

Crustal Matter

Exploring the differences between ambient air data and emissions inventory

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Abstract

Fine particulate matter (PM fine) is a complex mixture of tiny particles in the air. PM_{2.5} consists of particles that measure 2.5 micrometers in diameter or less, and is composed of sulfates, metals, crustal matter, and other elements. Crustal Matter, our component of interest, is simply fugitive dust originating from the earth's crust. National emissions inventory (NEI) has been using 31.4% to describe the ratio of crustal matter to total PM_{2.5}, while ambient air samples suggest a lower ratio. This study is being conducted to better understand this discrepancy, as well as improve the accuracy of the current ratio so that it more closely agrees with ambient air samples, which may lead to an improvement in the air quality management process. It is critical to explore this discrepancy so that US EPA and other environmental agencies take necessary action to use the most accurate ratio. Various statistical methods are being used in order to manipulate and understand the supplied data. Resulting from this statistical analysis, we have learned the various complexities of the ratio, such as varying ratio value across the United States, lower ratios being present in the east, and higher ratios in the west. Therefore, we have recommended different values of the ratio to be used for different parts of the nation.

Executive Summary

This study focuses on identifying and understanding the factors associated with the discrepancy in the ratio of crustal matter to total fine particulate matter between emissions inventory that uses a value of 31.4%, and ambient air data which suggests much lower values, specifics depending upon location. Our analysis provides suggestions on what ratio the Environmental Protection Agency should be using based upon EPA Regions according to our analysis of the ambient air data.

Introduction/Background

Fine particulate matter (PM_{2.5}) is a complex mixture of tiny particles of solids and liquids suspended in the air. PM_{2.5} consists of particles that measure 2.5 micrometers in diameter or less, and is composed of sulfates, metals, soil (crustal matter) or dust particles, and other elements. The component of interest, crustal matter, is nothing more than fugitive dust/soil that originates from the earth's crust. This consists of unpaved roads, agricultural tilling, construction, etc. The main source of PM_{2.5} comes from the combustion or burning of fuels via power plants, industries, and motor vehicles. Scientific studies have identified the following health problems to be associated with high exposure to PM_{2.5}: aggravated asthma, chronic bronchitis, and even premature death. A discrepancy has been identified with the ratio of crustal matter to fine particulate matter between ambient air samples and National Emissions Inventory (NEI) estimates. It is critical to better understand this discrepancy so that U.S Environmental Protection Agency, along with state and local environmental agencies, will take necessary action to use the most accurate ratio. The NEI has been using 31.4% to describe the ratio of crustal matter to total PM_{2.5}, while ambient air samples suggest a much lower ratio. Ambient air samples are taken from Speciation Trends Network (STN) sites and Interagency Monitoring for Protected Visual Environments (IMPROVE) sites.

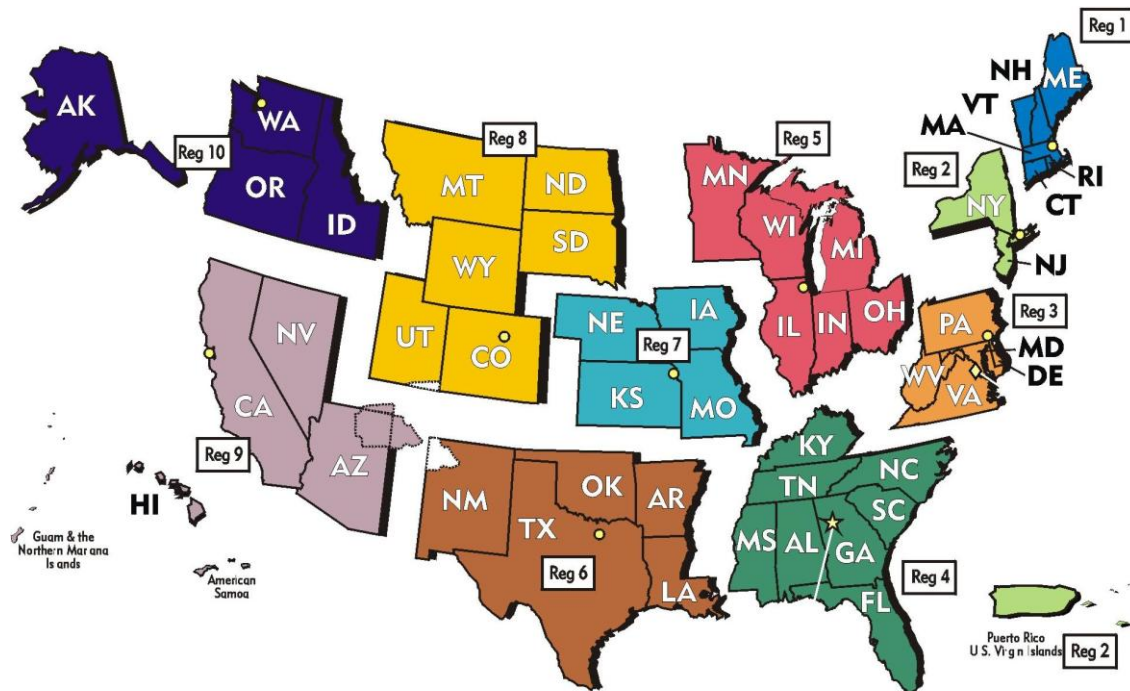
Objectives

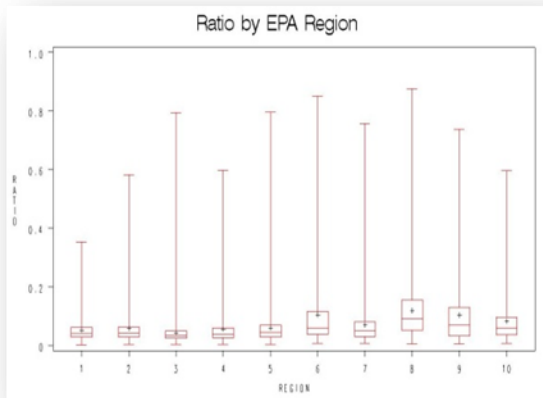
This study is being conducted to better understand the discrepancy between emissions inventory estimates and actual measurements from ambient air samples, as well as improve the accuracy of the current ratio being used.

Emission inventories are based upon engineering estimates, while ambient air measurements represent what is measured in the air. The ambient measurements are supported with a rigorous quality assurance program, so they are identified as the "truth."

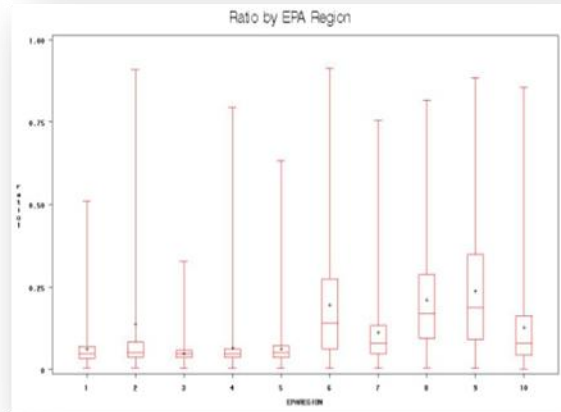
Methods and Analysis

Previously it has been discovered that higher ratios exist in the southern U.S. versus the north, and in the west compared to the east. The map below allows you to see the 10 specific EPA regions that make up the United States; pictured beneath the map are the box plots that show approximately what the ratios look like for each of the ten regions. As shown, the highest ratios appear to be in regions six through ten, all located west of the Mississippi River. With these western states, it can be seen that the ratios in the IMPROVE data are significantly higher than in the STN data. One possible factor contributing to this difference could be the greater amount of vegetation in the eastern United States.



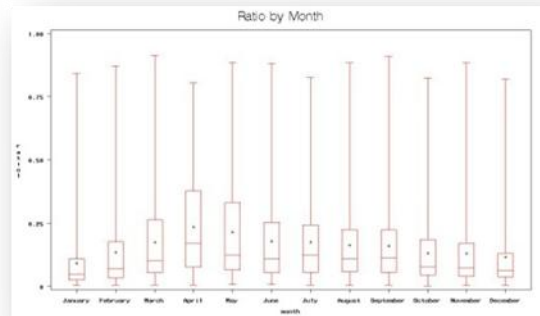
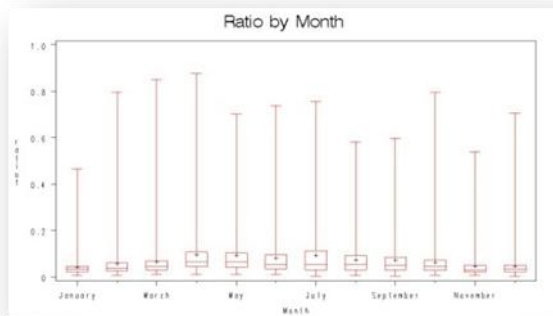


STN Data



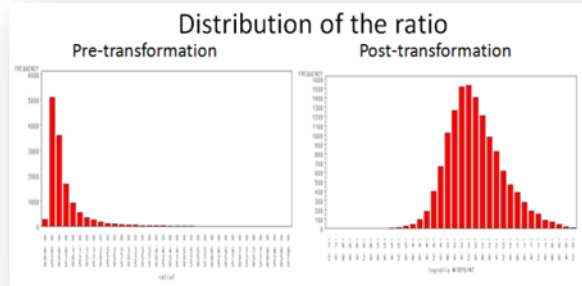
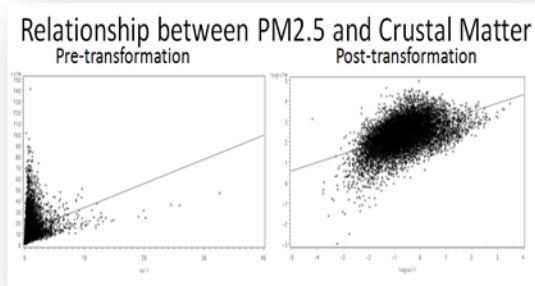
IMPROVE Data

Sequential box plots show ratios expressed by month; it can be seen that higher ratios occur in the spring and summer months as opposed to the fall and winter months. With the STN data (pictured on the left) the highest peaks occur in April and July; however, with the IMPROVE data (pictured on the right) only one peak (in April) is visible.

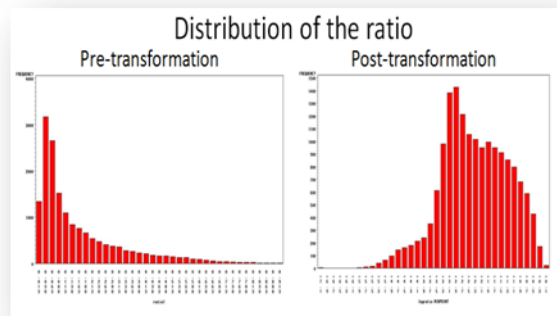
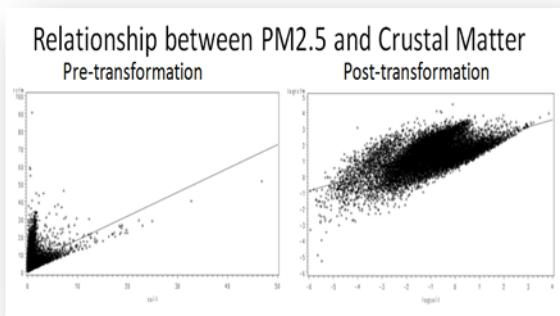


Current work being conducted shows that taking the natural logarithm of: the crustal matter, the PM2.5 measurements, as well as the ratio, normalizes the variable's distributions and allows assumptions associated with regression to be met. There is also a strong linear relationship between the log of PM2.5 and the log of crustal matter. Current models using some meteorology variables such as precipitation and wind speed explain 25% of the STN data, and 30% of the IMPROVE data. We are furthering this analysis by incorporating additional

meteorology and harvest data into models with the transformed data. The transformations as described can be seen below, first for the STN data, and again for the IMPROVE data. We have found these two networks to have remarkably similar patterns.

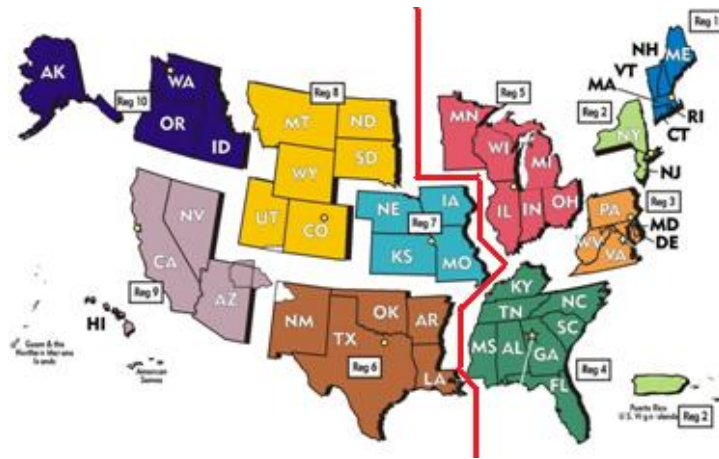


STN Data



IMPROVE Data

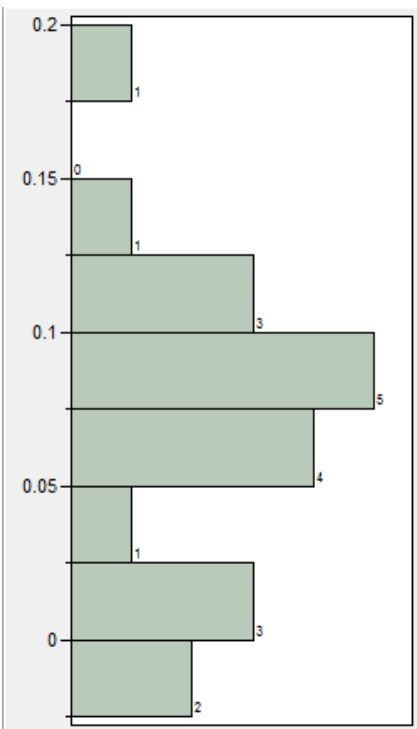
In addition, we have found that larger differences in the mean values of ratios exist between STN and IMPROVE data in the west, whereas in the east STN and IMPROVE ratios are fairly consistent. This conclusion was reached by taking the yearly mean values of ratios in both data sets on a state by state basis and subtracting the STN value from the IMPROVE value. Because not every state has both STN and IMPROVE data, this computation was only done for the forty two states that reside in both data sets. We found differences in the west to range from -0.025 to 0.2, and differences in the east only range from -0.0125 to 0.025 (as seen below); these findings suggest that IMPROVE measurements are higher than STN measurements in the west. Observing a difference of zero, as nearly obtained in the east, suggests overall consistencies between STN and IMPROVE measurements.



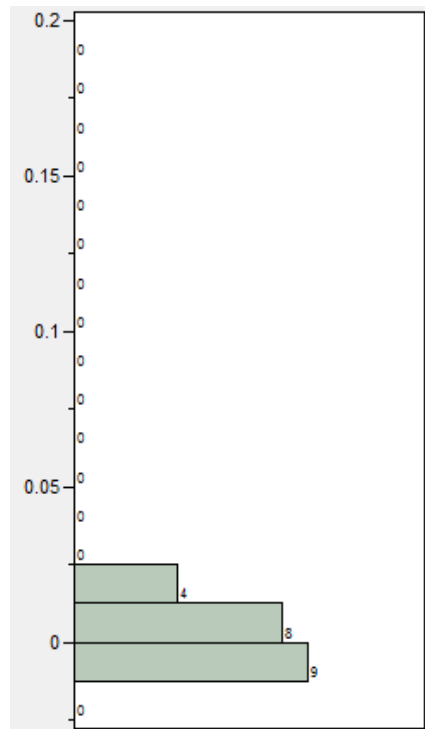
States in the "West"
 These include EPA regions 6-10

States in the "East"
 These include EPA regions 1-5

Site Comparisons: State by State
 Differences in STN and IMPROVE measurements



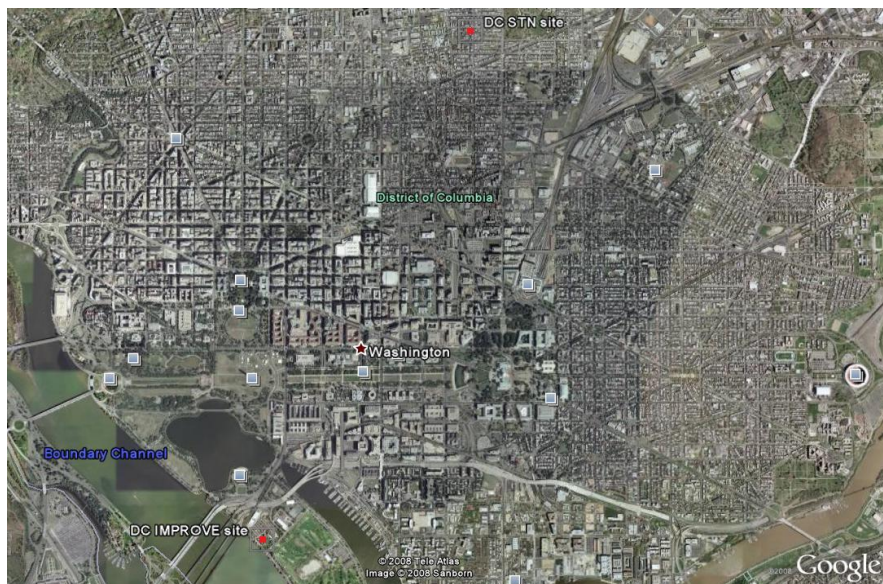
West



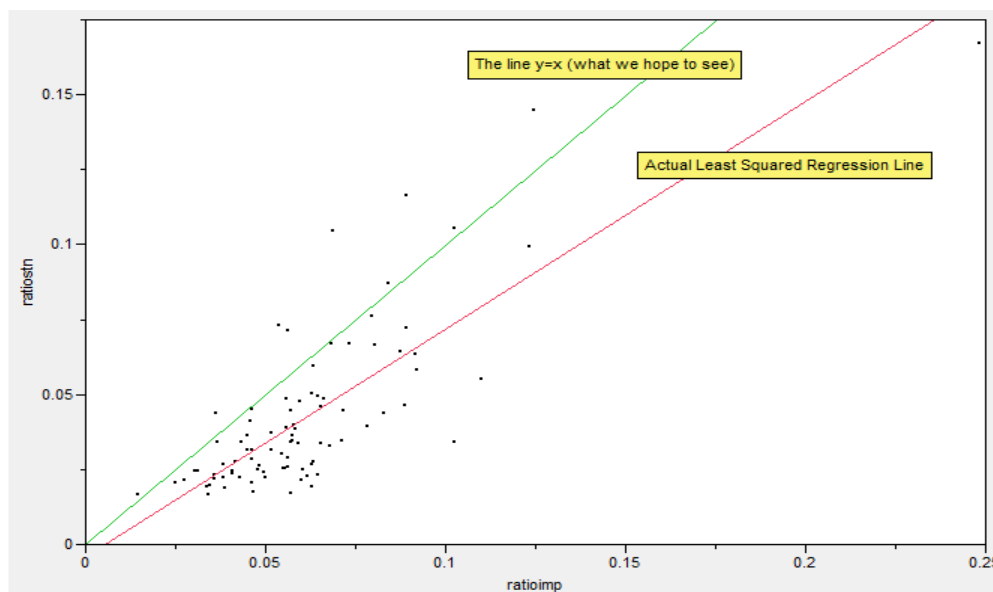
East

Furthermore, if STN and IMPROVE sites were collocated one would hope to find a difference of zero between the daily mean ratios, suggesting the measuring techniques to be practically identical, thus verifying the

accuracy of the collected STN and IMPROVE data. As a preliminary analysis, we examined the STN and IMPROVE sites in Washington, D.C (a Google earth image of DC, pinpointing the location of the two sites in red can be seen below). Although the sites are not collocated, they are less than four miles apart.



By plotting the daily ratio from the STN site versus the daily ratio from the IMPROVE site we obtained the following graph.



Ideally, if these sites were collocated, one would see a one to one correspondence (as illustrated by the green line). However, the least squares regression line (in red) shows that we do not quite obtain the one to one

correspondence. The slope of this regression line entails slightly higher measurements from the IMPROVE site; conversely, the resulting R-value of approximately 0.80 suggests they are highly correlated. A continuation of this analysis is ongoing and we hope to compare more IMPROVE and STN sites that are even closer.

Conclusions and Recommendations

According to our current analysis of the data, we believe there is sufficient evidence to conclude that the current ratio of 31.4% in use by Emissions Inventory is not accurate enough to be used to describe the nation’s entirety. Due to the high variability of the ratio based upon location, we suggest that different parts of the nation use different ratios. After taking into consideration both the mean and median, our current recommendations are as follows: EPA regions one through five use a default value of approximately five percent due to the fact that these regions do not differ greatly between rural (IMPROVE) and urban (STN) areas, and regions six through ten should use the approximated values found in the table below. Further analysis will hopefully provide more detailed suggestions for the U.S. Environmental Protection Agency.

Recommended Ratio Values		
EPA REGION	RURAL AREAS	URBAN AREAS
1-5	5%	5%
6	15%	8%
7	9%	6%
8	19%	11%
9	20%	8%
10	10%	7%

Acknowledgements

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