Section 1. Introduction

This document presents a proposal for enhancing the continuous particulate matter monitoring in the air monitoring networks operated by State and local agencies and tribal governments. The document addresses a range of topics including recommended performance requirements, regulatory modifications, and identification of outstanding technical issues and actions to be taken in the near future.

EPA is working with the Clean Air Science Advisory Committee (CASAC) technical subcommittee on particle monitoring; State and local agencies and tribal governments; and consortiums of State and local agencies on a strategy to enhance deployment and utility of continuous fine particulate mass monitors. This document is an important step in this cooperative effort as it provides a basis for comment on our intended approaches. Clearly, a substantial subsequent guidance development effort will be required to implement the directions in this proposal. Comments are welcome from all interested stakeholders on this document as well as the national air monitoring strategy it is intended to support.

The reader should be aware that the concepts and elements incorporated in this plan are singularly and collectively complex therefore creating a communications challenge. Other approaches were considered, but the potential drawbacks of a simplistic approach were not acceptable. That is, it would have been easy to develop a rigorous non-flexible program easily communicable but conveying little motivation for deployment. Similarly, a program without constraints would likely compromise data quality and interpretability. Thus, a decision was made to accommodate both flexibility and data comparability at the expense of developing and communicating a complex program.

The development of “acceptable” relationships between a Federal Reference Method (FRM) measurements and continuous monitors is stressed throughout this document. The reason for this is that so many objectives relate to the FRM measurement (e.g., NAAQS comparisons, air quality index reporting, air quality model application). In many instances, there is no technical reason to expect comparability between disparate measurement approaches. Such comparability is desired given the utility of relating continuous measurements to a wealth of existing FRM data and to incorporate a reference marker. The downside of this approach is that the value of an FRM measurement is assumed or inferred to be greater than that of a candidate method, when in some cases the candidate method may better reflect “true” characteristics of an aerosol. This topic is addressed in more detail in Section 7.

Background

EPA is motivated to develop the continuous monitoring program by the need to improve public data reporting and mapping, support air pollution studies more fully by providing continuous (i.e., hourly) particulate measurements, and to decrease the resource requirements of operating a large network of filter-based particulate samplers. This document also addresses an important gap in technical guidance for the continuous particulate matter program, created in part by a strong emphasis to date on compliance (Federal Reference Method) and chemical speciation sampling.

Approximately $170 million has been directed toward the deployment and operation of the $PM_{2.5}$ network since July 1997, and the $PM_{2.5}$ network continues to operate at a cost of $42 million annually. The majority of the annual expenses are for the operation and maintenance of the federal reference method samplers, $26.5 million. The introduction of continuous particulate matter monitors capable of addressing multiple objectives with reduced operator burden could produce desired network efficiencies. For example, the cost of operating a federal reference method sampler on a one-in-three day schedule for a year is approximately $19,000 (including operations, maintenance, data management, filters, and quality assurance audits). The cost of operating one of the available continuous (hourly) particulate matter samplers is approximately $8,000. EPA does not expect that all federal reference method samplers will be replaced; however, significant resources can be impacted by the use of more continuous samplers in lieu of some federal reference methods.

Assessments of existing criteria pollutant networks are being conducted as part of a separate but parallel National Air Monitoring Strategy effort. These assessments are providing direction for reducing the current number of $PM_{2.5}$ federal reference methods based on observed spatial redundancy (due to relatively broad homogeneous fine aerosol behavior throughout the eastern United States) and related factors. Such divestment in filter based methods is needed to support integration of a more comprehensive continuous mass network, as well as preparing for future coarse particulate monitoring requirements. This comprehensive air monitoring strategy also has defined progress in continuously operating PM monitors as a priority for implementation.

Over the last four years many monitoring agencies have expressed a strong desire for the development and acceptance of continuous methods for use as compliance samplers (i.e., federal equivalent methods). This sentiment has been expressed in a number of venues including the Air and Waste Management Association PM2000 conference; through the STAPPA/ALAPCO Monitoring Committee and the Standing Air Monitoring Work Group (SAMWG); and the CASAC Technical Subcommittee on Particle Monitoring. The CASAC Technical Subcommittee on Particle Monitoring met on January 22, 2001 in a workshop session dedicated to continuous particulate matter monitoring. This document provides further details on EPA's proposal to enhance continuous PM monitoring as a follow-up to that CASAC workshop. The approach utilizes the data quality objective process to develop continuous monitor performance specifications. State and local agencies and tribal governments would have a set of parallel options through a new Regional Equivalent Method program and an modification of the existing Correlated Acceptable Continuous monitors provision.

The principal challenge implied within this document is maintaining an acceptable balance between data quality and technological progress. The promulgation of the 1987 PM_{10} standards included a performance-based approach to the acceptance of PM_{10} methodology. The current $PM_{2.5}$

monitoring network has achieved relatively high data quality[1] due in large measure to the requirement of design-based methods (i.e., monitors with virtually identical components) and a thorough quality assurance program that followed through on a cycle of planning (data quality objectives), implementation (field/laboratory quality control), data assessment and reporting tasks. Risk in compromising data quality will emerge as an assortment of technologies are accommodated in the network. Consequently, the success of this program will rely not only on the initial data quality objective planning steps, but through a commitment to conducting the remaining quality assurance tasks and retaining the flexibility to take appropriate action in the use of data when systematic failures are encountered within the quality assurance system.

Document Layout

Section 2 examines the available collocated federal reference method and $PM_{2.5}$ continuous monitoring data. This examination illustrates both the successes and challenges of implementing PM continuous monitors. Section 3 and 4 detail the applicability of the correlated acceptable continuous (CAC) monitors and the regional equivalent monitors (REM) including testing requirements and the approval process. Section 5 focuses on network design emphasizing the suggested hybridization of federal reference method and continuous particulate monitors, and proposing a new minimum number of required $PM_{2.5}$ federal reference method sites. Section 6 provides the performance standards for using PM methods and a description of the data quality objective process utilized to derive the goals for precision and bias. The data quality objective process recognizes a number of variables such as measurement precision, population precision, sample bias, sample frequency, a 3-year standard, and sample completeness in order to predict the confidence in a decision around the annual average. Section 7 addresses the use of statistical transformations for each category of continuous methods. The use of such transformations need careful consideration in terms of number of variables, frequency of adjusting, and spatial scale of applicability. Section 8 provides some initial thoughts on developing boundaries for approval of methods across a spatial scale. This section details how a number of inputs such as aerosol composition using both monitored data and modeled data as well as overlaying this output with natural geographic boundaries, such as how State lines or city boundaries may be used. Section 9 provides design guidance on continuous monitoring methods. Section 10 identifies how this effort to enhance a network of continuous particulate monitors is linked to the national monitoring strategy. Section 11 provides a summary of the potential regulatory changes and schedule necessary to implement this plan. Section 12 provides a repository of issues and action items.

Applicability

The scope and intention of this document is focused on addressing continuous particle mass

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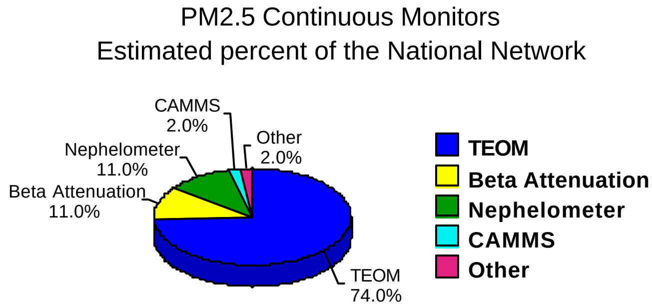
[1]"CY 2000 Quality Assurance Report of the $PM_{2.5}$ Ambient Air Monitoring Program," U.S.EPA Office of Air Quality Planning and Standards, October 2001.

monitors that provide in-situ sampling/analysis capability producing outputs that can be aggregated upward to one-hour reporting periods (e.g., TEOMs and beta attenuation gauges). The approaches proposed rely on the use of the data quality objective process to produce quantitative performance standards. This process would in concept accommodate alternative particulate matter measurement approaches beyond the more traditional continuous mass methods, assuming performance standards are achieved. Such acceptable examples that might provide a useful alternative to the federal reference method include the use of a continuous speciation monitor alone (e.g., sulfate only) or in combination with multiple speciation monitors (e.g., carbon, nitrate and sulfate), or other filter based methods that do not have current equivalency status (e.g., dichotomous sampler). The principles described in this document are not applicable to measurement systems beyond particulate matter (e.g., utilizing particulate matter measurements to replace ozone or other discrete gaseous measurements).

Figure 2-1 Percent of PM2.5 Continuous Methods used Nationally



The beta attenuation monitor (BAM)[3] is operated at several locations (second in number to the TEOM) throughout the western United States with a limited number of new locations in the east. The California Air Resources Board and other organizations sponsored a field study of several major $PM_{2.5}$ commercially available monitors indicating high performance of the BAM conducted during relatively volatile aerosol conditions.[4] EPA's Environmental Technology Verification Program (ETV) included two test sites; one in Pittsburgh, PA in the summer of 2000; and one in Fresno, CA in the winter of 2000-2001. This verification program included a number of $PM_{2.5}$ continuous monitors being deployed by State and local agencies including the BAM, the TEOM operated at 50C, the TEOM operated with the sample equilibration system at 30C, and the CAMMS[5]. While the verification reports do not offer conclusions as to the performance of the monitors, inspection of these reports indicates that the Met One BAM performed consistent at both test sites. The final verification reports from these field studies are available from the U.S. EPA web site.[6]

The Nephelometer is used at many sites in the Pacific Northwest. This monitor can have

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[3]Manufactured by Met One Instruments.

[4]Reference the CARB report here.

[5]Manufactured by Thermo Andersen.

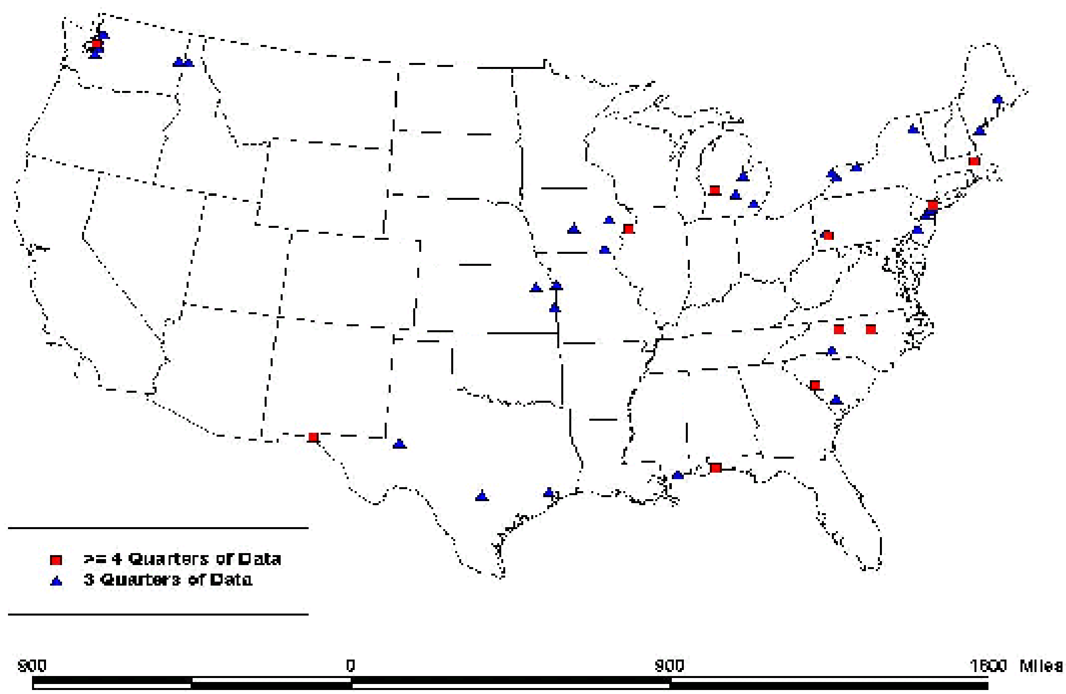
[6]Environmental Technology Verification Statements and Reports:
http://www.epa.gov/etv/verifrpt.htm#07

advantages over PM2.5 continuous methods with respect to its ease of operation. However, Nephelometers can have problems with high humidity and care should be taken to assure sample streams are conditioned so as not to have moisture interfere with the scattering output. There are several manufacturers of Nephelometers, so care also needs to be taken when comparing data from a monitor at one site to another. Although Nephelometers do not provide for a direct output of fine particualte concentration, they can be useful when calibrated against filter based methods to provide for diurnal and day to day signal of fine particulate.

Analysis of the Variety of Relationships for 47 Collocated $PM_{2.5}$ Continuous and FRM Sites

The AIRS database included 11 sites with at least a years worth of collocated $PM_{2.5}$ continuous monitoring and FRM data based on a Spring, 2001 retrieval. An additional 36 sites were included for analyses if they had at least 3 quarters of data with at least 11 valid collocated pairs per quarter for a total of 47 sites (Figure 2-2) forming the basis for the analyses presented in this section.

Figure 2-2 Map of 47 Sites used in $PM_{2.5}$ Continuous Monitors Analyses



Intercomparisons of FRMs and $PM_{2.5}$ Continuous Monitoring Data:

Of the 11 sites with at least 4 quarters of complete data, 8 sites used TEOM monitors with the factory installed correction factor applied for the entire data set. This factory installed correction factor adds 3 ug to the intercept and 3% to the slope for data coming from a TEOM. A table summarizing the range of concentration values from each of the FRM and continuous monitors at these sites is provided below:

Table 2-1 Concentration Ranges for 8 Sites with Collocated PM2.5 FRM and TEOM Monitors

MSA	Site ID	N	Primary Monitor Type	Concentration Range of Data (µg/m^3)						
				Mean	SD	Min	Q1	Median	Q3	Max
Aiken, SC - Augusta, GA	450370001	144	Continuous	14.50	6.42	1.37	9.85	13.46	18.88	34.75
			FRM	14.49	6.55	2.40	9.75	13.00	18.00	34.20
Davenport, IA - Moline - Rock Island, IL	191630015	453	Continuous	12.00	6.49	2.92	7.26	10.53	15.30	48.81
			FRM	12.81	7.31	2.30	7.30	11.50	16.90	46.70
Winston - Salem, NC	370670022	525	Continuous	16.23	8.05	2.66	10.29	14.45	20.95	64.02
			FRM	16.89	8.70	1.60	10.60	15.00	21.70	69.70
New York, NY	360050110	295	Continuous	15.40	9.26	4.69	8.85	12.85	19.24	85.38
			FRM	15.21	9.17	3.60	8.30	12.30	20.00	53.00
Pensacola, FL	120330004	214	Continuous	14.41	6.74	-17.7	9.90	13.02	17.94	45.83
			FRM	14.03	6.89	1.00	8.60	12.70	18.41	49.30
Pittsburgh, PA	420030064	344	Continuous	16.68	12.00	1.21	7.27	13.19	22.50	68.92
			FRM	20.87	13.39	3.10	11.00	17.20	26.55	78.50
Raleigh-Durham, NC	371830014	389	Continuous	15.02	6.89	2.78	10.00	13.66	18.98	45.88
			FRM	15.59	7.52	3.00	10.10	14.40	20.00	52.80
Seattle, WA	530330057	340	Continuous	13.30	6.39	3.38	9.08	11.87	15.48	44.42
			FRM	12.64	7.25	2.80	7.80	10.95	15.40	46.90

Inspection of Table 2-1 indicates that most of the sites appear to produce similar PM2.5 concentrations regardless of whether an FRM or TEOM is used. Only the Pittsburgh, PA site showed a large discrepancy between the mean of the FRM and PM2.5 continuous monitor. Due to this discrepancy, the Allegheny County monitoring staff were contacted to confirm the operation of the TEOM and use of default corrections factors. While the operation of the instrument was determined to be correctly identified, it was mentioned that the site is located in a community orientated location in close proximity to a large local source.

Scatter plots were produced for each of the 11 sites with at least a years worth of complete data. Data were plotted for each day where both a FRM value and a corresponding average 24-hour continuous $PM_{2.5}$ value were available. Separate plots for linear and log-normal concentrations were plotted for each site. The scatter plots can be separated into several categories: scatter plots with good agreement most of the time - illustrated by most points being on a straight line (Figures 2-3 through 2-6 and 2-9); scatter plots with a small but discernable amount of spread about the best fit line - as illustrated by a mild spread about the best fit line (Figures 2-7 and 2-8); scatter plots with good agreement part of the time and poor agreement in others - illustrated by a large increasing spread with concentration (Figures 2-10 and 2-11); and scatter plots that do not appear to correspond well with any pattern - illustrated by a large spread about the 1:1 relationship regardless of the concentration (Figures 2-12 and 2-13).

These first four figures represent sites in the southeastern United States where the $PM_{2.5}$ continuous monitor appears to track the FRM reasonably well:

Figure 2-3 Raleigh-Durham, NC

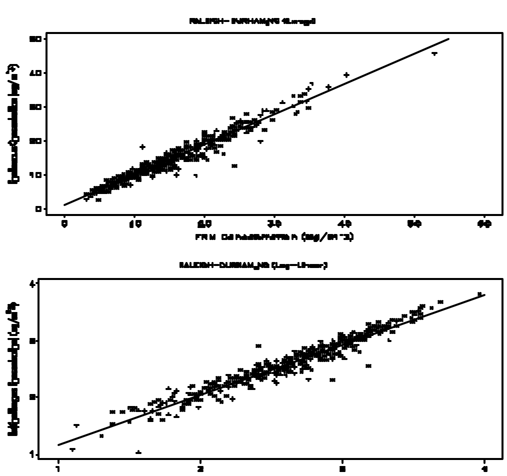


Figure 2-4 Winston-Salem, NC

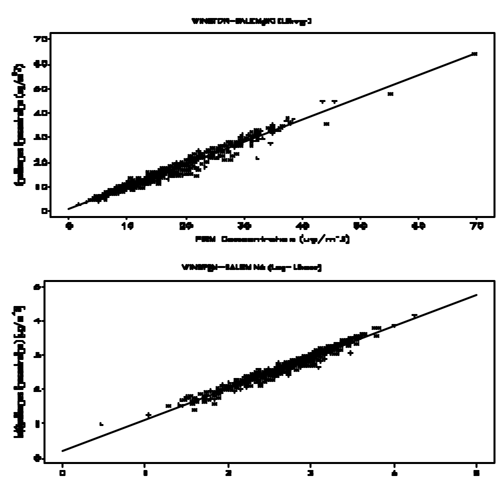


Figure 2-5 Aiken, SC - Augusta, GA

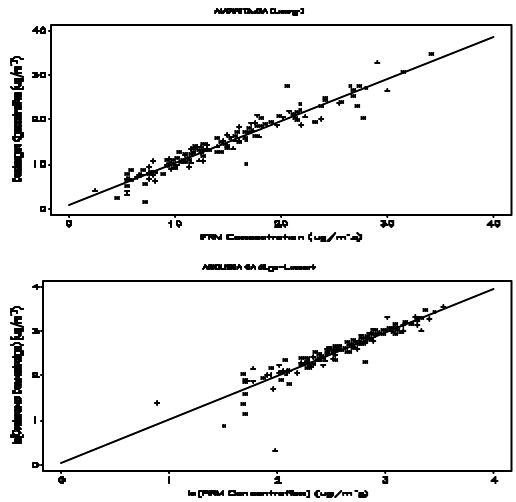
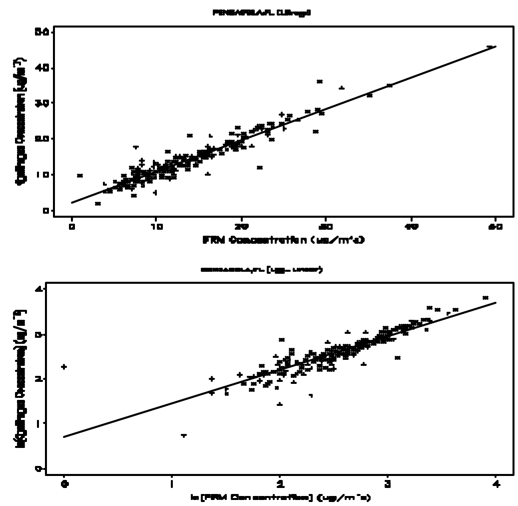


Figure 2-6 Pensacola, FL



The following scatter plots represent cities in the Northeast with some discernable spread about the best fit line, but not severely distorted.

Figure 2-7 New York, NY

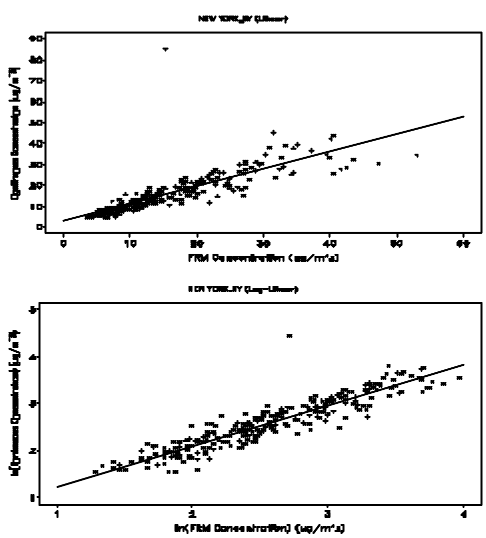
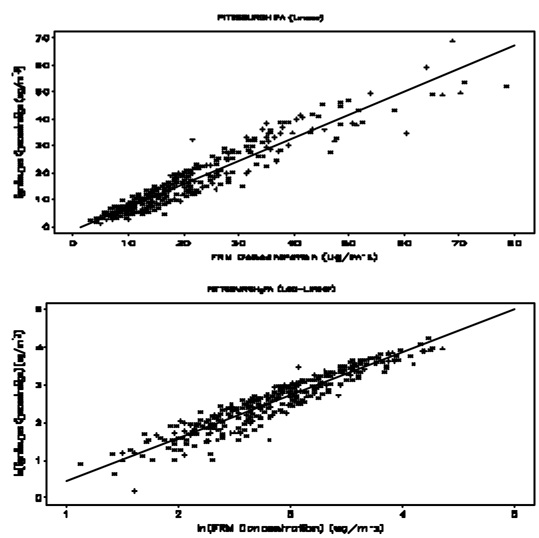
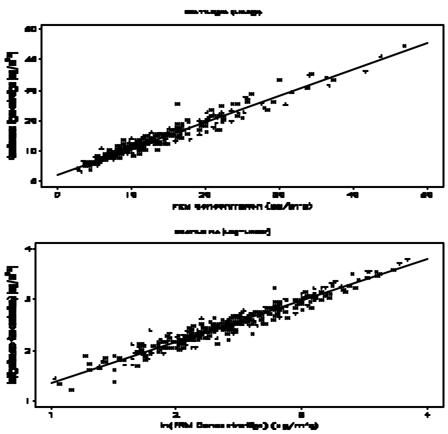


Figure 2-8 Pittsburgh, PA



The following figure is from a northwest site. The scatter plot shows a good fit about the best fit line.

Figure 2-9 Seattle, WA



These figures, using data from sites in the upper mid-west, represent a clear spread with concentration. This is likely an effect of seasonal aerosol changes.

Figure 2-10 Davenport, IA

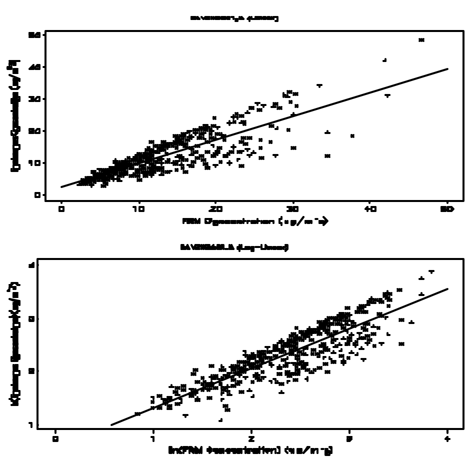
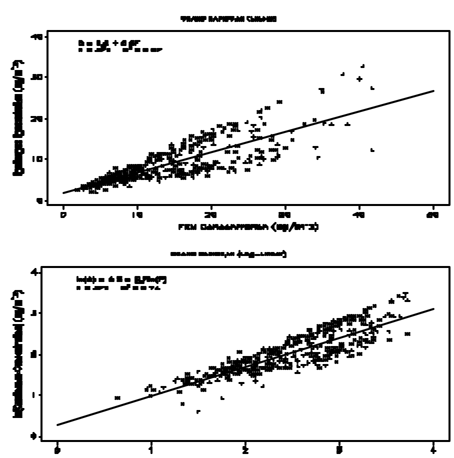


Figure 2-11 Grand Rapids, MI



These figures represent data from air sheds where the TEOM and FRM do appear to correspond well.

Figure 2-12 El Paso, TX

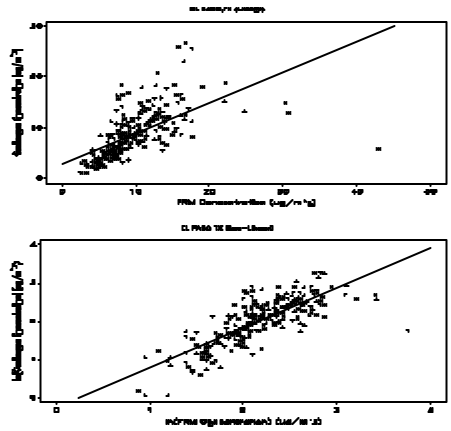
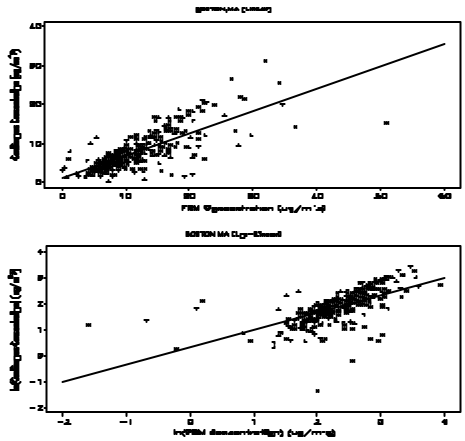


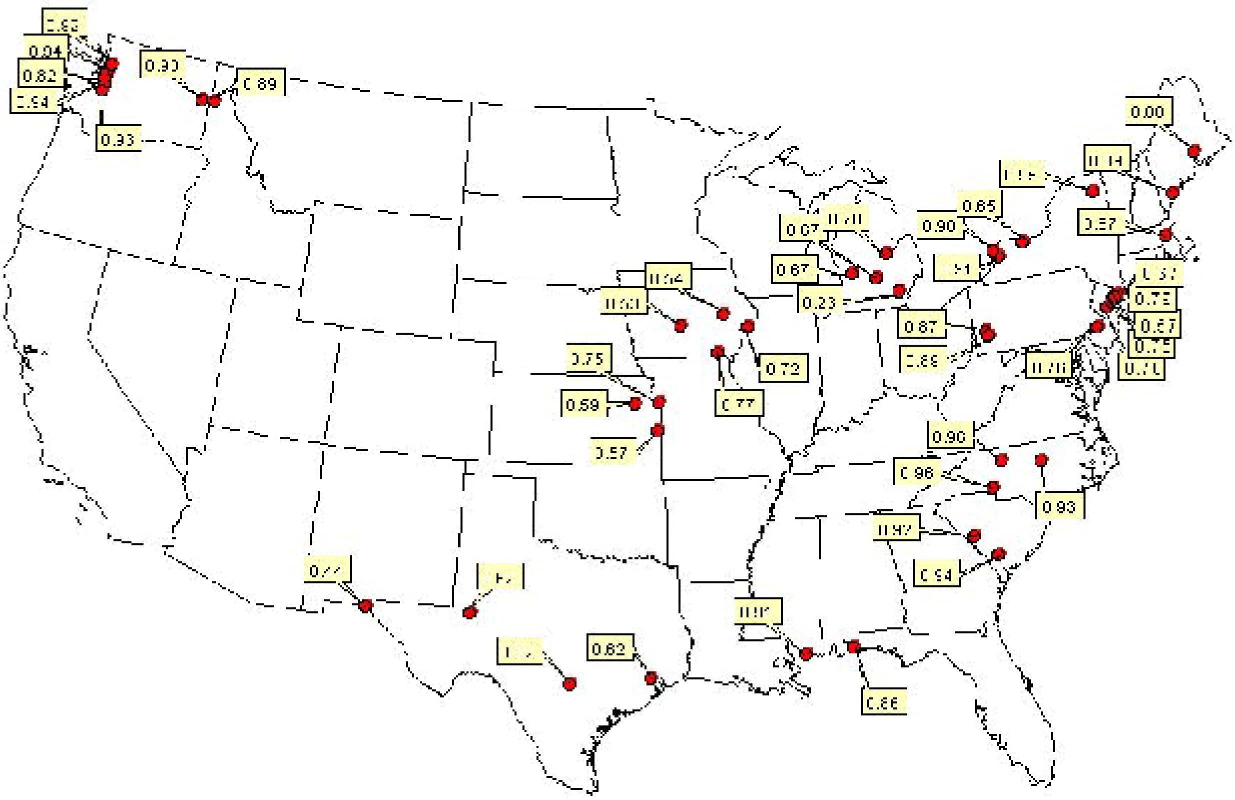
Figure 2-13 Boston, MA



Correlation between $PM_{2.5}$ Continuous Monitors and FRMs

Another way to look at the data is to evaluate the goodness of fit between a model using $PM_{2.5}$ continuous data to explain FRM measurements. The map below (Figure 2-14) illustrates the correlation coefficient (R^2) at each of the available 47 sites. All 47 sites are able to be used because a linear model will not affect the correlation regardless of whether a site specific model is used, the standard correction factors are applied or no model is used at all. The map also indicates that geographical area plays a large role in how high a correlation coefficient is observed. This is likely due to the aerosol encountered at specific sites, the concentration of fine particulate and an effect of the season. Areas exhibiting high correlation include the Southeast, Northwest and selective locations of the Northeast. Areas with poor correlation are likely the result of either regional scale winter time volatilization as demonstrated in Iowa and Kansas or micro-scale to urban-scale influences of local sources such as in Boston and El Paso.

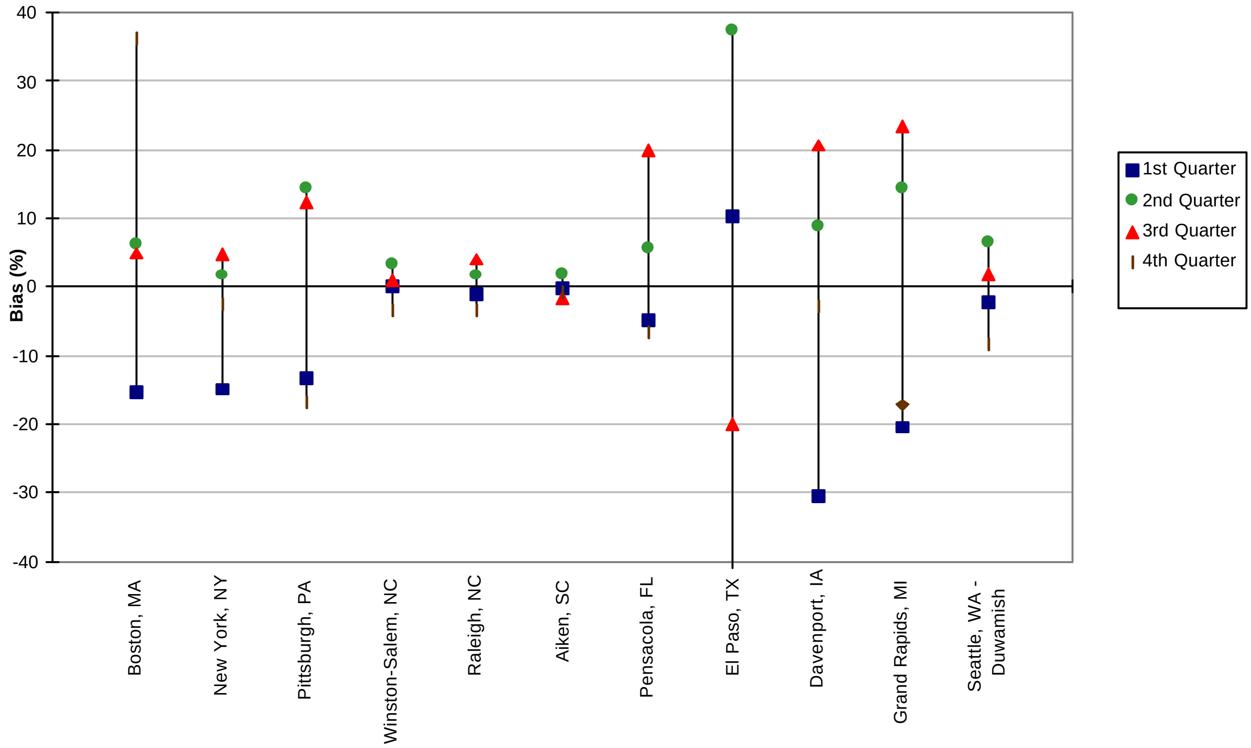
Figure 2-14 Correlation between FRMs and $PM_{2.5}$ Continuous Monitors



Bias by Season

In many air sheds across the United States the species and concentration of the aerosol encountered varies by season. Changes in the species and concentration of the aerosol can lead to changes in performance of a $PM_{2.5}$ continuous monitor. In the illustration below the spread of bias is presented for those sites with at least 4 quarters of complete data. Bias data were calculated by comparing the FRM and collocated continuous monitoring data for days when both instruments produced a valid 24 hour value. Since some monitoring agencies choose to use a standard correction factor in the reporting of their data while others did not, each set of data was first fit to it's own linear model and then the bias were calculated by quarter. Additional graphics depicting the bias by quarter for those sites without 4 complete quarters are available in attachment 1. The tighter the fit between season the better the opportunity to use that continuous instrument to produce FRM-like measurements. Generally, cooler quarters produced the largest negative biases. This is likely due to the larger difference between the operating temperature of the TEOM and the ambient temperature of the atmosphere. The relatively high operating temperature of the TEOM during these cooler months leads to evaporation of a portion of the aerosol that are collected on a filter based sampler.

Figure 2-15 PM2.5 Bias Data for TEOM Monitors by Quarter



Analysis of the Acceptability of the Relationship relative to the Data Quality Objective Process and Class III equivalency.

In the section above, a few of the sites appeared to have $PM_{2.5}$ continuous monitors that are replicating the FRM measurements very well with other sites not performing well and many sites in between. A site may be expected to replicate the FRM very well by virtue of having a scatter plot close to unity, a high correlation coefficient and a low bias. But with a variety of performances across sites, at what level should a site be considered acceptable? In this section data from 160 collocated FRM/FRM sites and 47 collocated $PM_{2.5}$ continuous/FRM sites are compared to various levels of the Data Quality Objective (DQO) process and the equivalency criteria. For the DQO criteria, precision and bias statistics are determined for each site and results are presented as a function of the percentage of sites that satisfied the criteria. For the equivalency criteria, linear regression is performed for each site and results are presented as a function of the percentage of sites that satisfied the criteria.

Table 2-2 Percentage of Collocated Sites meeting individual DQO and Equivalency Criteria

Criteria	160 Collocated FRM/FRM (% of sites meeting criteria)	47 Collocated FRM/Continuous Sites (% of sites meeting criteria)
Data Quality Objective		
Bias 5%	86.9	34.0
Bias 10%	97.5	53.2
Precision 5%	28.1	0.0
Precision 10%	68.8	12.8
Precision 20%	NA	61.7
Equivalency		
Slope (1±0.05)	77.5	91.5
Intercept (±1 µg)	82.5	97.9
Correlation ($0.97)	66.2	10.6

Interpreting Table 2-2 leads to several observations:

C Evaluations of the collocated FRM/FRM sites against the existing goals of ±10% bias and ±10% precision, indicate that precision is the limiting factor. Most (97.5%) of the sites meet the bias goal and 68.8 % meet the precision goal. As will be demonstrated in section 6, bias strongly influences the uncertainty of a 3 year mean, while precision has little effect due to the large number of samples in 3 years of data. Therefore, we have confidence that the FRM network is performing well, as indicted by 97.5% of the sites meeting the bias statistic.

C Evaluating the FRM/FRM sites against the existing criteria for Class III equivalency[7] indicates that correlation is the limiting factor with 66.2% of the sites passing. That's

[7] 40 CFR 53

important since we believe we have a well-operating $PM_{2.5}$ FRM network; however, over one-third of the sites would fail the Class III equivalency testing criteria. If a collocated network of FRM cannot largely meet the equivalency criteria, it will be very difficult for a network of FRMs collocated with $PM_{2.5}$ continuous monitors to meet this criteria.

- Evaluations of the collocated FRM/continuous sites against the existing goals of ±10% bias and ±10% precision indicate that precision is also the limiting factor with 53.2 % of the sites meeting the bias goal and only 12.8 % meeting the precision goal. As mentioned above and demonstrated in section 6, bias strongly influences the uncertainty of a 3-year mean, while precision has little effect due to the large number of samples in 3 years of data. If the precision goal could be reduced to ±20%, then 61.7% of the sites in the analysis would have satisfied this criteria. Although an even less stringent precision goal could potentially be chosen, bias has now become the limiting factor for performance of the continuous monitors. While precision could potentially be relaxed and we would still have a high degree of confidence in the 3 year annual mean, the need to monitor for other monitoring objectives necessitates controlling precision to some degree. A detailed explanation of the DQO process will be explained in section 6.

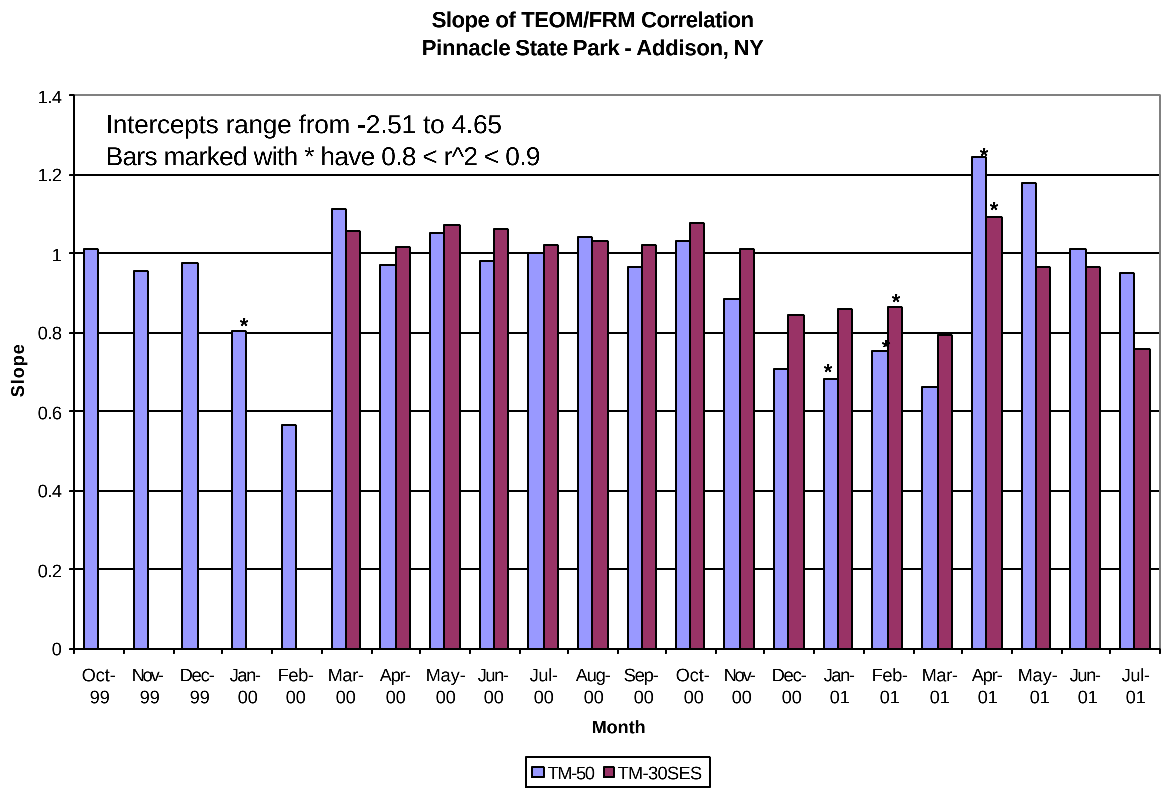
- Evaluating the FRM/continuous sites against the existing criteria for Class III equivalency indicates that correlation is the limiting factor with 10.6% of the sites passing. If it can be demonstrated that the continuous monitors are producing FRM-like measurements that meet the goals established in the DQO process rather than the equivalency criteria, than the correlation criteria becomes irrelevant.

Note: In addition to this analysis the EPA has produced assessments of the quality of the $PM_{2.5}$ monitoring program for the currently operating FRMs for calendar year 1999 and 2000. The calendar year 1999 report is final and can be reviewed on-line at the EPA web site: http://www.epa.gov./ttn/amtic/. The calendar year 2000 report is in review and a draft copy can be obtained from the same web address.

Analysis of Collocated TEOMs with a FRM

In New York State two sites have operating collocated TEOMs with a FRM. Additionally, a site in Raleigh North Carolina also has two TEOMs and a FRM. At each site one of the TEOMs is run with an operational temperature of 50C, while the other is operated at 30C and utilizing a Sample Equilibration System (SES). Data are compared to the operating FRM at the sites, which for all 3 locations is a R&P 2025 FRM. The site with the longest record of data is located at Pinnacle State Park in Addison, NY. This site is located in a rural area of New York's Southern Tier. The illustration below provides some indication of the improvement a TEOM operated at 30 degrees C with a SES can have over operating the conventional TEOM at 50 C. The improvement is most pronounced in the cold weather months of November through March. A table summarizing regressions for all 3 sites by month is available in attachment A.

Figure 2-16 Slope of TEOM/FRM at Pinnacle State Park, NY



Data courtesy of New York State Department of Environmental Conservation and University of Albany, Albany NY.

Conclusion

Although this analyses is very limited it's becoming clear that some areas of the country may already be operating PM continuous monitors that produce data with similar quality to that of the FRM. If a mechanism to approve the use of these continuous monitors could be made where the performance of the instrument is defined to be acceptable than a large resource savings may be gained by divesting of some of the FRM operations. Other areas of the country may not be producing PM2.5 continuous data that could be used to replace the FRM. For these areas, agencies may need to pursue improvements to their instrumentation or new technologies altogether. Comparing the performance of sites that have a collocated FRM/FRM pair with a collocated FRM/continuous pair to the expected equivalency criteria revels that the correlation statistic (r^2 $0.97) would be the limiting factor for either FRMs or continuos monitors to meet equivalency. If this is the case than an evaluation of the expected statistical criteria for equivalency of a continuos monitor should be made. Section 6 of this document examines the performance standards of $PM_{2.5}$ continuous monitors in detail.