Improvements in the Point Source Emissions Inventory for Georgia

Jaemeen Baek, Alper Unal, Di Tian, and Armistead Russell

Georgia Institute of Technology, School of Civil and Environmental Engineering
311 Ferst Dr, Atlanta, GA, 30341
Email: gtg700i@mail.gatech.edu

ABSTRACT

Efficient and accurate estimation of temporal and spatial variations of emission sources of pollutant precursors is essential in creating a reliable emissions inventory. To acquire the most accurate emissions, a complete survey of every major pollutant source should be implemented.

In order to improve the accuracy of the emission inventory for the state of Georgia (excluding major metropolitan cities), we developed the point source emission inventory for all non-electric generating companies which emit more than 25 tons/year of any of the six pollutants (i.e., CO, SOx, NOx, VOC, PM10 and NH_3). 1308 companies out of all companies in the EPA NEI96 (National Emission Inventory, 1996), the Title V Permit List, Toxic database, and Georgia Manufacturer's database were selected, and 79 of them participated in the survey.

Another objective of this project is to quantify errors in emission inventories. It is widely acknowledged that there are certain amount of uncertainty in emission inventories but it is not well known what type of errors and how much of errors reside in them. Thus during quality assurance and quality control (QA/QC) work, errors in emission inventories are categorized and quantified. Common errors that were found in this study include using revoked emission factors or assigning wrong source classification codes to the emission processes. Other errors were due to the limitation of the paper survey. For example, sometimes relations between emission processes and their corresponding emission estimates are unclearly defined.

Our preliminary analysis showed that there are significant differences in emissions estimates for the companies that are common with our survey and EPA's NET99 database. We also found that approximately 50 companies in our database that have significant emissions but are missing in NET99 database. In this paper, not only our methods and our findings are discussed, but also improvement of the point source inventory as compared with NET 99.

INTRODUCTION

In the state of Georgia, point sources contribute to more than 5 % of emissions of all six pollutants. They made up approximately 96 % of sulfur dioxides (SO_2), 35 % of nitrogen oxides (NO_X), 17 % of fine particulate matter ($PM_{2.5}$), 14 % of ammonia (NH_3), 7 % of coarse particulate matter (PM_{10}), 7 % of volatile organic carbons (VOCs), and 4 % of carbon monoxide emissions (CO), as given in EPA's National Emissions Trends (NET) 99 database (EPA, 2002).

It should be noted that accuracy of NET99 database for point sources has been doubted since, except Atlanta area, most of the data in EPA NET99 point source database was projected from 1980s and early 1990s (Southwick, 2004). Projection is mainly used to estimate changes in emissions based upon growth. However, changes such as adding processes, changing processes, or shutting down the plant is not taken into account. These changes might have great impact on emissions. Therefore, in order to improve the accuracy of the emission inventory for the state of Georgia, we developed a point source emission inventory for all non-electric generating companies in Georgia excluding major metropolitan cities (Atlanta, Columbus, Macon and Augusta) for the year 2000. In this study we focused on companies that emit more than 25 tons/year of any of the six pollutants (i.e., CO, SO_X, NO_X, VOCs, PM_{10} and NH_3).

Another objective of this study is to identify sources of quantify uncertainty in the point source emission inventory. Uncertainty can be defined as "a statistical term that is used to represent the degree of accuracy and precision of data" (McInnes, 2001) and can be mainly due to uncertainty in emission factors or activity data. In this study, we quantified uncertainties in the point source emission inventory, especially resulted from incompleteness of emission inventories.

METHODOLOGY

We first developed a pre-survey in order to identify companies that emit more than 25 tons/year for any of the six pollutants. Those companies filtered in pre-survey participated in the main survey. Microsoft Access was used to develop a database from the survey results. In the next step we did a Quality Assurance/Quality Check (QA/QC) to the database In the cases where errors were identified in survey forms we submitted complementary surveys. It should be noted that Data Input, QA/QC, and Complementary Surveys were iterated until we were confident about the quality of the data. Figure 1 summarizes the overall methodology followed in this study.

Pre-survey

In identifying major point sources, the Title V Permit List; Toxic database; and Georgia Manufacturer's database were utilized, in addition to the prior EPA NEI96 inventory. All of the companies in Title V permit list and Toxics database were included in the survey. Companies in Manufacturer's database were screened by number of employees and type of industrial sectors. This effort provided 1308 companies to be surveyed. Out of 1308 companies, 100 of them that responded to our survey had emissions greater than 25 tons/year of the listed pollutants.

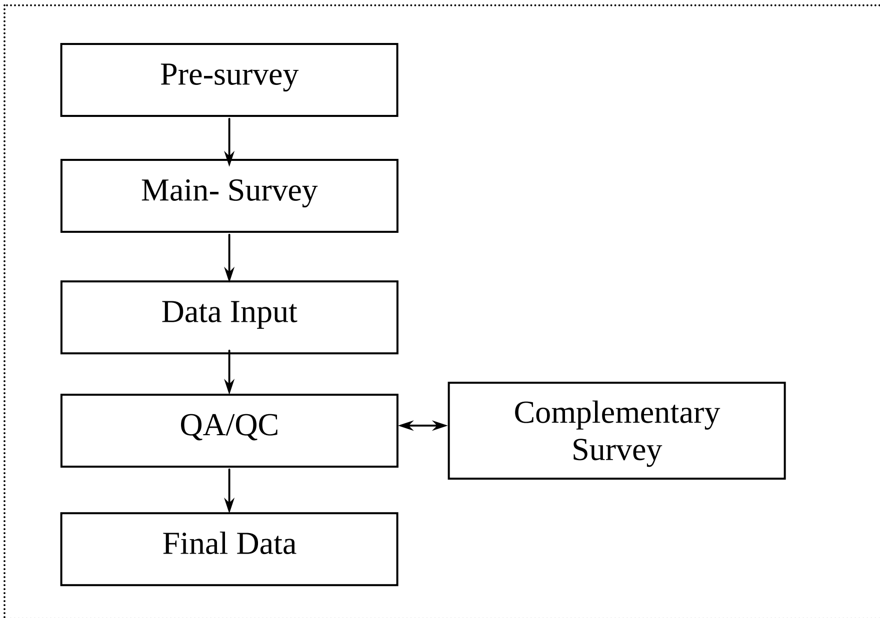


Figure 1. The overall process of the study.

Main Survey

Survey forms for plants with emission larger than 25 ton/year include both plant general information and detailed information for emission estimates such as fuel burning process information, and miscellaneous process information. Forms used in this survey can be found elsewhere (FAQS, 2004).

Data input

Data in survey forms were entered into Microsoft Access tables using data input program which was developed using Visual Basic for Applications (VBA). Objectives of data input program are: 1) to provide easy-to-use graphical user interface (GUI) to reduce errors during data entering, 2) to provide easy access to National emissions inventory Input Format (NIF) codes to reduce working time and to maintain consistency, 3) to check relations between tables (e.g., county FIPs, site ID, unit ID and process ID among general facility information, fuel burning process information and emission estimates information), and 4) to check range of input data based on EPA quality assurance guidelines for NIF (EPA, 1999).

GUI input is prepared such that it resembles survey forms, so that users can easily match the paper form with GUI. Figure 2a shows the GUI to enter general facility information and Figure2b shows the report generated by the program to check completeness of survey data. This report lists all emission processes in a company, stacks and control devices connected to those processes, validity of SCC and existence of emission estimates. Also users can access codes defined for NIF version 2.0, such as control device codes, emission calculation method codes, fuel type codes, pollutant codes, and unit codes. By using codes during data entering, we can maintain consistency with NIF codes and also reduce unnecessary effort for converting general notions to codes.

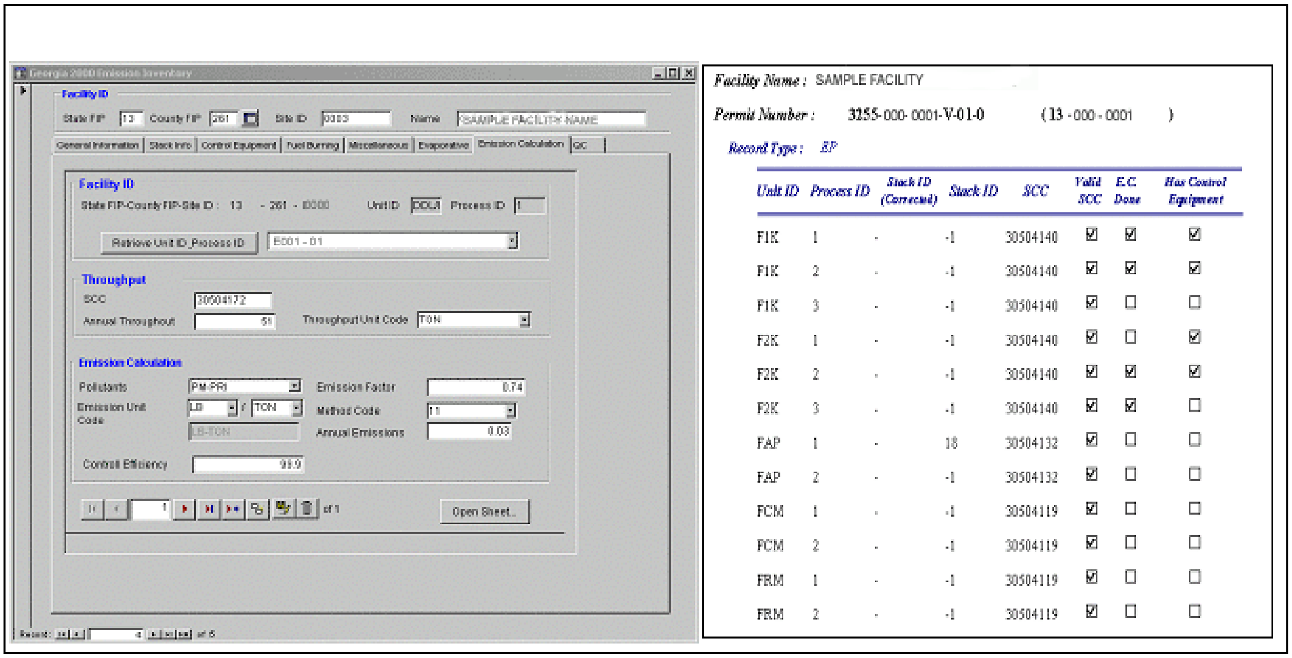


Figure 2. (a) GUI of the data input program (b) Report generated to check completeness of surveyed data

In order to keep all information which is needed to calculate emissions, new tables that correspond to tables in NIF version 2.0 are used for data entering and for QA/QC. Primary key and foreign key function in Microsoft Access© are used to maintain identification of emission processes and relationships between tables. Also, to limit the range of input data, validation rules is defined.

QA/QC

QA/QC is an essential part of this study developed not only to check quality of data but also to analyze and quantify errors in surveyed data for further uncertainty analysis. Criteria for QA/QC are as follows:

- Criteria for fuel burning/miscellaneous/evaporative processes:
  - ✓ Every emission unit and process should have related stack information.
  - ✓ Every emission unit and process should have emission estimates.
  - ✓ Every emission unit and process should have suitable source classification code (SCC)

- ✓ Material used for emission unit and process should match with material assigned to SCC
- ✓ Same data reported in different tables should be same (Table 1 lists items which are reported more than one table in survey).

- QA/QC criteria for stack information:
  - ✓ All parameter should have been reported
  - ✓ Ranges of stack parameters should match with QA guidance by EPA

- For emission calculations:
  - ✓ If companies report they use EPA emission factor method to estimate emissions, the values of emission factors should be same as those in EPA FIRE version 6.23 (EPA, 1999).
  - ✓ Units of emission factors and units of yearly throughput should be same
  - ✓ Result of emission values should be same as values calculated using reported emission factors and throughputs

Table 1. Items common in more than one table

Items	Table in survey form
Yearly throughput	Fuel burning process
	Miscellaneous process
	Emission calculation
VOC emissions and uncontrolled VOC	Evaporative process
	Emission calculation
Control efficiency	Control equipment
	Emission calculation
Emission process and connected release point ID	Fuel burning process
	Stack information

Any record that fails to satisfy these criteria is corrected, and some of corrected data are reported to companies to confirm correction. In addition to the QA/QC inherent in the data input program, a separate QA/QC program was developed. This program was developed to automatically check QA/QC criteria and to provide GUI which users can review all tables and records. Table 2 summarizes the main components and their functions in QA/QC program. Figure 3a presents the GUI of QA/QC program to check fuel burning processes and Figure 3b shows an example report created by QA/QC program for complementary survey.

Table 2. Components of the QA/QC program and functions

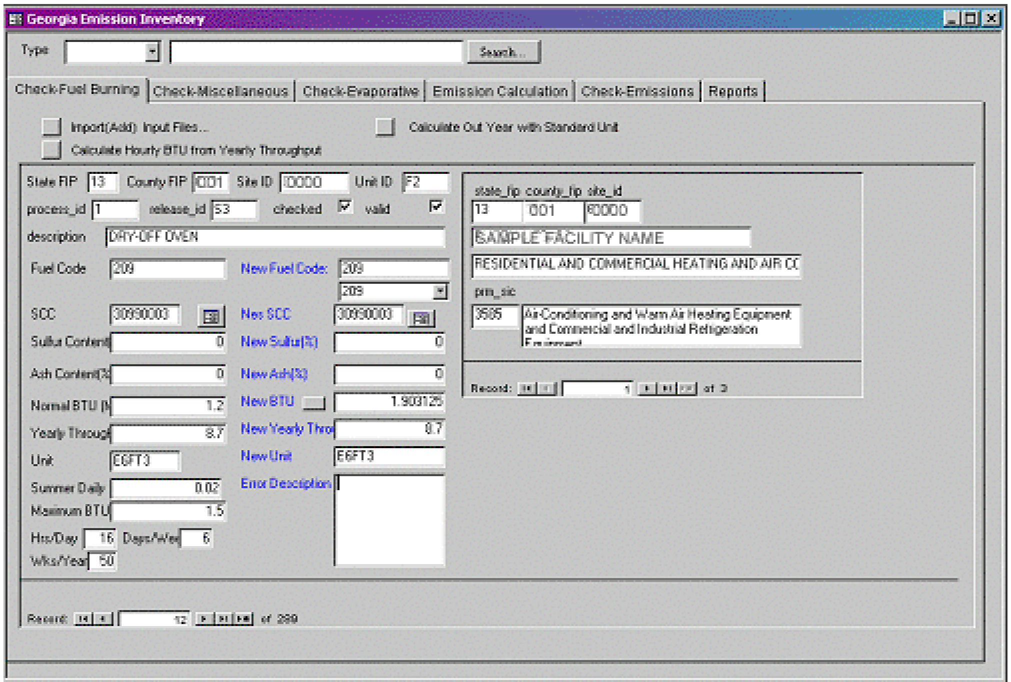
Components	Main functions
Fuel burning process	• Calculate normal BTU using fuel consumptions and operation time • Check SCC
Miscellaneous process	• Check SCC
Evaporative process	• Calculate VOC emissions based on material balance
Preparation for emission calculation	• Add emission estimates for emission processes which don't have reported emission calculation • Calculate emissions using emission factors in FIRE version 6.23 • Assign control efficiencies from control equipments • Assign yearly throughputs from fuel burning processes
Emission calculation	• Check emission calculation record one by one • Check miscalculation • Assign error code and error description if needed
Reports	• Check relations between tables • Create reports for complimentary survey
Export to NIF	• Convert internal tables to NIF tables • Convert NIF tables to IDA format

Complementary survey

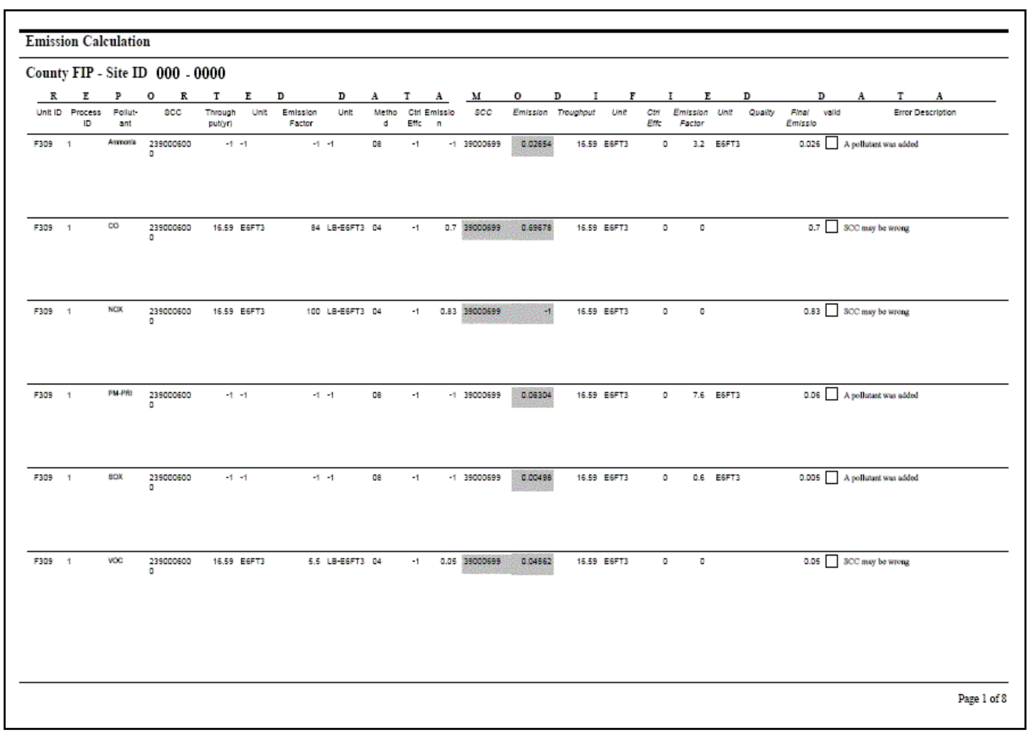
The purpose of complementary survey is: 1) to supplement missing information in survey form; 2) to confirm the corrections made during QA/QC are necessary or not; and 3) to let companies be aware of errors in their survey forms, so that they can improve it.

Complementary survey lists all information related with possible errors and comments on errors thus companies can re-check information and add comments on comments. Most of the complementary surveys were for gathering more information on stacks and correcting errors in emission calculations.

(a)



(b)



Emission Calculation

County FIP - Site ID 000 - 0000

REPORTED DATA											MODIFIED DATA										
Unit ID	Process ID	Pollut-ant	SCC	Throughput(yr)	Unit	Emission Factor	Unit	Method	Ctrl Effc	Emission	SCC	Emission	Troughput	Unit	Ctrl Effc	Emission Factor	Unit	Quality	Final Emissio	valid	Error Description
F309	1	Ammonia	2390006000	-1	-1	-1	-1	08	-1	-1	39000699	0.02654	16.59	E6FT3	0	3.2	E6FT3		0.026	☐	A pollutant was added
F309	1	CO	2390006000	16.59	E6FT3	84	LB-E6FT3	04	-1	0.7	39000699	0.69678	16.59	E6FT3	0	0			0.7	☐	SCC may be wrong
F309	1	NOX	2390006000	16.59	E6FT3	100	LB-E6FT3	04	-1	0.83	39000699	-1	16.59	E6FT3	0	0			0.83	☐	SCC may be wrong
F309	1	PM-PRI	2390006000	-1	-1	-1	-1	08	-1	-1	39000699	0.06304	16.59	E6FT3	0	7.6	E6FT3		0.06	☐	A pollutant was added
F309	1	SOX	2390006000	-1	-1	-1	-1	08	-1	-1	39000699	0.00498	16.59	E6FT3	0	0.6	E6FT3		0.005	☐	A pollutant was added
F309	1	VOC	2390006000	16.59	E6FT3	5.5	LB-E6FT3	04	-1	0.05	39000699	0.04562	16.59	E6FT3	0	0			0.05	☐	SCC may be wrong

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Figure 3. (a) GUI of QA/QC program (b) Example report for complementary survey

RESULTS

In this section we will summarize the results of this study and present findings from data analysis. We first present responses to our survey and then present findings from QA/QC. Later we give quantitative summary of our study as well as comparison to NET99 database.

Responses to the Survey

Table 3 shows the responses to pre-, main-, and complementary surveys. For the pre-survey, we sent forms to 1308 companies and received about 300 replies, approximately 23 percent. Out of these 300 companies, 79 of them reported that they emit more than 25 tons per year. We submitted 54 complimentary surveys which had a response percent of 55 percent.

Table 3. Results of the paper survey and the complementary survey

	Forms Sent to companies	Replies (%)
Pre-survey	1300	300 (23%)
Survey	300	79 (26 %)
Complementary survey	54	30 (55%)

QA/QC

In QA/QC we identified 12 categories for possible error for emissions estimation. Table 4 shows type, description, and number of records for each error category. Code "00" and code "09" indicate that there is no error in emission calculation. Code "09" indicates that emission calculation comes from evaporative process information using material balance. As seen in Table 4, 71% of emission calculations were correct.

As seen in Table 4, the most frequent errors were the ones where there were no corresponding emission estimates for emission processes (8.6%, code 07). Next highest number of errors occurred for the cases where emission estimates for some of the pollutants were missing (7.9%, code 08).

Frequencies of errors for each of the pollutants were found to be different. Table 5 shows the frequency of error types for different pollutants. In case of NH_3 it should be noted that most of the companies didn't report ammonia emissions since ammonia estimates had not been included in emission inventories before.

One of the interesting finding is that the third most frequent error in CO, NO_X, PM_{10} and VOC is "Using revoked emission factors", error code 01. It's because some companies used the previous emission factors while emission factors for LPG boilers and diesel boilers were changed in 1998. And errors due to reporting one combined emission estimate for more than two emission processes (error code 11) contribute more than 10% for CO, NO_X and SO_X. Sometimes this type of error is inevitable because companies cannot separately measure emissions from every emission units, especially when emission units are small.

Table 4. Error types and frequency of errors

	Code	Description	Counts (%)
Not Errors	00	No error	2,235 (55.0%)
	09	Emission estimate is calculated using evaporative processes information by material balance	653 (16%)
	Total		71.0%
Errors	01	Revoked emission factors are used	236 (5.8%)
	02	Units of emission factors don't match with units of activity	21 (0.5%)
	03	Units of yearly throughput is wrong	
	04	Typo in survey form	13 (0.3%)
	05	Miscalculation in emission estimates	18 (0.4%)
	06	Value of emission factor is wrong	12 (0.3%)
	07	Emission process doesn't have corresponding emission estimates	346 (8.5%)
	08	Emission process have corresponding emission estimates, but some pollutants are missing	324 (7.9%)
	10	Typo or omission during data entering	
	11	Emissions from more than two emission processes are reported as one record	144 (3.6%)
	12	Wrong SCC is assigned to emission process	61 (1.5%)
	Total		4063

Table 5. Number of records grouped by error types

Error codes	NH_3	CO	NO_X	PM_{10}	SO_X	VOC	Total
01	-	68 (33.7%)	24 (15.4%)	71 (30.0%)	-	73 (33.3%)	236 (20.1%)
02	1 (0.4%)		5 (3.2%)	4 (1.7%)	5 (4.1%)	6 (2.7%)	21 (19.8%)
04	-	1 (0.5%)		6 (2.5%)	1 (0.8%)	5 (2.3%)	13 (1.1%)
05	-	4 (2.0%)	2 (1.3%)	7 (3.0%)	1 (0.8%)	1 (0.5%)	15 (1.3%)
06	-	1 (0.5%)	6 (3.9%)	2 (0.8%)	2 (1.6%)	1 (0.5%)	12 (1.0%)
07	41 (17.2%)	54 (26.7%)	66 (42.3%)	82 (34.6%)	42 (34.1%)	64 (29.2%)	349 (29.7%)
08	185 (77.7%)	36 (17.8%)	10 (6.4%)	32 (13.5%)	41 (33.3%)	20 (9.1%)	324 (27.6%)
11	6 (2.5%)	22 (10.9%)	27 (17.3%)	28 (11.8%)	25 (20.3%)	36 (16.4%)	144 (12.3%)
12	5 (2.1%)	16 (7.9%)	16 (10.3%)	5 (2.1%)	6 (4.9%)	13 (5.9%)	61 (5.2%)
No. of records with errors	238	202	156	237	123	219	1175
No. of total records	254	403	490	1053	411	1452	4063

After identifying the sources of errors we corrected them through complimentary surveys as explained in methodology section. Table 6 presents the changes of emission estimates due to these corrections. The biggest change occurred for NH_3 and CO, 12.7 and 12.6 percent respectively, whereas the smallest change occurred for SO_X, with 0.1 percent.

Table 6. Changes of emissions due to corrections (ton/year)

Error Codes	NH_3	CO	NO_X	PM_{10}	SO_X	VOC
01	-	11.9	-9.7	0.4	-	-0.1
05	-	-3.7	-2.5	-0.6	-0.1	-238.3
06	-	0.0	0.0	0.0	0.3	0.0
07	4.4	317.3	879.6	67.2	5.1	525.5
08	41.0	1,661.7	190.3	7.8	9.9	9.9
11	0.7	3.3	-10.7	1.8	0.0	-72.0
12	4.3	20.7	-32.8	0.0	0.0	0.0
Grand total (ton/yr)	50.4	2,011.1	1,014.3	76.6	15.2	229.1
Changes (% of original surveyed data) after correction	12.7%	12.6%	4.4%	1.1%	0.1%	2.2%

It was found from QA/QC study that in order to reduce errors, it is important to communicate with companies and let them know about the possible areas of errors. For example, using revoked emission factors or wrong emission factor values, miscalculations, and typos should be reported to companies so they can fix their emission inventories. One of the best ways of avoiding errors is to develop software that includes all data input and QA/QC functions, so that companies can fill out the forms and check errors by themselves.

Summary of Survey Results and Comparison to NET99

From our corrected survey results it is found that point sources emit approximately 24,000 tons of nitrogen oxides, 20,000 tons of sulfur dioxides, 18,000 tons of carbon monoxide, 10,000 tons of VOC and 7,000 tons of particulate matter per year as shown in Table 7. Total emissions with respect to different source categories as well as percent contributions, as given with SCC level 1, are also given in Table 7. Biggest contribution to CO emissions comes from external combustion boilers. This is also true for SO_X. For NH_3, PM_{10}, and VOC biggest contribution is from industrial processes. For NO_X biggest contributor is internal combustion engines.

Contributions of SCC level 1 groups are compared with those in NET99. Table 8 shows contributions of SCC level 1 groups to emissions from non-EGU devices in NET99. Industrial processes are the major sources for CO, NH_3, VOC, and PM_{10}, whereas external combustion boilers are for NO_X and SO_2. The biggest difference between these values and our survey findings is in CO and NO_X. It should be noted that industrial processes is also significant contributor in our survey for CO (i.e., 34 percent), as seen in Table 7. Also contribution of external combustion boilers to NO_X emissions is significant in our survey as well (i.e., 33 percent). Differences between Table 7 and 8 might be due to dissimilarity in companies covered in both inventories and/or incompleteness.

Table 7. Total emissions grouped by SCC level 1 (tons/year)

SCC level1	CO	NH_3	NO_X	PM_{10}	SO_X	VOC
External Combustion Boilers	10,454 (58%)	22 (5%)	7,902 (33%)	1,562 (23%)	12,115 (58%)	1,011 (10%)
Internal Combustion Engines	1,280 (7%)	9 (2%)	12,302 (51%)	119 (2%)	2,862 (14%)	1,357 (13%)
Industrial Processes	6,179 (34%)	416 (93%)	3,969 (16%)	5,111 (74%)	6,018 (29%)	7,151 (70%)
Petroleum and Solvent Evaporation	2.3 (1%)	-	3 (0%)	2 (0%)	0.0	754 (7%)
Waste Disposal	-	-	-	94 (1%)	-	-
Total	17,915	447	24,176	6,888	20,995	10,264

Table 8. NET99 point source emissions from non-EGU equipments grouped by SCC level 1 (tons/year)

SCC level 1	CO	NH_3	NO_X	PM_{10}	SO_X	VOC
External Combustion Boilers	23,410 (14%)	226 (2%)	40,069 (58%)	12,849 (28%)	48,117 (58%)	7,198 (21%)
Internal Combustion Engines	844 (1%)	0 (0%)	8,848 (13%)	0 (0%)	0 (0%)	285 (1%)
Industrial Processes	146,195 (85%)	15,575 (98%)	19,712 (29%)	33,280 (72%)	34,809 (42%)	15,185 (43%)
Petroleum and Solvent Evaporation	19 (0%)	0 (0%)	78 (0%)	0 (0%)	38 (0%)	12,323 (35%)
Waste Disposal	313 (0.2%)	0 (0%)	110 (0%)	9 (0%)	8 (0%)	165 (0%)
Total	170,982	15,802	68,820	46,139	82,974	35,160

In order to identify differences in the 2000 emission inventory and NET99, we made a detailed comparison. For this comparison we identified common companies in both NET99 and our survey database. It should be noted that there might be differences between two emission inventories due to different base years, but we assumed that difference due to errors in emission inventories are much greater than difference due to different base years. It is found that out of 79 companies in the 2000 emission inventory and 339 companies in NET99, 30 companies are common in both databases. Table 9 shows the changes in emissions of 30 common companies for both inventories.

As seen in Table 9, biggest difference occurred for CO, PM_{10}, NH_3, and SO_2. Change in NH_3 is very big since in NET99 NH_3 emissions are very small, which might be due to the fact that

NH_3 emissions were not reported in earlier emissions inventories.

Table 9. Changes of emissions in 30 common companies. (ton/year)

	CO	NH_3	NO_X	PM_{10}	SO_2	VOC
Emissions of common companies in 2000 survey	15,304	439	18,460	3,470	18,265	6,680
Emissions of common companies in NET99	61,587	48	20,564	6,928	27,921	5,936
Changes (2000 survey – NET99)	-46,265	392	-2,082	-3,450	-9,652	809
Changes (%) to NET99 emissions	-75%	816%	-10%	-50%	-35%	13%

Figure 4 presents a cumulative probability plot for change in emissions between our survey and NET99 for different pollutants. Each of the points in the graphs represents common companies between NET99 and our survey. For all of the pollutants, except NH_3 and VOC, 60 percent of the companies have differences less than zero, indicating that NET99 emissions for these companies are larger. Another important finding is that for NO_X, NH_3, CO, and VOC for some companies differences are more than 200 percent. In theses case our survey emission estimate is more than two times higher than NET99's estimates.

Changes of emissions are mainly due to poor accuracy of NET99. As stated earlier, most of emission estimates in EPA NET99 for point sources are projected data based on 1990's or 1980's emissions except that companies located in Atlanta in NET99 database which have been updated based on a 1999 emission inventory surveyed by Georgia EPD in 2002 (Southwick, 2004).

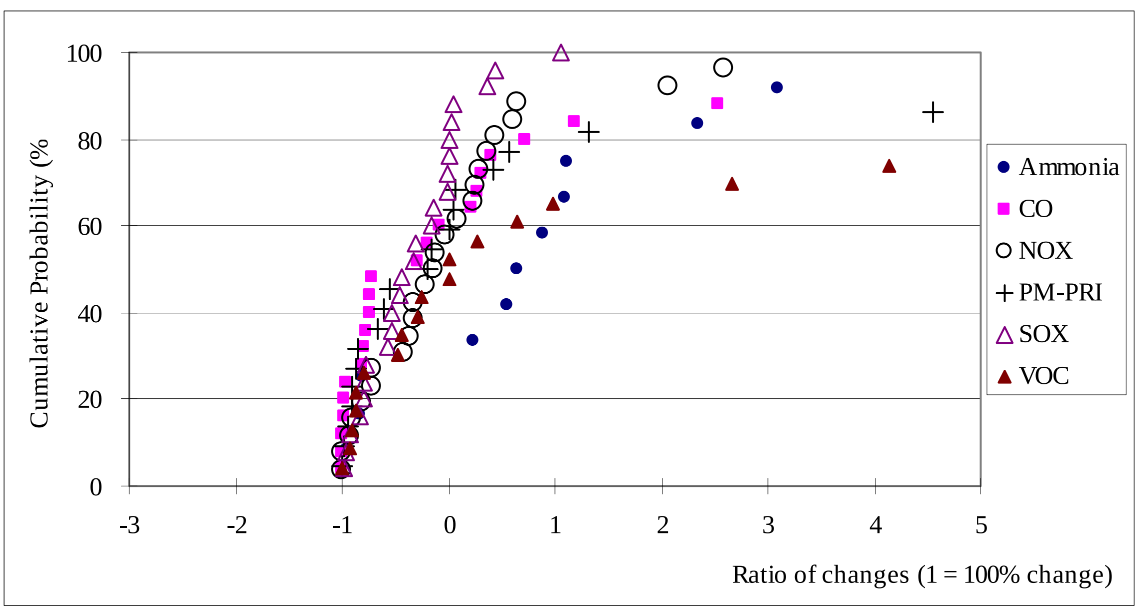

Figure 4. Cumulative probability distribution of ratios of changes in emissions

In our survey we have 49 companies which do not exist in NET99 database. Table 10 presents emissions for these 49 companies as well as overall emissions from our survey.

Table 10. Increase of emissions by new companies

	NH_3	CO	NO_X	PM10	SO_X	VOC
Emissions from 30 common companies	439	15,304	18,460	3,470	18,265	6,680
Emissions from rest of the 49 companies	8	2,610	5,716	3,419	2,731	3,584
Total emissions	447	17,915	24,176	6,888	20,996	10,264

CONCLUSIONS AND DISCUSSIONS

Efficient and accurate estimation of temporal and spatial variations of emission sources of pollutant precursors is essential in creating a reliable emissions inventory. To acquire the most accurate emissions, a complete survey of every major pollutant source should be implemented. In this study, in order to improve the accuracy of the emission inventory for the state of Georgia (excluding major metropolitan cities), we developed the point source emission inventory for all non-electric generating companies which emit more than 25 tons/year of any of the six pollutants (i.e., CO, SOx, NOx, VOC, PM_{10} and NH_3). Out of 1300 companies 300 of them fell in this category. And of these 300, 79 of them replied to our survey.

We developed software that allowed us to input data into Microsoft Access database as well as enabled us to do QA/QC on the database. Most frequent errors that were found in QA/QC include using revoked emission factors and reporting combined emission estimate for more than two emission processes. It is found that percent change in emissions after correction ranges from 0.1 percent, for SO_X, to13 percent, for NH_3 and CO.

Comparison of our emissions to NET99 showed that for the same companies NET99 overestimated CO more than four times. For NO_X, PM_{10}, and SO_X this number is between 1.1 and 2.0. For VOC NET99 underestimated by 1.1 times and it underestimated NH_3 by 9 times. Another important finding is the fact that 49 companies that are included in this study do not exist in NET99. Total emissions from these 49 companies made up approximately 2,600 tons of CO, 5,700 tons of NO_X, 3,400 tons of PM_{10}, 2,700 tons of SO_X, 3,500 tons of VOC, and 8 tons of NH_3 emissions per year. These two findings indicate that NET99 point source inventory for non-egu companies in the state of Georgia (excluding major metropolitan cities) have significant errors. This study successfully identified some of the sources of this uncertainty and developed accurate emissions database.

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KEYWORDS
Point source emission inventory, uncertainty, NET99