Coarse PM Methods Evaluation Study: Study Design and Results

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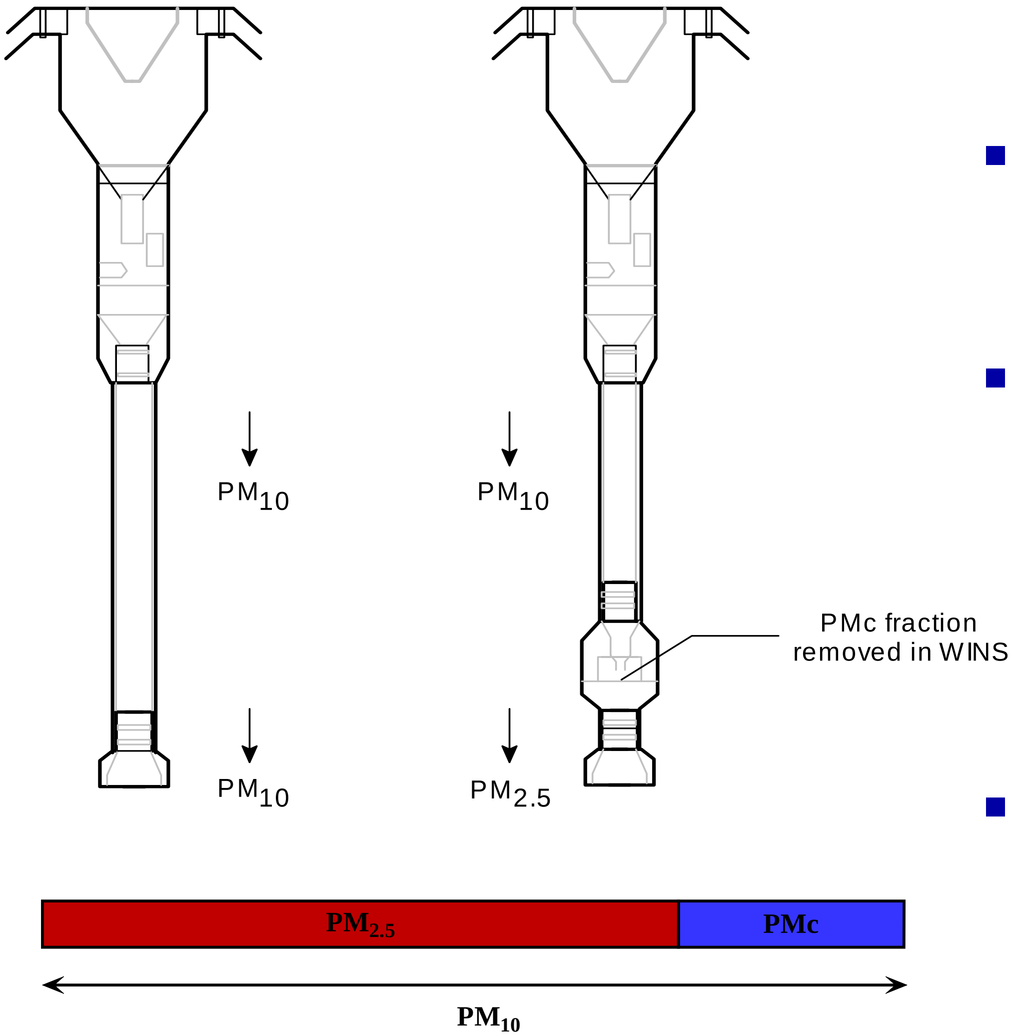
BACKGROUND

- U.S. courts have ruled that PM_{10} represents a "poorly matched indicator" of PM because it includes the $PM_{2.5}$ fraction. EPA has consented to establish separate standards for the fine and coarse fractions of PM_{10}

STUDY OBJECTIVES

- Conduct multi-site performance evaluations of leading methods (integrated and semi-continuous) for monitoring the coarse fraction of PM_{10} ($PMc = PM_{10} – PM_{2.5}$). Size fractionation must be based on aerodynamic diameter and measurements must be referenced to mass concentration
- Evaluate the relative performance and precision of PMc samplers under a wide range of weather conditions and aerosol types

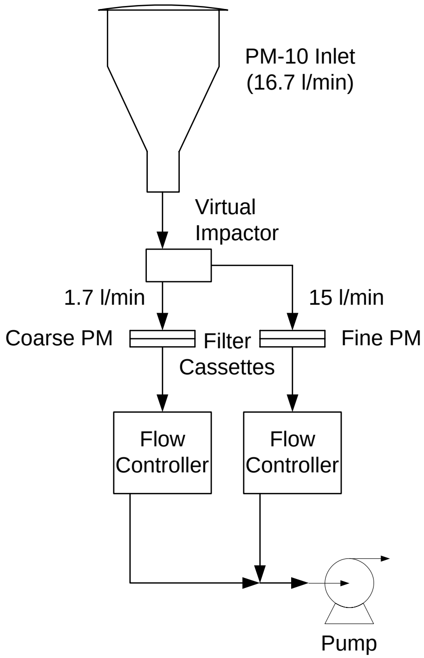
$PM_{2.5}$ and PM_{10} FRM Samplers



$PMc = PM_{10} – PM_{2.5}$

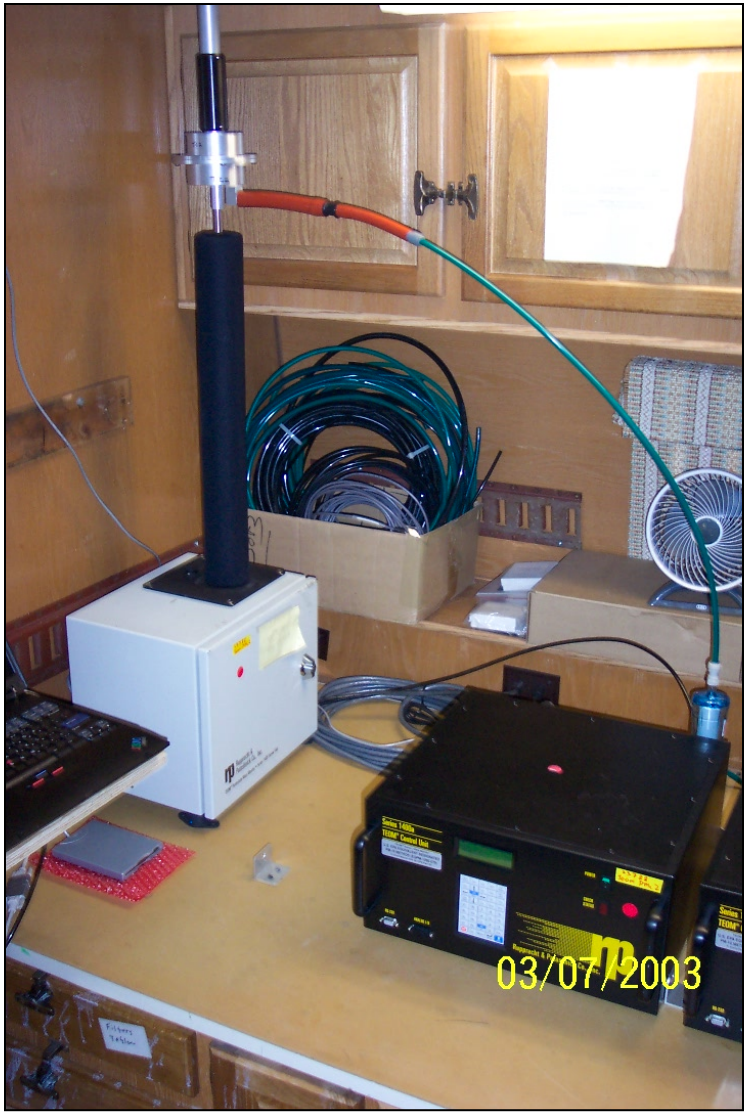
- **Standard low-vol PM_{10} inlets aspirating at 16.7 lpm (actual conditions)**
- **$PM_{2.5}$ aerosol fractionation using a WINS equipped with DOS impaction oil**
- **Filters were conditioned at 22C and 35% RH, analyzed gravimetrically. Post-sampling filters archived at -30C for subsequent chemical analysis**
- **3 FRM pairs from BGI, R&P, and Thermo-Andersen equipped with teflon filters (4^{th} FRM pair equipped with quartz filters)**

R&P Partisol-Plus 2025 Dichot



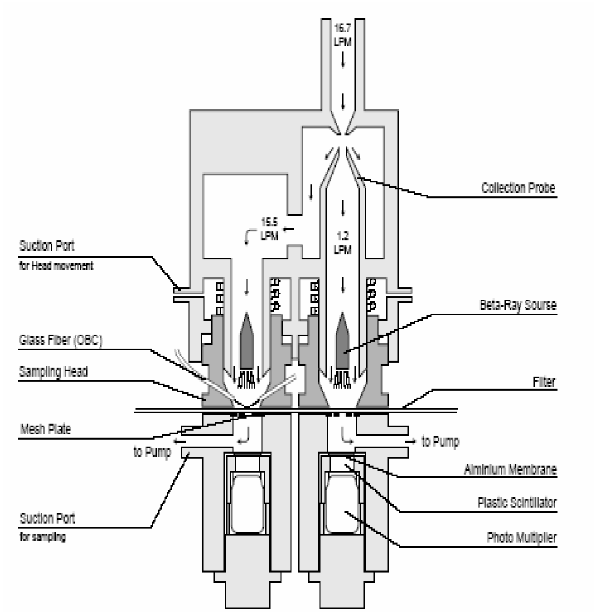
- **Standard PM_{10} inlet aspirating at 16.7 lpm (actual)**
- **Aerosol fractionation by custom virtual impactor (15 lpm and 1.67 lpm)**
- **$PM_{2.5}$ and PMc mass collected on 47 mm teflon filters for gravimetric analysis**
- **Sequential sampler with multi-day capability**
- **4 units used in our study (3 teflon and 1 quartz)**

R&P Coarse Particle TEOM



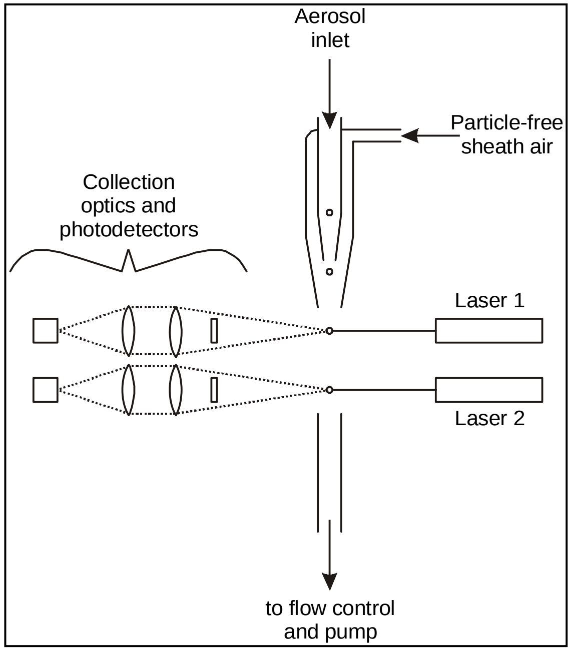
- Modified PM_{10} inlet aspirating at 50 lpm (actual)
- PM_{10} aerosol is fractionated by a custom virtual impactor (2 lpm coarse flow and 48 lpm fine flow)
- PMc fraction is heated to 50 C to remove particle bound water
- Coarse aerosol is collected and quantified by a standard TEOM sensor
- 3 units used in our study

Tisch SPM-613D Dichot Beta Gauge



- Standard PM_{10} inlet aspirating at 16.7 lpm
- Aerosol heated if <25C
- Aerosol fractionation by custom virtual impactor
- $PM_{2.5}$ and PMc mass collected on polyflon tape roll
- $PM_{2.5}$ and PMc mass quantified hourly using separate beta sources and detectors
- 3 units used in our study

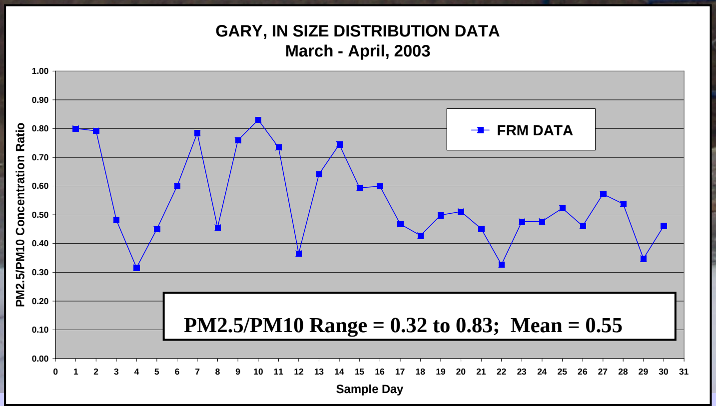
TSI Model 3321 Aerodynamic Particle Sizer



- Standard PM_{10} inlet aspirating at 16.7 lpm (actual)
- Isokinetic fraction of PM_{10} aerosol removed at 5 lpm and enters the APS inlet
- APS sizes individual particles aerodynamically using time of flight approach
- Single particle volume converted to mass using mean density provided by user
- Total aerosol mass is sum of individual particle masses
- APS provides only PMc; not applicable for $PM_{2.5}$ or PM_{10}
- Only sampler in study which provides detailed size distribution information
- 2 units used in our study

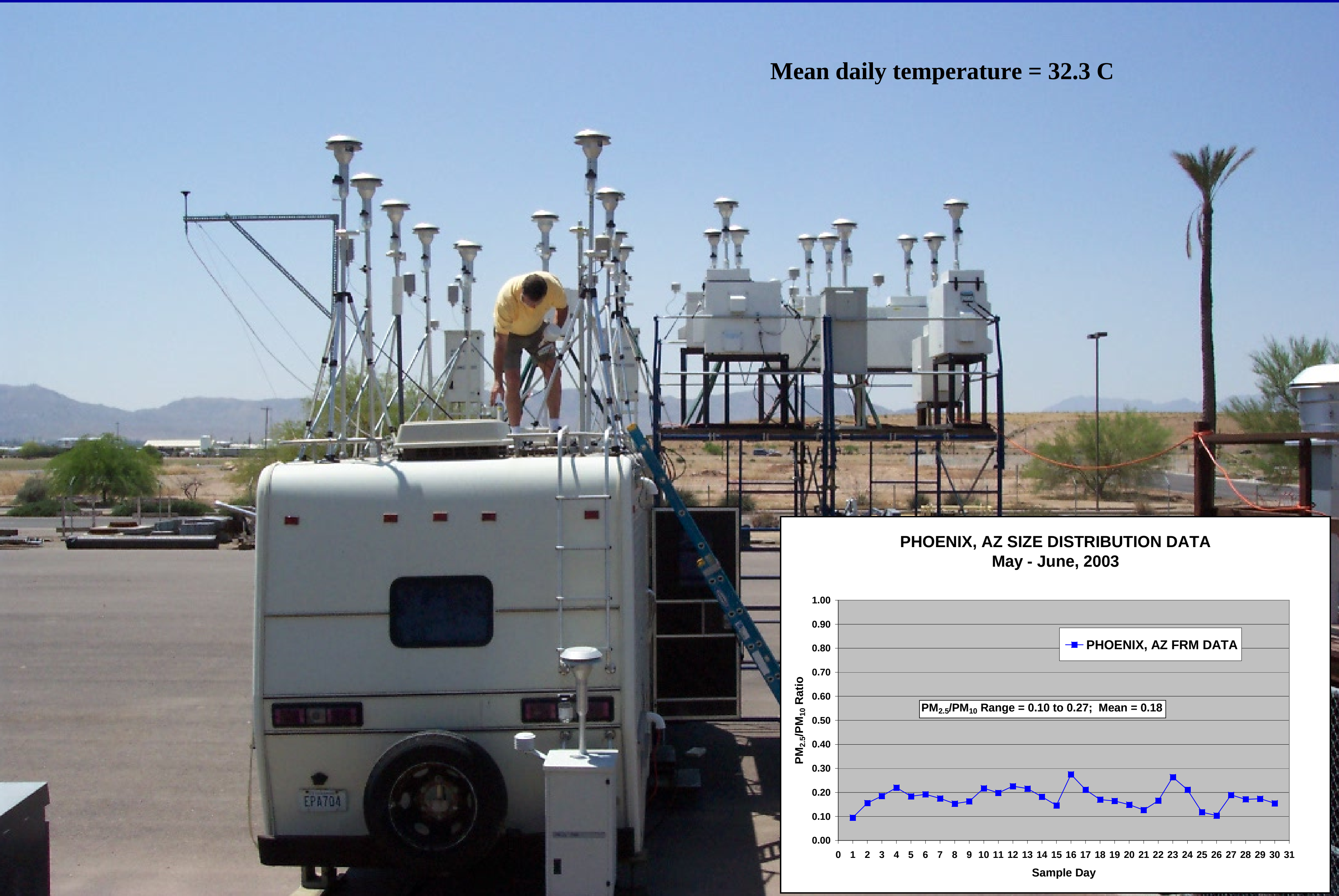
Gary, IN

Mean daily temperature = 4.6 C



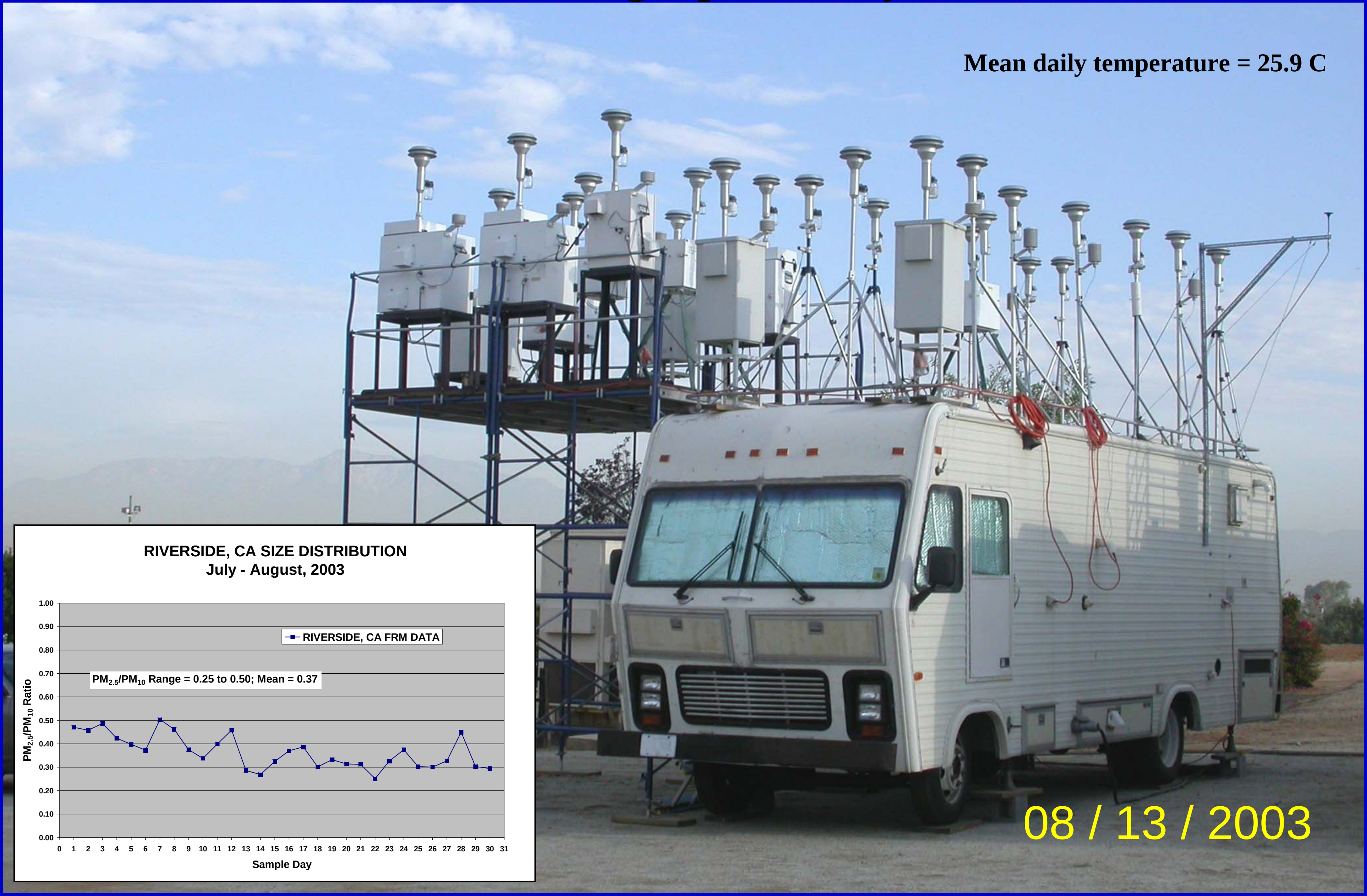
Phoenix, AZ

Mean daily temperature = 32.3 C

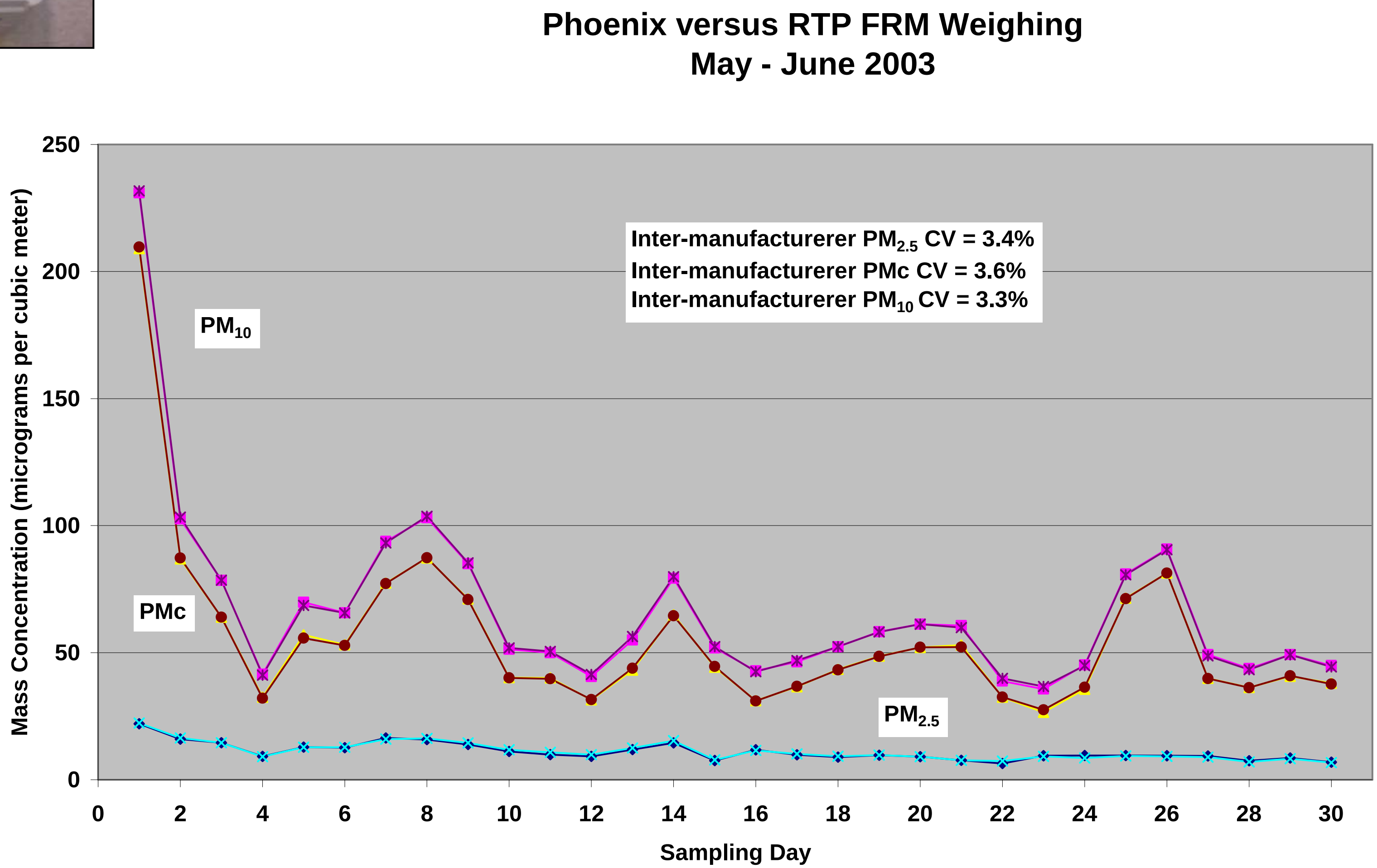


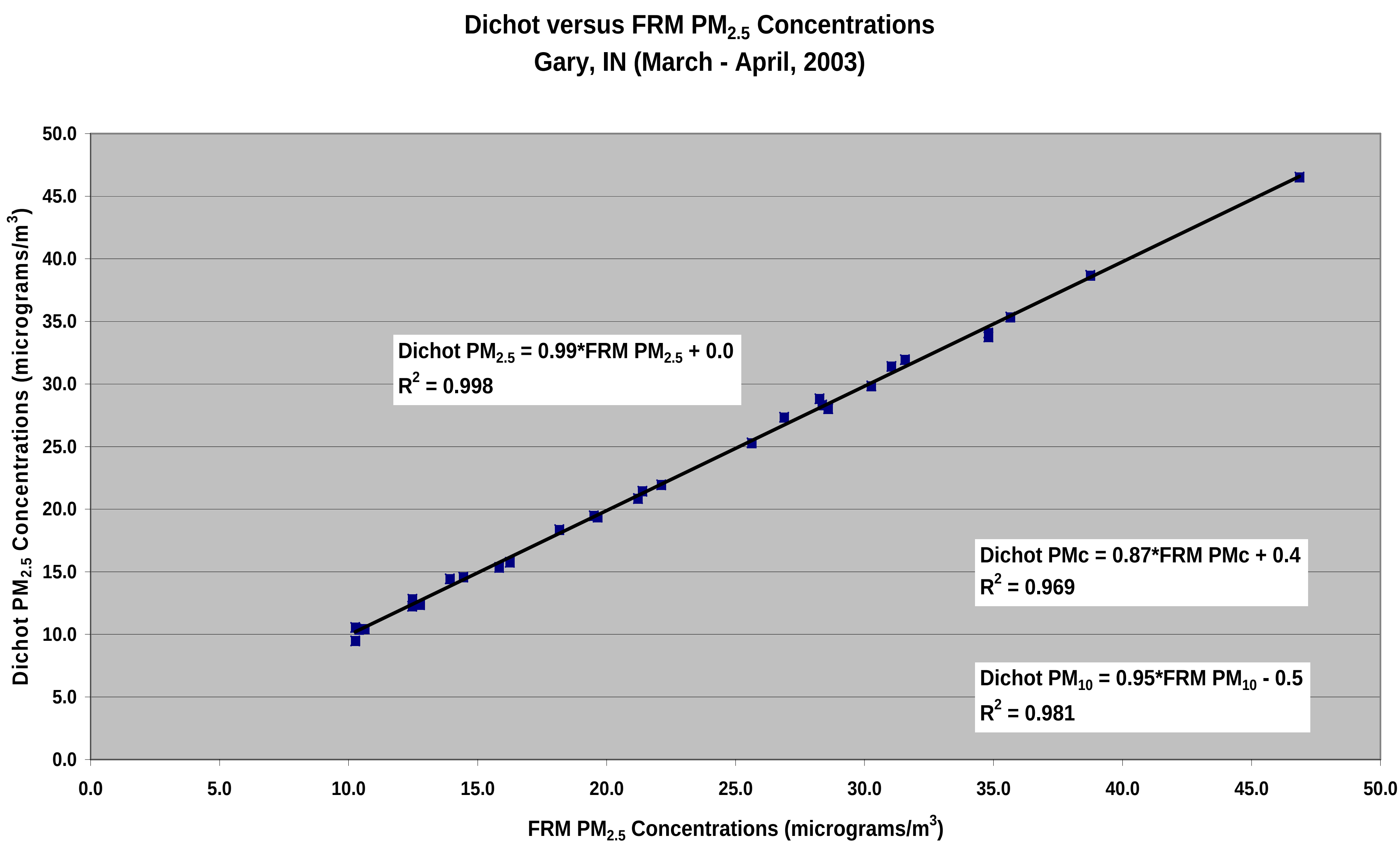
Riverside, CA

UCR Ag Ops Facility



$PM_{2.5}$ and PM_{10} FRM Performance





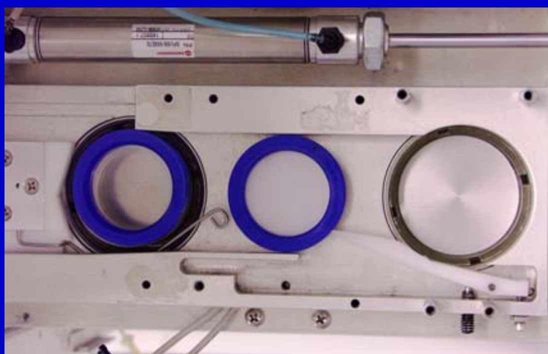
Dichot versus FRM PM2.5 Concentrations
Gary, IN (March - April, 2003)
Dichot PM2.5 = 0.99*FRM PM2.5 + 0.0
R2 = 0.998
Dichot PMc = 0.87*FRM PMc + 0.4
R2 = 0.969
Dichot PM10 = 0.95*FRM PM10 - 0.5
R2 = 0.981
Dichot PM2.5 Concentrations (micrograms/m3)
FRM PM2.5 Concentrations (micrograms/m3)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0

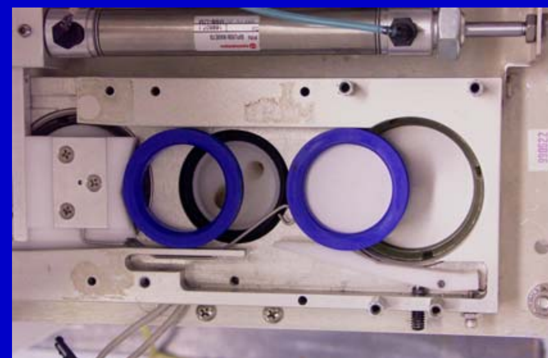
R&P Dichots vs. FRM

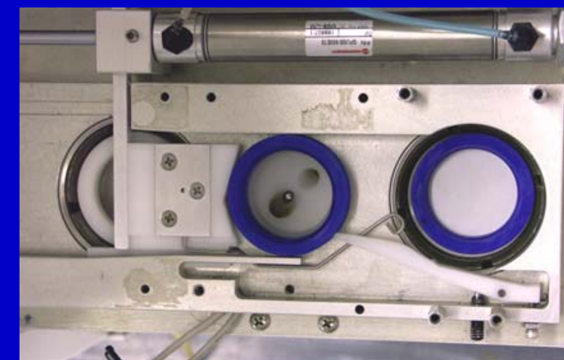
Metric	Gary, IN	Phoenix, AZ	Riverside, CA
$PM_{2.5}$	Slope = 0.99 Int. = +0.0 R^2 = 0.998 Ratio to FRM = 0.99	Slope = 1.24 Int. = -1.6 R^2 = 0.97 Ratio to FRM = 1.09	Slope = 0.998 Int. = +0.0 R^2 = 0.995 Ratio to FRM = 1.00
PMc	Slope = 0.87 Int. = +0.39 R^2 = 0.969 Ratio to FRM = 0.89	Slope = 0.70 Int. = +5.0 R^2 = 0.98 Ratio to FRM = 0.79	Slope = 0.95 Int. = +0.25 R^2 = 0.98 Ratio to FRM = 0.96
PM_{10}	Slope = 0.95 Int. = -0.47 R^2 = 0.981 Ratio to FRM = 0.94	Slope = 0.75 Int. = +5.9 R^2 = 0.98 Ratio to FRM = 0.84	Slope = 1.00 Int. = -1.21 R^2 = 0.99 Ratio to FRM = 0.97

R&P 2025 Update

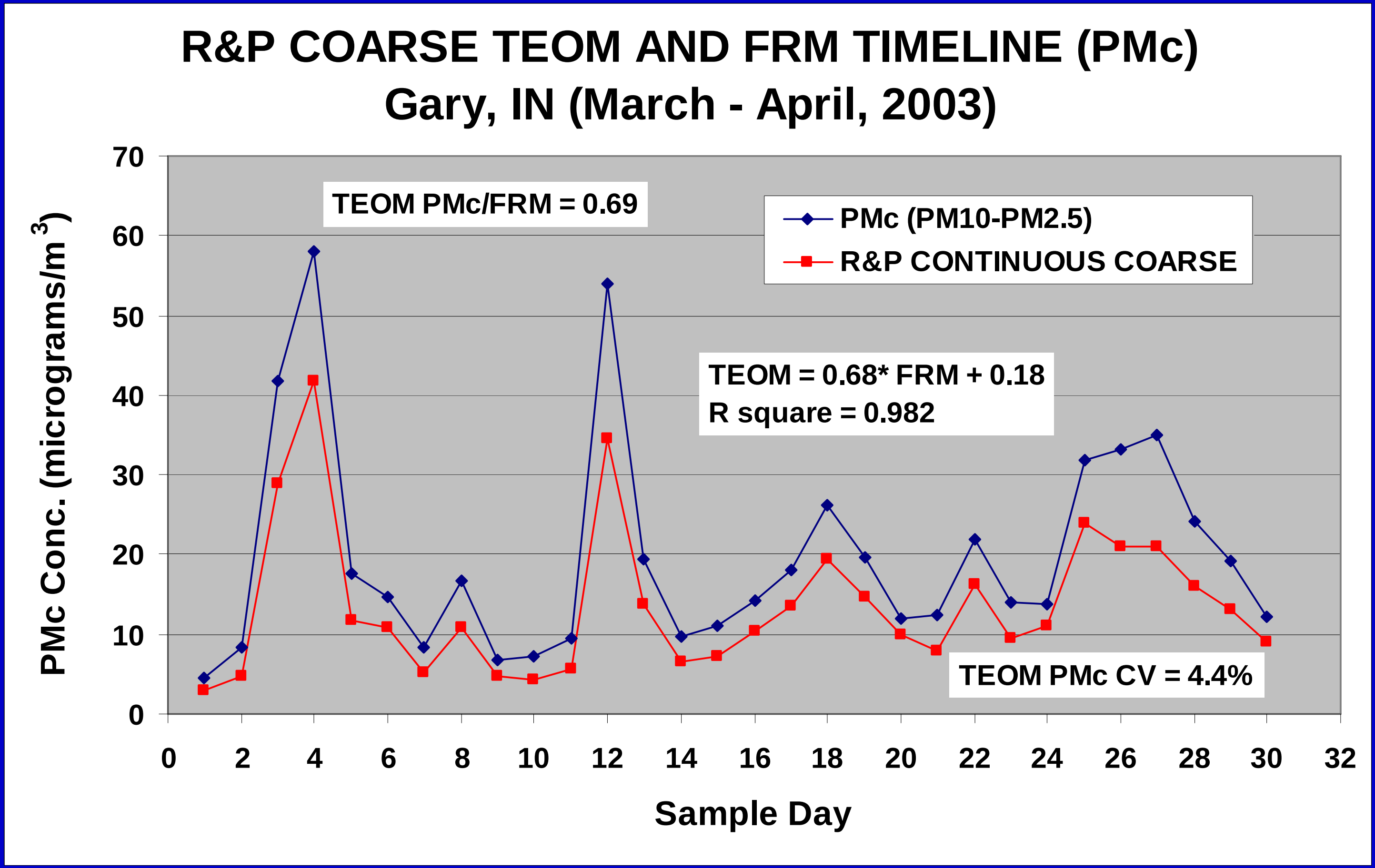
Redesigned Cassette Transfer Mechanism



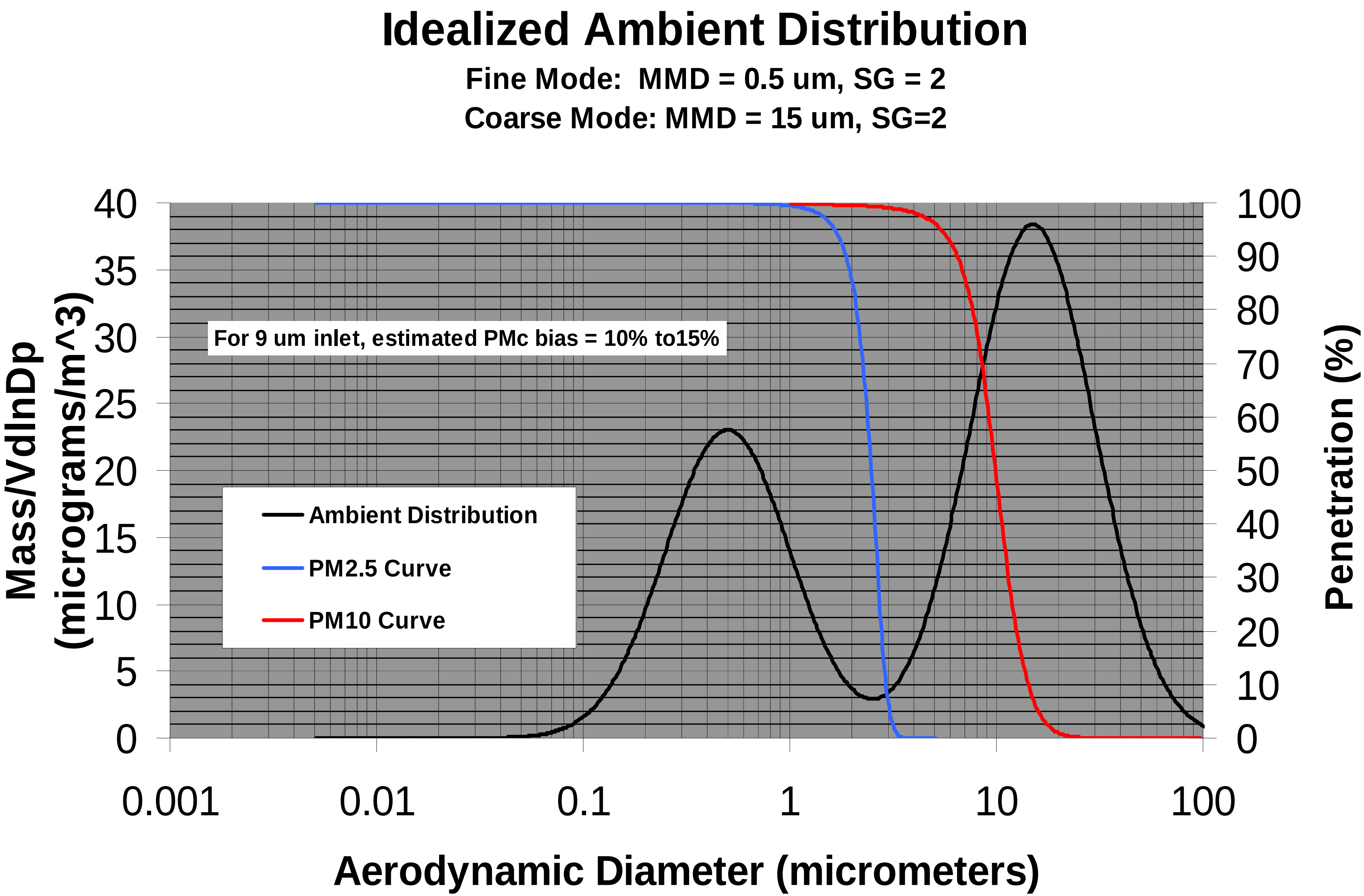




New Product: Single Event 2025 Dichot



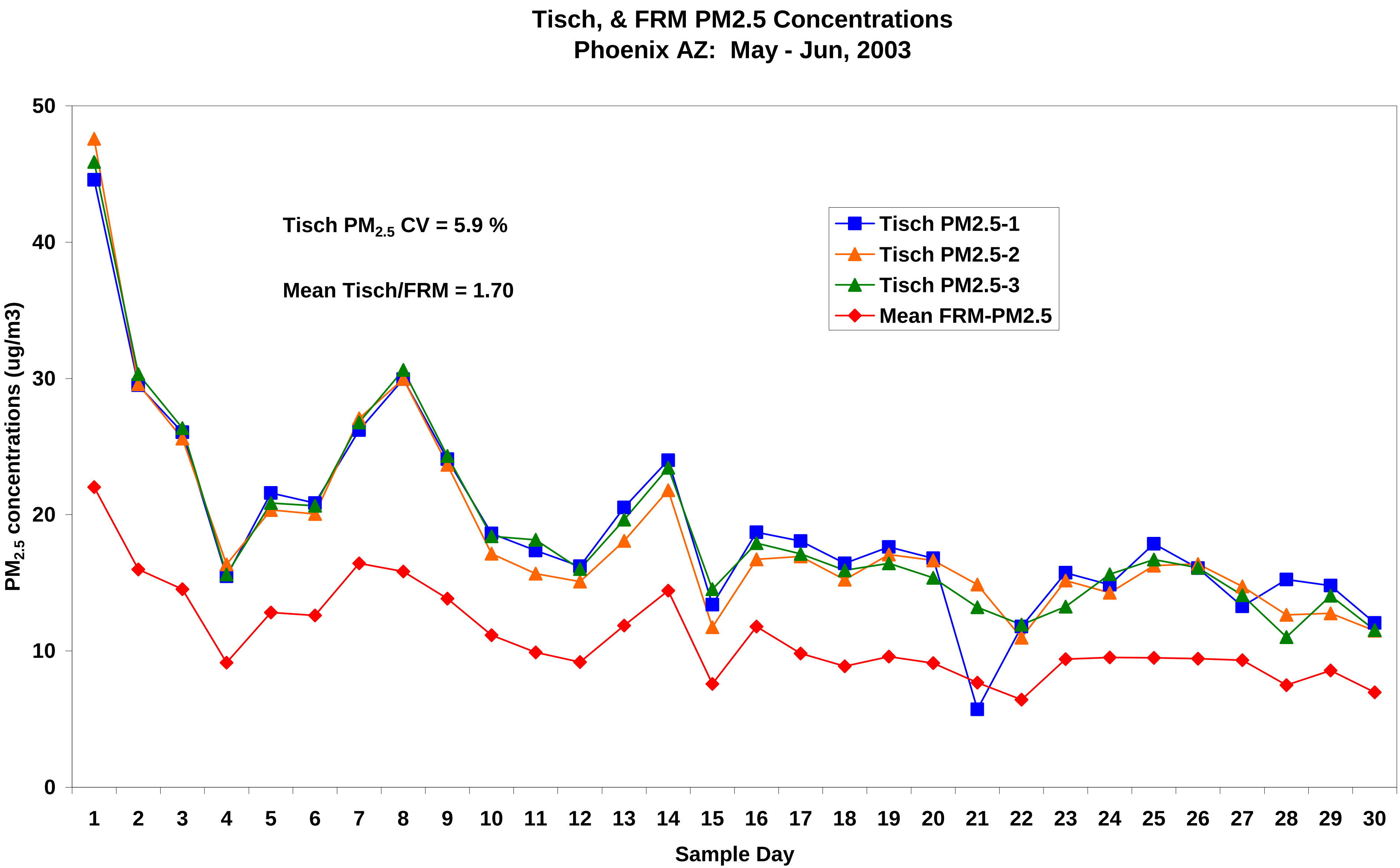
Metric	Gary, IN	Phoenix, AZ (May – June, 2003)	Riverside, CA	Phoenix, AZ (Jan 2004)
PMc	Slope = 0.68 Int. = +0.18 R^2 = 0.982 CV = 4.4% Ratio to FRM = 0.69	Slope = 0.79 Int. = +12.8 R^2 = 0.951 CV = 6.6% Ratio to FRM = 1.05	Slope = 0.74 Int. = -0.64 R^2 = 0.948 CV = 1.7% Ratio to FRM = 0.76	Slope = 0.77 Int. = +0.70 R^2 = 0.995 CV = 2.6% Ratio to FRM = 0.80



Idealized Ambient Distribution
Fine Mode: MMD = 0.5 um, SG = 2
Coarse Mode: MMD = 15 um, SG=2
For 9 um inlet, estimated PMc bias = 10% to15%
Ambient Distribution
PM2.5 Curve
PM10 Curve
Mass/VdlnDp (micrograms/m^3)
Penetration (%)
Aerodynamic Diameter (micrometers)
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
60
70
80
90
100
0.001
0.01
0.1
1
10
100

Coarse TEOM Update

- Diameter of the 50 lpm inlet's PM_{10} impaction nozzle has been increased to increase cutpoint from approximately 9 micrometers to 10 micrometers
- Redesigned inlet will be evaluated under static conditions in the laboratory by USC using primary calibration aerosols
- Recommended operating temperature of the coarse TEOM has been reduced from 50 ^{o}C to 35 ^{o}C

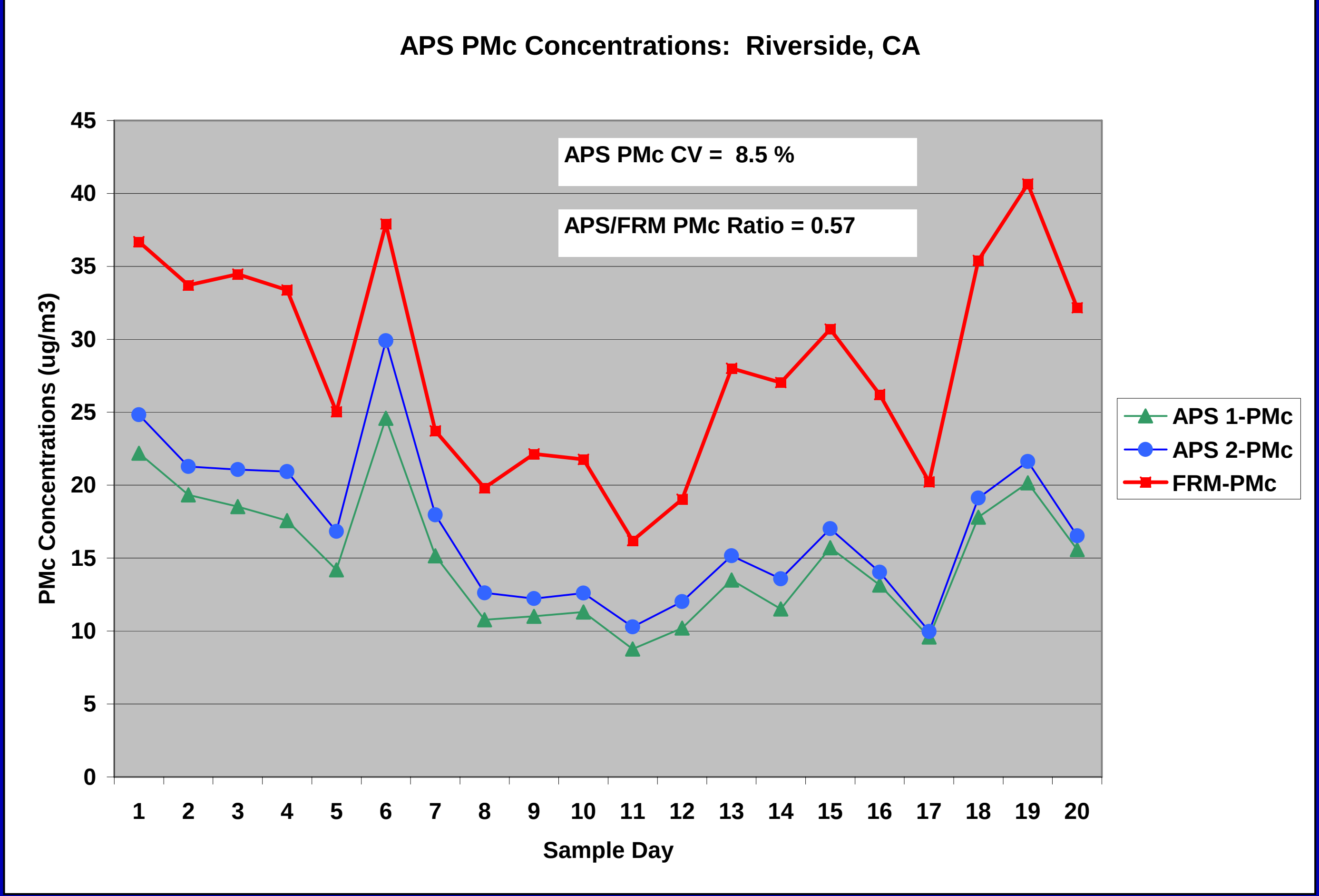

Tisch, & FRM PM2.5 Concentrations
Phoenix AZ: May - Jun, 2003
Tisch PM2.5 CV = 5.9 %
Mean Tisch/FRM = 1.70
Tisch PM2.5-1
Tisch PM2.5-2
Tisch PM2.5-3
Mean FRM-PM2.5
PM2.5 concentrations (ug/m3)
Sample Day
0
10
20
30
40
50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

Tisch Beta Gauge Dichot vs the FRM

Metric	Gary, IN	Phoenix, AZ (May – June, 2003)	Riverside, CA	Phoenix, AZ (Jan 2004)
$PM_{2.5}$	Slope = 1.17 Int. = +1.6 R^2 = 0.945 Ratio to FRM = 1.26	Slope = 2.03 Int. = -3.4 R^2 = 0.946 Ratio to FRM = 1.70	Slope = 2.07 Int. = -6.9 R^2 = 0.904 Ratio to FRM = 1.64	Slope = 1.43 Int. = -0.11 R^2 = 0.939 Ratio to FRM = 1.43
PMc	Slope = 0.885 Int. = +0.34 R^2 = 0.978 Ratio to FRM = 0.91	Slope = 0.92 Int. = +5.9 R^2 = 0.995 Ratio to FRM = 1.04	Slope = 1.17 Int. = -2.7 R^2 = 0.957 Ratio to FRM = 1.08	Slope = 0.99 Int. = +1.66 R^2 = 0.994 Ratio to FRM = 1.05
PM_{10}	Slope = 1.02 Int. = +2.5 R^2 = 0.987 Ratio to FRM = 1.09	Slope = 1.02 Int. = +7.8 R^2 = 0.996 Ratio to FRM = 1.16	Slope = 1.53 Int. = -10.6 R^2 = 0.880 Ratio to FRM = 1.29	Slope = 1.07 Int. = +2.9 R^2 = 0.998 Ratio to FRM = 1.14

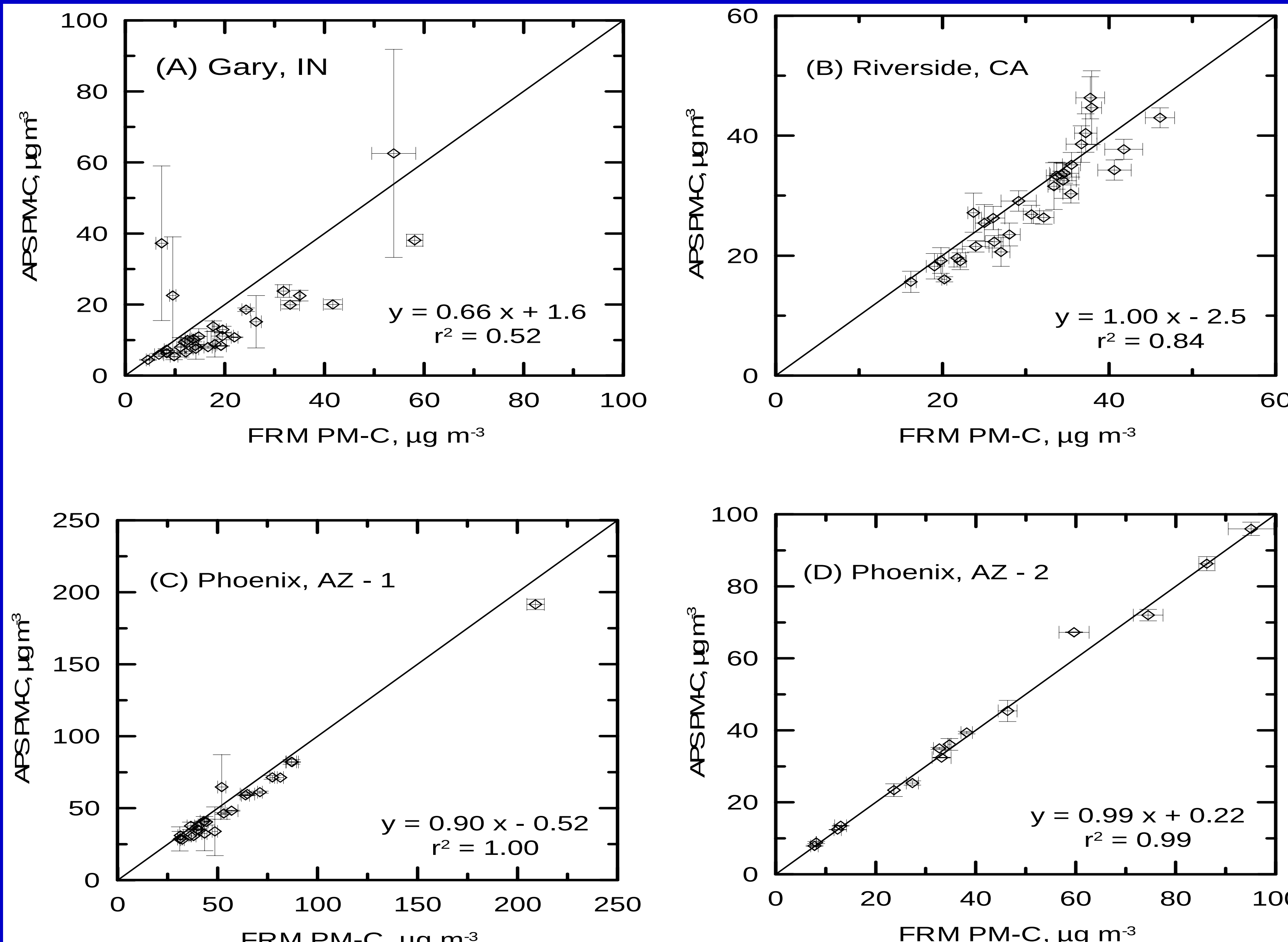
Tisch SPM-613D Update

- Flow system has been redesigned to provide true volumetric flow control based on actual T and P
- Ambient temperature sensor has been added and can now be calibrated by the user
- Inlet heater has been modified to maintain aerosol RH below 45%
- New virtual impactor has been designed and will be evaluated



Metric	Gary, IN	Phoenix, AZ (May – June, 2003)	Riverside, CA	Phoenix, AZ (Jan 2004)
PMc	Slope = 0.42 Int. = +0.48 R^2 = 0.80 Ratio to FRM = 0.42	Slope = 0.56 Int. = -0.20 R^2 = 0.99 Ratio to FRM = 0.55	Slope = 0.66 Int. = -2.3 R^2 = 0.82 Ratio to FRM = 0.58	Slope = 0.61 Int. = +0.16 R^2 = 0.993 Ratio to FRM = 0.62

Summary of APS 3321 Results



Summary of Results

- FRMs show strong inter-manufacturer precision (CV<6% for all three metrics) with no tendency for producing negative PMc values
- Precision of the semi-continuous samplers ranged from very good to acceptable
- Correlation (as R^2) of semi-continuous samplers with the collocated FRMs is usually strong (>0.95)
- All five measurement methods show potential for measuring ambient PMc concentrations. Progress has already been made to address some sampler-specific measurement uncertainties identified during the field studies. New PMc sampler designs have been developed and should be evaluated.

Future Work

- Continue analysis of all collected field data. Compare the relative hourly performance of semi-continuous methods.
- Continue to work with the sampler manufacturers to identify and correct instrument performance issues
- Perform additional field studies to evaluate second generation PMc samplers. Also evaluate any viable new PMc sampler designs.
- Use study results as guidance during regulatory development of PMc testing requirements and acceptance criteria.

Acknowledgements

- Indiana Department of Environmental Management (Gary site)
- Maricopa County Environmental Services Department (Phoenix site)
- University of California-Riverside, Agricultural Operations (Riverside site)

Disclaimer

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- Mention of trade names or commercial products does not constitute endorsement or recommendation for use.