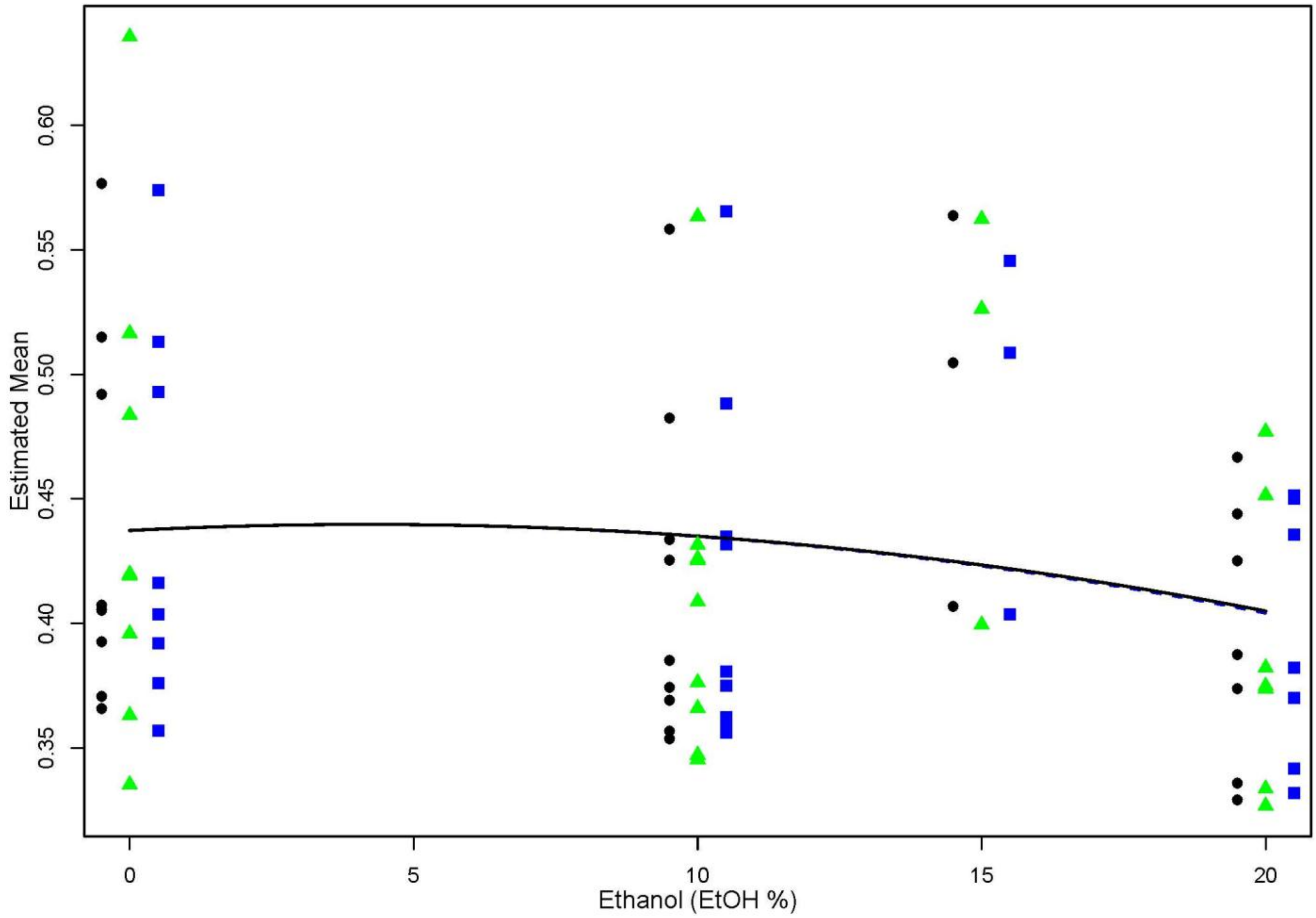


Fig. 17. Quadratic Fit to Model Estimated Mean Bag 1 NMHC Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

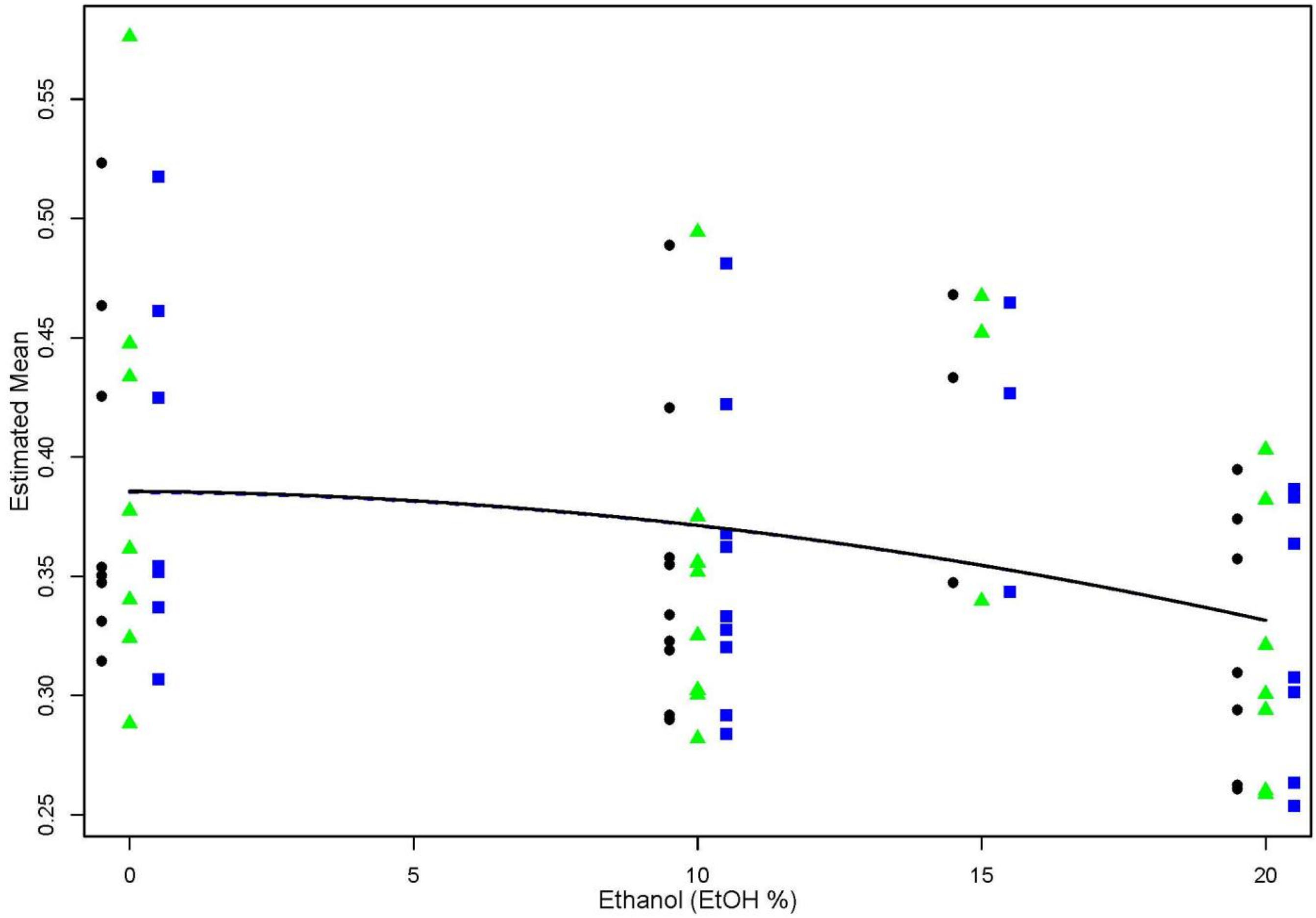


Fig. 18. Quadratic Fit to Model Estimated Mean Bag 1 NMOG Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

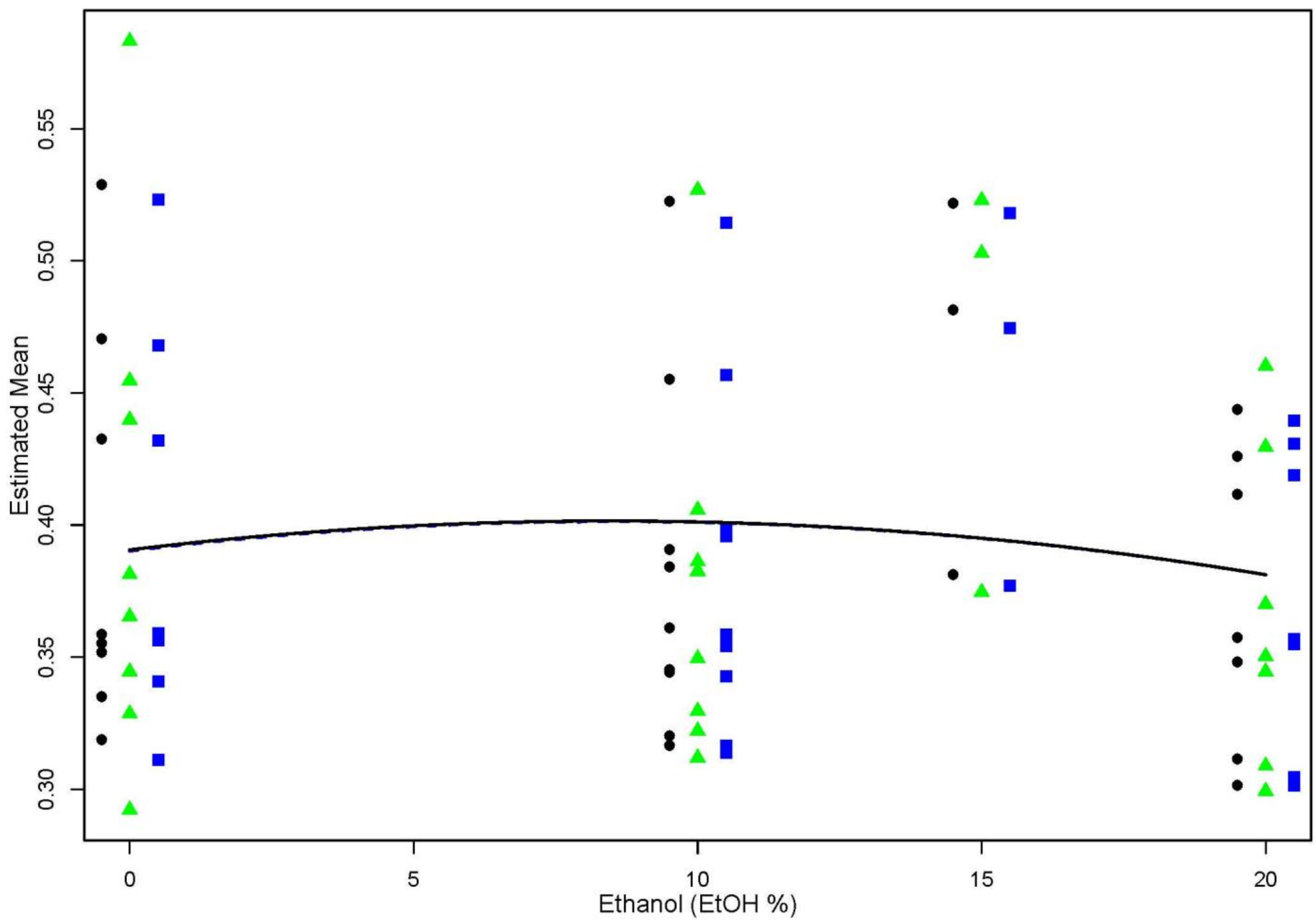


Fig. 19. Quadratic Fit to Model Estimated Mean Bag 2 CH4 Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

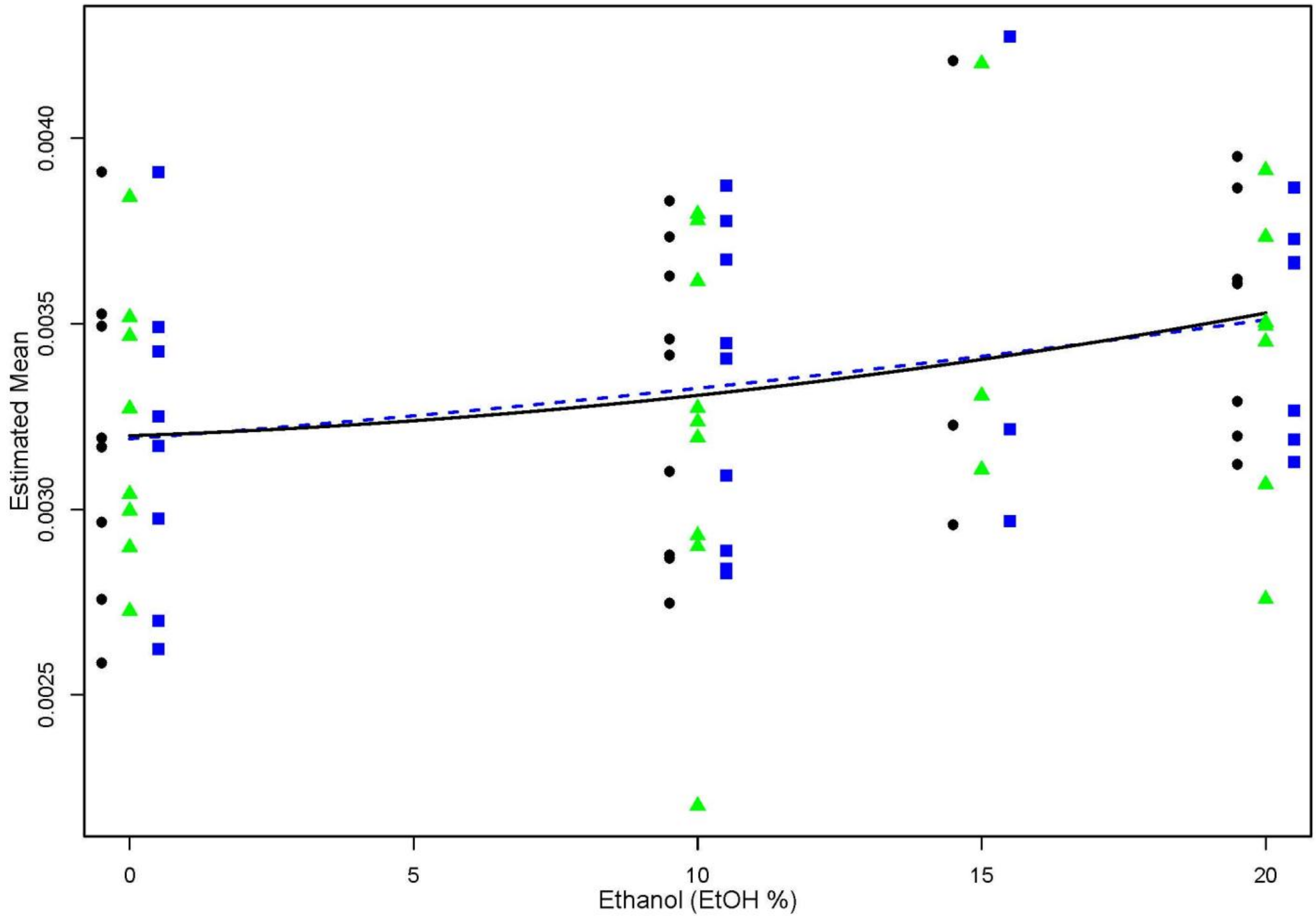


Fig. 20. Quadratic Fit to Model Estimated Mean Bag 2 CO Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

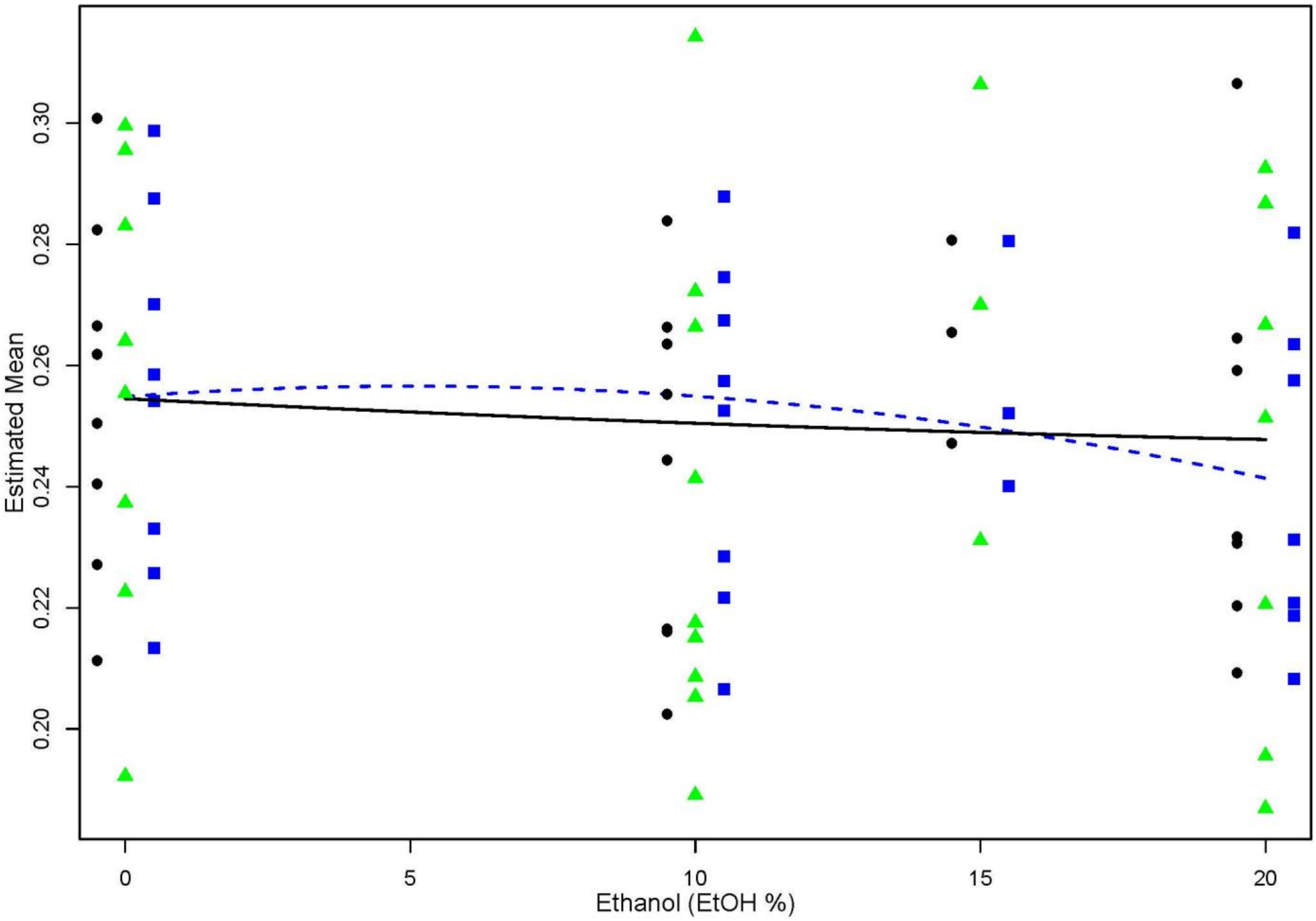


Fig. 21. Quadratic Fit to Model Estimated Mean Bag 2 CO2 Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

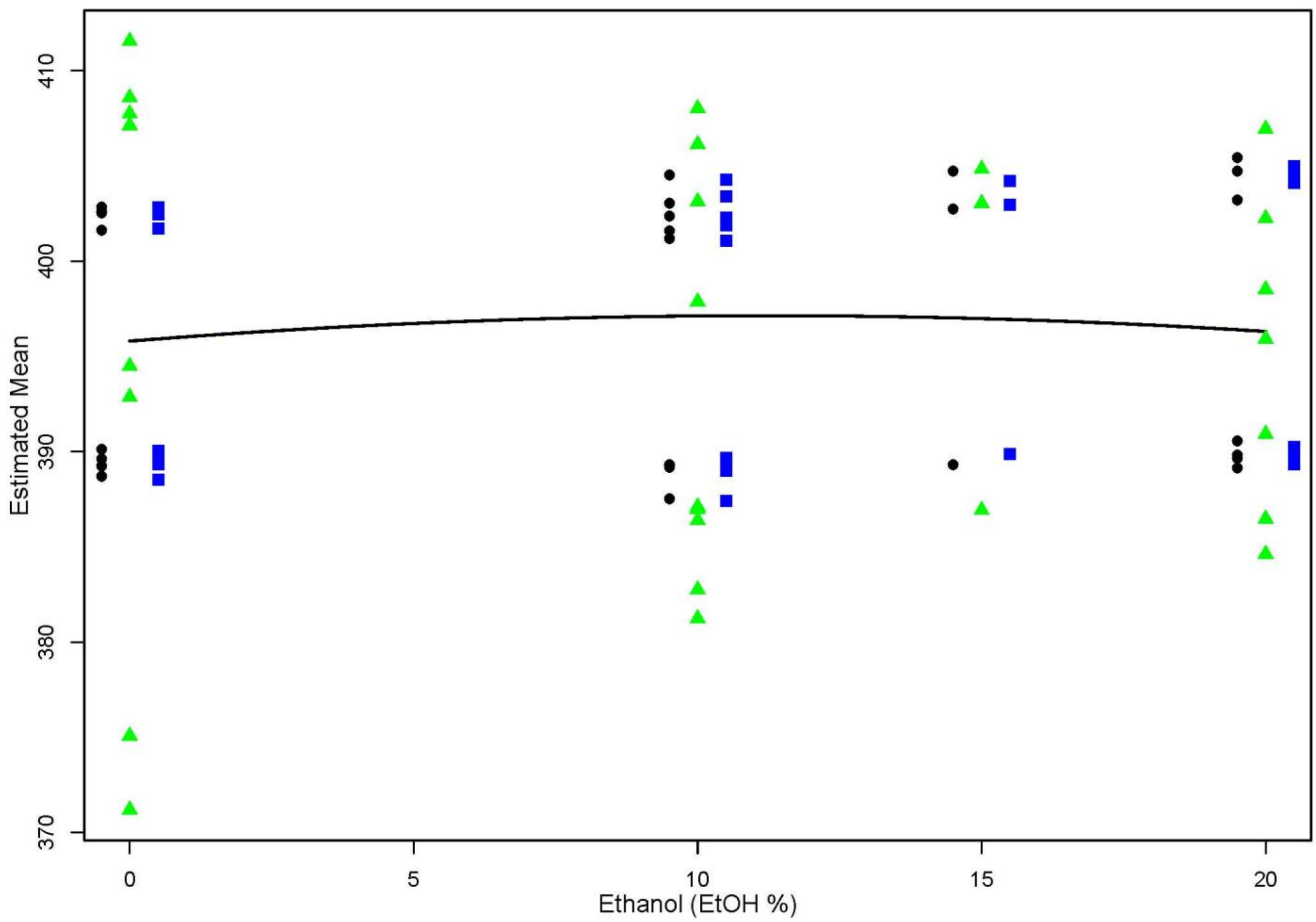
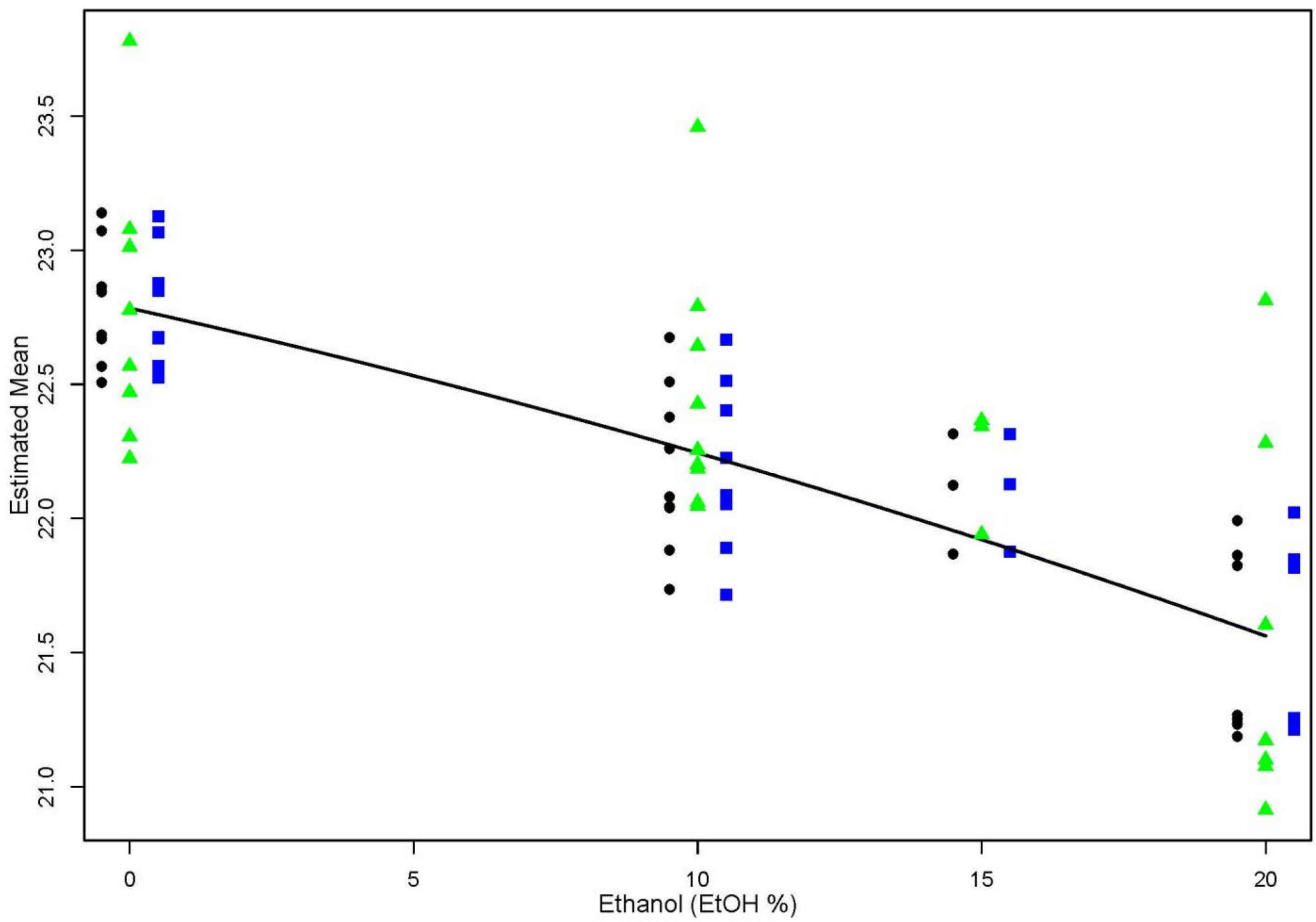


Fig. 22. Quadratic Fit to Model Estimated Mean Bag 2 FE Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).



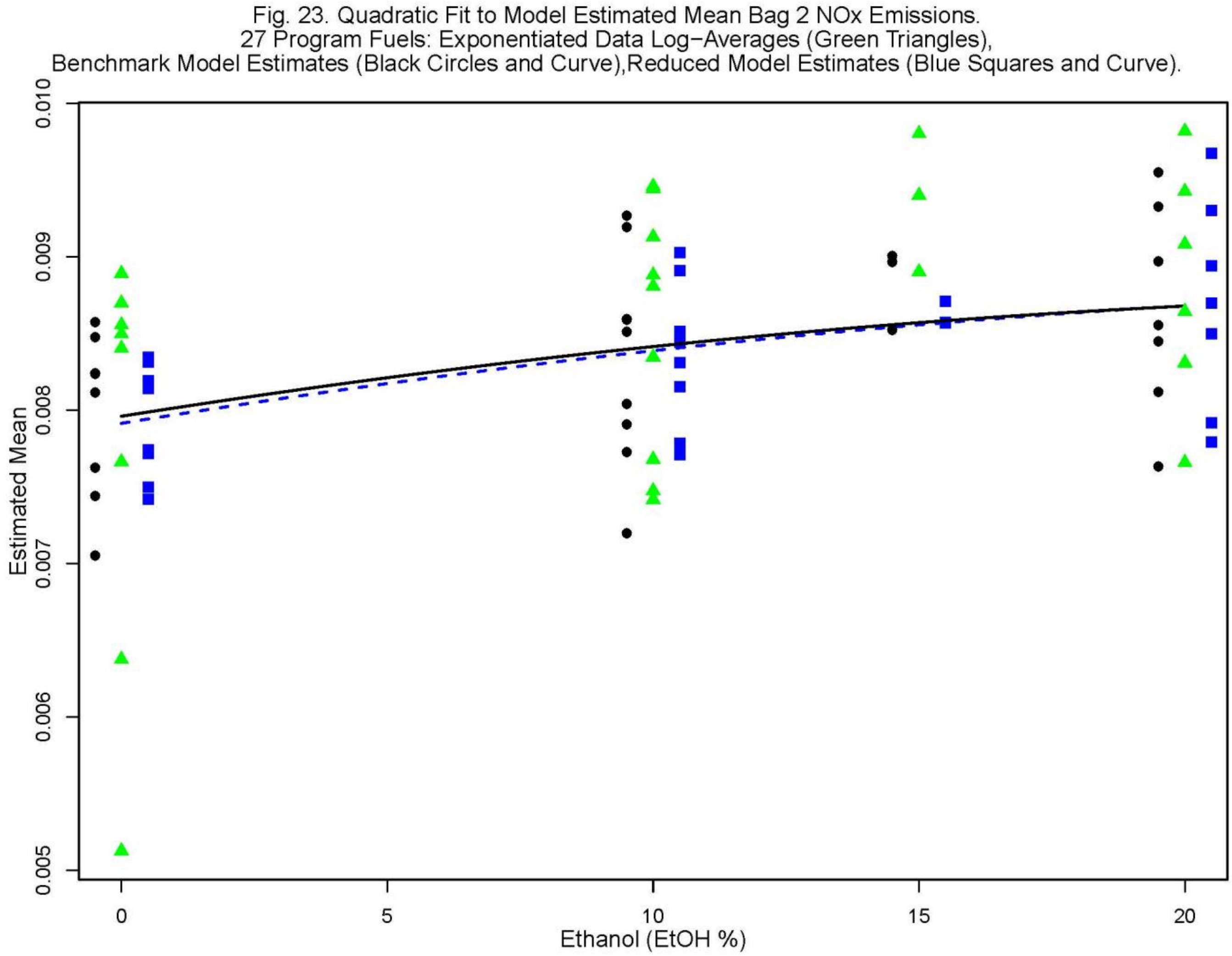


Fig. 23. Quadratic Fit to Model Estimated Mean Bag 2 NOx Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).
Estimated Mean
0.005
0.006
0.007
0.008
0.009
0.010
0
5
10
15
20
Ethanol (EtOH %)

Fig. 24. Quadratic Fit to Model Estimated Mean Bag 2 PM Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

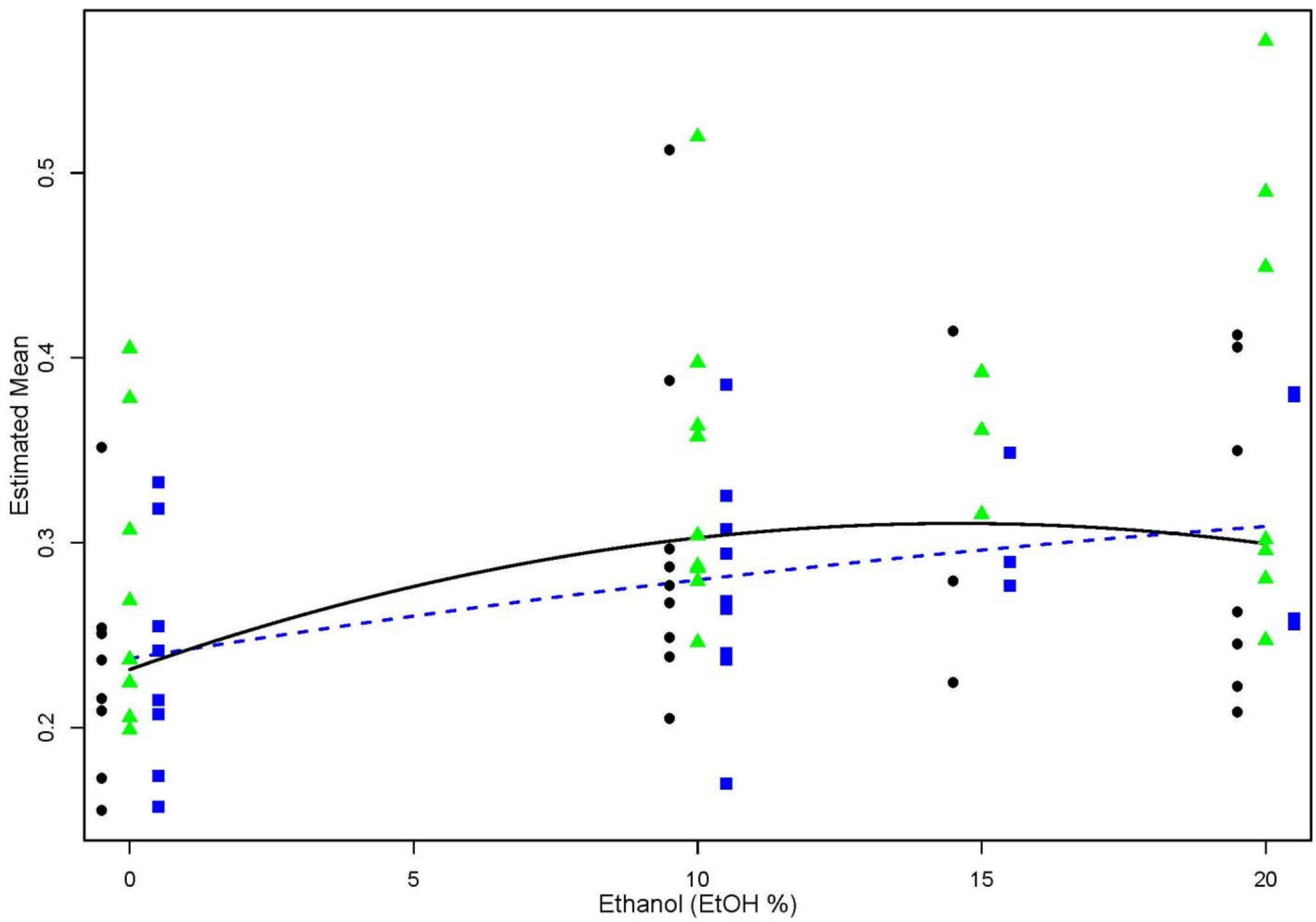


Fig. 25. Quadratic Fit to Model Estimated Mean Bag 2 THC Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

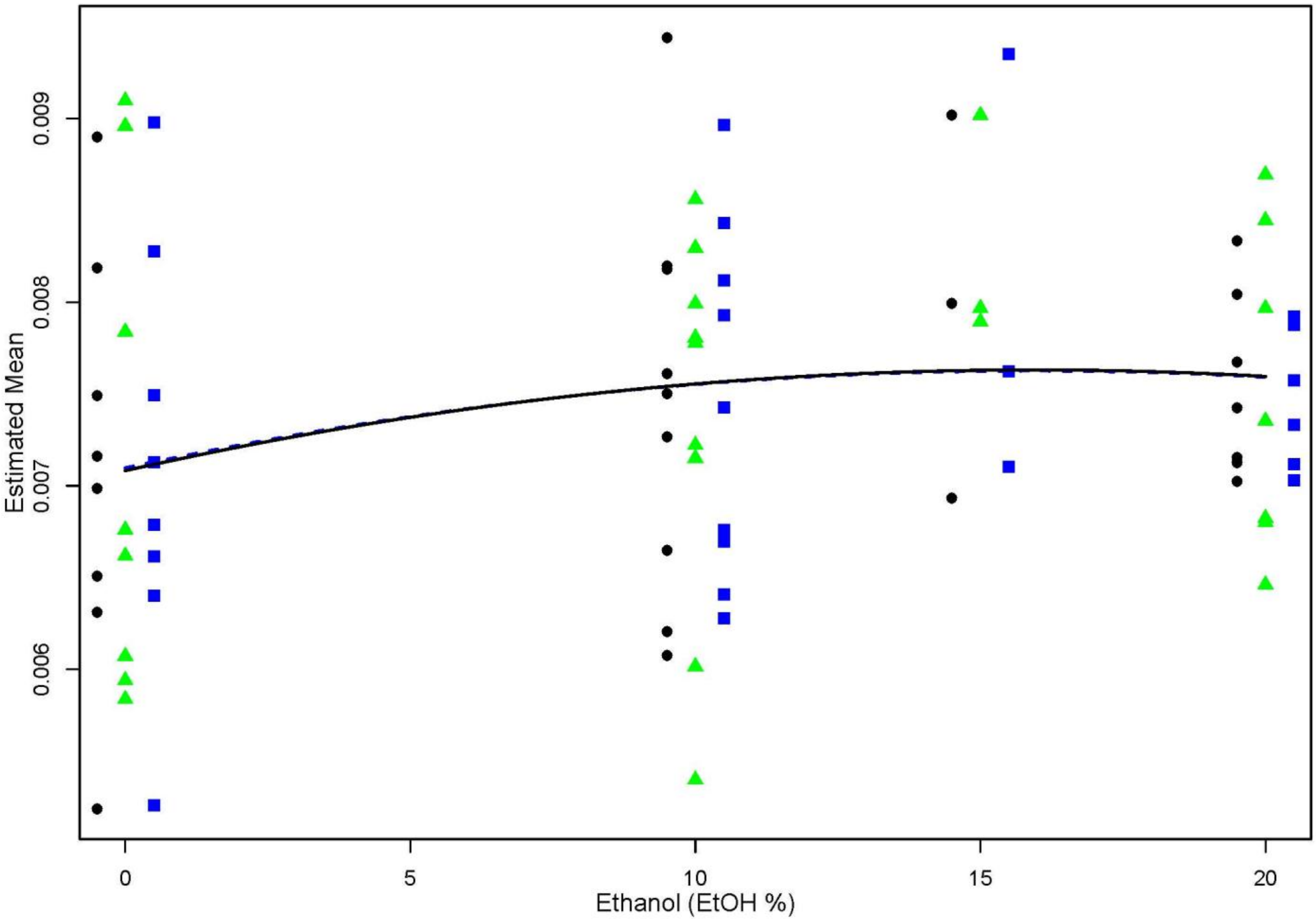


Fig. 26. Quadratic Fit to Model Estimated Mean Bag 2 NMHC Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

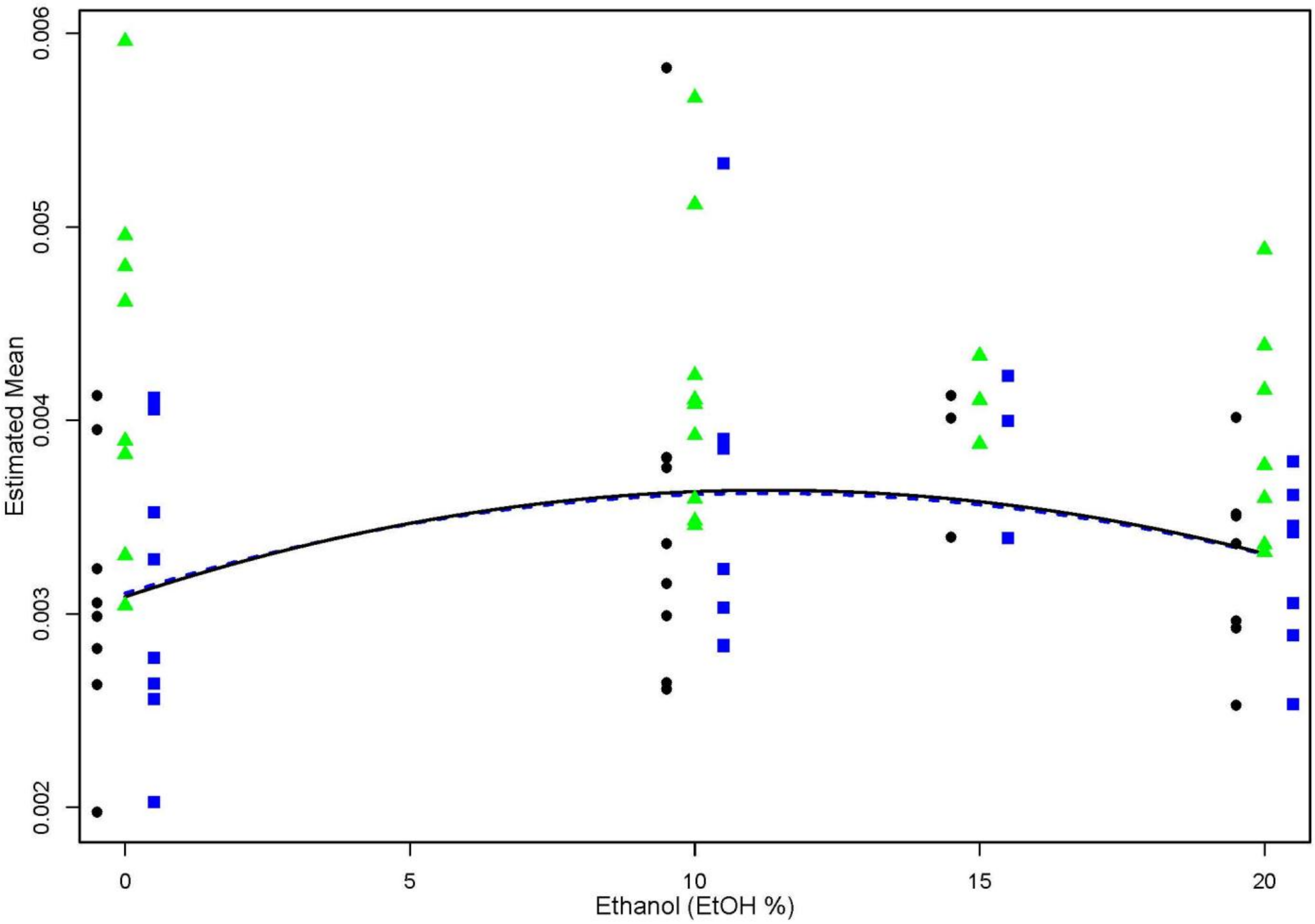


Fig. 27. Quadratic Fit to Model Estimated Mean Bag 2 NMOG Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

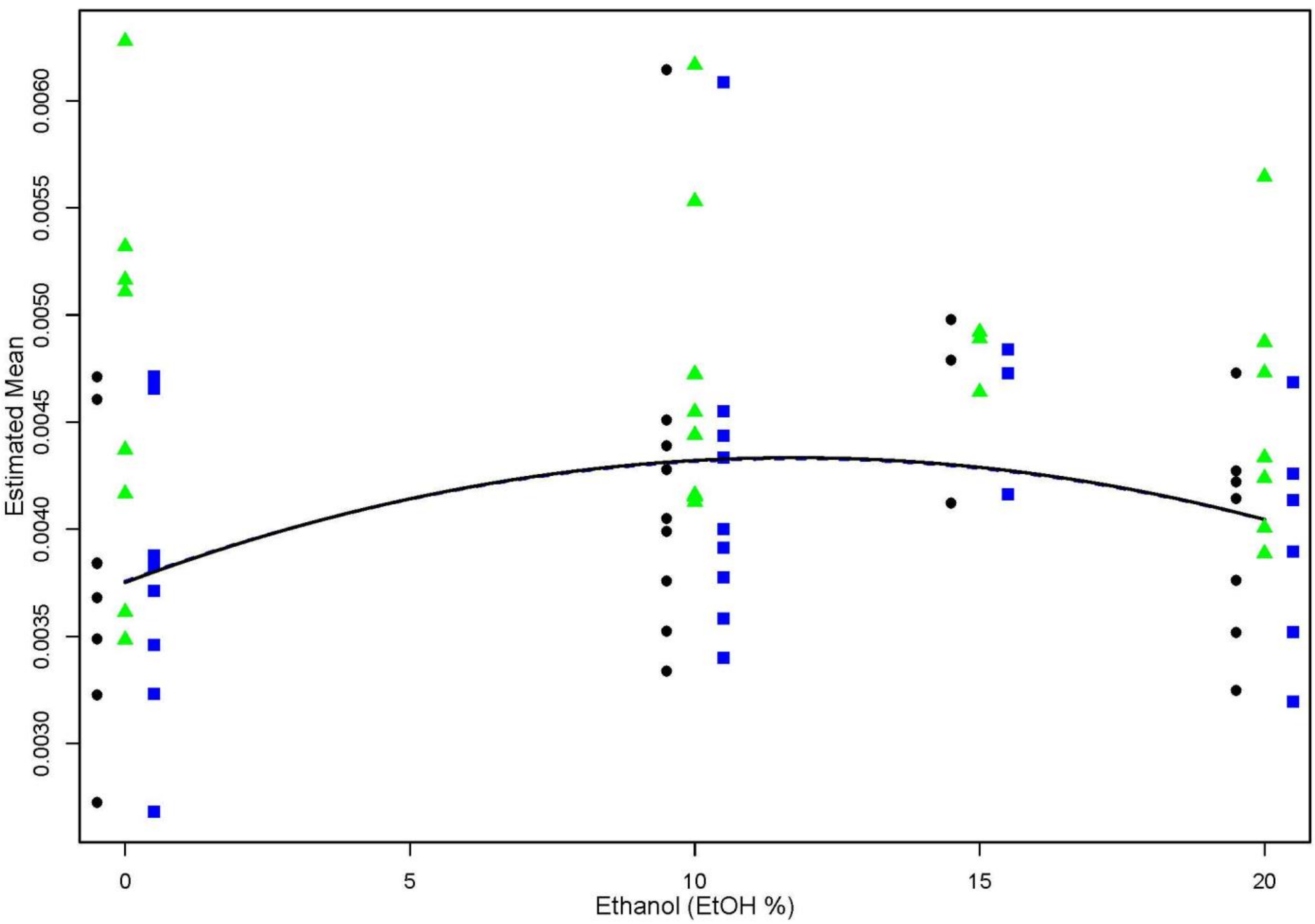


Fig. 28. Quadratic Fit to Model Estimated Mean Bag 3 CH4 Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

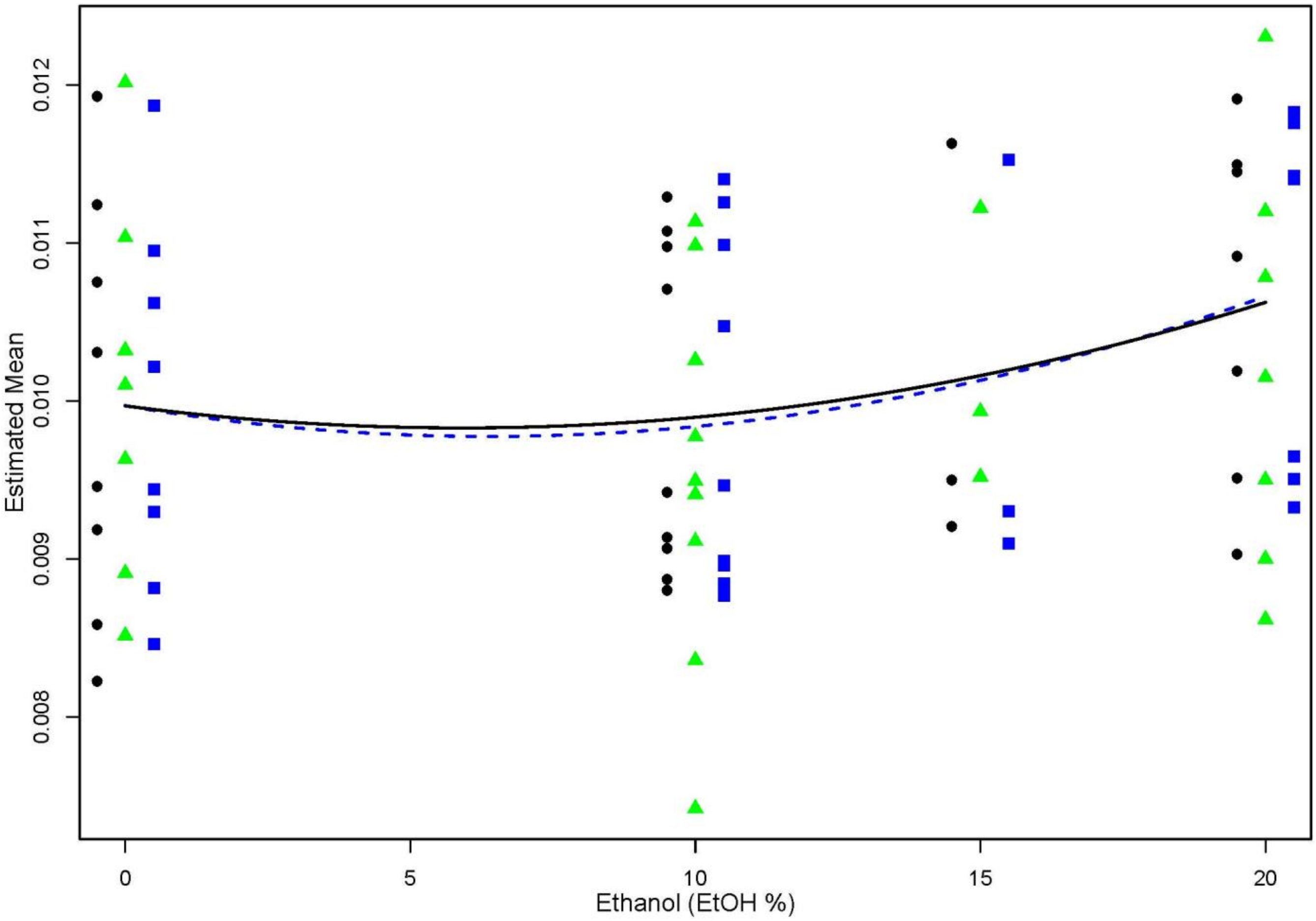


Fig. 29. Quadratic Fit to Model Estimated Mean Bag 3 CO Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

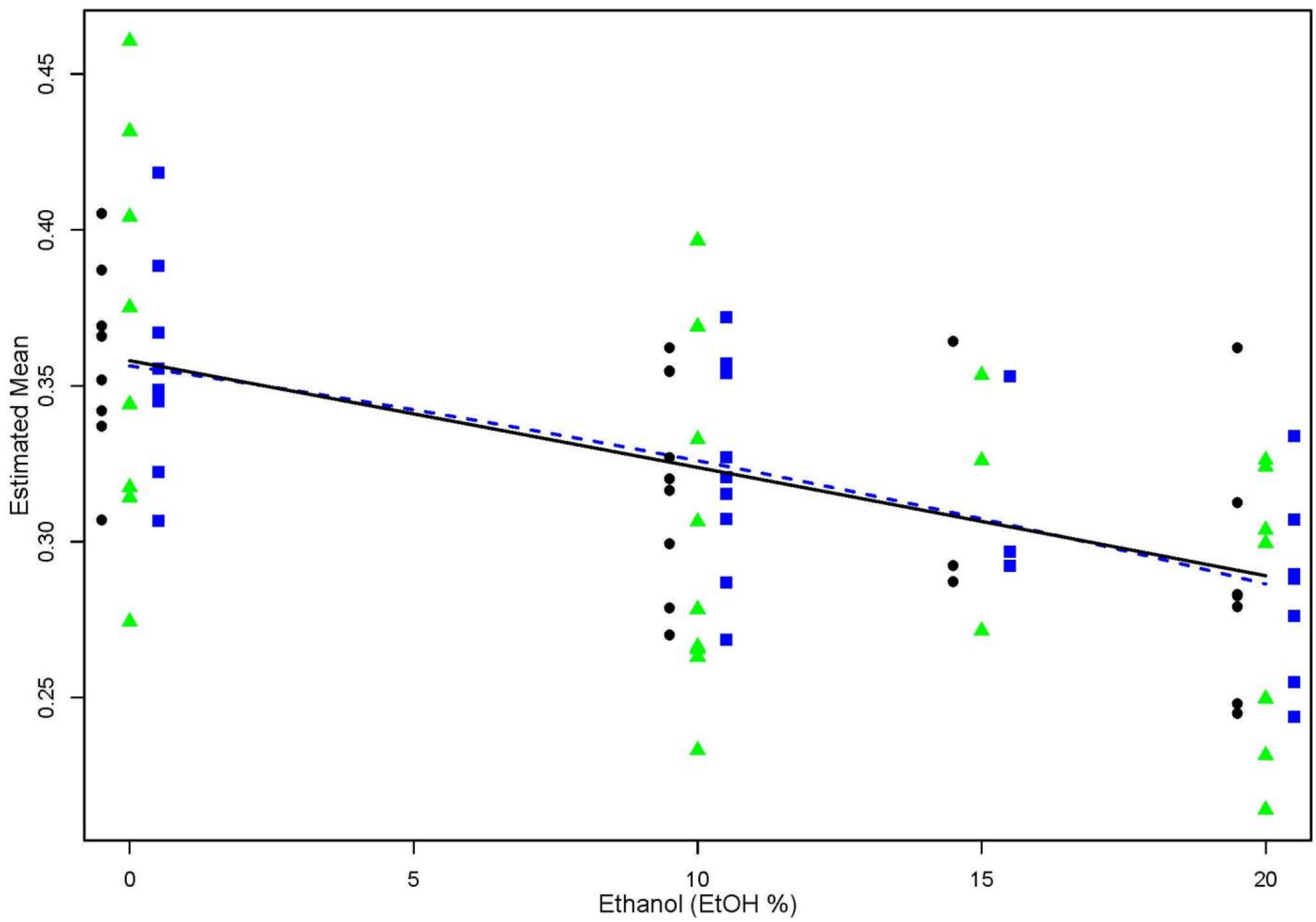


Fig. 30. Quadratic Fit to Model Estimated Mean Bag 3 CO2 Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

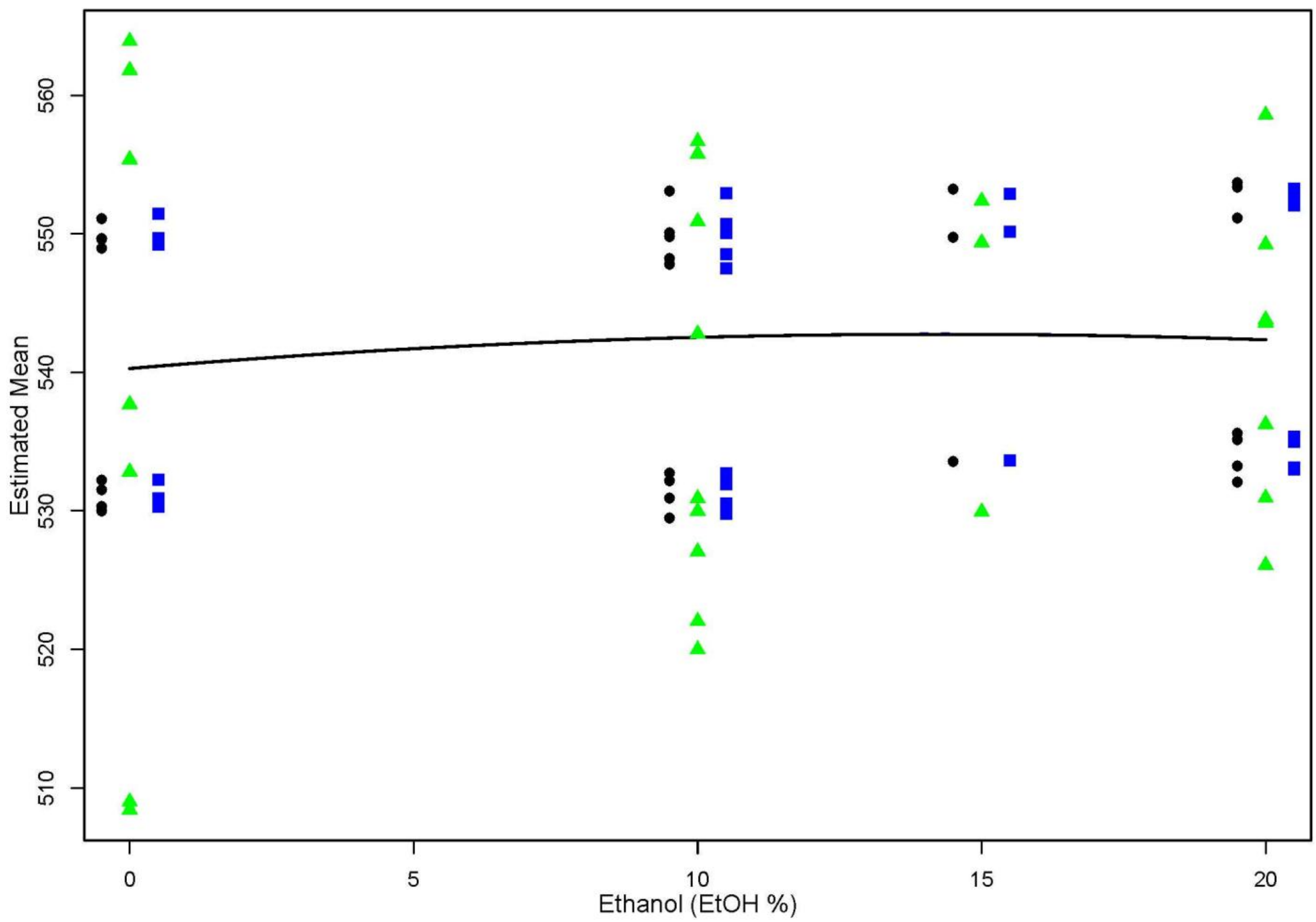


Fig. 31. Quadratic Fit to Model Estimated Mean Bag 3 FE Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

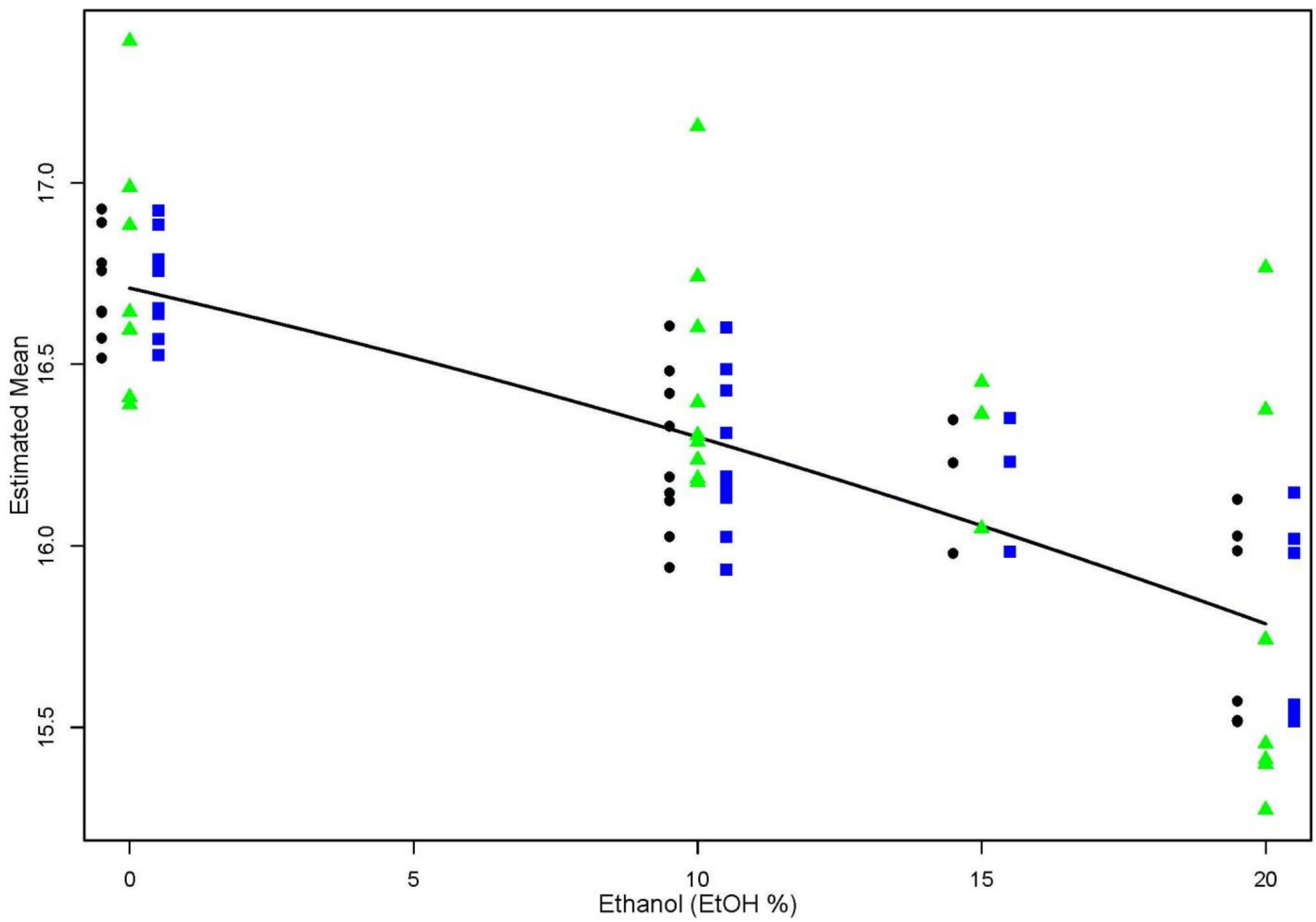


Fig. 32. Quadratic Fit to Model Estimated Mean Bag 3 NOx Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

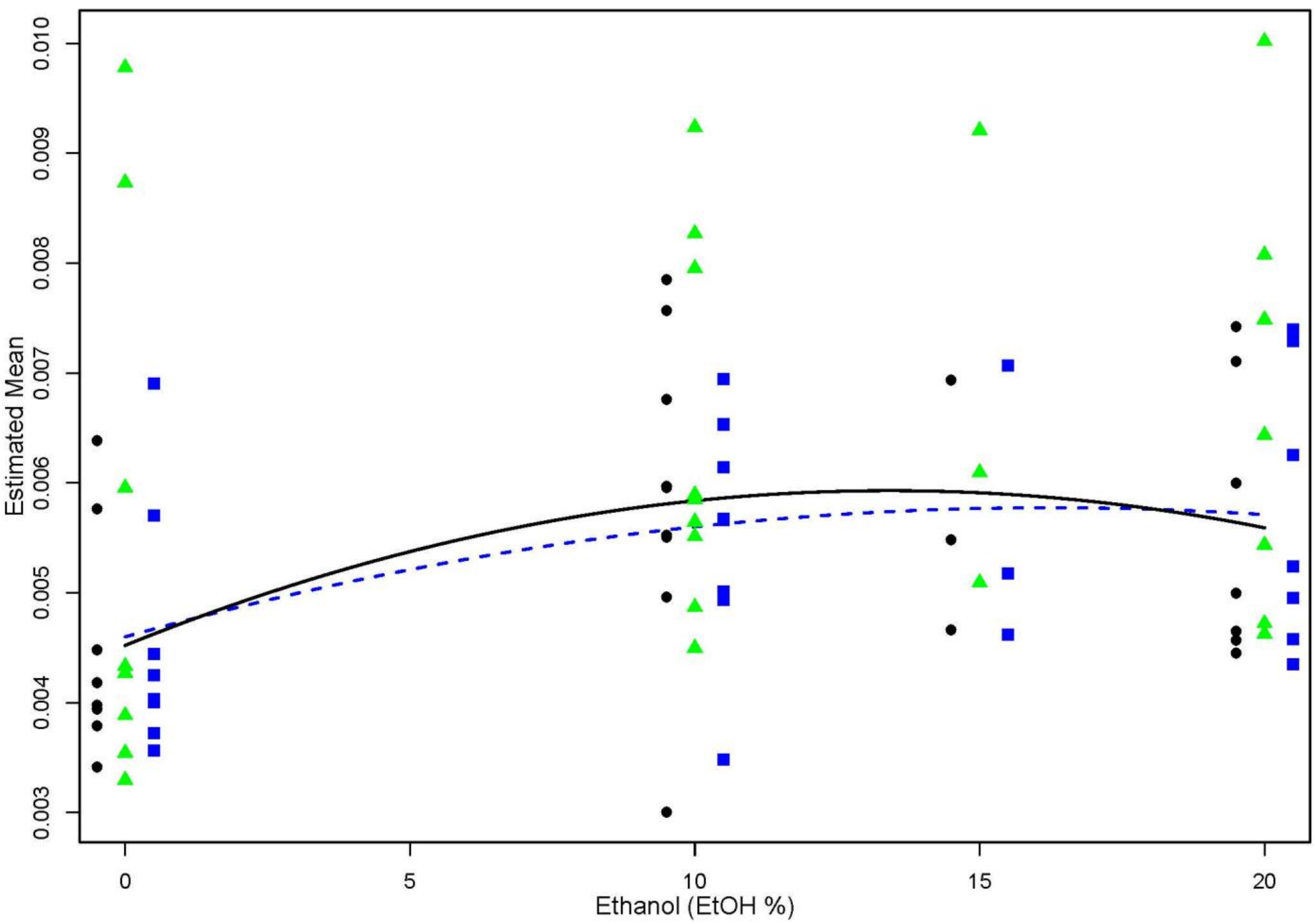


Fig. 33. Quadratic Fit to Model Estimated Mean Bag 3 PM Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

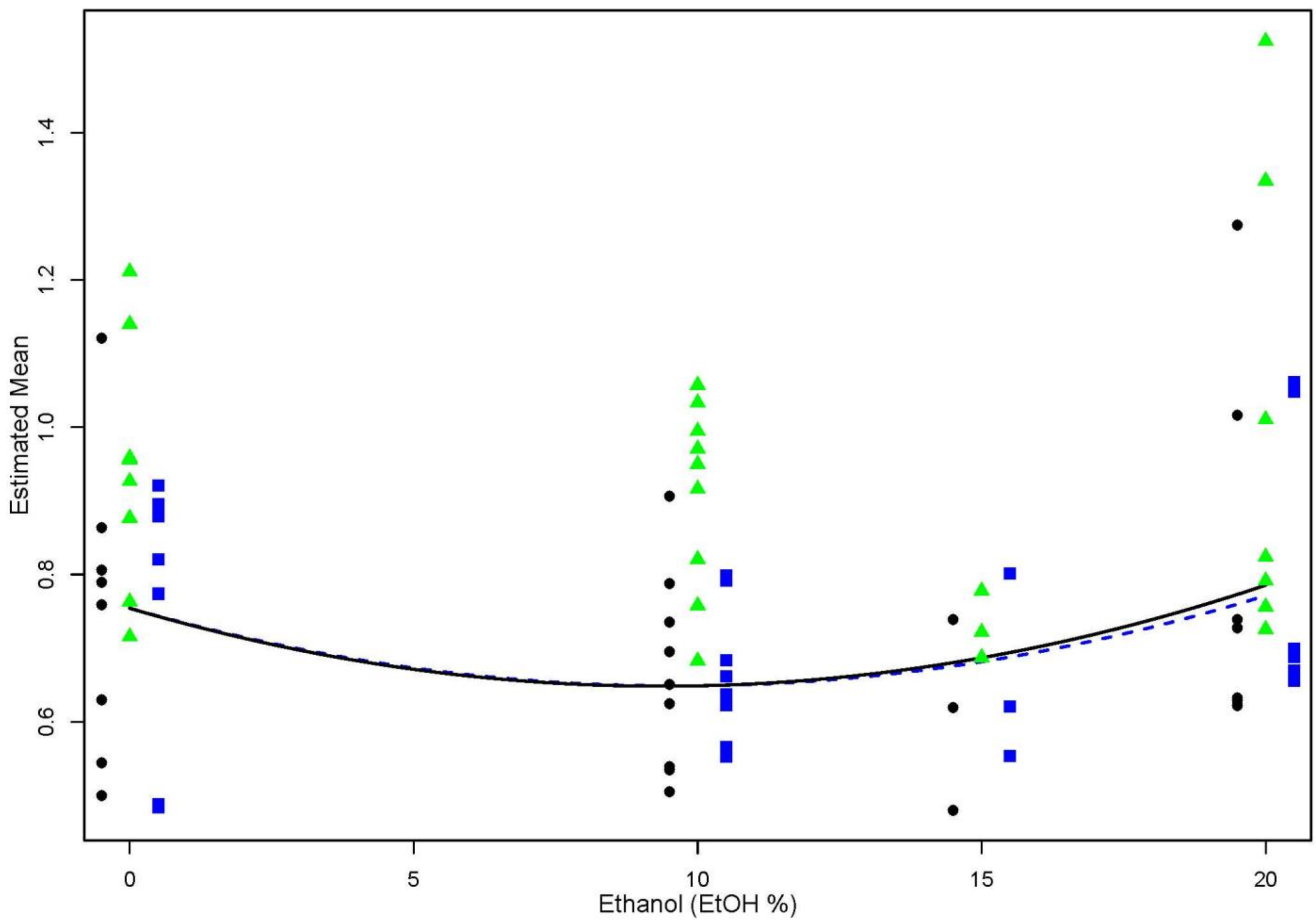


Fig. 34. Quadratic Fit to Model Estimated Mean Bag 3 THC Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

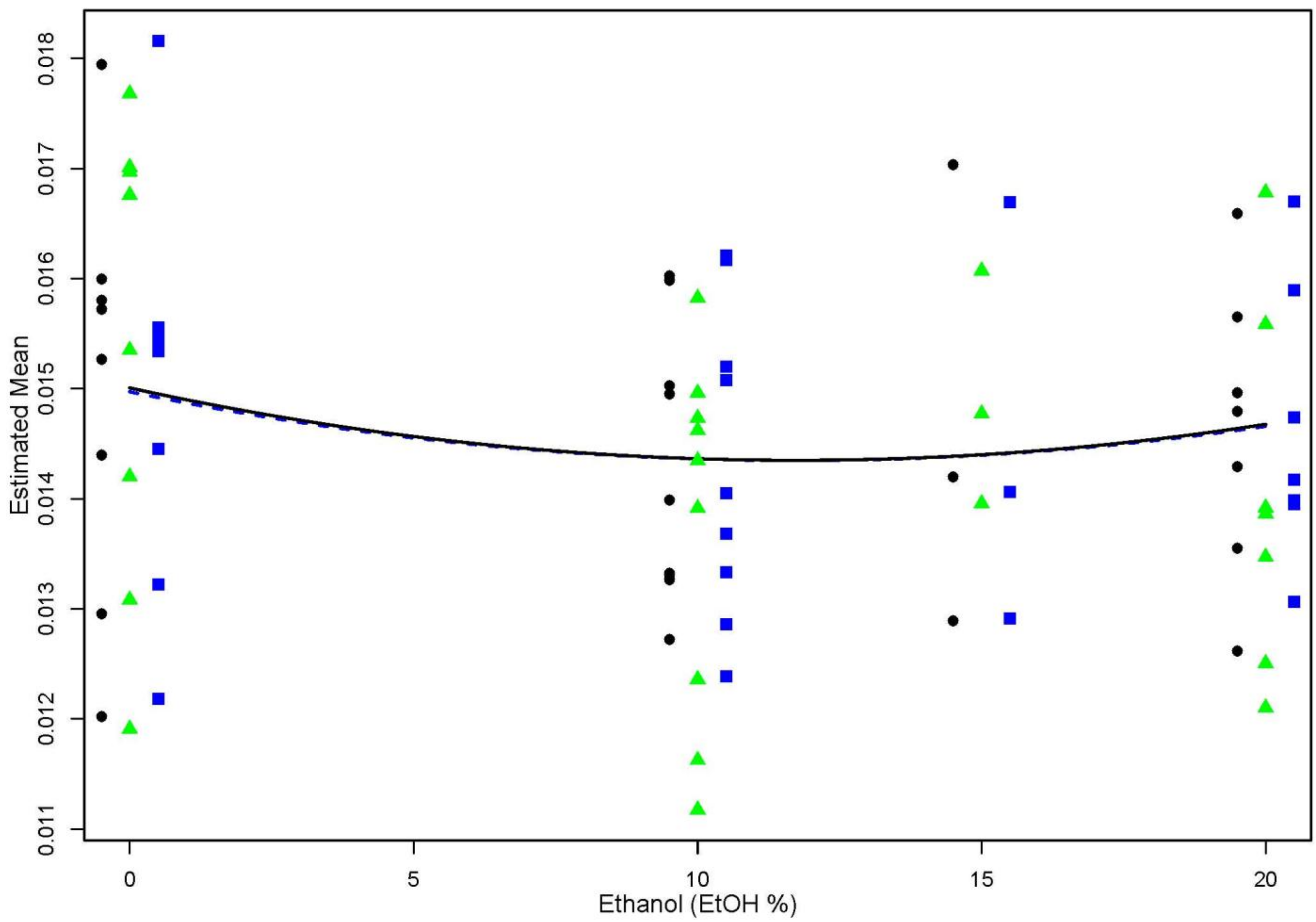


Fig. 35. Quadratic Fit to Model Estimated Mean Bag 3 NMHC Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).

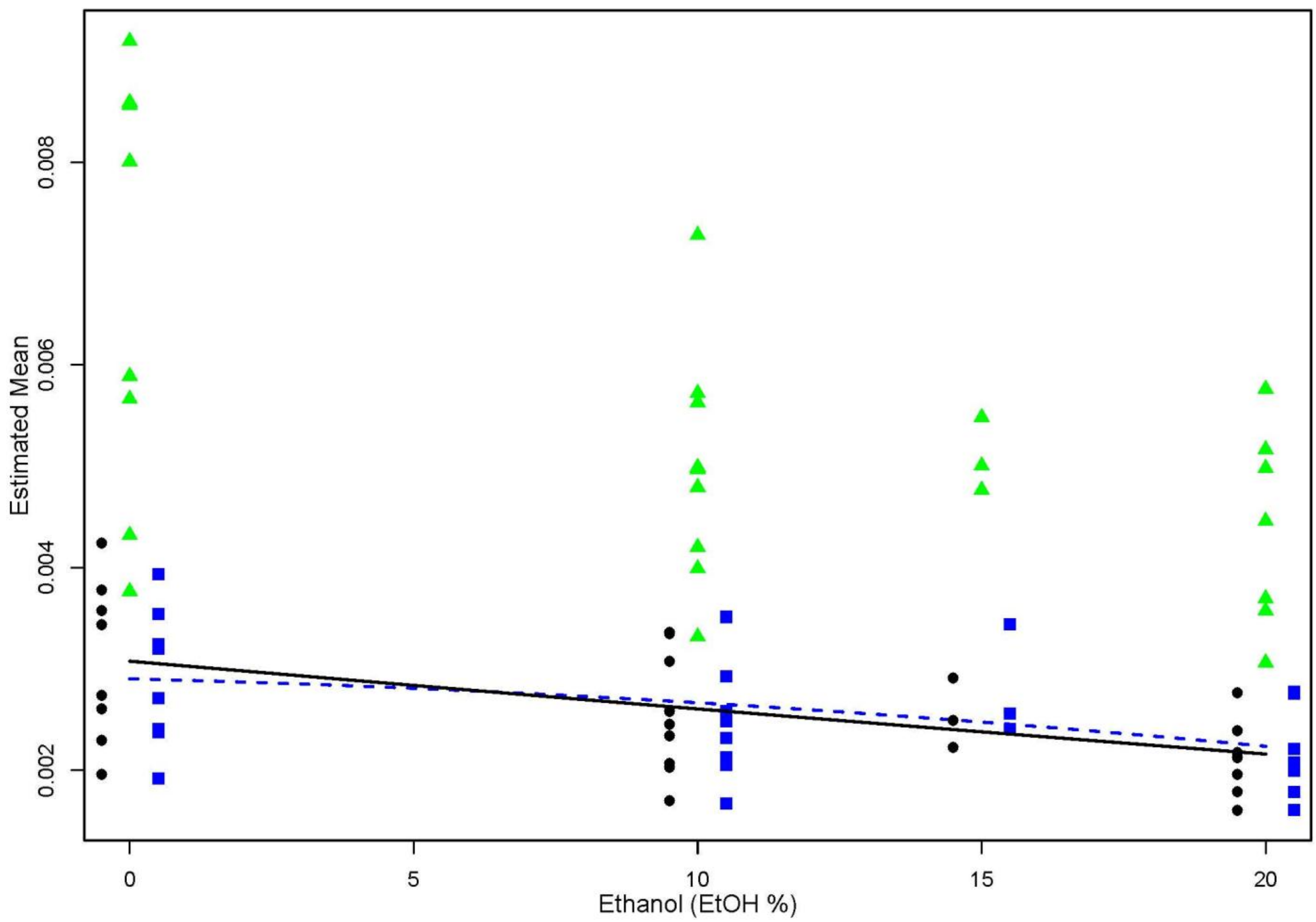
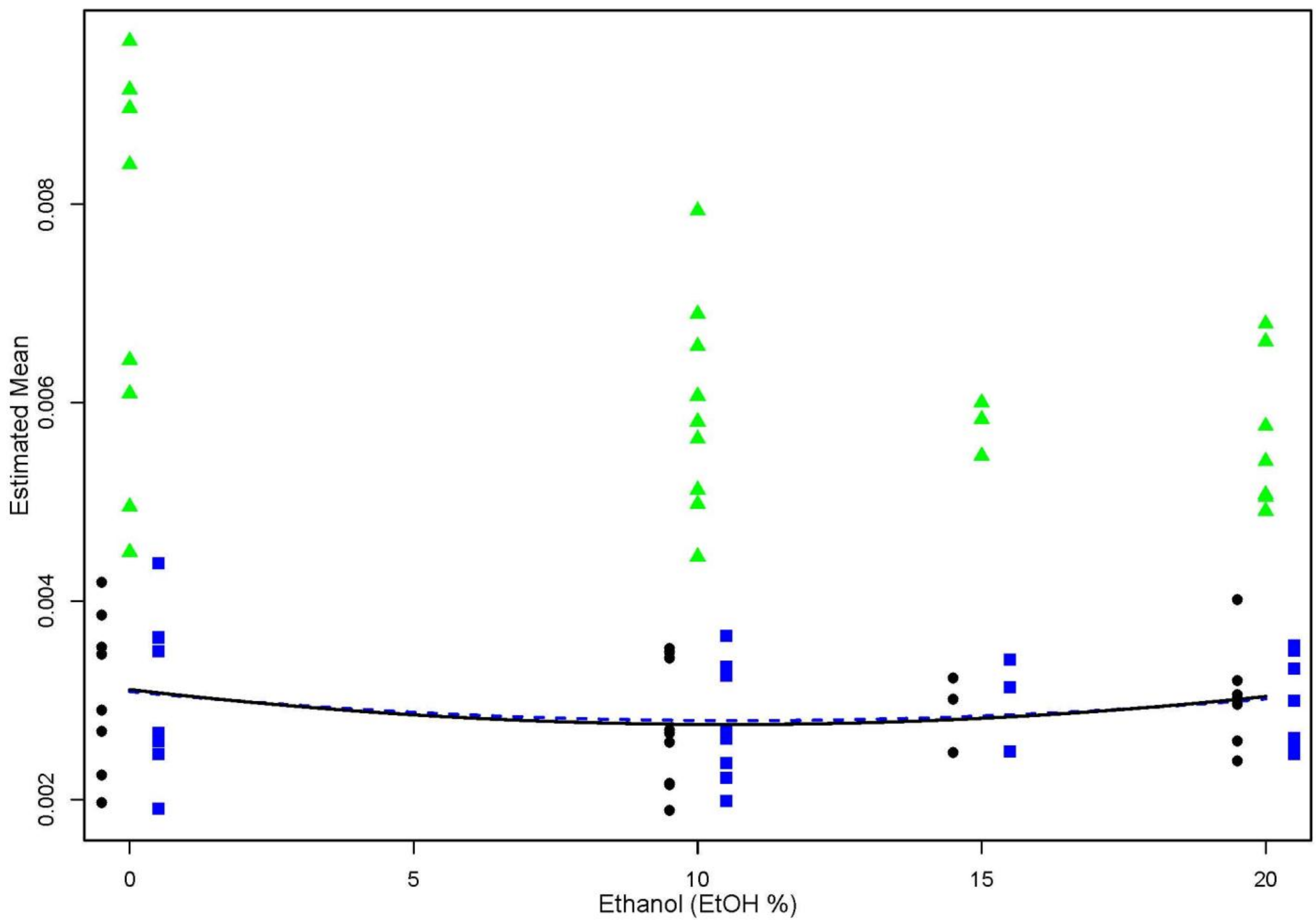


Fig. 36. Quadratic Fit to Model Estimated Mean Bag 3 NMOG Emissions.
27 Program Fuels: Exponentiated Data Log−Averages (Green Triangles),
Benchmark Model Estimates (Black Circles and Curve),Reduced Model Estimates (Blue Squares and Curve).



Addendum:

Responses to EPA Comments on the 5/3/2011 Draft Report

Addendum
Responses to Comments on Draft Final Report

Comments were received from some of the program participants on a draft final report dated 5/3/2011. All of the comments are appreciated. In some instances, notably the comments from EPA, concerns were raised about portions of the report. Some of these concerns are important and require responses so that an understanding of the intent or a clarification of misperceptions can inform a better understanding of the results and conclusions. The comments received from EPA are shown below in boldface and italics. Responses to those comments are in plain text font.

Comments from EPA Staff on Dick Gunst's Draft Final Report, dated May 3, 2011, entitled: Statistical Analysis of Emissions Data Collected in Phase 3 of the EPAct/V2/E-89 Program

General Comments

The report includes multiple statements regarding the representativeness and applicability of the vehicle sample, fuel matrix and models fit to the Phase 3 dataset (executive summary; I.A (page 2), I.B (page 2), I.D (page 4)). While it is reasonable and appropriate to raise questions and issues with respect to the representativeness of the vehicles and fuels, as well as the interpretation and application of the data, the statements contained in the report are presented definitively, despite the fact that they not the subject of and do not derive from the analyses presented in the report. Given the author's lack of involvement in or knowledge of the vehicle selection process (through no fault of his own), which is outside the scope of this report, drawing such broad and definitive conclusions is not appropriate in this document.

These statements are global, vague, and misrepresent the conclusions drawn in the report. It is entirely appropriate and the professional responsibility of an independent statistical consultant to identify limitations of a data base that necessarily result in limitations in the conclusions that can be drawn from analyses of the data base. This is a fundamental obligation of a professional statistician to his client, in this case NREL.

The gratuitous last statement is irrelevant. The author's not having been involved in the selection of vehicles does not affect in any way conclusions about the vehicles that are present in the data base. There is no dispute that the characteristics of those vehicles that are stated in the report are factual. What appears to be in dispute is the ability to generalize conclusions drawn from this data base to other vehicles. Absent any additional information about representativeness, the conclusions from these analyses must be limited to these 15 vehicles. No inference is made by the author about representativeness beyond the characteristics of the Phase 3 data base. The inferences drawn and the cautionary limitations imposed on these inference are the subject of and do derive from analyses performed on the Phase 3 data.

It is EPA's and other interested parties' burden to document and defend the extrapolation of the results of this work beyond the 15 vehicles included in this data base. The author recognizes this and fully expects that EPA and other parties will do so. He cannot generalize the conclusions based on this data base alone – and neither should any other interested party.

The recommendation that the benchmark model (containing all possible terms) be used for emission predictions (versus any reduced model) can be taken to assume that terms are meaningful until proven otherwise, rather than the reverse, and does not address potential issues such as overfitting to artifacts in the Phase 3 dataset. Further, it does not allow for application of physical science in selection of models for application, as mentioned elsewhere in the report, nor for follow-up analyses such as verification of candidate models against independent data.

Reasons for recommending the use of the Benchmark Model are stated in the report. There is no prohibition from using any reduced model for specific purposes or if relevant scientific or engineering knowledge indicates that a reduced model is more appropriate than the Benchmark Model. This is clearly stated in the report. The author, at several program meetings and in conference calls, requested that such knowledge be articulated so that informed judgments could be made on relevant reduced models. No such guidance was provided. Moreover, months of debates took place about which reduced models were "best" based solely on statistical criteria. The issue in this modeling is that polynomial model terms are being fit: 12 of the 17 model terms are functions of the five fuel parameters. It should be expected that the selection of a unique "best" model would be fraught with difficulties if selection is based solely on statistical analyses of the data.

The author never assumed or stated that all the model terms were "meaningful until proven otherwise." On the other hand, he does not concur that overfitting is worse. The author demonstrated in several ways the comparability of the complete Benchmark Model with reduced models using the Phase 3 data, the only data available to him to do so. He had no "independent data" with which to compare Benchmark and reduced model fits. To the extent that such analyses can demonstrate a clear benefit to using reduced models, reduced models should be used. Clear preference for reduced model fits cannot be made from the Phase 3 data alone. The recommendation to use the Benchmark model is exactly that, a recommendation. It remains the author's recommendation from an analysis of the Phase 3 data.

Specific Comments

Executive Summary

o In this section and/or the Introduction, it would be helpful to put this report into the context of the broader EPAct process, including additional analyses by EPA, NREL and CRC, including evaluation of past studies, validation using independent datasets ***and ongoing emission measurements, such as Phases 4 and 5 of the EPAct program.***

The author of this report was contracted to model and analyze the Phase 3 data. He is not involved with any analyses being conducted by EPA or CRC. He is not involved with evaluating past studies or validation using independent data sets.

Section I

o Section I.D. The third paragraph covers issues with the dataset that have been resolved within the project group. Discussion of the treatment of zeros and missing values is obviously relevant to the statistical analysis but might be better placed in Section III.

The cited paragraph has been removed since the data base was updated following the circulation of the draft report.

Section II

o Section II.B.2, Paragraph 2. The vehicles selected for inclusion do represent a small fraction of all makes and models, but do represent a majority of vehicle sales in their model year. The point that vehicles represent random effects would apply even if the sample were larger.

No comment or action is required.

Section IV

o Section IV.A. We grant that the outcome of a model selection process is not "best" in any absolute sense, but only contingent upon the experimental design, the sample used, and the assumptions and criteria used to define and conduct the process. Readers familiar with statistical analysis can appreciate these points. Nonetheless, for uninitiated readers, characterizing the search for a "best fit" as "fallacious" tends to give the strong impression that the statistical analyses are essentially irrelevant and that selection of a "best model" can therefore be pretty much subjective or arbitrary Based on these considerations, we suggest the consideration of a more neutral term to characterize the model selection, such as "Challenge," rather than "Fallacy."

This point is well taken. The title of this section is changed as suggested.

- ***Section IV.A. More generally, can we not ask whether fitting of thousands of subsets is actually superior to backwards elimination, which does arrive at a single "best fit," contingent on the operational definition used. Again, this result is not an "absolute best," but does greatly narrow the field of candidates requiring additional evaluation in terms of the physical science, which is a very difficult and intensive process.***

  Yes, we can definitively state that the identification of better subsets using best subset algorithms is superior to backward elimination. This has been documented since the late 1970s in numerous peer-reviewed statistics journal articles and in textbooks. Backward elimination might produce one of the better subsets but there is no guarantee that it will do so. It is true that best subset algorithms can provide hundreds or thousands of better subsets – and that is the issue with identifying reduced model fits. Nevertheless, all the better reduced models are identified. The difficulty is which one(s) to choose for further evaluation.

- ***Section IV.A. Models developed independently by the author and EPA using different procedures produced similar or identical reduced models for several pollutants. This point might bear mentioning.***

  EPA has not concluded its modeling or presented its final model fits. These might change before it does so. A comment like this would be speculative prior to EPA releasing its final results.

- ***Section IV.A. 131,072 reduced models are possible, but only a very small fraction deserve serious consideration, due to hierarchy and other considerations, as noted later in the report.***

  No comment or action are required.

- ***Section IV.A. This discussion does not allow for the possibility that the benchmark model could reflect overfitting of the data due to artifacts of the program design or measurement errors in the data.***

  Artifacts of the design or measurement errors in the data do not, as implied here and elsewhere, solely affect the Benchmark Model. All reduced models would be suspect for the same reasons. Design issues or problems with the data base do not render reduced models preferable to the Benchmark Model.

- ***Section IV.A. (last bullet). This discussion could to make it clearer that such scientific or engineering judgment is not reflected in this report – and then Section VI.B could highlight it as work to be done by others before implementing emission models.***

  It is clear from the detailed documentation provided in this report that scientific or engineering knowledge, apart from statistical science, was not used in the model selection process. The author is not going to speculate what work other parties might conduct before implementing emissions models.

o Section IV.B.1, second to last paragraph. Doesn't setting the benchmark fit as the standard by which all reduced fits are evaluated depend on an a priori assumption that all terms in the benchmark are meaningful until proven otherwise? It is not clear that the physical science would support such an assumption, at least not for all terms for all emissions and bags. The list of terms chosen during design of the fuel matrix is a composite of all terms thought to have an effect on any of several pollutants of interest.

The recurring use of the phrase "meaningful until proven otherwise" begs a serious and questionable assertion and hides a very relevant issue. It begs the assertion that reduced models are preferable unless the Benchmark Model can be shown to only contain "meaningful" terms. This implies that reduced model fits do so. The Benchmark Model is the basis for all reduced model fits. If the Benchmark Model does not contain all possible meaningful model terms then neither do any of the reduced model fits. To the extent that relevant science and engineering knowledge is able to specify "meaningful" model terms, those terms are in the Benchmark Model. To the extent that science and engineering cannot do so, the Benchmark Model has not eliminated any of the possible ones. The same cannot be asserted for reduced model fits.

A second comment on the "meaningfulness" of the Benchmark Model terms relates to the fact that the true underlying nonlinear function of the emissions models is unknown. Each emission might be a different nonlinear function of the five fuel parameters. The forms of these functions are not known. The Benchmark Model is the closest Taylor Series approximation to those nonlinear functions that is available using this data set. Reduced models are further approximations using fewer of the Taylor Series model terms. To the extent that there is a clear delineation between the "meaningful" and "non-meaningful" model terms, the reduced model fits are entirely appropriate. The difficulty is that there is no such clear delineation using the Phase 3 data alone.

The hidden, relevant question occurs in the absence of such scientific or engineering knowledge. This cost of using the Benchmark Model is that some of the model terms might not be statistically significant. The inclusion of any such model terms increases the variability of the predictions but it does not incur bias in the predictions assuming, as is necessary in all model fits, that all the relevant terms are included in the Benchmark Model. Based on the fuel design that selected the 27 fuels and the desire to use only polynomial functions of the fuel terms in the various models, the Benchmark Model contains all the possible relevant model terms.

Reduced model fits might reduce the variability of model predictions by eliminating model terms that are not statistically significant. In doing so they risk biasing predictions if the variable selection process eliminates terms that are needed for accurate prediction of the fuel effects. Reduced model fits cannot guarantee that no bias is incurred because of the model terms selected.

These latter comments do not negate the importance of reduced model fits. On the contrary, the author routinely recommends the fitting of reduced models – but not in the modeling of the Phase 3 data.

- The difficulty with the reduced model fitting and the cause of so much concern over selecting the final reduced model fits is that these model fits have polynomial model terms. Polynomial model fits are well known to produce great difficulties when one is attempting to identify one model fit as the best according to any criteria.
- The Benchmark Model does not contain 17 distinct model terms. Of the 17 model terms, 12 are functions of the 5 fuel properties, the linear terms in the model. It is very difficult to *uniquely* characterize which of the 17 model terms best predicts each emission because the deletion of some model terms will have their predictive ability compensated for by other model terms that contain the same fuel parameters.
- The relationship between increasing EtOH and decreasing T_{50} that is shown in Fig. I.D.1 suggests that there may be some model fits where these two terms can approximately substitute for one another, rendering unique selection of one reduced model even more difficult.
- “Meaningful until proven otherwise” does not, in this case, refer to distinct model terms. It refers to which of the polynomial representations of the 5 fuel properties a scientist or engineer would choose to include. A case in point is the T_{90}^2 model term. When the original fuel matrix design was formulated, 5 fuels were to be included precisely because some program participants wished to estimate the effects of this model term (Mason, R.L. and Buckingham, J.P. (2008). “Re-Design of Fuel Matrices for EPAct Program,” Southwest Research Institute.). This desire reflects the great difficulty of knowing beforehand the exact characterization of linear, quadratic, and cross-product terms in these 5 fuel properties.

The report documents the difficulty in selecting a single reduced model fit that can be stated to be preferable to all other reduced model fits. What the above argument does is add to the relevance of the full Benchmark Model. It is far more relevant than the EPA comments permit and is not only relevant if all model terms are “meaningful until proven otherwise.”

Section V

o Section V.B. For clarity, it could be helpful to use the term “Bag” instead of “Phase”, when referring to the LA92 cycle, to avoid confusion between phases (bags) of the cycle, as opposed to Phases of the EPAct program.

No objection; changes were made.

o Section V.B. If the reduced models give very similar fits to the benchmark model, can it be argued that advantage is not gained by retaining additional terms? (Same question arises when looking at the plots illustrating effects of removing the T90-squared term—can it not be equally reasonable to exclude T90-squared?) .

This question has been answered in several ways above, notably in the response to the comments on Section IV.B.1.

o Section V.B. It is interesting to note that the model for composite NOx with the lowest Cp contains four terms, whereas the corresponding lowest-criterion models for Bags 1, 2 and 3 contained 12, 6 and 6 terms, respectively. This outcome may be an example of a situation where measurement variability or other artifacts in the results may lead to inclusion of additional terms. Such cases suggest the importance of thinking carefully about inclusion of multiple terms that may not prove to be robust or meaningful.

This comment contributes to my recommendation for using the Benchmark Model. First, the example cited relies solely on statistical methods to select the "best" model, the one with the smallest C_p value. The author has argued repeatedly that there is no single "best" model fit. Nevertheless, choice of a reduced model requires selection from among the many better model fits. Selecting the ones with the smallest C_p value is but one of many possible choices that ignores both robustness and whether the terms are "meaningful."

Second, if one desires robustness in the selection of model terms, the example used is the antithesis of robust. The Bag 1 fit contains 12 model terms with some T_{50} and some T_{90} terms, the Bag 2 fit contains only 6 terms with all T_{50} terms eliminated, and the Bag 3 fit also contains 6 model terms with all T_{90} terms eliminated. There is no robustness in the selection of the model terms either in terms of the number of terms or the specific terms selected.

Section VI

o Section VI.A, paragraph 3. The mention of influential vehicles seems to refer to analyses beyond those presented in the report, i.e., additional analysis by George Hoffman. In terms of interpretation, we suggest that it is at least as likely that the influence observed could be attributed to measurement issues with the influential vehicles per se, as to any of the vehicle or model characteristics listed.

The discussion of influential vehicles did not rely on any analyses performed by EPA staff. The author conducted numerous investigations of influential vehicle effects. Those results were not included in this report because the author does not recommend eliminating any of the influential vehicles bases on an analysis of the data in the Phase 3 data base alone. Identification of influential vehicles must be separated from determining the cause(s) of the influence. The Phase 3 data base does not include the type of information stated in this comment that might allow a cause to be identified and, subsequently, any decision on an accommodation of the influential vehicles other than inclusion in the modeling and analyses.

- ***o Section VI.B.1 (5th para). Aside from the issue of censoring, it is not clear that backwards elimination is inherently deficient in relation to comparison of multiple fits. Besides being commonly used in experimental work, backwards elimination has the advantage of allowing goodness-of-fit tests for the removal of specific parameter(s), which are not possible when comparing multiple values of criteria such as Cp or BIC.***

  The deficiencies of backward elimination relative to best subset fits are well known. This was addressed above. It is not clear to what "goodness of fit" refers since these methods are ordinarily used to assess model assumptions, not the removal of parameters from a model.

- ***o Section VI.B.1. The discussion in this section appears to show a strong preference for retaining all terms that may be meaningful, at the risk of retaining additional terms that may not be robust or meaningful. While this stance is not unreasonable, it is not clear that it is necessarily normative in relation to a stance that prefers to retain terms shown to be meaningful and robust, even at some risk of dropping terms that may be meaningful. Paragraph 5 underscores the point by making an unqualified recommendation that the benchmark models be used for prediction over any reduced model. However, it is not clear (especially to an uninitiated reader) how this recommendation squares with the previous statement in IV.A (page 19) that "it is far preferable to use scientific or engineering knowledge to select from among the better fitting models one or more model fits that are consistent with accepted knowledge …", which appears to recommend use of one or more reduced models. It would be helpful to the reader if the discussion balanced these two recommendations and clarified how they relate to each other. Finally, when models are published, it is important to note that the inclusion (or exclusion) of model terms is taken as an interpretation of the physical science, to the effect that parameters included in the model not only exist but are also meaningful and important, and vice versa for excluded parameters. In addition to the generation of predictions as such, model selection inevitably takes on an interpretive or "symbolic" role.***

  All of these comments are addressed above.

- ***o Section VI.B.2. This section could include discussion of areas for further investigation to tie this report into ongoing work to be presented in reports released by other participants in the EPAct program.***

  This work relates solely to the modeling and analysis of the Phase 3 data. To comment on how this work relates to any other work on this project or to work undertaken by other participants would be speculative on the part of the author.