Presentation to the Clean Air Scientific Advisory Committee, Ambient Air Monitoring and Methods Subcommittee

September 21, 2005

Development of the PM Monitoring Program, Including a Federal Reference Method (FRM) for $PM_{10-2.5}$

Objectives of Meeting

- Provide Peer Review on:
  - $PM_{10-2.5}$ Federal Reference Method (FRM)
- Provide Consultation on
  - Field evaluation of $PM_{10-2.5}$ methods
  - Optimization of the $PM_{2.5}$ FRM
  - Equivalency criteria for $PM_{2.5}$ continuous methods
  - Monitoring data quality objectives for $PM_{10-2.5}$
  - Equivalency criteria for $PM_{10-2.5}$

Development of a $PM_{10-2.5}$ Monitoring Program:

- The $PM_{10-2.5}$ monitoring program is expected to have:
  - **Data Quality Objectives** that define the qualitative and quantitative statements that clarify the monitoring objectives, define the appropriate type of data, and specify the tolerable levels of decision errors for the monitoring program.
  - A **Network Design** describing criteria for location of monitors, including scale of representativeness.
  - **Sampling Methods** to achieve the monitoring objectives, including:
    - FRMs - to serve as the method of comparison for all other methods
      - Approval of $PM_{10-2.5}$ continuous methods.
      - Quality Assurance – performance evaluation audits with independent FRMs to determine bias.
    - Federal Equivalent Methods (FEMs) - continuous monitors widely deployed as the primary method used in comparison to a possible daily standard.
      - Equivalency criteria for these based on data quality objectives being developed for $PM_{10-2.5}$ monitoring program.
      - Quality Assurance – collocation with like methods to determine precision.
    - Speciation samplers – Need filter-based methods to determine chemical composition.
  - **Data Reporting and Assessment Activities**

Network Design Issues for $PM_{10-2.5}$

- EPA Staff has recommended an urban coarse particle indicator of $PM_{10-2.5}$ ($UPM_{10-2.5}$).
  - Intended to characterize risk from urban sources such as re-suspended road dust typical of high traffic-density areas and emissions from industrial sources.
- EPA minimum monitoring requirements may be based on prioritization criteria, including CBSA population size and estimated $UPM_{10-2.5}$ concentrations.
- Staff considering a network design similar in concept to $PM_{2.5}$ monitoring for the daily standard.
  - Areas of high population density that also indicate high-traffic emissions.
  - Populated locations in proximity to primary industrial sources of urban particles.
  - High population density suburban locations to establish overall community levels.
  - Monitoring also required at rural NCore Level 2 multi-pollutant sites.
  - Potential other non-urban locations for science purposes.
  - Speciation requirements under consideration.

What options were considered for a $PM_{10-2.5}$ FRM

- Commercially available or final prototype monitoring technologies.
- Consultation with CASAC Ambient Air Monitoring and Methods Subcommittee in July of 2004 provided input on selection of FRM.
  - Included assessment of the relative strengths and weaknesses of each method tested in the EPA-ORD study for:
    - Purposes of using it as a reference method, a measurement principle, and as a method that would provide the basis for approval of candidate reference and equivalent methods.
    - Meeting multiple monitoring objectives
  - Methods tested in EPA-ORD study:
    - Collocated $PM_{2.5}$ and PM_{10} FRM Samplers
    - R&P Model 2025 Sequential Dichotomous Sampler
    - Kimoto SPM-613D Dichotomous Beta Gauge
    - R&P Continuous Coarse Tapered Element Oscillating Microbalance (TEOM)
    - TSI 3321 Aerodynamic Particle Sizer (APS)
  - Individual comments provided general, but not unanimous support for collocated PM_{10} and $PM_{2.5}$ low-volume FRMs to measure $PM_{10-2.5}$.

Federal Reference Method for $PM_{10-2.5}$

- Collocated measurements of low-volume (16.67 lpm) Federal Reference Methods for:
  - PM_{10}
  - $PM_{2.5}$
- $PM_{10-2.5} = PM_{10} – PM_{2.5}$
- 24-hour samples +/- 1 hour
- Sampling of air based on volumetric control at actual local conditions of temperature and pressure
- Gravimetric laboratory analysis
- Procedures for $PM_{2.5}$ method found in 40 CFR Part 50, Appendix L.
- Procedures for PM_{10} same as $PM_{2.5}$, except:
  - Second stage impactor is replaced with a straight tube.
  - These procedures are more stringent than existing PM10 FRM in 40 CFR, Part 50, Appendix J.
  - New descriptor for these measurements tentatively "PM_{10c}"

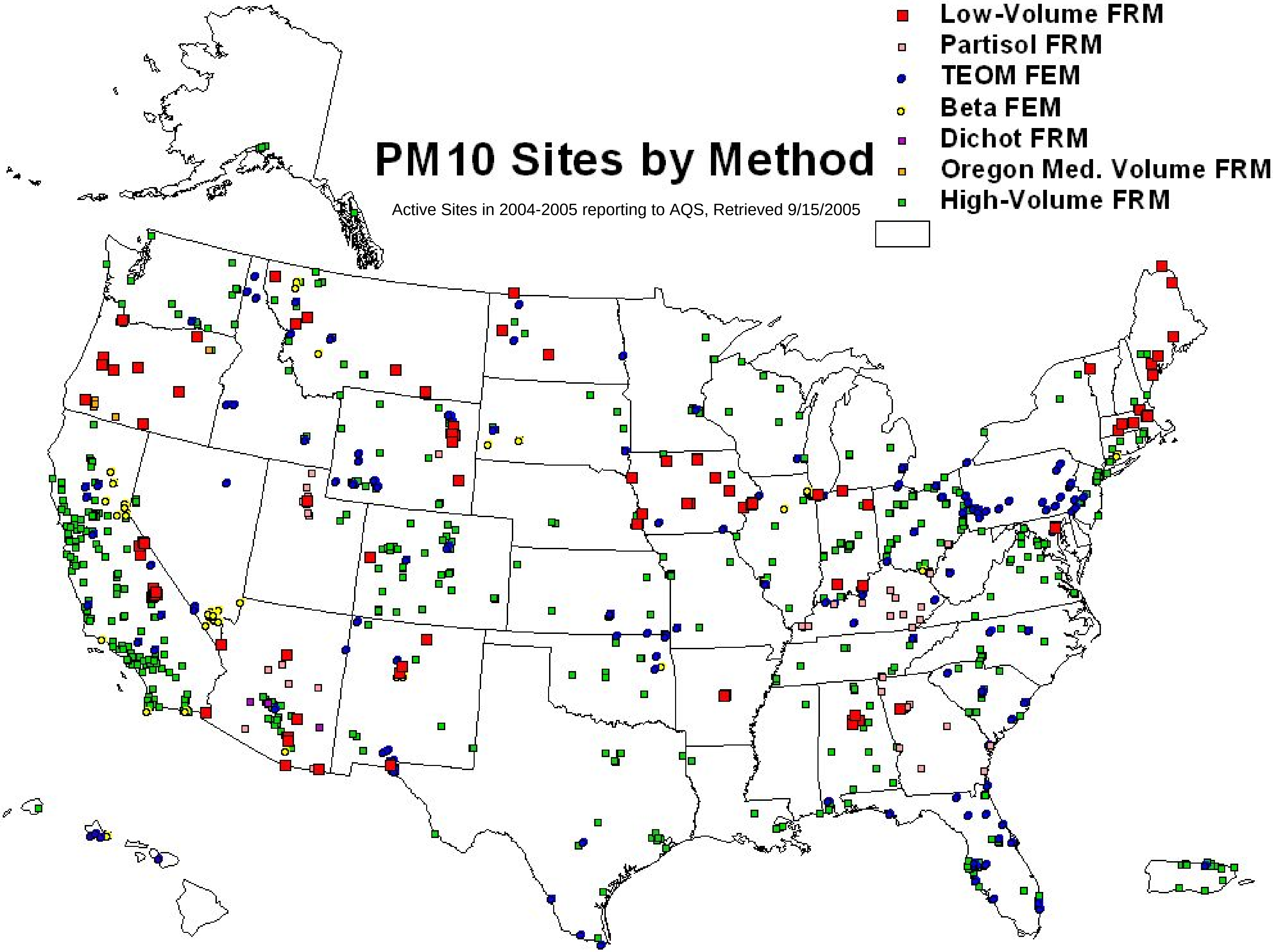
R&P PM2.5 FRM Sequential Sampler

BGI PM2.5 FRM

Andersen PM2.5 FRM Sequential Sampler

Readily Available Candidate Federal Reference Methods for $PM_{10-2.5}$

Candidate Methods for the $PM_{10-2.5}$ FRM	$PM_{2.5}$ (FRM codes)	PM_{10} as PM_{10c} (FRM codes)
Andersen Model RAAS 100 Single Channel	119	130
Andersen Model RAAS 200 Audit Sampler	128	131
Andersen Model RAAS 300 Multi-Channel Sampler	120	132
BGI PQ200 Air Sampler	116	125
R&P Partisol Model 2000 Single Channel Air Sampler	117	126
R&P Partisol Model 2000 Single Channel Audit Sampler	129	NA
R&P Partisol Model 2025 Sequential Air Sampler	118	127


PM10 Sites by Method
Active Sites in 2004-2005 reporting to AQS, Retrieved 9/15/2005
Low-Volume FRM
Partisol FRM
TEOM FEM
Beta FEM
Dichot FRM
Oregon Med. Volume FRM
High-Volume FRM

$PM_{10-2.5}$ FRM Selection Issues

$PM_{10-2.5}$ FRM	Scientific Issues
Advantages	- Provides for maximum comparability to existing and developing PM methods for PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$. - Lower limit defined by the $PM_{2.5}$ FRM - Upper limit defined by low-volume PM_{10} FRM - Provides measured concentrations for PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$ - Highly precise - Tied to some of the $PM_{10-2.5}$ health studies - Extensive wind tunnel testing on louvered PM_{10} inlet - Multiple field studies - Same face velocities for each sampler
Disadvantages	- Does not provide for a direct single measurement of $PM_{10-2.5}$ - Integrated sample does not provide high time resolution

$PM_{10-2.5}$ FRM Selection Issues

$PM_{10-2.5}$ FRM	Implementation Issues
Advantages	- Can be used to meet multiple monitoring objectives - Method is already in the public domain; therefore, can be easily adopted as part of a proposed rulemaking for the NAAQS - Multiple makes and models can be easily approved as FRMs without the need for additional testing or extensive Agency review - Commercially available - Easy to convert existing $PM_{2.5}$ FRMs to PM_{10c} FRM - Some State and local agencies have already deployed the low volume PM_{10} FRM (PM_{10c}) in their network - Does not require environmentally controlled shelter - Minimal operator training necessary - Filter media would be consistent between all PM FRMs
Disadvantages	Not expected to be useful as a widely deployed method to compare with a daily NAAQS - Two samplers require larger sampling footprint on sample platforms

$PM_{10-2.5}$ FRM Selection Issues

$PM_{10-2.5}$ FRM	Operational Issues
Advantages	- Presence of $PM_{2.5}$ aerosols in the PM_{10} sample collection increases the adhesion of larger particles. -- Additive biases may be eliminated or reduced by subtraction. -- Existing $PM_{2.5}$ FRMs are providing data that are meeting the data quality objectives for the $PM_{2.5}$ monitoring program. -- PM_{10} data from low volume FRMs are providing credible data with similar data quality to the $PM_{2.5}$ method. -- Operational procedures for the PM_{10} and $PM_{2.5}$ FRMs are the same. -Negative numbers are rare and near detection limit of method
Disadvantages	- Labor intensive and therefore costly to operate - Availability of data usually takes 2 to 4 weeks, at a minimum

Summary of Progress on Developing the Monitoring Program for $PM_{10-2.5}$

- Recommendations for Data Quality Objectives are almost complete – part of consultation.
- Network Design is being developed.
- Sampling Methods:
  - Staff recommendation (pending outcome of peer review)
    - The $PM_{10-2.5}$ difference method is the most appropriate choice for a proposed FRM to:
      - Serve as the basis of comparison in approving continuous monitoring technologies as Federal Equivalent Methods
      - Provide performance evaluation data for an operational $PM_{10-2.5}$ network.
  - Performance criteria for approval of $PM_{10-2.5}$ continuous monitors as FEMs are being developed – part of consultation.
  - A strategy for deployment of a speciation component to a $PM_{10-2.5}$ network will need to be developed.
- Data Reporting and Assessment Activities – expect to follow other recent and planned improvements for data access and assessments of real-time and validated data,

$PM_{2.5}$ Federal Reference Method – (Attachment 3)

- $PM_{2.5}$ FRM (40 CFR Part 50, Appendix L) identifies large number of requirements
- Quality Assurance Guidance Document 2.12 – Monitoring $PM_{2.5}$ in the Ambient Air Using Designated Reference or Class I Equivalent Methods.
- Each agency must also have an approved:
  - Quality Assurance Project Plan
  - Standard Operating Procedure
- Recommending four changes to the $PM_{2.5}$ FRM to improve performance and minimize burden on agencies conducting the monitoring.

Very Sharp Cut Cyclone (VSCC)

- Approved as a second stage separator on several $PM_{2.5}$ Federal Equivalent Methods (FEMs).
- Test data indicates performance curve is virtually identical to the WINS fractionator.
- Field data demonstrates FEMs with VSCC provide $PM_{2.5}$ concentrations virtually identical to concentrations measured by collocated FRMs.
- Advantages:
  - Operates longer in the field without maintenance
  - Does not use oil
- Recommend:
  - Replacing the WINS with the VSCC, or
  - Allowing the VSCC to be used interchangeably with the WINS on the FRM
  - WINS would become a FEM

WINS Oil

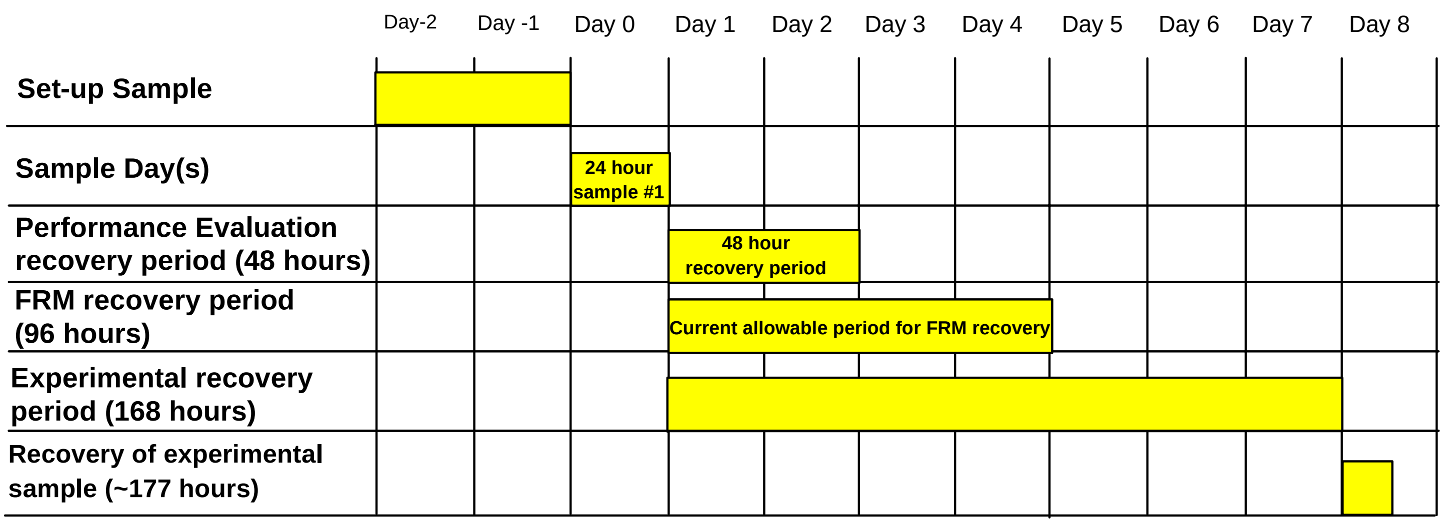
- DOW 704 oil specified in FRM had on occasion crystallized in areas with cold and damp weather conditions.
  - Testing found continued accurate particle separation; however, concerns led to search and identification of a new oil.
- Dioctyl sebacate (DOS) oil working well in the network since 2000.
  - Approved for use as part of a national user modification.
- Recommend using this oil as part of a FRM, or
  - As part of a FEM, if the VSCC becomes the sole second-stage separator used in the $PM_{2.5}$ the FRM.

$PM_{2.5}$ FRM – Filter Recovery Time

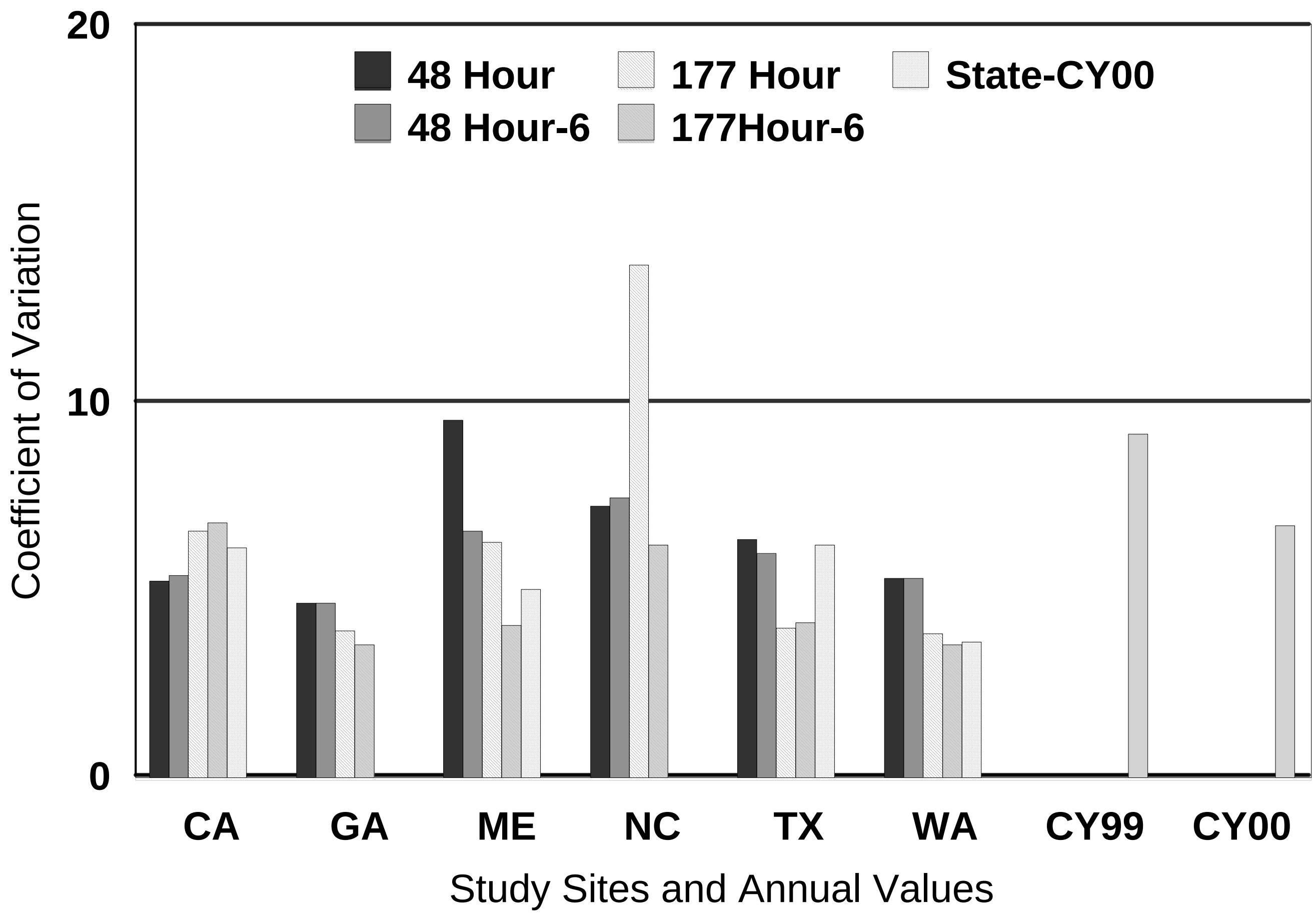
- Appendix L specifies recovery of filter within 96 hours after the end of the sample collection.
- This requirement was identified by a workgroup of State, local and EPA staff as burdensome with an unknown amount of value for ensuring the quality of the data.
- Study conducted at 6 sample locations throughout the country to determine if filters remaining in sampler up to morning following the seventh day after sample collection would still meet the bias and precision goals of the program.
  - Supporting information from seventh location.
- After successful completion and review of a designed study, a national user modification was issued allowing filters to be recovered up to 177 hours past the end of sample collection.
  - However, most samples are still recovered within current requirement. For instance, on a 1-3 day sample frequency up to 3 samples could be recovered within 177 hours. At 9 am of the morning following the last sample collected three filters with 24 hours of sample collection each would have been in the sampler for:
    - 9 hours
    - 81 hours
    - 153 hours

$PM_{2.5}$ Filter Recovery Study Participants and Design

State/Site	Contact(s) and Organization	48 hr. sample retrieval	177 hr. sample retrieval
CA Rubidoux	Rene Bermudez & Rudy Eden South Coast AQMD	Andersen Portable (2)	Andersen Sequential (2)
GA Athens	Herb Barden & Greg Noah EPA Region 4	BGI Portables (2)	R & P Single (3) Andersen Single (2)
ME Augusta	Andy Johnson & Rick Marriner Maine Dept. of Environmental Protection	Andersen Portable (2)	R & P Single (1) R & P Portable (1)
NC RTP	Tim Hanley & Nealson Watkins EPA OAQPS	Andersen Single Channel (2) BGI Single Channel (2) R&P Single Channel (2)	BGI Single Channel (1) Andersen Sequential (3) R & P Sequential (2)
TX Austin	Ed Michel Texas Natural Resource Commission	Andersen Portables (2)	R & P Sequential (3)
WA Seattle	Bob Franks Puget Sound Clean Air Agency	Andersen Portables (2)	R & P Sequential (3)

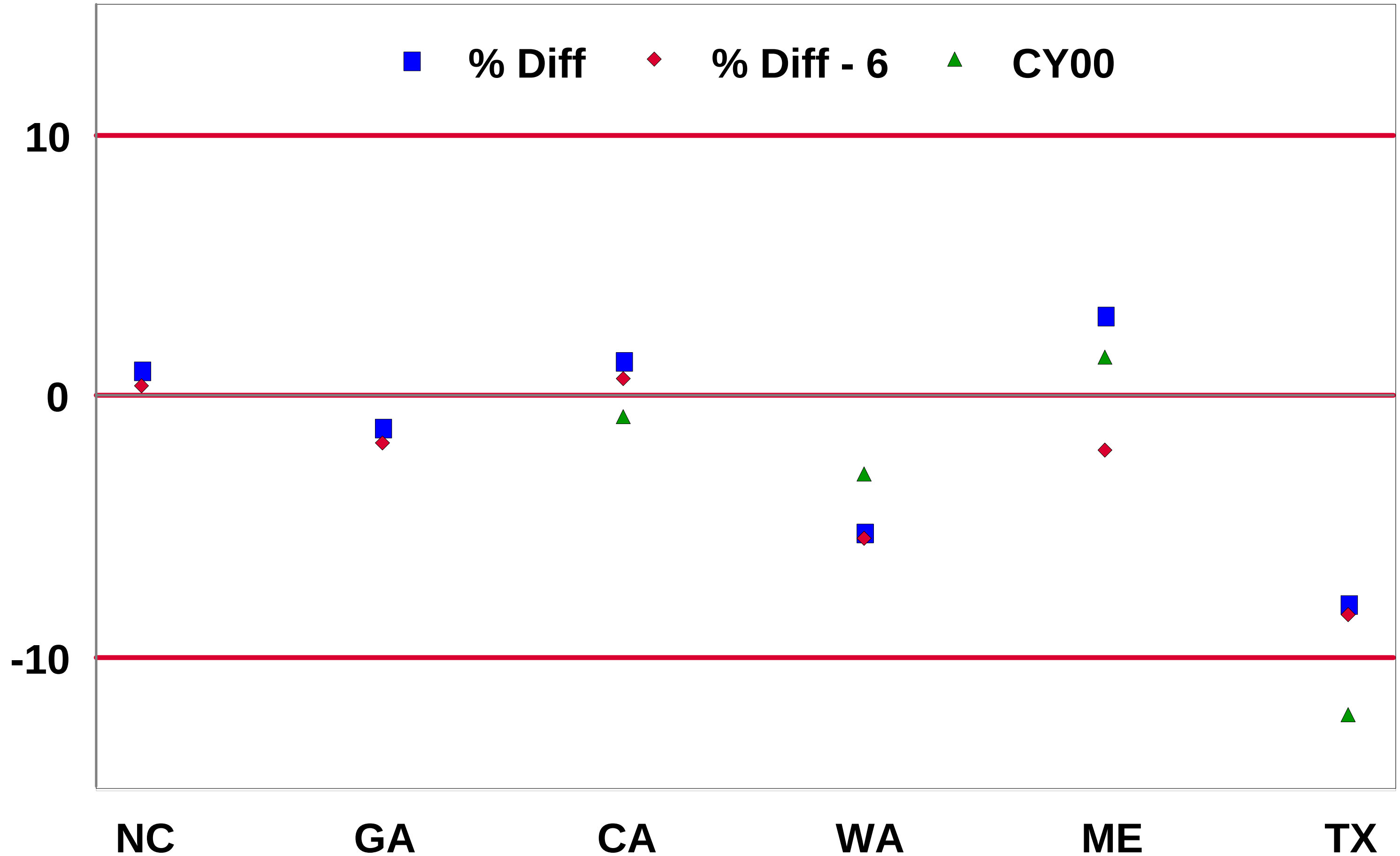


$PM_{2.5}$ Filter Recovery Extension Study – Precision Results

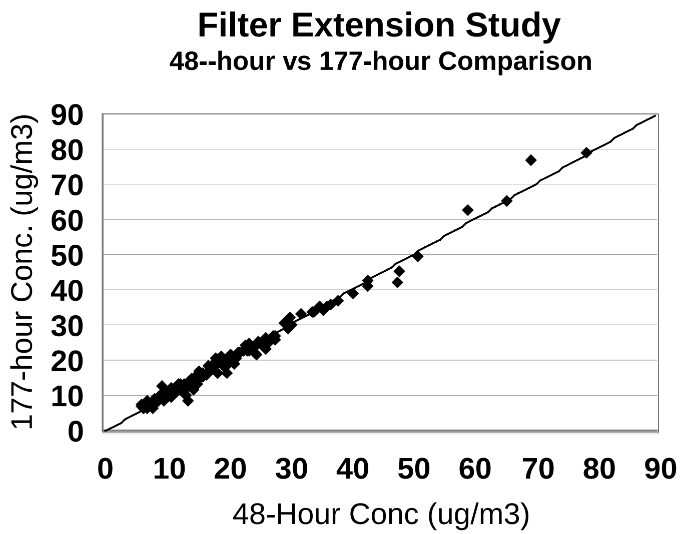


"48 Hour-6" and "177 Hour-6" refer to sampling events where all concentrations were above 6 µg/m³

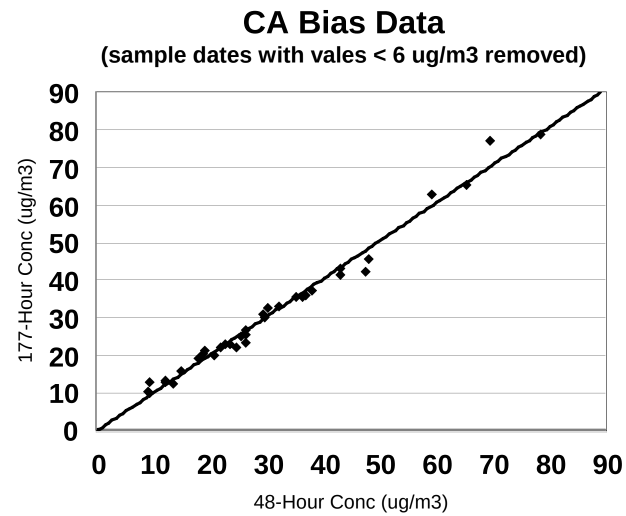
$PM_{2.5}$ Filter Recovery Extension Study – Bias Results



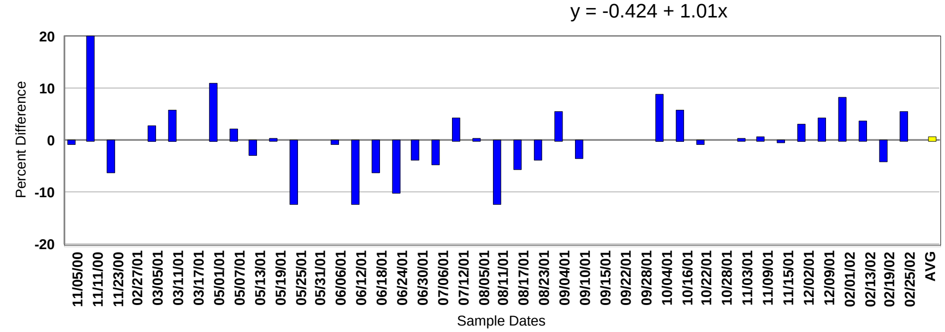
$PM_{2.5}$ Filter Recovery Extension Study – Bias Results – Overall and for Rubidoux CA, Site



R-square = 0.987 # pts = 144
y = -0.471 + 1x



R-square = 0.984 # pts = 35
y = -0.424 + 1.01x



Requirement	Class I Equivalent	177-Hour Data
Precision	5%	5%
Slope of regression	1 +/- 0.1	1
Intercept of Regression	0 +/- 1	- 0.471
Correlation	> 0.97	0.99

PM2.5 FRM – Filter Transport Temperature and Post Sampling Recovery Time

- Two approaches defined in FRM:
  1. Filter shall be maintained as cool as practical and continuously protected from exposure to temperatures over 25 degrees C
     - If met, filter is to be post-weighed within 10 days following the end of the sample period.
  2. If the filter sample is maintained at 4 degrees C or less during the entire time between retrieval from the sampler and the start of the conditioning, then the period shall not exceed 30 days.
- Neither approach is very practical
- Additional guidance on this allows for a trade-off between the two temperatures and the maximum number of days until post-weighing.

- Shipping procedures are inconsistent with sampling and post-sampling conditions in the sampler, where samples are exposed to ambient temperature.
- Filter Recovery extension study demonstrated that filters residing in sampler at ambient conditions for up to several days have an acceptable bias

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- Recommend changing requirements to read that recovered samples are to be maintained at sub-ambient temperature conditions or up to four degrees C in cold weather situations, during transport from the sample station to the gravimetric laboratory.
  - If this criteria is met then up to 30 days would be provided to post weigh the sample.

$PM_{2.5}$ Method Equivalency Criteria – (Attachment 4)

- Extensive statistical investigation with EPA – OAQPS, EPA - ORD, RTI, and Battelle

- Data Quality Objective process that provide an analytical connection between **equivalency criteria and expected data quality in network**

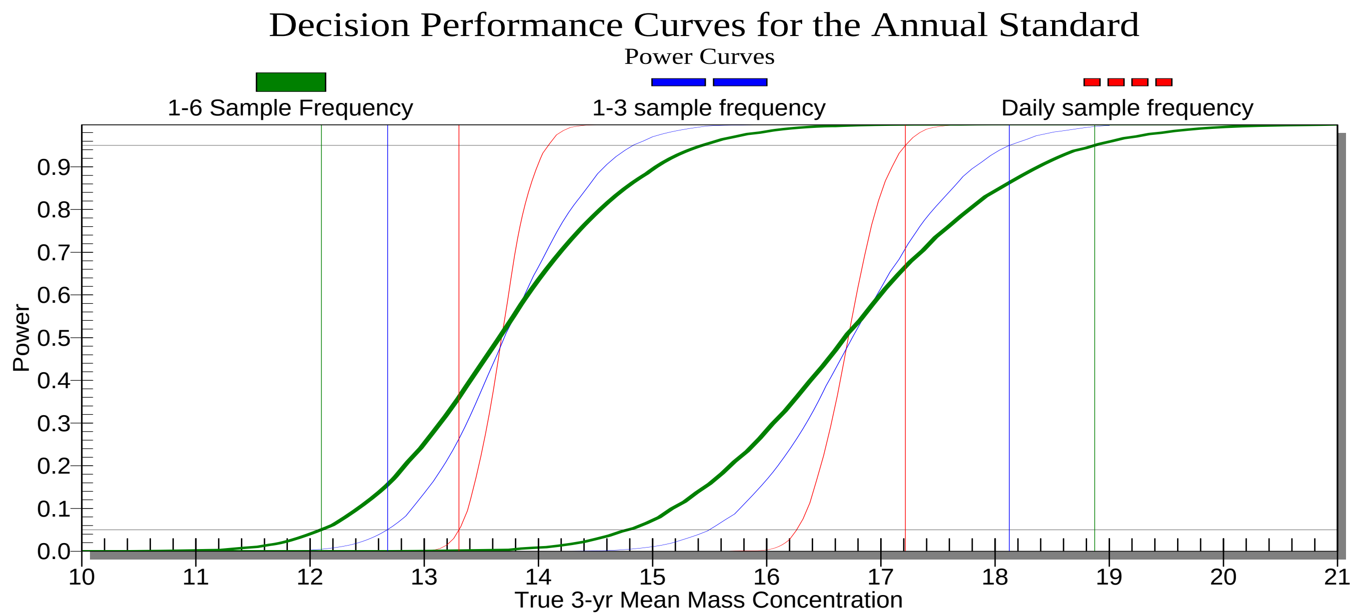
  - The $PM_{2.5}$ DQOs are based on (among other assumptions) sampling every sixth day.

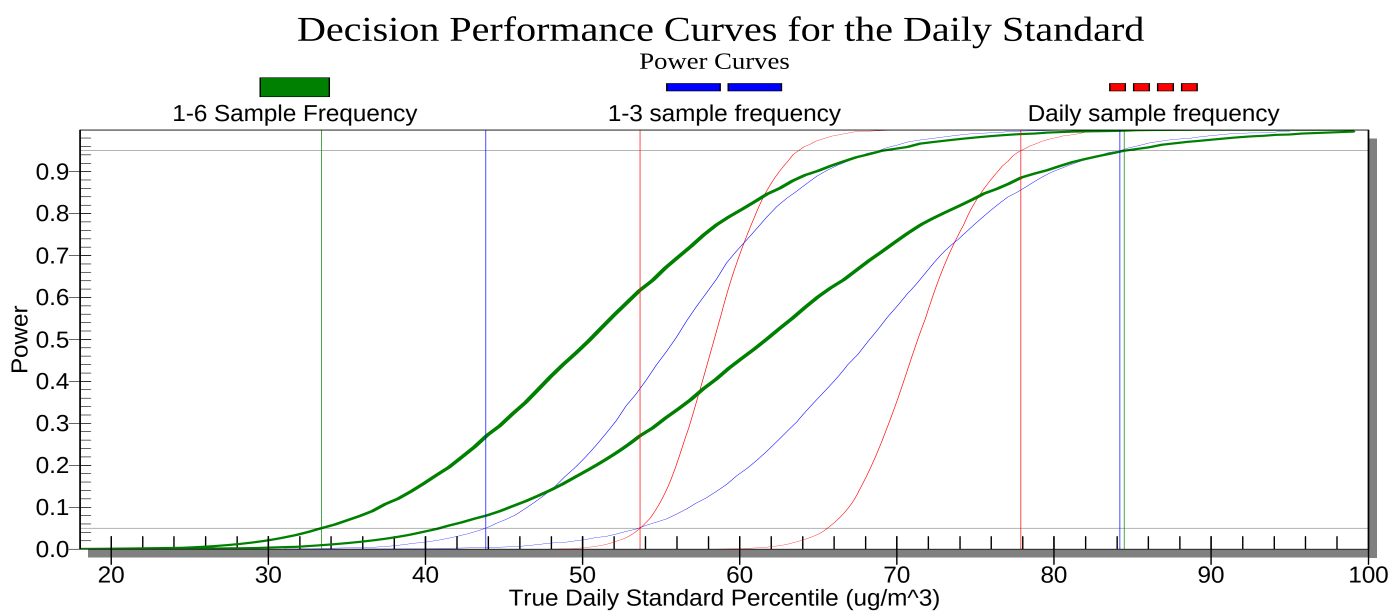
  - The "continuous" methods produce data on a daily basis. This yields an opportunity for relaxed standards in the measurement accuracy while maintaining the same overall decision quality.

- EPA Staff recommend proposing as applicable to both National Equivalency and Approved Regional Methods

Decision Performance Curves for $PM_{2.5}$

Input Parameters	**Level**
Type I and II errors	0.05
Annual Standard	15 µg/m³
Daily Standard	65 µg/m³
Daily Percentile	98
Seasonality ratio	5.3
Population CV	0.8
Autocorrelation	0
Sampling frequency	1 in 1 1 in 3 1 in 6
Bias	0.1
Measurement CV	0.1
Completeness	0.75

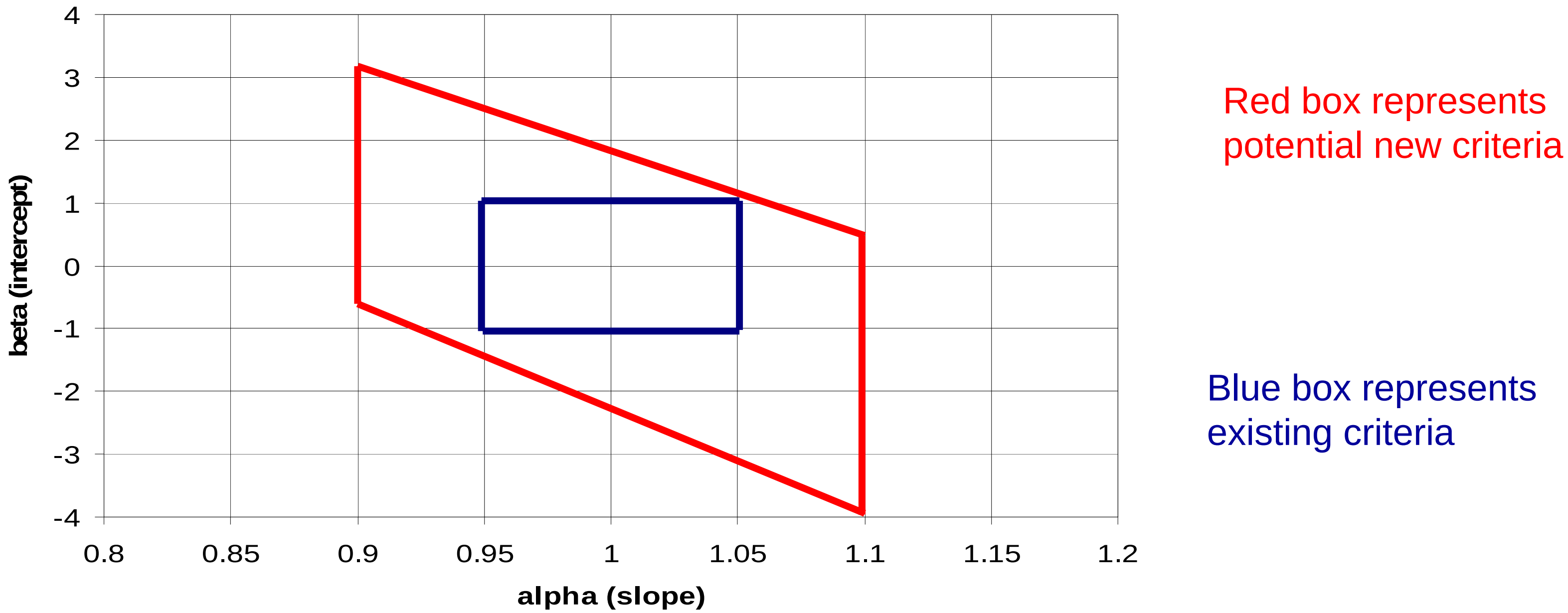




Summary of Measures and Criteria being Recommended

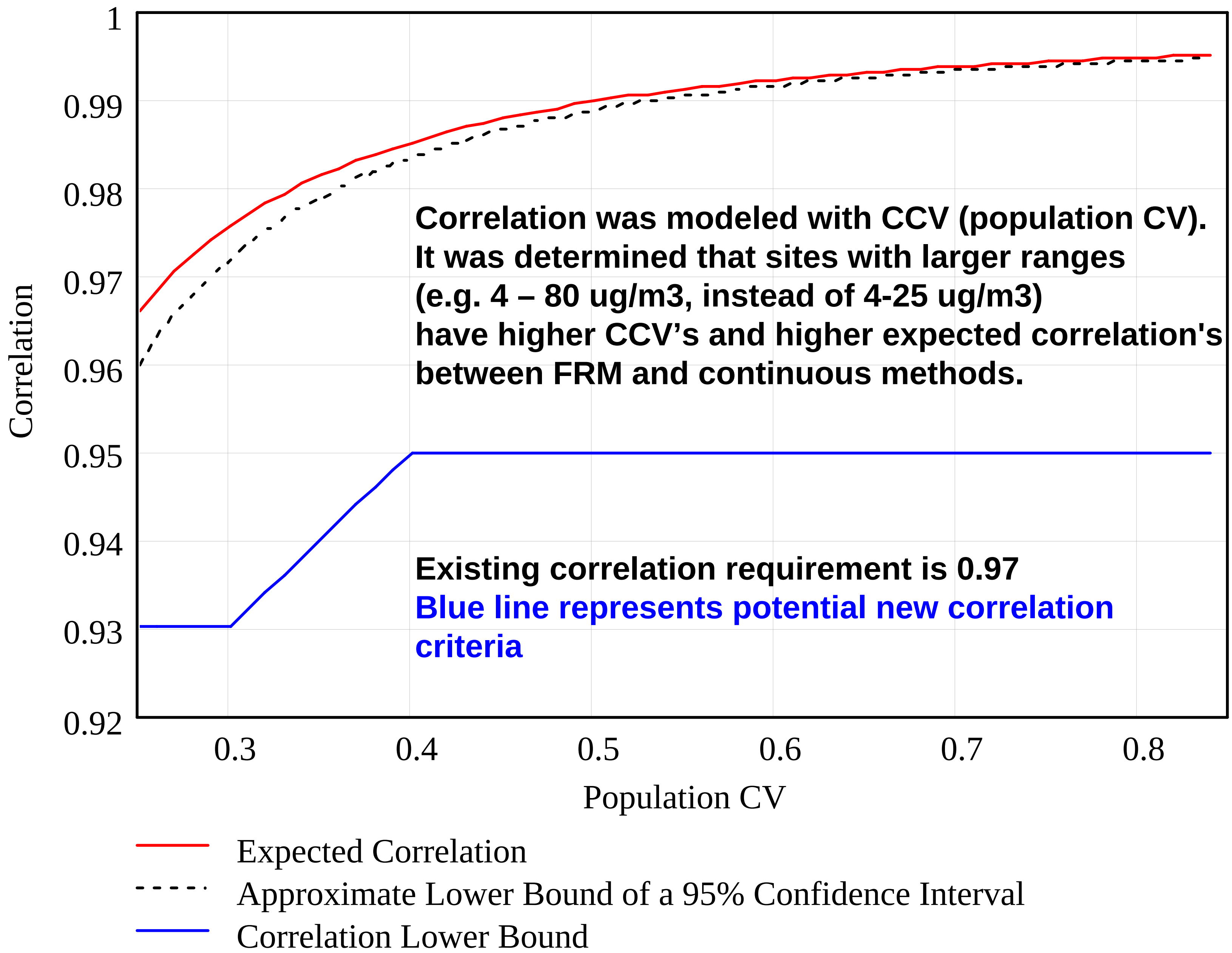
- Basis of comparison is the FRM
  - FRM precision <= 7.5%
  - Determine Concentration Coefficient of Variation (CCV)
    - Used to determine required correlation
- Candidate Sampler (the $PM_{2.5}$ continuous monitor)
  - Precision <=15% - Collocation of two or more monitors of the same make and model
  - Correlation lower bound (Note correlation, not squared correlation)
    - 0.93 if *CCV* <0.3
    - 0.87 + 0.2**CCV* if 0.3 <= *CCV* < 0.4
    - 0.95 if 0.4 <= *CCV*
  - Multiplicative Bias (the slope or alpha) - must fall between 0.90 and 1.10
  - Additive Bias (the intercept or beta) is function of multiplicative bias
    - -0.529 to +3.17 for slopes of 0.90
    - -3.991 to +0.530 for slope of 1.10

Existing versus Recommended Additive and Multiplicative Bias Criteria for Equivalency of PM2.5 Continuous Monitors



- Linear regression is used to find the multiplicative and additive components of the bias.
  - Both components are seen in real data from semi-continuous instruments.
  - The multiplicative bias is held at ±10%.
  - The limits on the additive portion depend on the multiplicative portion and the desired gray zone.

Potential New Correlation Criteria



Summary of $PM_{2.5}$ Method Equivalency

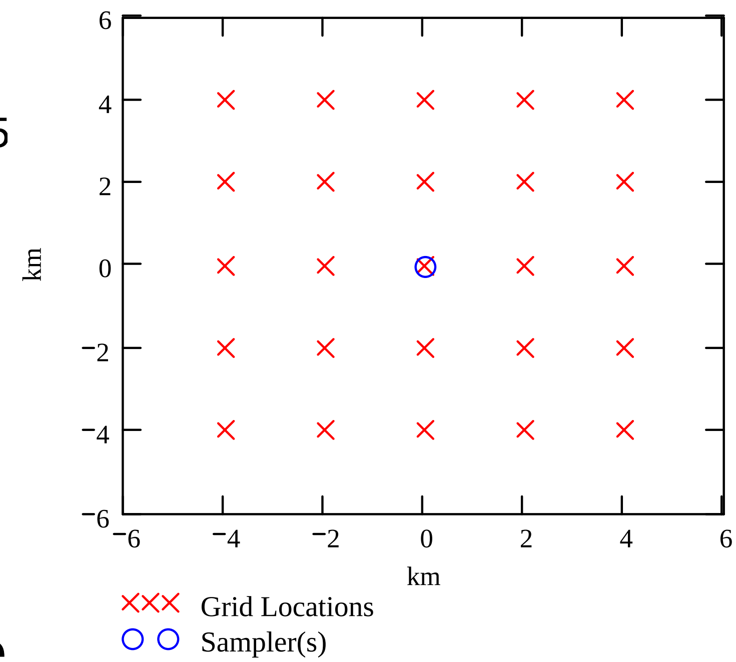
- The requirements are derived from the $PM_{2.5}$ DQO simulation model.
- The calculations for establishing equivalency include a precision calculation and the usual calculations based on linear regression against the standard: correlation, intercept, and slope.
- The calculations can be performed on most spreadsheet packages.
- The correlation requirements are based on sample population of the test sites; therefore, testing can benefit from selection of sites with expected high population CV.
- Example in attachment 4 illustrates easily repeatable data set for Instrument Companies and Monitoring Agencies to follow.

$PM_{10-2.5}$ Monitoring Network Data Quality Objectives (Attachment 5)

- Last year CASAC reviewed the methodology for developing the DQOs. The overall approach to the process was agreed to, but several issues were identified. A team of statistical modelers from OAQPS/ORD looked at:
  - Investigating spatial variability.
  - Investigating bimodal distributions.
  - General testing of the relative sensitivity to various input parameters.

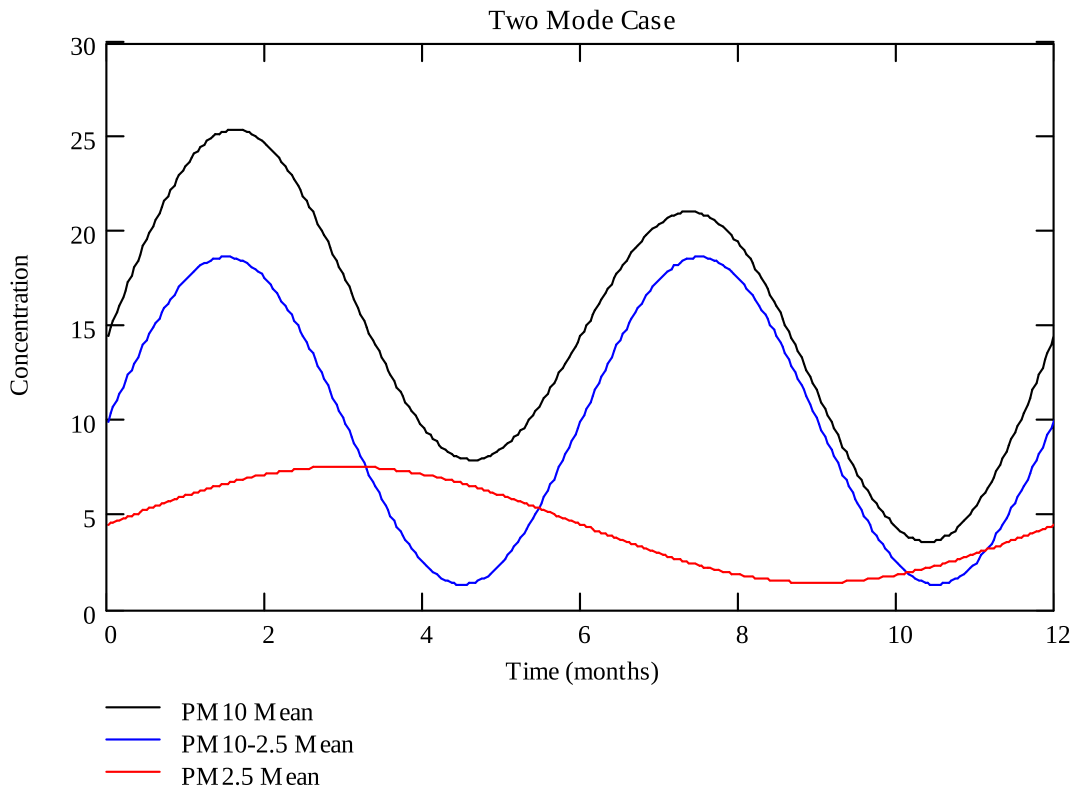
Coarse PM DQO Methods – Spatial Variability

- The new model simulates an 8 km x 8 km grid for the $PM_{10-2.5}$ fraction for each day of the 3-year period with the temporal variation as before.
  - Sampling is simulated only at the center of the grid.
  - $PM_{2.5}$ is assumed uniform across the grid.
  - "Truth" for the grid is defined as the average of the 3-year mean 98th percentiles for each grid point.
  - Exponential spatial model used.



A single truth is needed to compare with the sample derived estimate.

Coarse PM DQO Methods – Bimodal Distributions



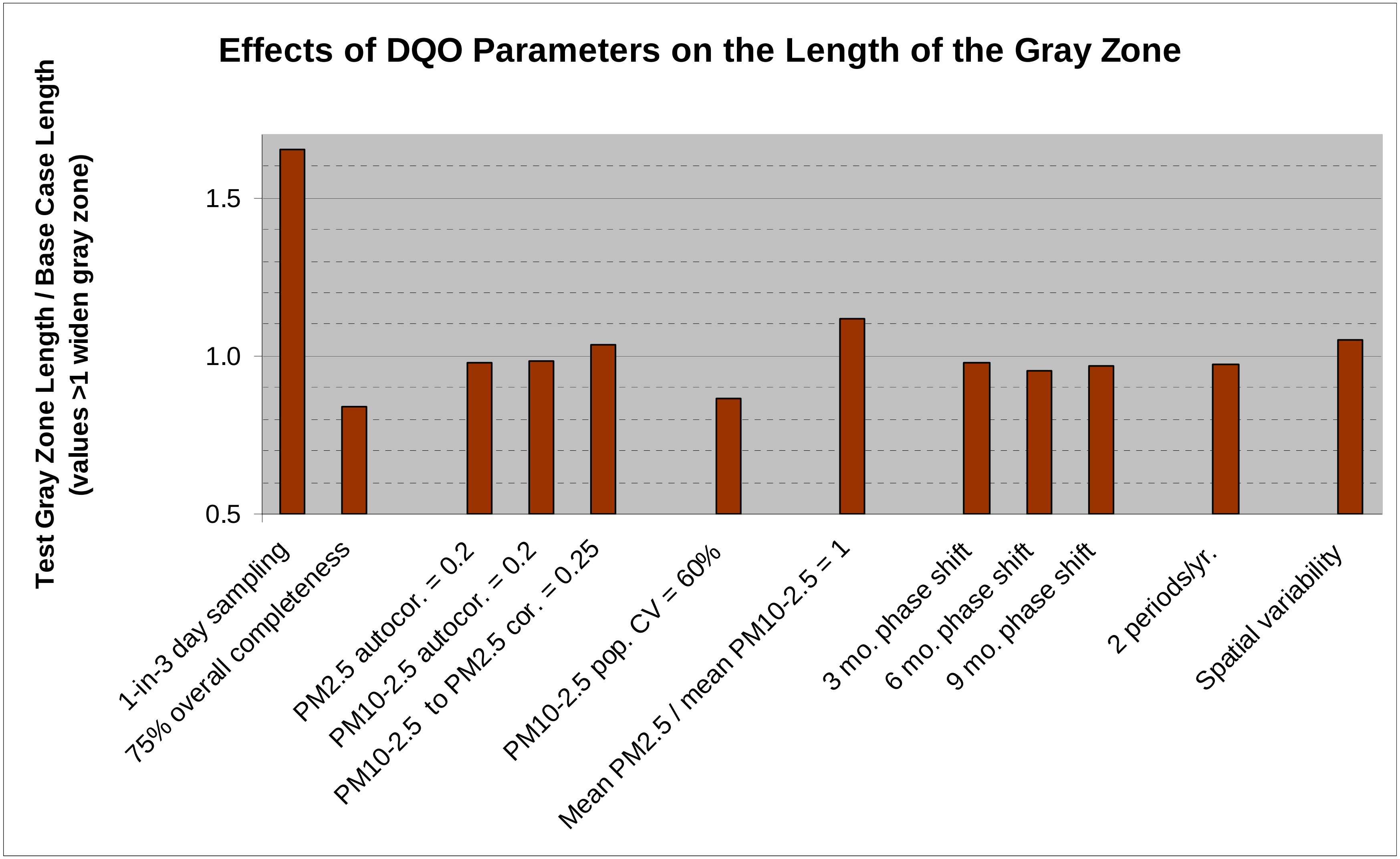
- Bimodal distributions and phase shifts between the $PM_{10-2.5}$ and $PM_{2.5}$ annual cycles were investigated.
- The temporal pattern applies to the entire $PM_{10-2.5}$ spatial surface.

The cycles for the $PM_{10-2.5}$ and $PM_{2.5}$ means are pure sine waves. Previous work has shown that the gray zones are insensitive to the shape of the curves.

Coarse PM DQO
Results of the Sensitivity Testing

- The sensitivity testing consisted of running the new model with a variety of input parameters changing 1 parameter at a time.
  - To run the model a daily NAAQS of 35 µg/m^3 was assumed for the three-year mean 98th percentile. However, the results are scaled to be relatively insensitive to this choice.
  - The relative increase in the length of the gray zone for the daily NAAQS was used as the response variable.
- The base case included: daily sampling, no spatial variability, 1 $PM_{10-2.5}$ mode, no phase shift, 10% precision and bias and 75% completeness for both $PM_{2.5}$ and PM_{10}, no correlations.

Effect of Changing Parameters



Conclusions

- Performance curves not as sensitive to spatial variability and distributions as they are to other parameters such as completeness, sampling frequency and bias.

- Will incorporate a component of spatial variability into DQO for $PM_{10-2.5}$.

- Given the effect of sampling frequency on the performance curves, daily sampling is recommended for use as the default input parameter

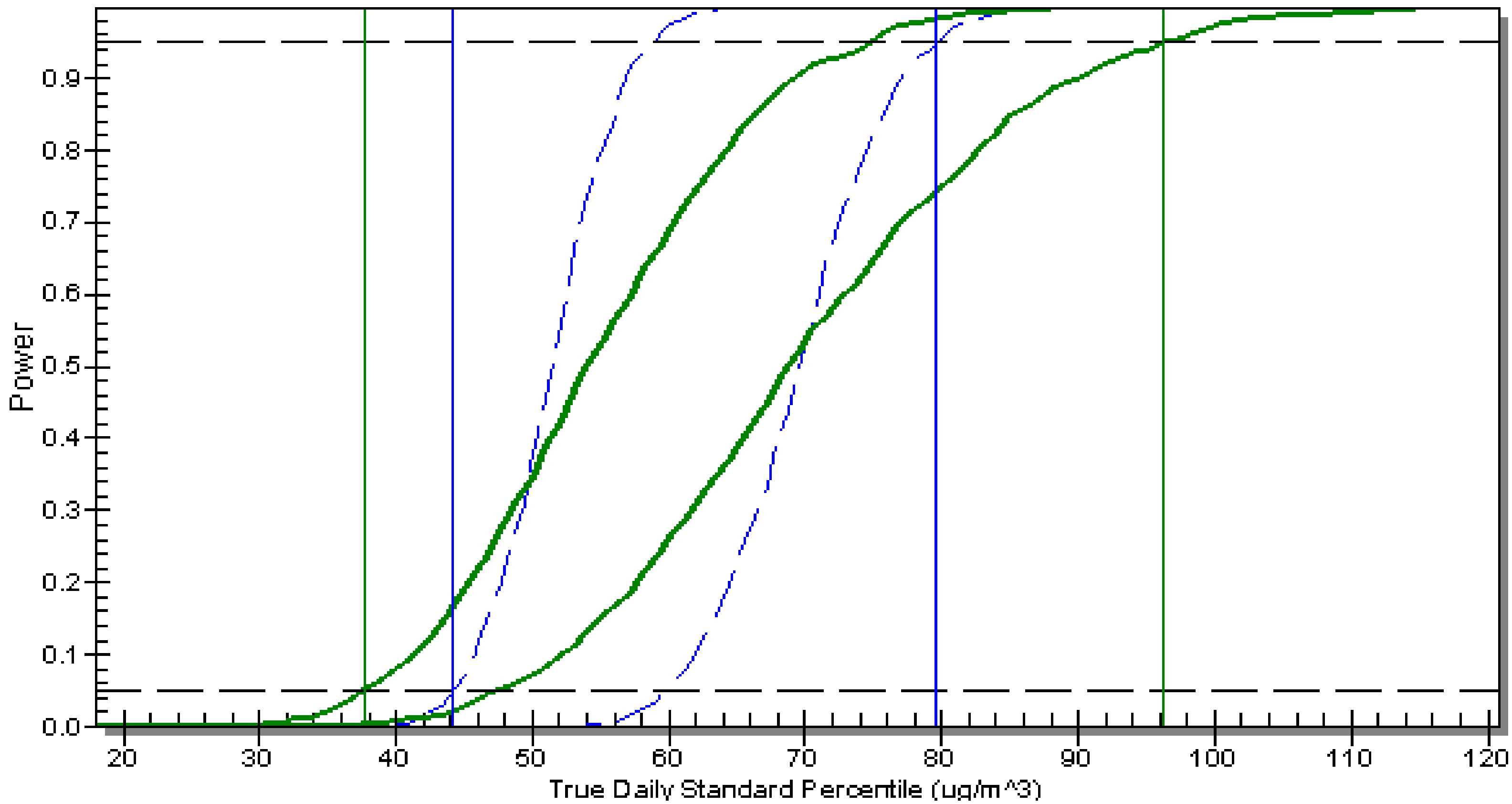
$PM_{10-2.5}$ Method Equivalency Development (Attachment 6)

- $PM_{10-2.5}$ method equivalency development is an extension of:
  - $PM_{10-2.5}$ monitoring network data quality objectives
  - $PM_{2.5}$ method equivalency criteria development
- Continuous methods are expected as candidate equivalent methods
    - Operate at a daily sampling frequency with hourly data
    - Effective completeness that is likely to be higher than reference methods
  - These two factors strongly influence the width of the gray zone (a means of measuring decision quality)
  - Consequently, the continuous methods can be allowed relaxed standards for the precision and bias.

Parameter Settings for the DQO example

	Base Case		Alternative Scenario	
	Level	**Percentile**	**Level**	**Percentile**
Daily Standard	60 µg/m³	98th	60 µg/m³	98th
PM Fraction Characteristics	**$PM_{10-2.5}$**	**$PM_{2.5}$**	**$PM_{10-2.5}$**	**$PM_{2.5}$**
Seasonality ratio	14	5.3	14	5.3
Population CV	1	0.8	1	0.8
Autocorrelation	0	0	0	0
Global Characteristics	**Setting**		**Setting**	
Phase shift	0		0	
$PM_{2.5}$ to $PM_{10-2.5}$ correlation	0		0	
Mean $PM_{2.5}$ / mean $PM_{10-2.5}$	0.45		0	
$PM_{10-2.5}$ Periods per year	1		1	
$PM_{10-2.5}$ Spatial sill	1		1	
$PM_{10-2.5}$ Spatial Range	20		20	
Sampling frequency	3		1	
Measurement Error Characteristics	**PM_{10}**	**$PM_{2.5}$**	**PM_{10}**	**$PM_{2.5}$**
Bias	0.1	0.1	0.15	0
Measurement CV	0.1	0.1	0.15	0
Completeness	0.75	0.75	0.75	1
Output	**Lower Bound**	**Upper Bound**	**Lower Bound**	**Upper Bound**
Daily Gray Zone	37.7 µg/m³	95.6 µg/m³	44.8 µg/m³	79.8 µg/m³

Decision Performance Curves for developing $PM_{10-2.5}$ Method Equivalency

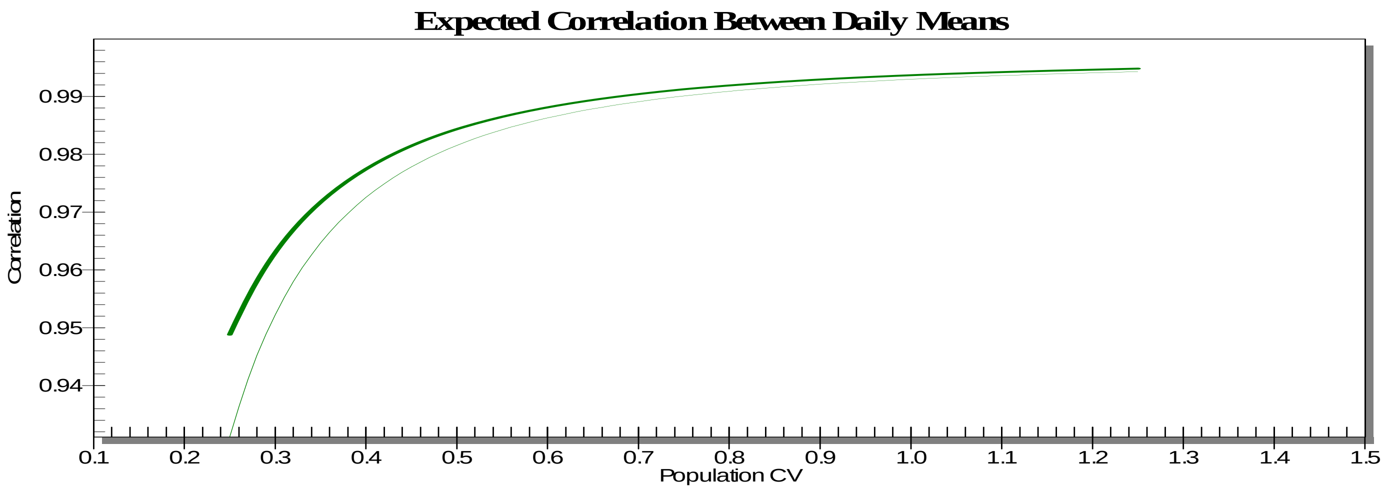


DQO case = green or solid

Alternative Case = blue or dashed

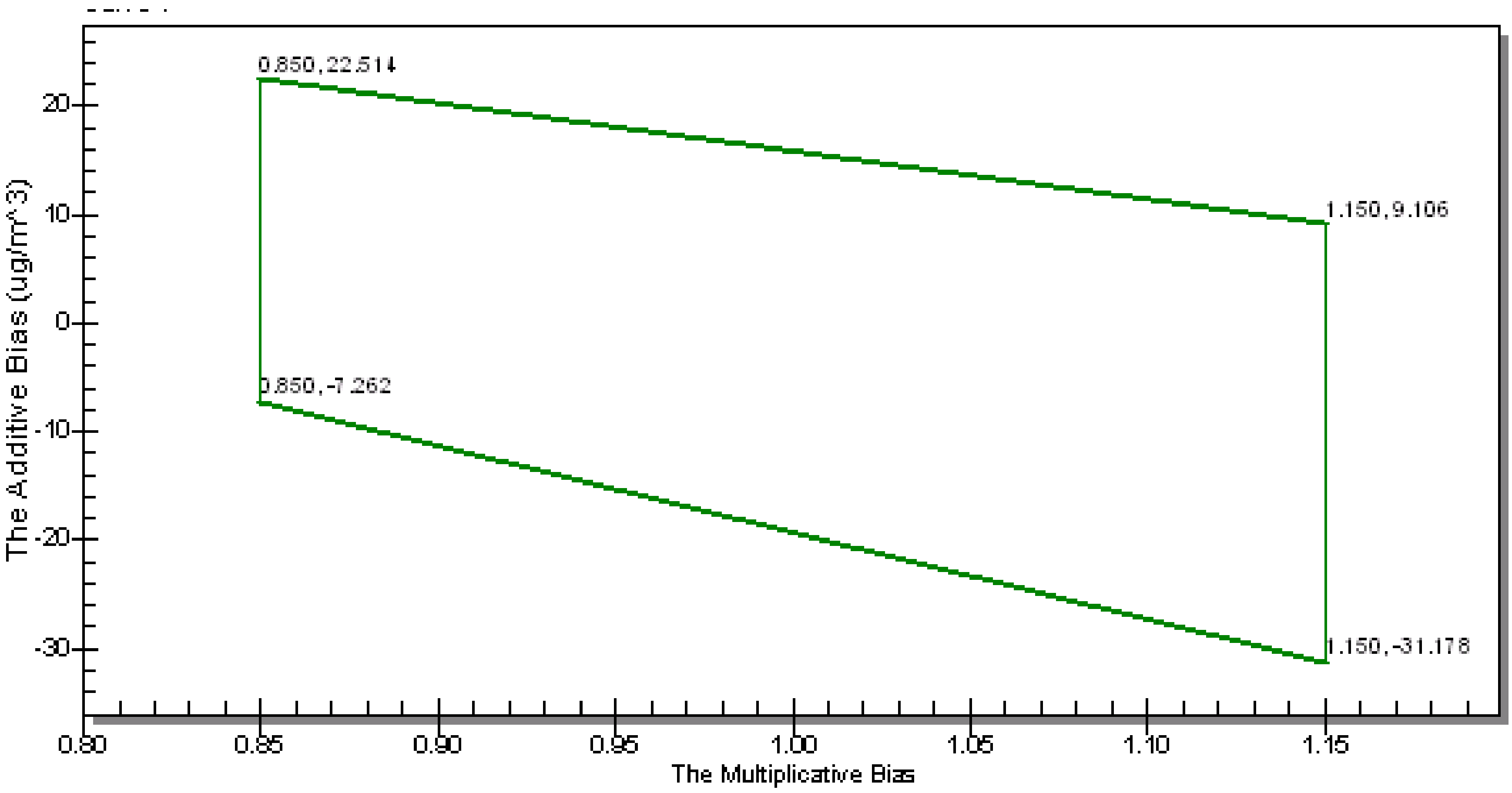
Determining a Minimum Correlation for $PM_{10-2.5}$ Method Equivalency

- Expected Correlation is a function of:
  - Coefficient of variation (CV) of the concentrations (population) measured
    - Acceptance criteria would vary with the measured coefficient of variation of the daily means from the reference method
  - Number of FRM and candidate samplers operated
  - Measurement CV
  - Number of sample days



Expected correlation (solid) and approximate lower bound (dashed)

Additive and Multiplicative Bias for $PM_{10-2.5}$ Method Equivalency



Summary of $PM_{10-2.5}$ Equivalency Criteria

- Follows same basic approach for establishing performance criteria as $PM_{2.5}$
- Network DQOs are a work in progress and will affect establishment of final criteria
- Level of NAAQS will affect the final criteria for additive bias
- Performance criteria could be strengthened to meet other monitoring objectives, pending success of methods in field studies