The Performance of Continuous $PM_{2.5}$ Monitors in New York

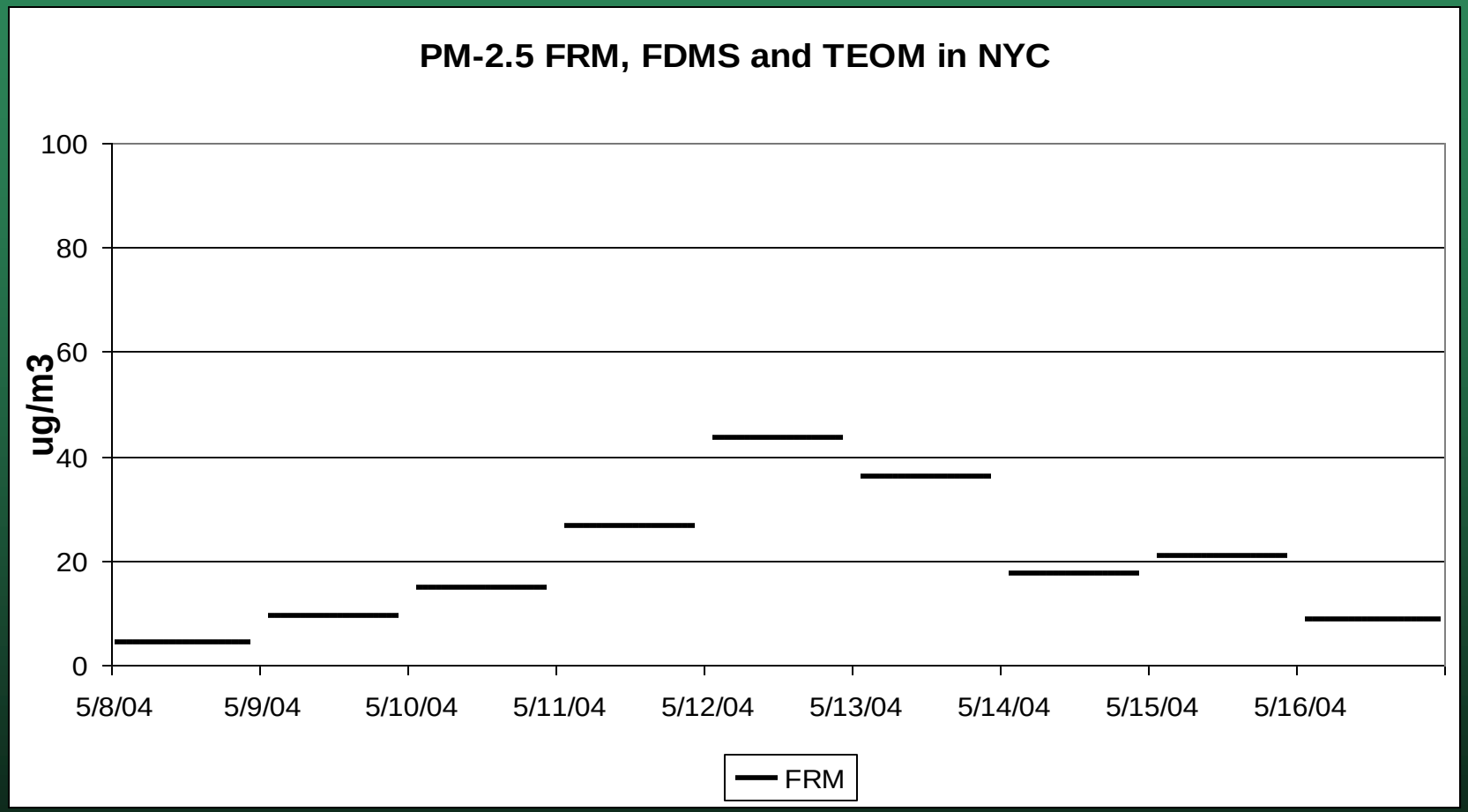
After More than 10 Years of Coexistence:

- Can the Continuous Monitors match the FRM?
- Should the FRM match the Continuous Monitors?

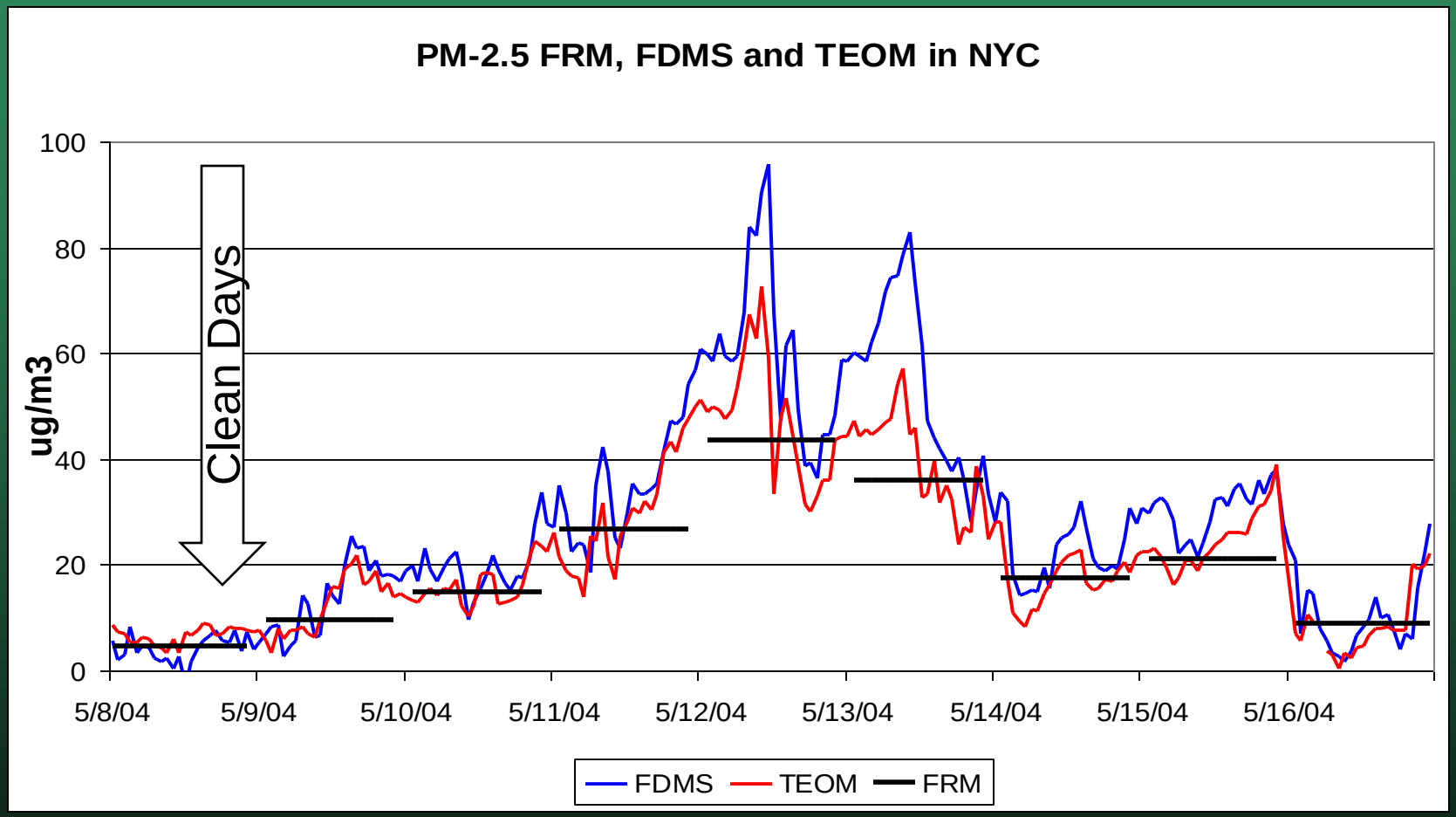
Dirk Felton, P.E.
AWMA PM Workshop
October 20, 2011
Toronto, Canada

NYS Department of Environmental Conservation

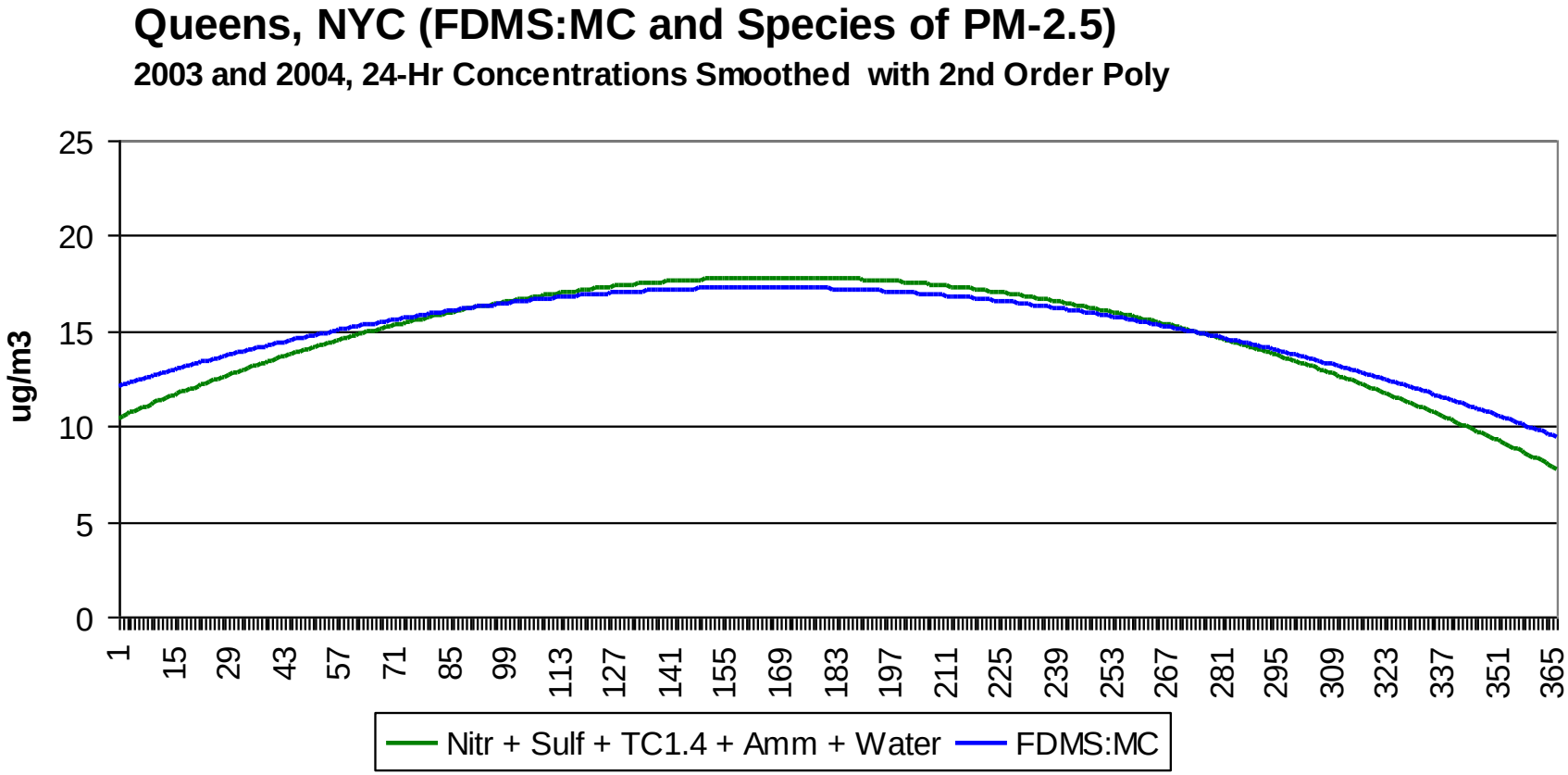
What's wrong with the FRM?



How do FRMs and FEMs Compare?

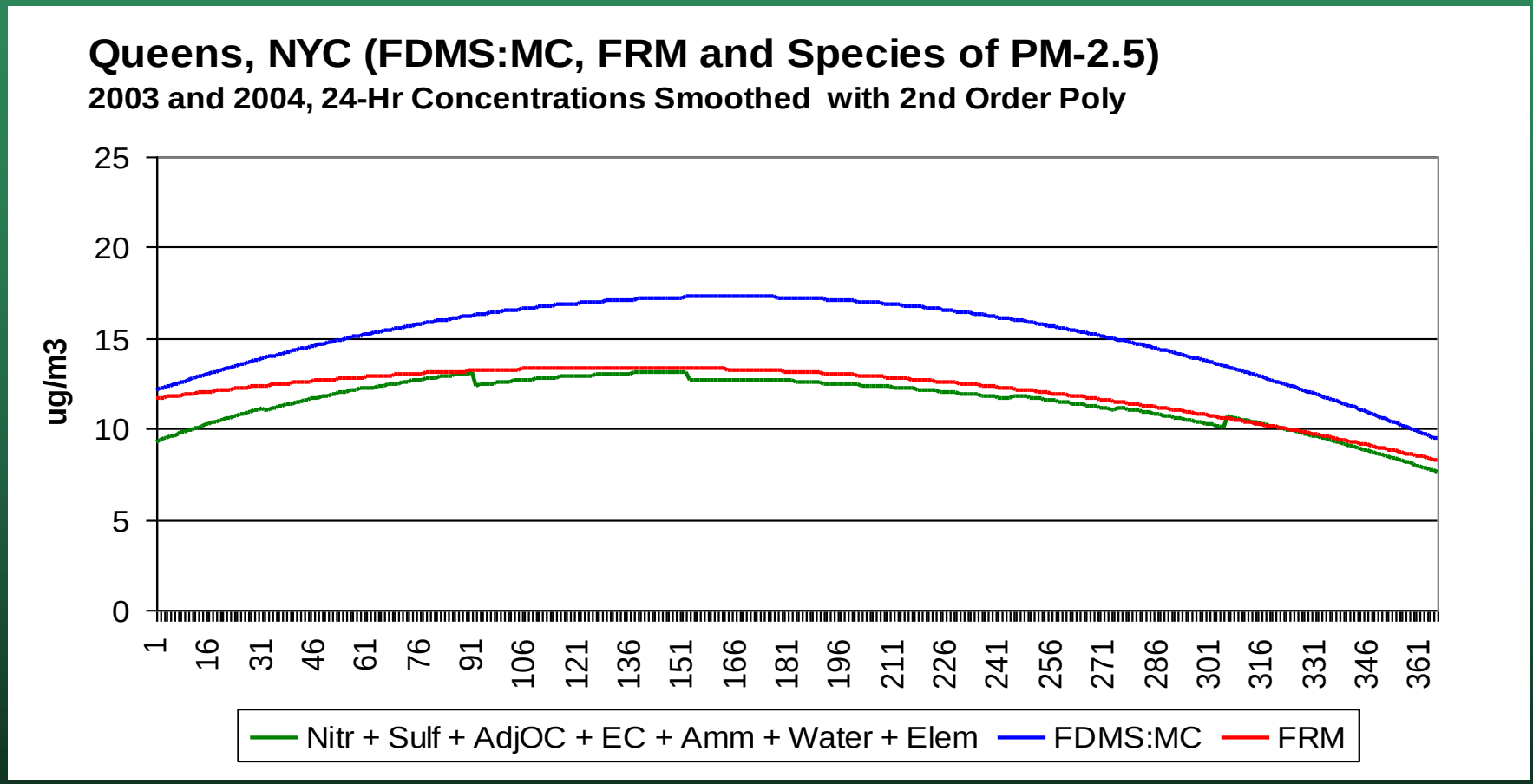


Which $PM_{2.5}$ data are Correct? The FEM measurements compare favorably to adjusted CSN measurements



Nitrate: As reported by STN
TC: Multiplied by 1.4
OC: Blank Corrected (–1 ug/m3)
Water: Added from thermodynamic theory (Retained in Ammonium Sulfate)

The FRM data can be derived from adjusted CSN data



Nitrate: Adjusted to match 2003 EPA Retention Study Results (by % of CSN)

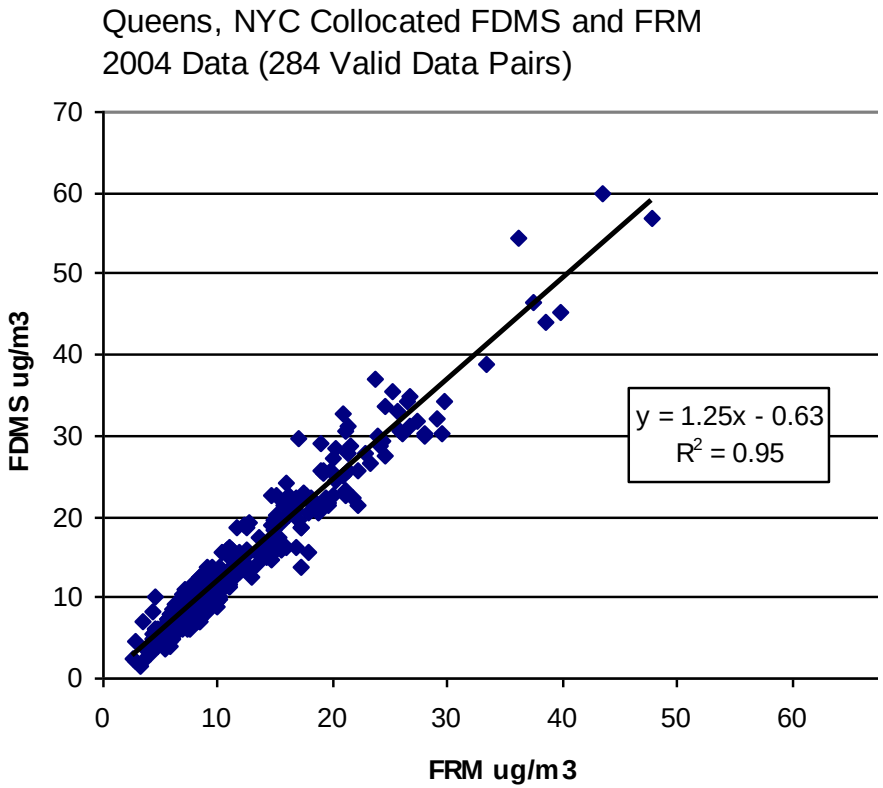
OC: Adjusted with Julian Day % reduction from (FDMS – FRM) vs (FRM – 50 Deg TEOM)

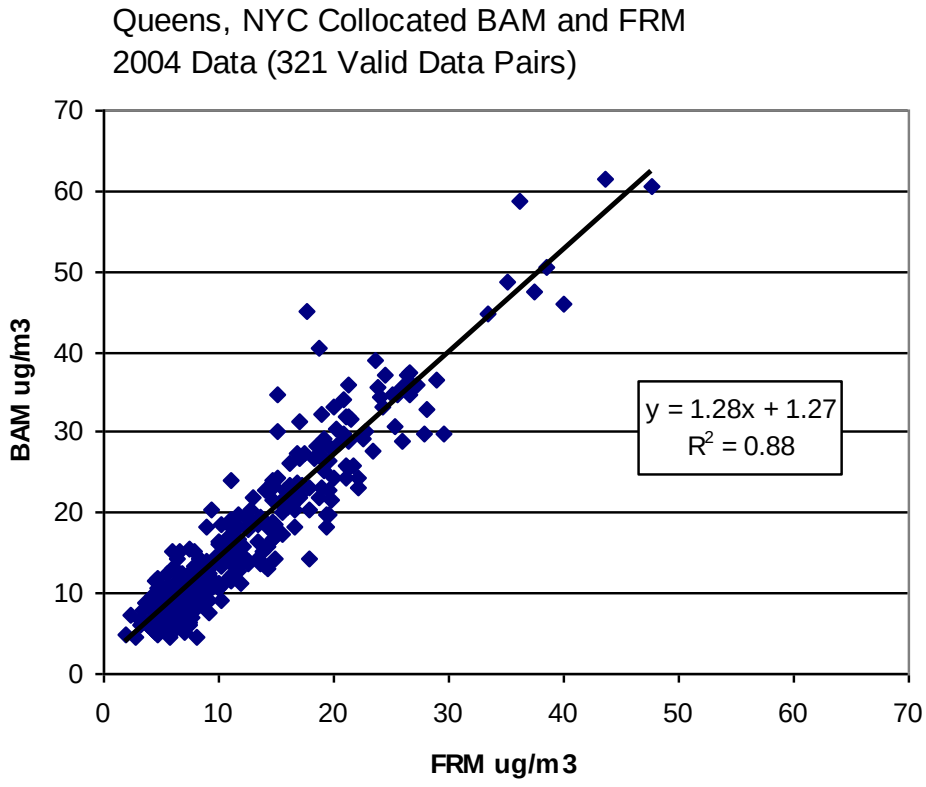
Water: Added from Theory, The FRM does retain water.

FRM and Pre-FEM Continuous PM Monitor Comparison 2003 and 2004 – Queens, New York

Pre-FEM Comparison with the FRM

The TEOM FDMS and the BAM 1020 both were about 26% higher than the FRM but they agreed within a few percent of each other (They uniformly disagreed with the FRM)

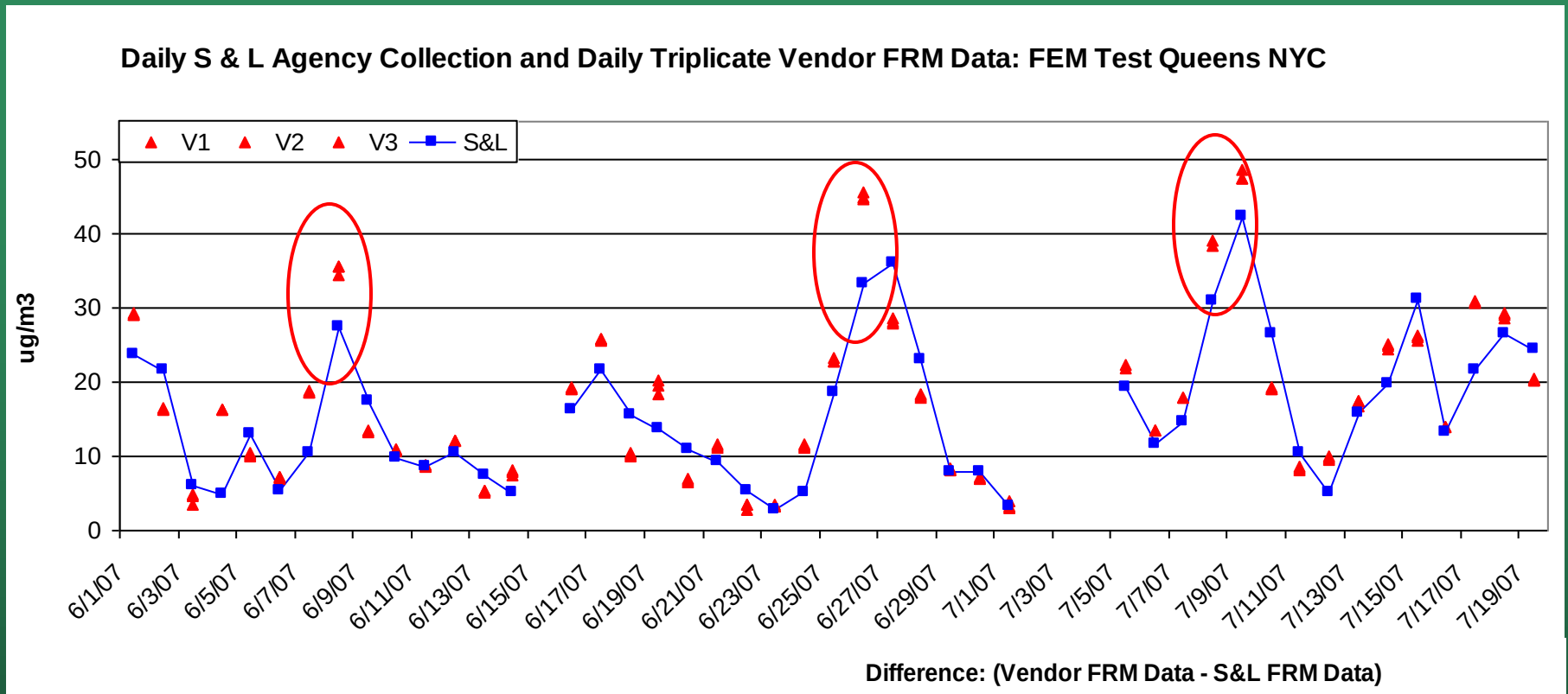


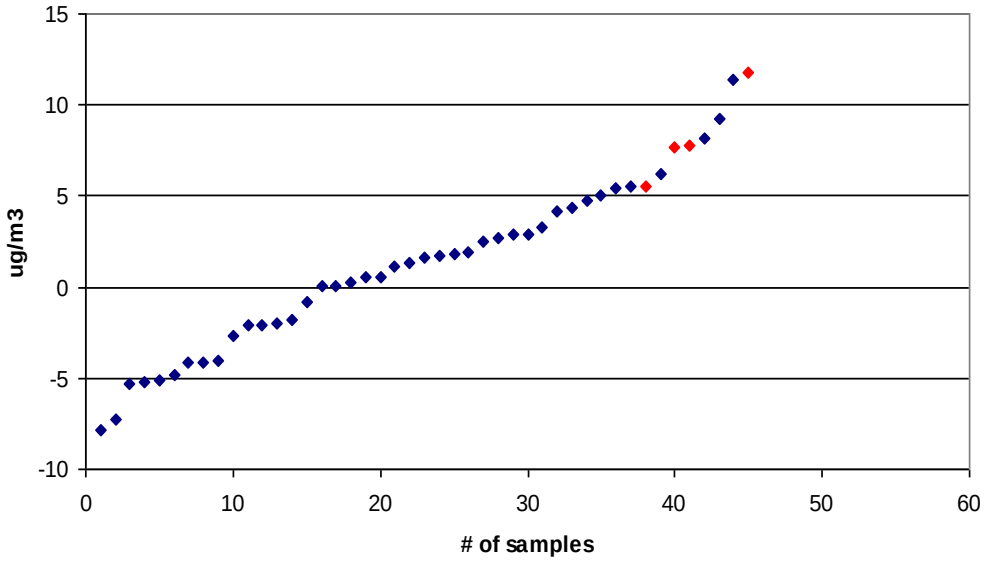


2006: FEM Class III Designation Criteria

- 5 Field Test Campaigns
  - 3 Winter and 2 Summer
  - 1 Site Winter & Summer (Results Averaged)
- 23-25 Hr samples (not midnight – midnight)
- Triplicate Ave. Vendor Candidate FEM & FRM
- 23 Valid Days of Data Required for each site
  - 46 Valid Days for Winter/Summer Site
- Minimum criteria for multiplicative (slope), additive (intercept) bias and precision

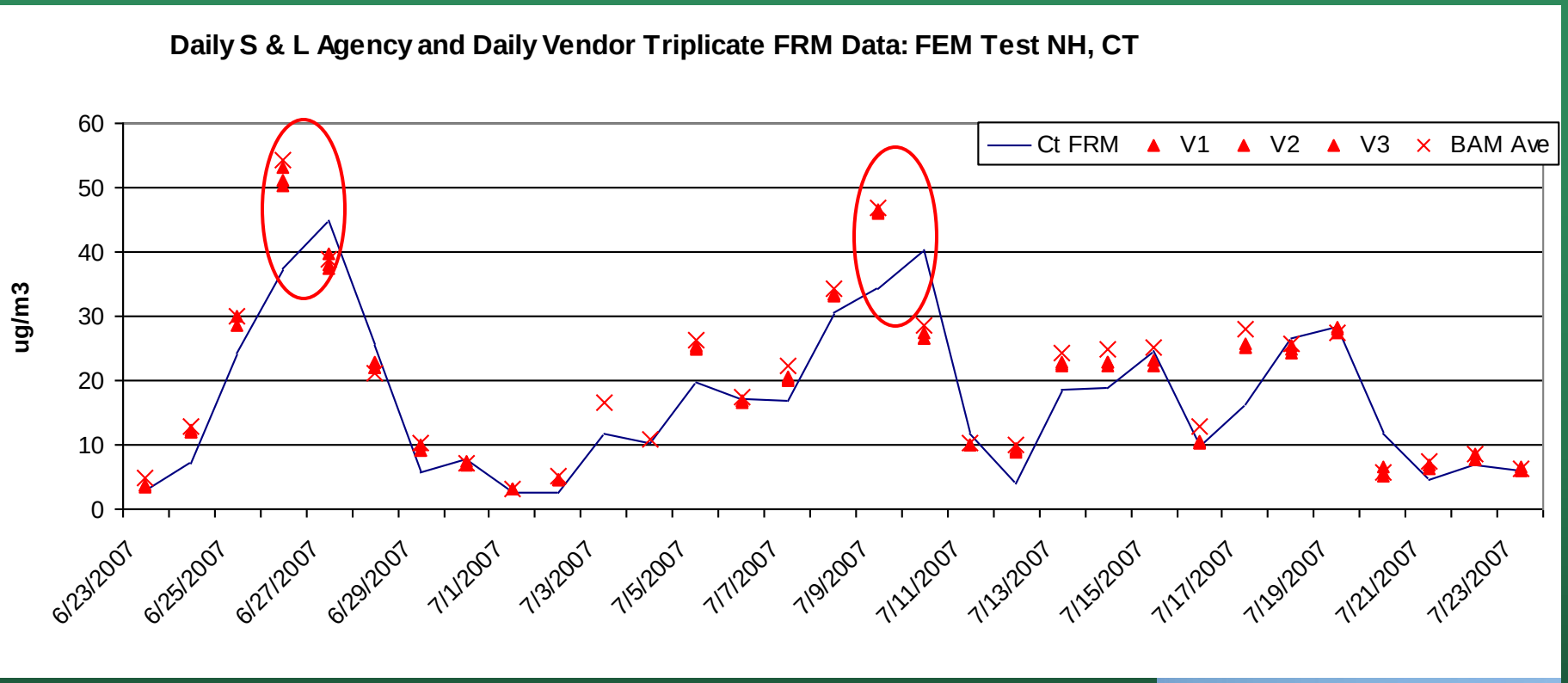

Our site in Queens, NY was chosen by ThermoFisher for the Summer 2007 1405DF FEM Equivalency Test
Thermo
Thermo





The first thing to notice is that the vendor data is higher than the S&L Agency data on high days. In urban areas, the proportion of volatile mass is often higher on days with high $PM_{2.5}$ concentration.

Vendor: ThermoFisher



In this example, the S & L Agency is different, the vendor is different but the results are the same.

The FEM test protocols produce “FRM” data that is not comparable enough to routine FRM data to provide a basis for determining how a candidate Class III FEM will operate in a real world application.

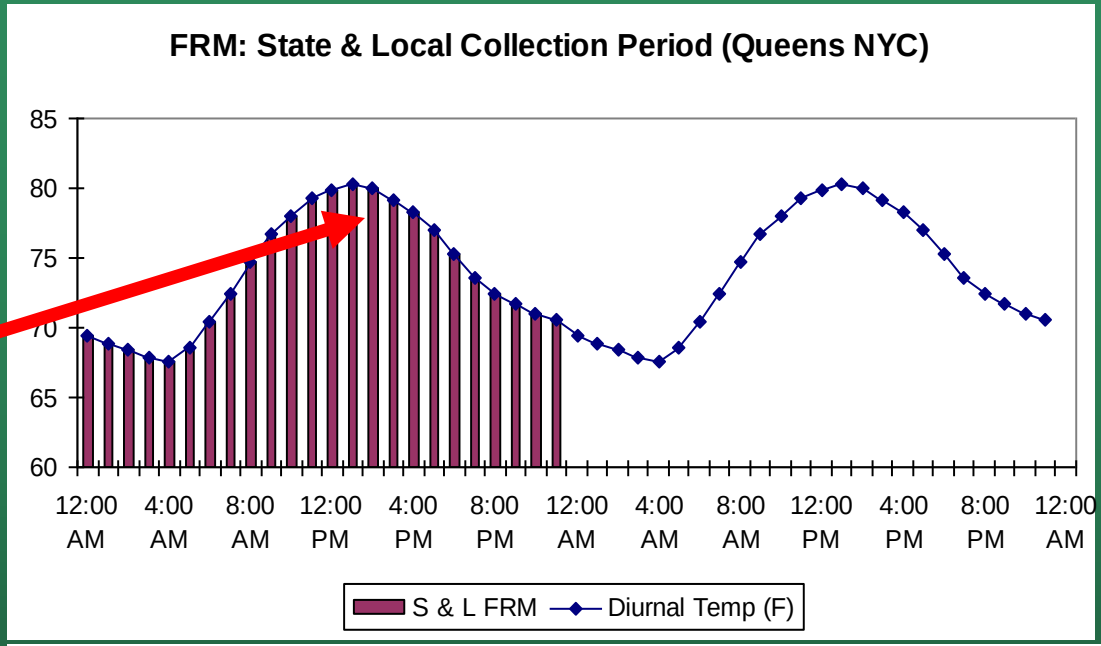
Vendor: MetOne

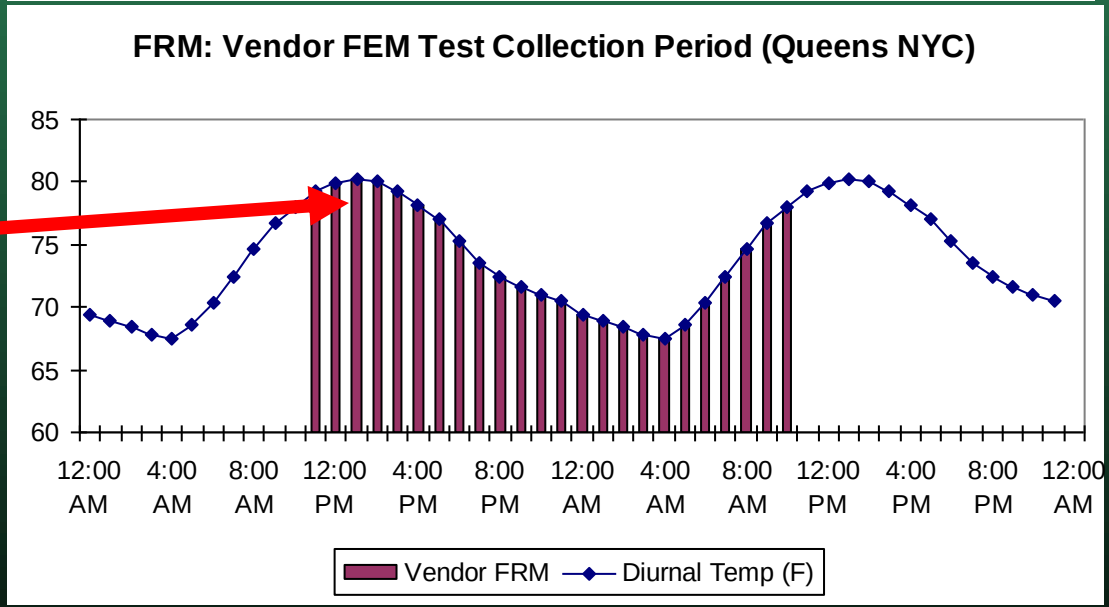
FRM Losses:

The sample collection interval also effects the FRM's ability to retain volatile mass:

Collecting the sample from midnight to midnight exposes the sample to the highest evaporative losses in the hottest part of the day when the sample is at relatively high loading.

Collecting the sample from 11:00 am to 11:00 am exposes the sample to the highest ambient temperatures before much of the mass has been collected.





(Summer test site actual average diurnal temperatures: Ave 74^0 F)

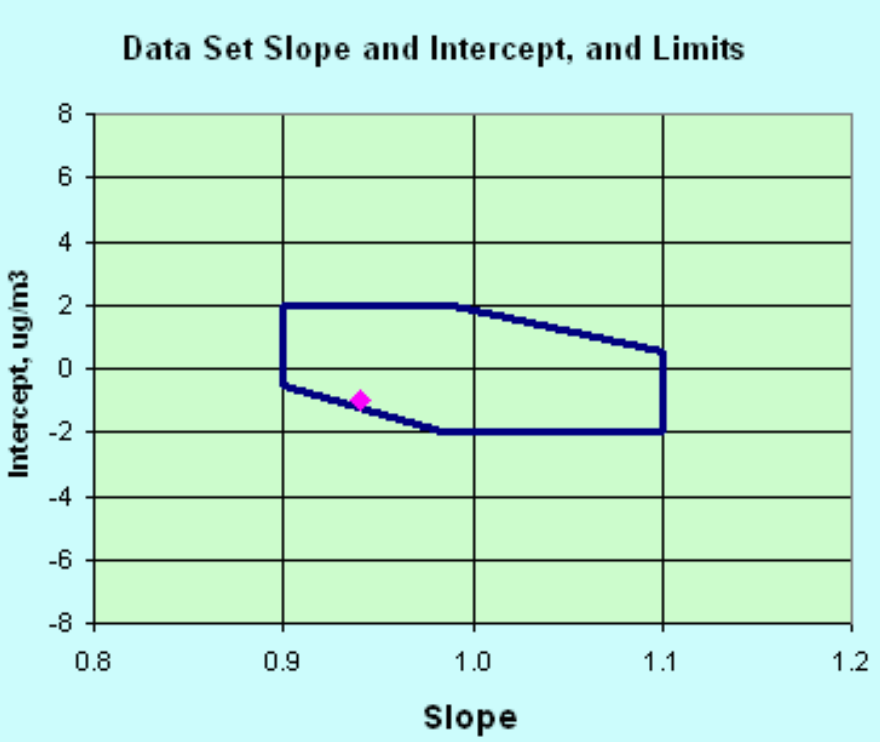
Allen Park, Mi

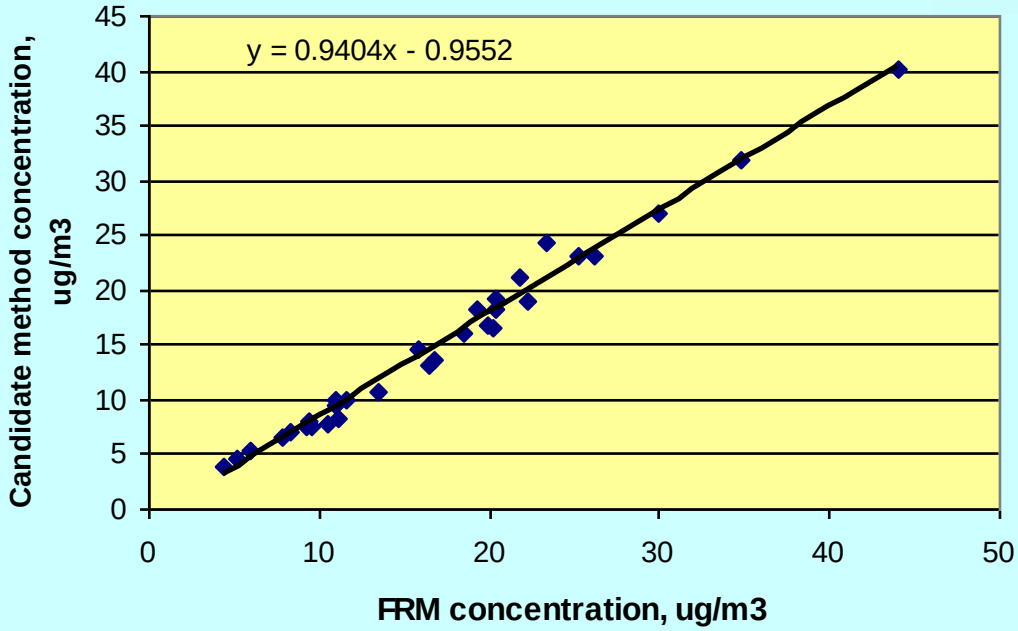
MetOne
Winter FEM Test Site

Dates of Operation by Met One:
2/6/07 to 3/8/07
No involvement by MDEQ other than supplying location and power

Mary Ann Heindorf
Photo from MetOne
10-23-07 Presentation

The FEM Designation Criteria was Met for:
Triplicate Average FRM
Triplicate Average BAM





Mary Ann's analysis showed that of the 3 BAMs, one did not meet the FEM designation criteria when it was correlated with any of the 3 FRMs.

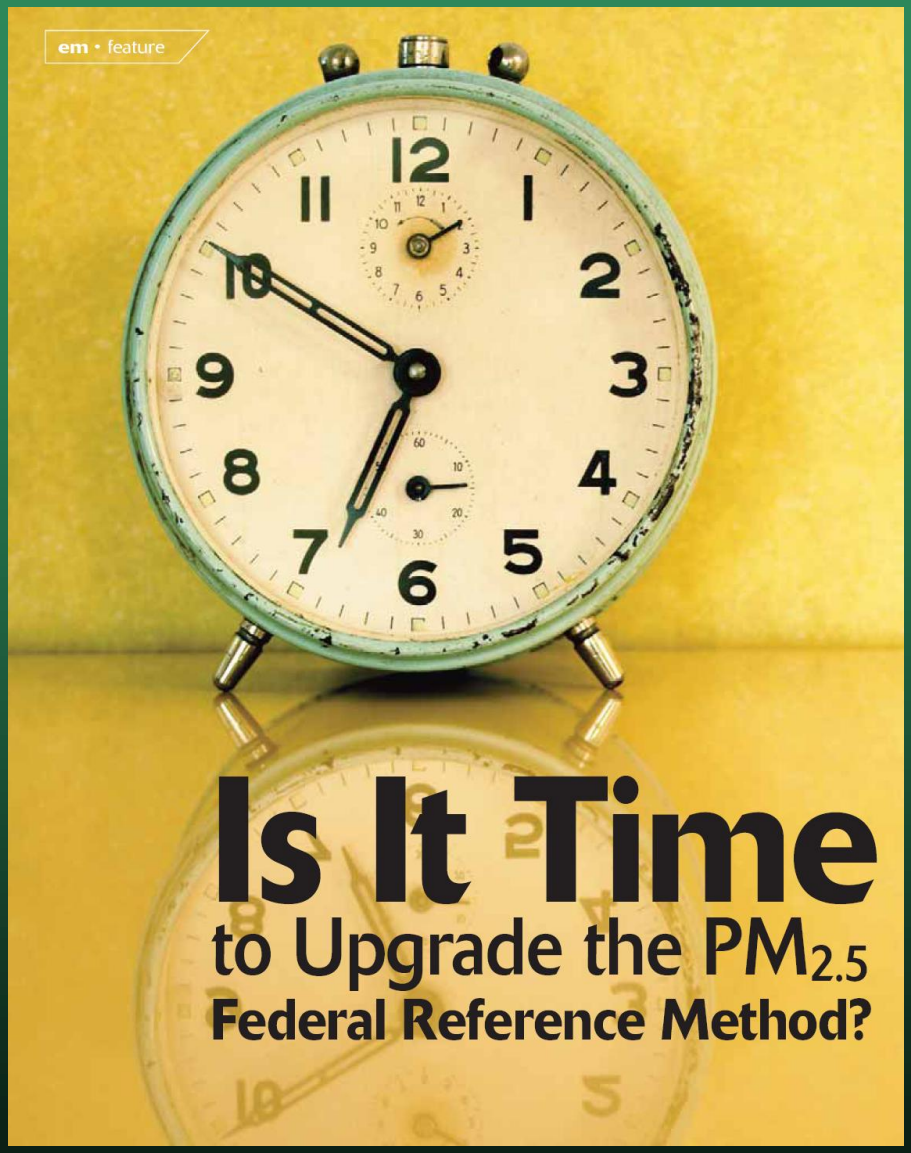
What's wrong with the Class III FEM Designation Criteria?

- The FEM test specifications contain four errors:
  - The filters should have been collected in exactly the same fashion as a typical S&L operation
  - The Summer and Winter test results should not be averaged (Averaging pos and neg Bias – voids the purpose)
  - The triplicate FEM values should not be averaged for any site. Each FEM should have to pass the evaluation criteria on its own. S&Ls are not allowed to average the results for routine monitoring.
  - The test should include the PM-2.5 DQOs.

Class III FEM's Received Designation

- Met One BAM 1020 (3/12/08)
- TEOM 1405 DF
- TEOM 8500 with FDMS
- Thermo 5014 (BAM)
- Thermo 5030 Sharp
- Grimm EDM 180

AWMA: on Top of the Issues



AWMA EM Magazine
February, 2009

This Article discussed the Bias between the FEMs and the FRM and proposed upgrading the FRM to include more of the volatile fraction of PM-2.5.

FEM Shootout – Installed Dec-Jan 2010

8500 VerC 1405 DF BAM 1020 1405i (No Neph)

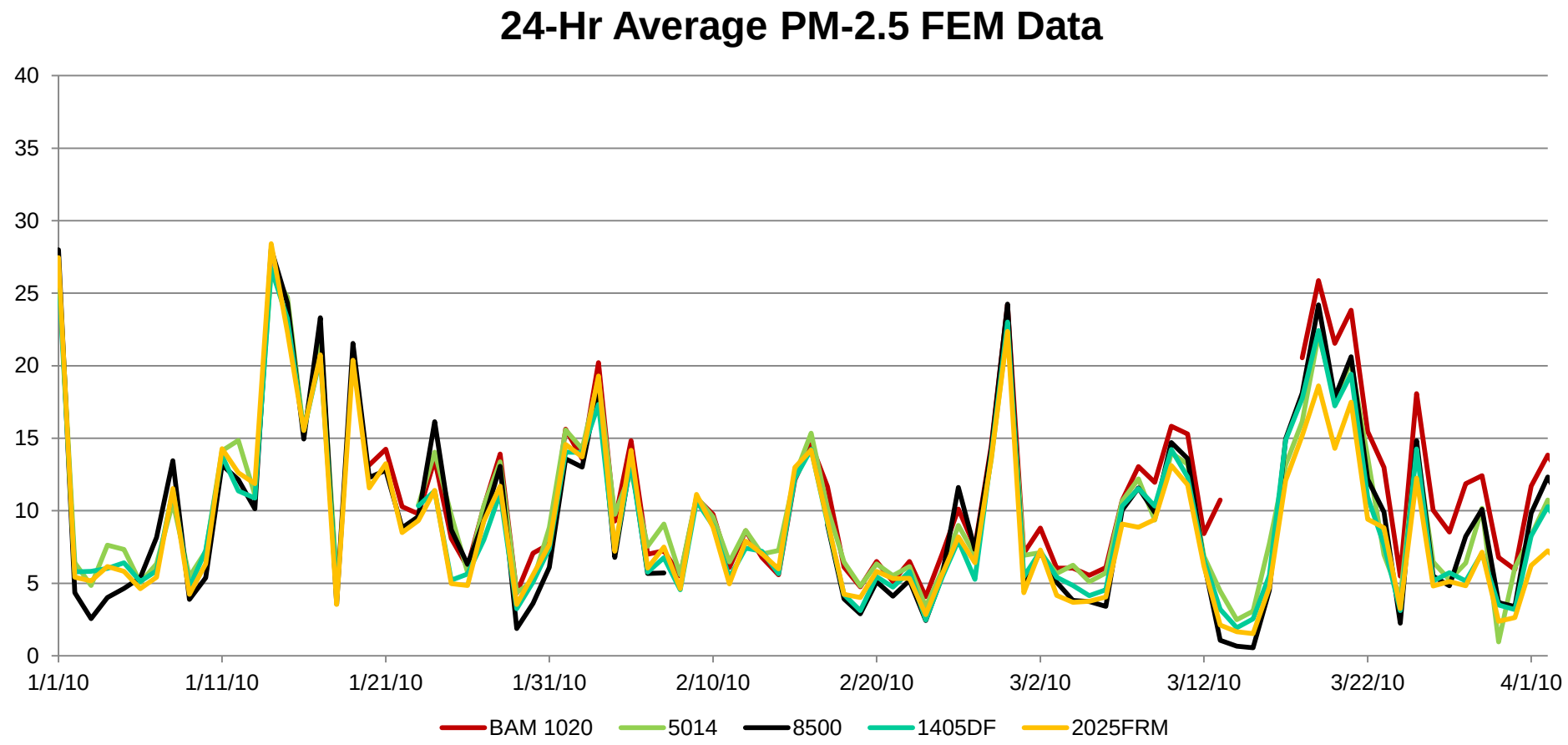
FEM Shootout

- The comparison continued through August 2010
- The site also has a daily PM-2.5 and PM-10 FRM

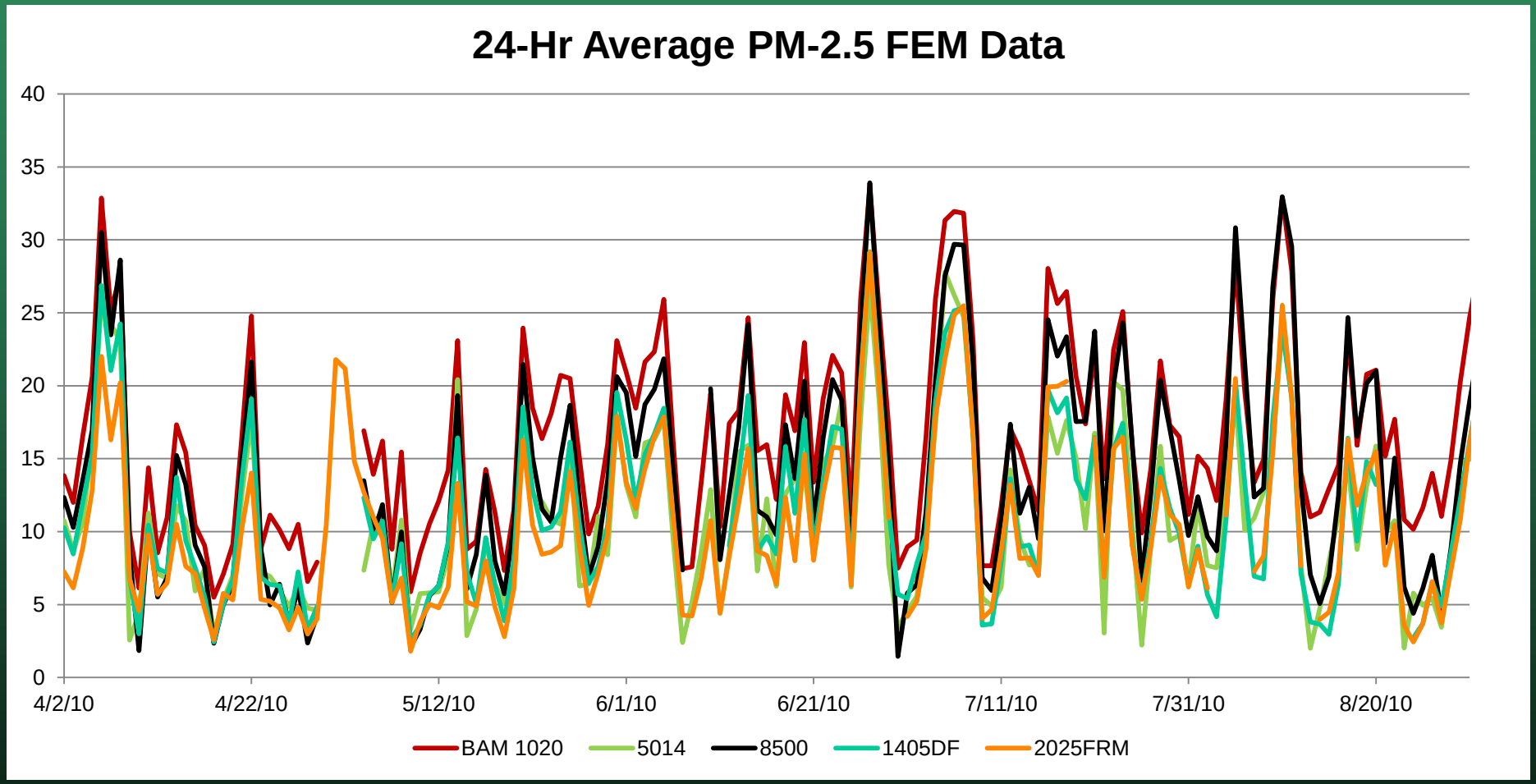
FEM Shootout: Inlets

5014i BAM 1020 1405 DF 8500 VerC

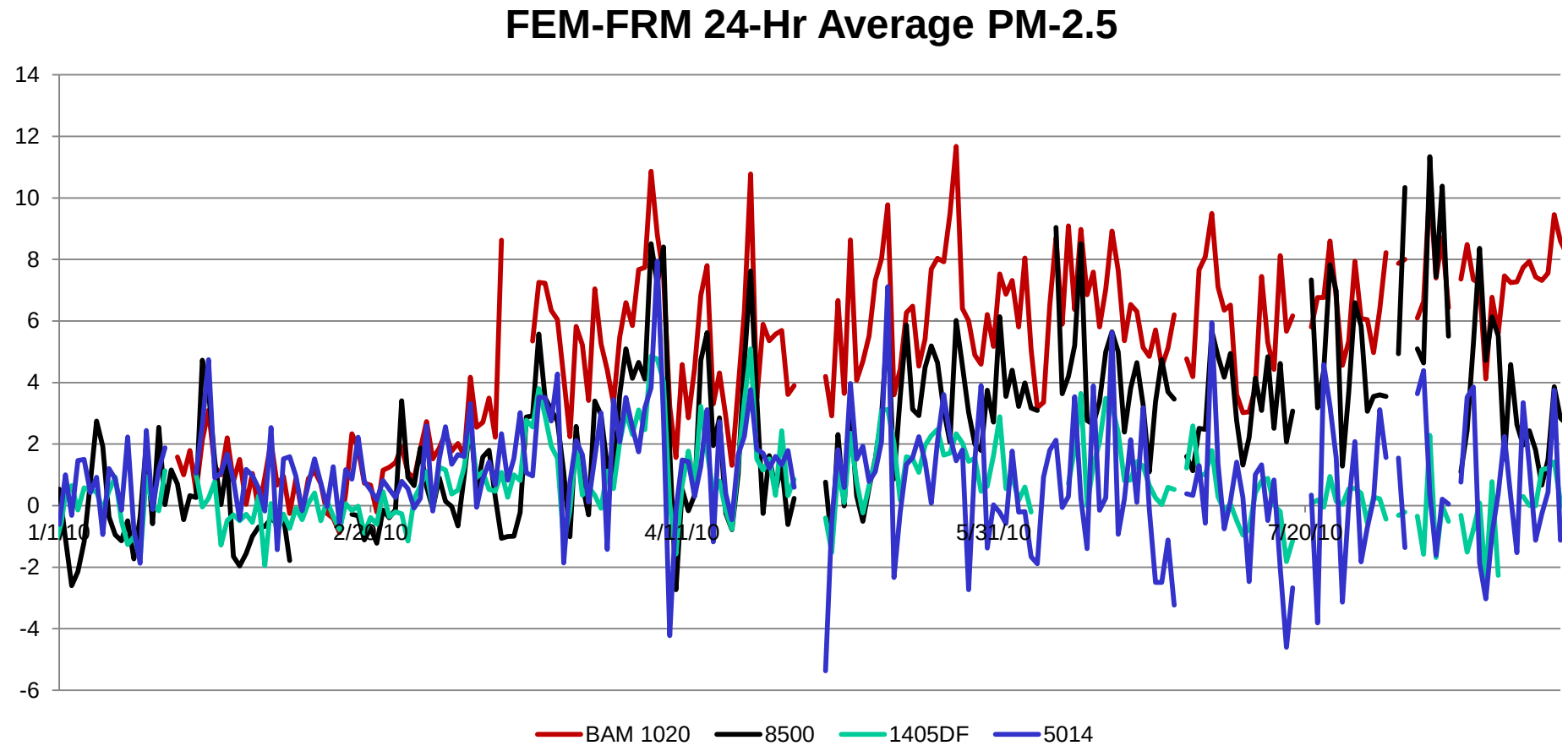
Queens, NY FEMs and FRM Time Series



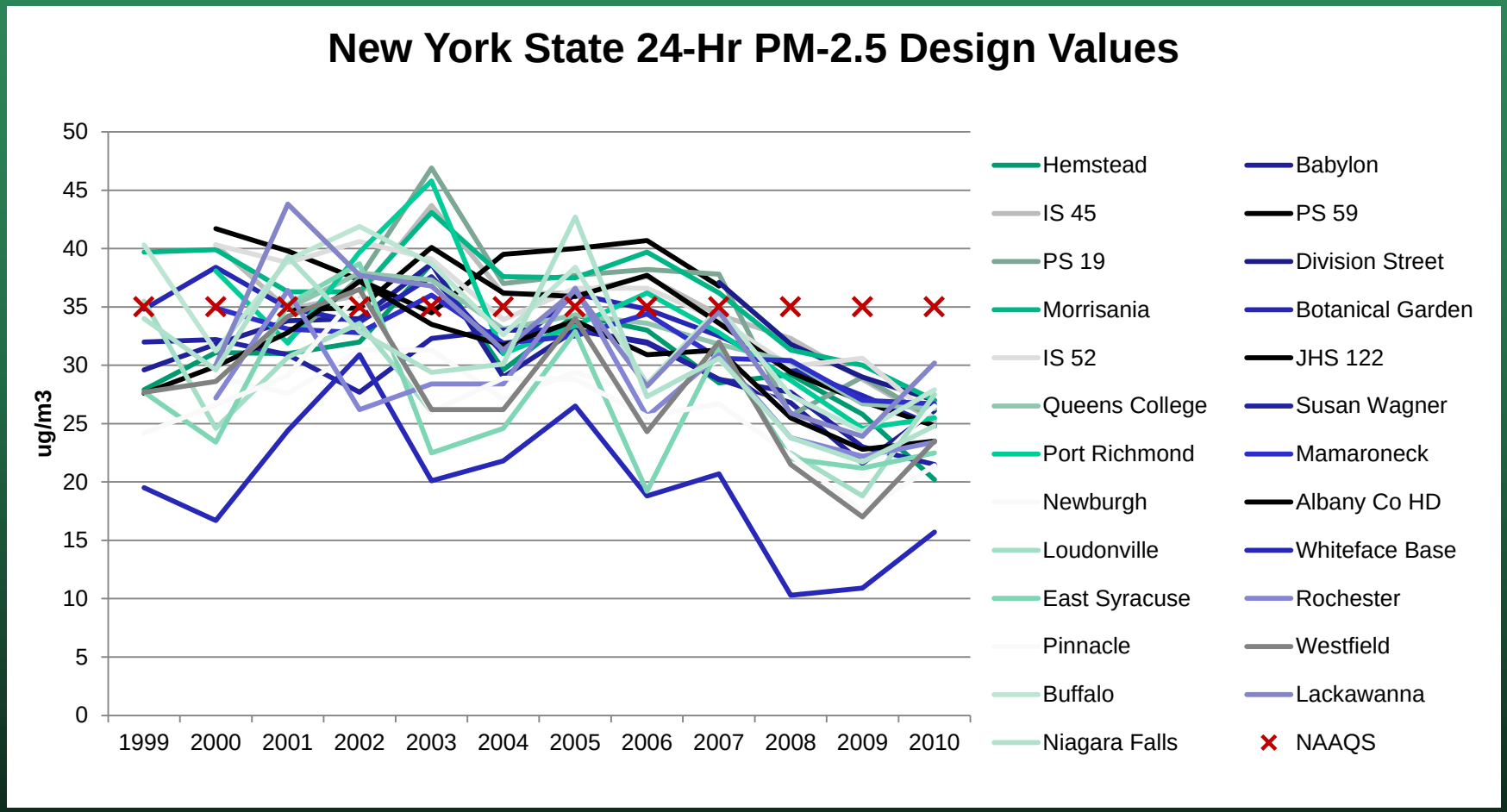
Queens, NY FEMs and FRM Time Series



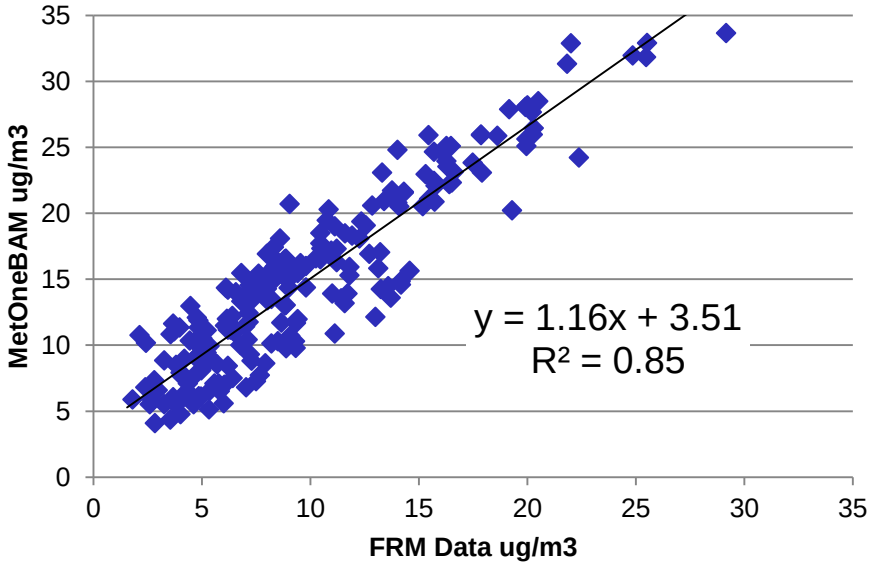
At this location, all of the FEMs are higher as it gets warmer



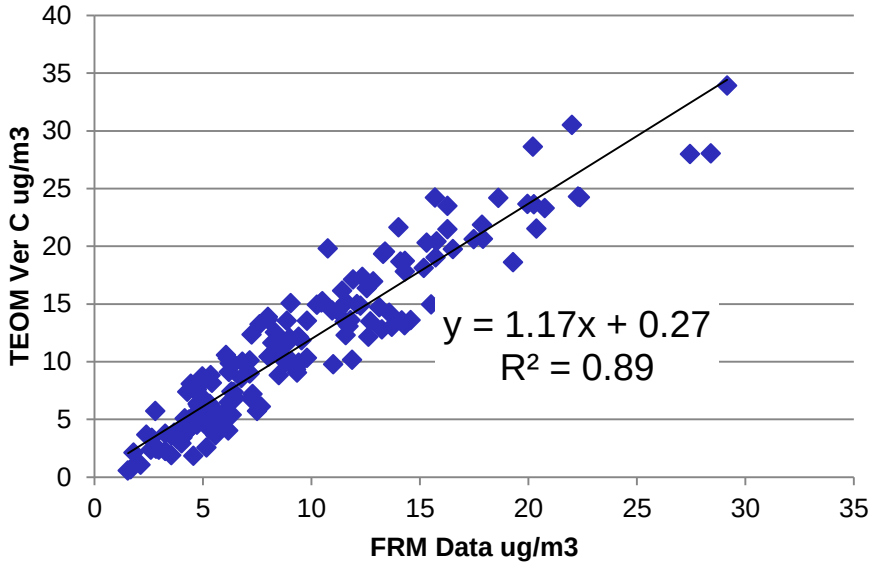
PM-2.5: 24-Hr Trends (FRM)



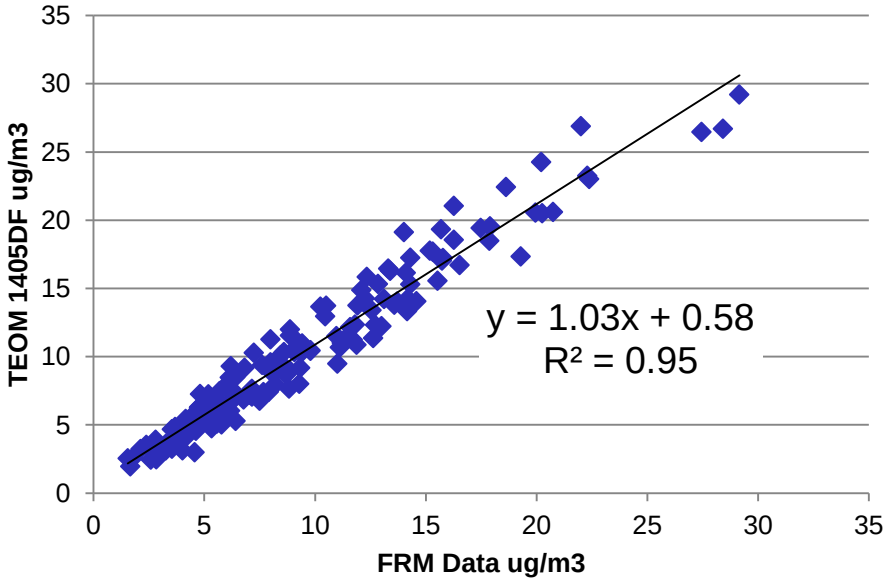
MetOne BAM vs FRM



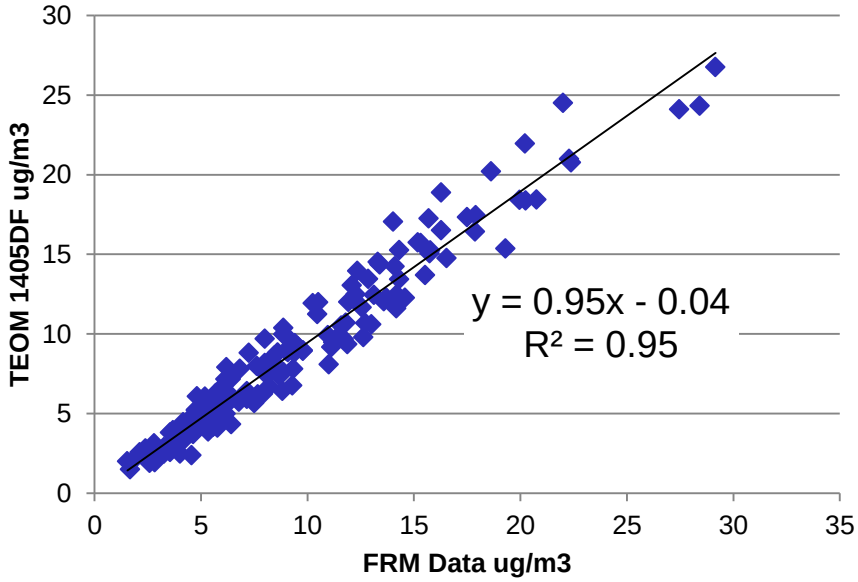
TEOM FDMS Ver C vs FRM



TEOM 1405DF vs FRM



TEOM FEM 1405DF vs FRM



Data Assessment Techniques

FEM Designation Criteria:

- Correlation ≥ 0.95 and slope and intercept within irregular parallelogram

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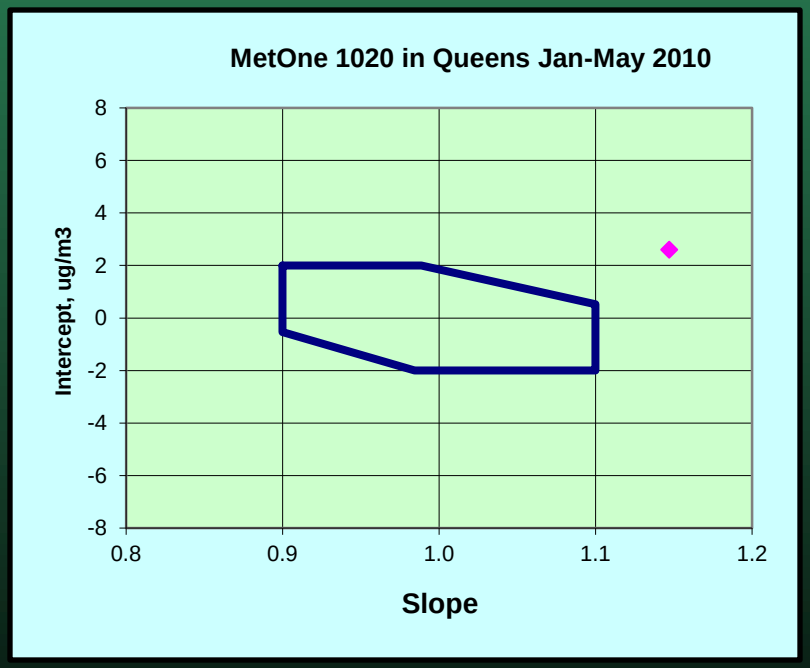
Necessary for Monitoring Program Integration:

- Evaluation as Component of Network Data Quality Objectives: Bias ± 10% and CV ± 10%
- Determine Confidence Interval at NAAQS
- Comparison on individual episode days (important for 24-Hr standard)

FEM Test Results for MetOne BAM

Regression statistics		Slope[1]	Intercept[2]	Correlation (r)
Statistics for this test site:		1.147	2.598	0.87164
Limits for	Upper:	1.100	-0.092	
PM2.5 Class III	Lower:	0.900	-2.000	0.95000
Test Results (Pass/Fail):		FAIL	FAIL	FAIL



116 Valid Pairs

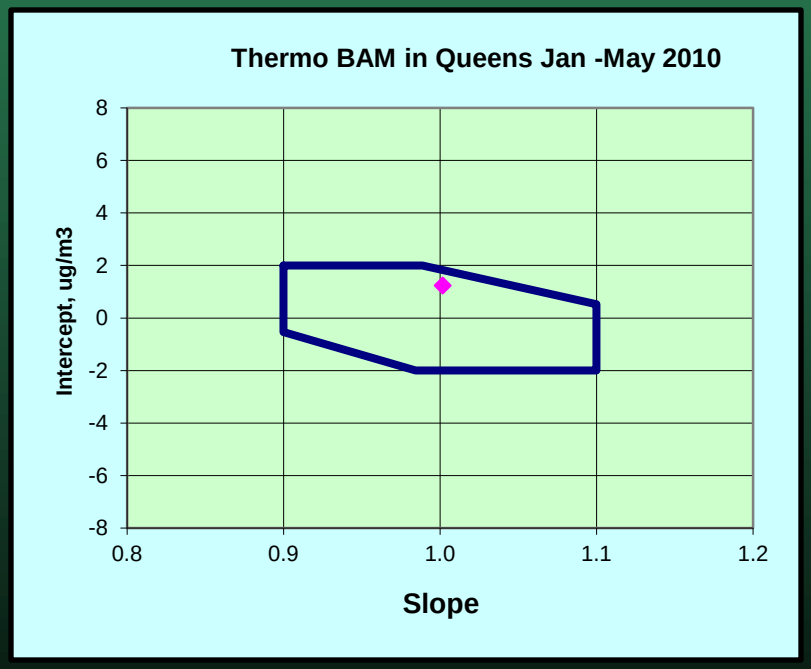
D(%) = 18.53
(16.21-20.85)

CV(%) = 20.97

D & CV ≠ meet DQOs

FEM Test Results for Thermo 5014 BAM Mass Concentration Channel

Regression statistics		Slope[1]	Intercept[2]	Correlation (r)
Statistics for this test site:		1.002	1.234	0.94951
Limits for PM2.5 Class III	Upper:	1.100	1.825	
	Lower:	0.900	-2.000	0.95000
Test Results (Pass/Fail):		PASS	PASS	FAIL



133 Valid Pairs

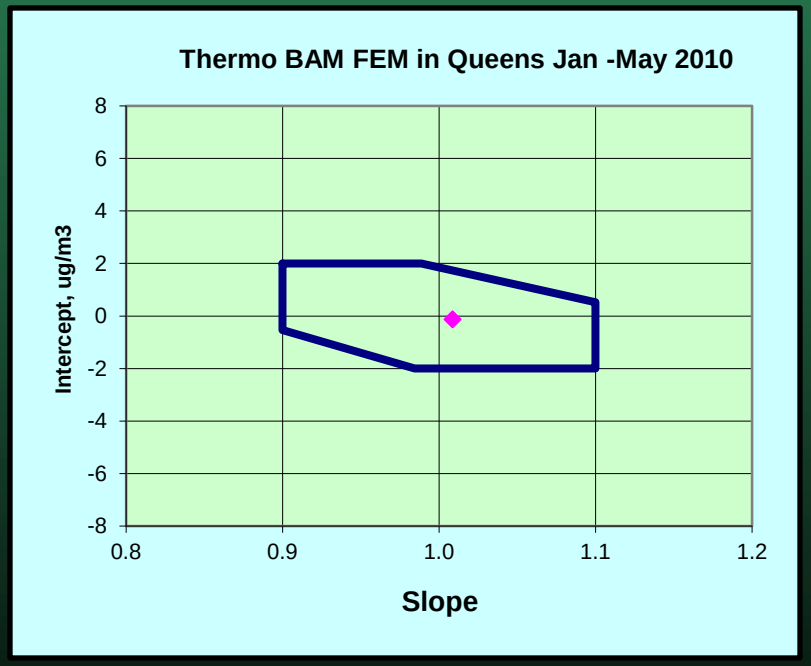
Bias:D(%) = 9.99
(8.15 to 11.82)

CV(%) = 18.31

CV ≠ meet DQO

FEM Test Results for Thermo 5014 BAM with FEM Algorithm

Regression statistics		Slope[1]	Intercept[2]	Correlation (r)
Statistics for this test site:		1.009	-0.135	0.94894
Limits for	Upper:	1.100	1.734	
PM2.5 Class III	Lower:	0.900	-2.000	0.95000
Test Results (Pass/Fail):		PASS	PASS	FAIL



133 Valid Pairs

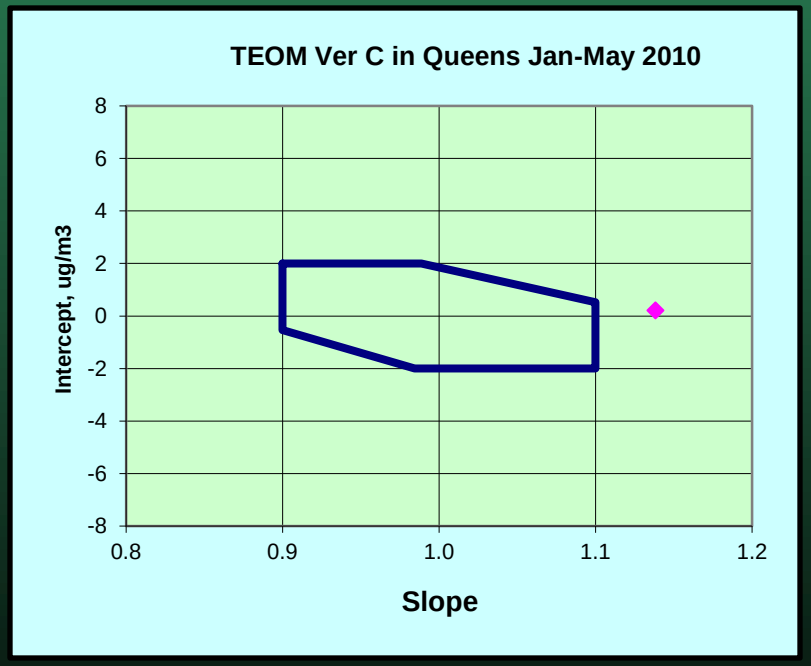
Bias:D(%) = -9.13
(-7.61 to -10.66)

CV(%) = 26.59

CV ≠ meet DQO

FEM Test Results for TEOM Ver C Mass Concentration Channel

Regression statistics		Slope[1]	Intercept[2]	Correlation (r)
Statistics for this test site:		1.138	0.213	0.93469
Limits for PM2.5 Class III	Upper:	1.100	0.023	
	Lower:	0.900	-2.000	0.95000
Test Results (Pass/Fail):		FAIL	FAIL	FAIL



128 Valid Pairs

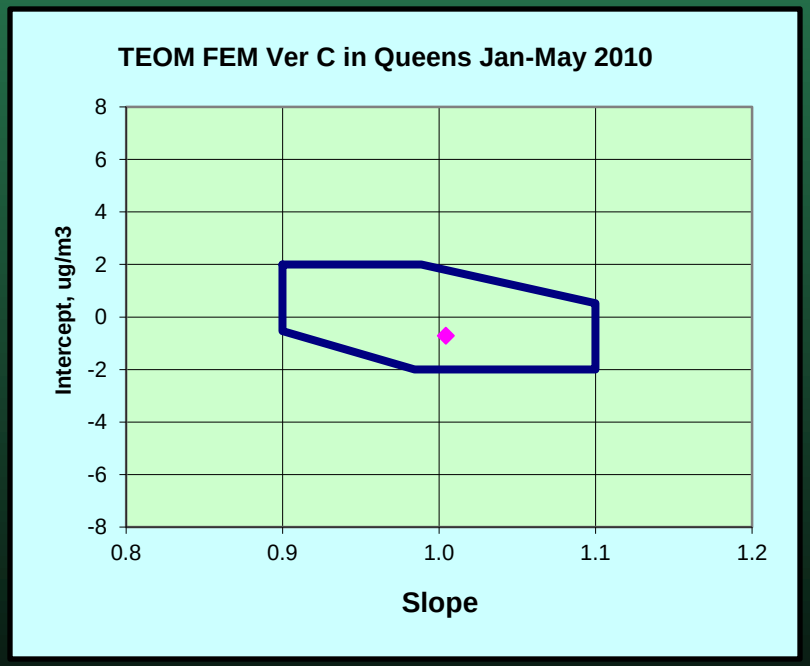
Bias D(%) = -6.88
(-10.44 to -3.33)

CV(%) = 22.43

CV ≠ meet DQOs

FEM Test Results for TEOM Ver C FEM Algorithm Channel

Regression statistics		Slope[1]	Intercept[2]	Correlation (r)
Statistics for this test site:		1.005	-0.719	0.93699
Limits for PM2.5 Class III	Upper:	1.100	1.790	
	Lower:	0.900	-2.000	0.95000
Test Results (Pass/Fail):		PASS	PASS	FAIL



128 Valid Pairs

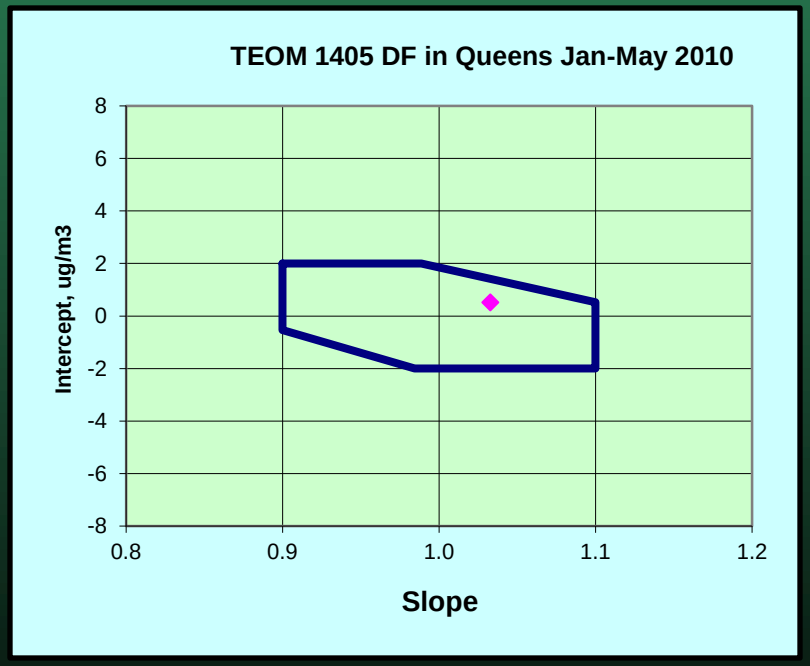
Bias D(%) = -29.44
(-32.46 to -26.43)

CV(%) = 25.32

D&CV ≠ meet DQOs

FEM Test Results for TEOM 1405DF Mass Concentration Channel

Regression statistics		Slope[1]	Intercept[2]	Correlation (r)
Statistics for this test site:		1.033	0.508	0.96712
Limits for PM2.5 Class III	Upper:	1.100	1.416	
	Lower:	0.900	-2.000	0.95000
Test Results (Pass/Fail):		PASS	PASS	PASS



133 Valid Pairs

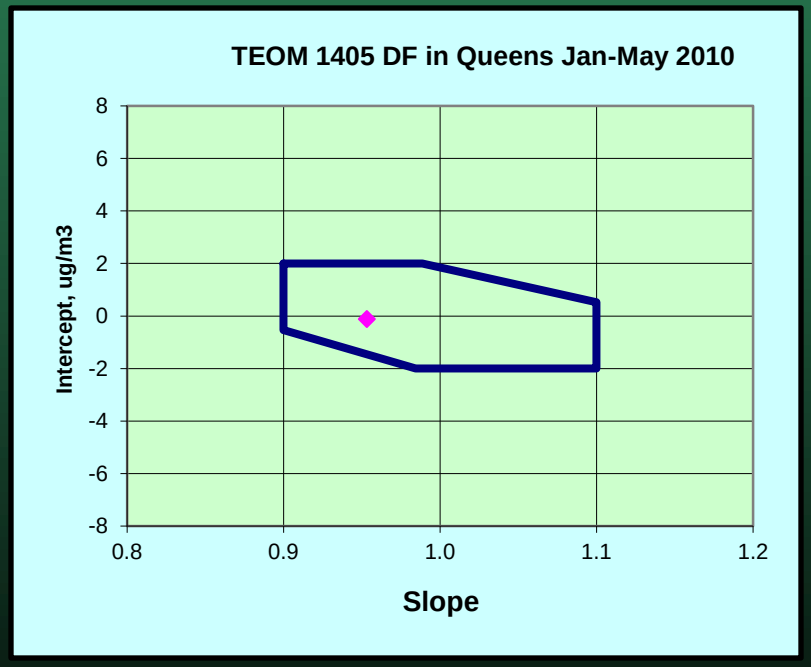
Bias D(%) = 3.47
(2.26 – 4.68)

CV(%) = 11.07

DQOs: Almost

FEM Test Results for TEOM 1405DF with FEM Algorithm

Regression statistics		Slope[1]	Intercept[2]	Correlation (r)
Statistics for this test site:		0.953	-0.125	0.96755
Limits for PM2.5 Class III	Upper:	1.100	2.000	
	Lower:	0.900	-1.462	0.95000
Test Results (Pass/Fail):		PASS	PASS	PASS



133 Valid Pairs

Bias: D(%) = -12.8
(-12.03 to -13.61)

CV(%) = 11.7

DQOs: Almost Met

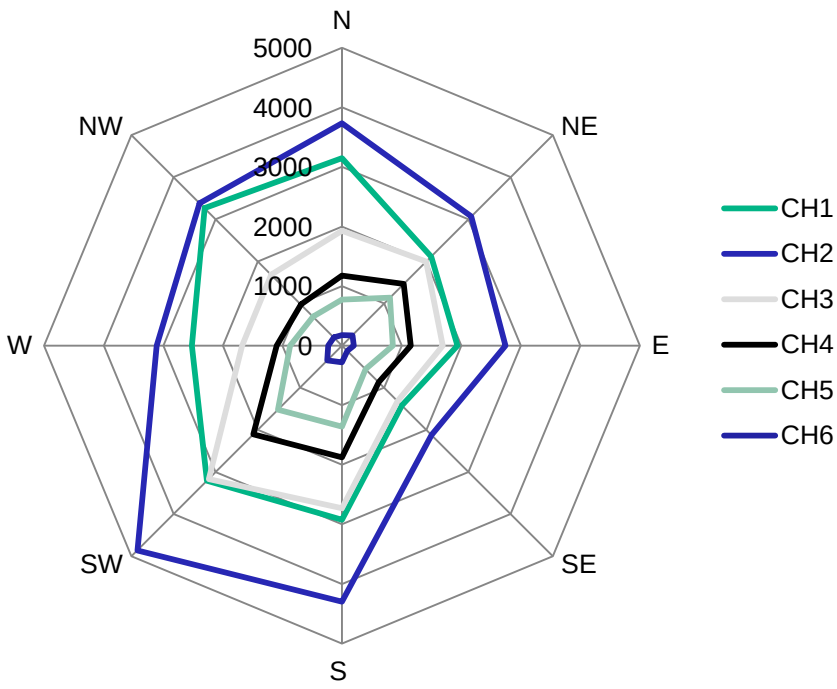
Resolution: What does not work?

- It is better to modify the FRM to make it include more of what we breathe (this is the point isn't it or do we choose to have a substandard indicator?)
- Require the FRM filters to be chilled at midnight at the end of the sample period.
- This will not fix all of the difference between the FEMs and the FRM but it will make it possible to install monitors that can meet multiple monitoring objectives.
- The CFR design of the PM2.5 FRM does not have to changed, just the post sampling period filter conditioning
- If you don't want to fix the FRM, only run FEMs.

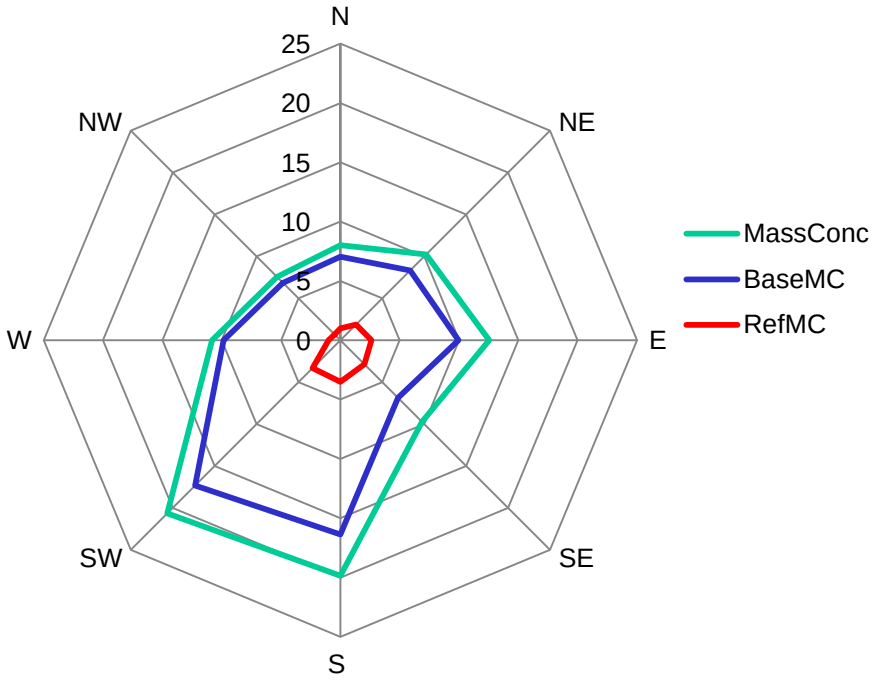
Future Work

PM and Pollutants such as BC, EC, OC, Sulfate and NO_2 can be correlated with Particle Number and Size

TSI 3031 (20 nm – 500 nm)

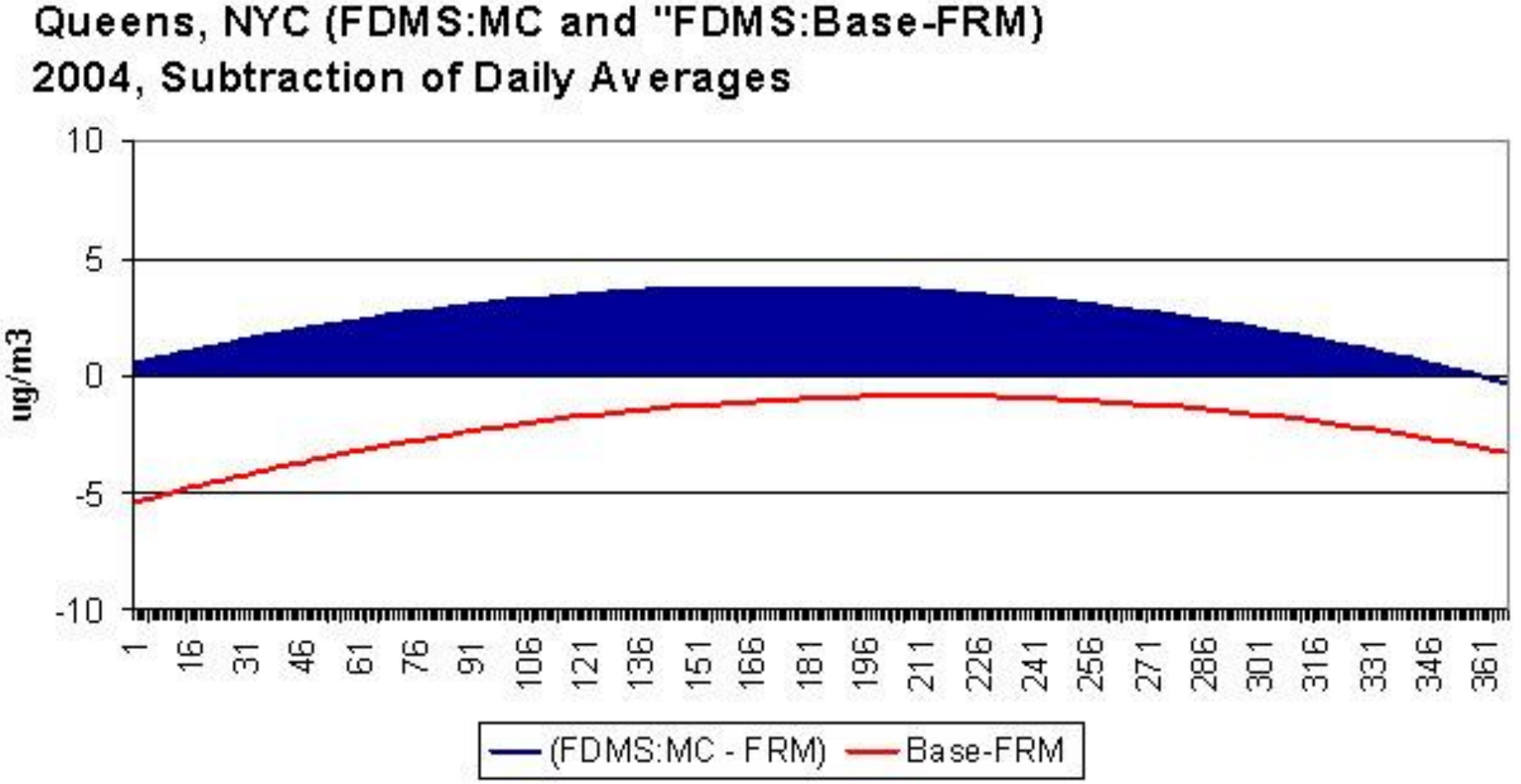


FDMS TEOM 8500

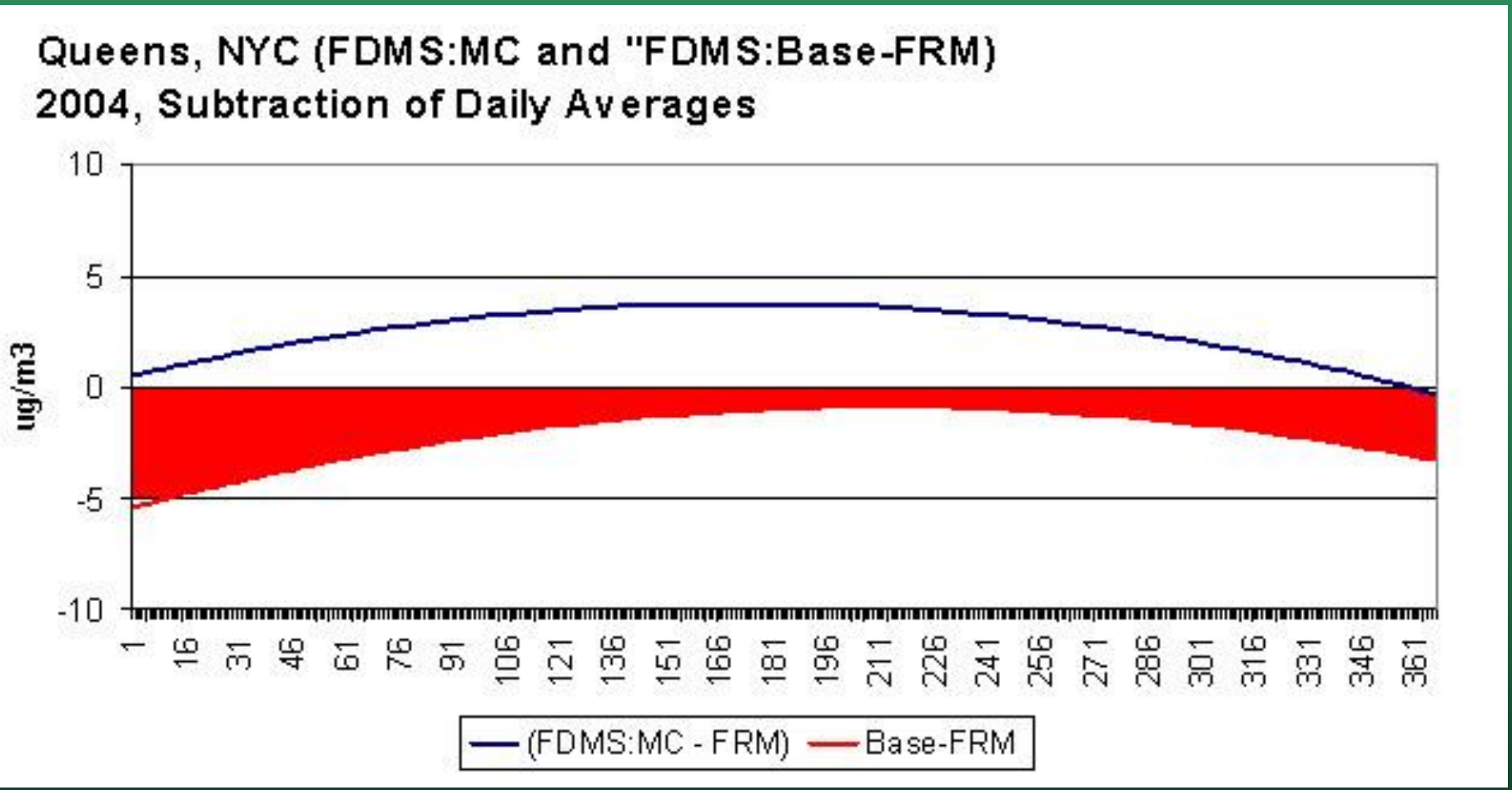


End of Presentation

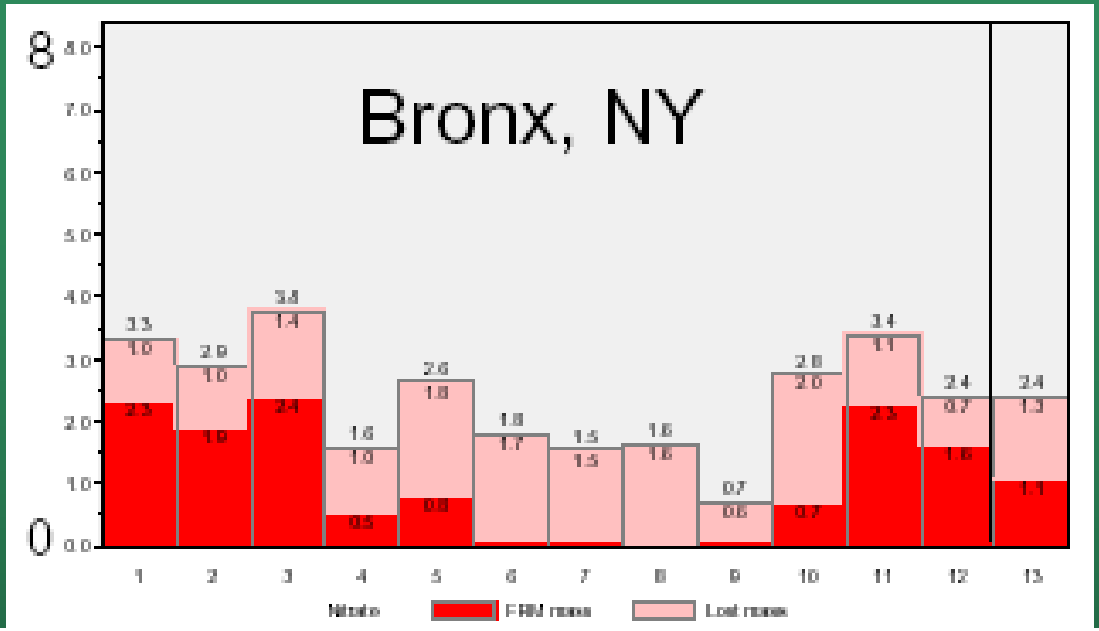
HazeCam image of Lower Manhattan www.hazecam.net



The Blue shaded area represents mass that is not retained by the FRM but is retained by the FDMS.

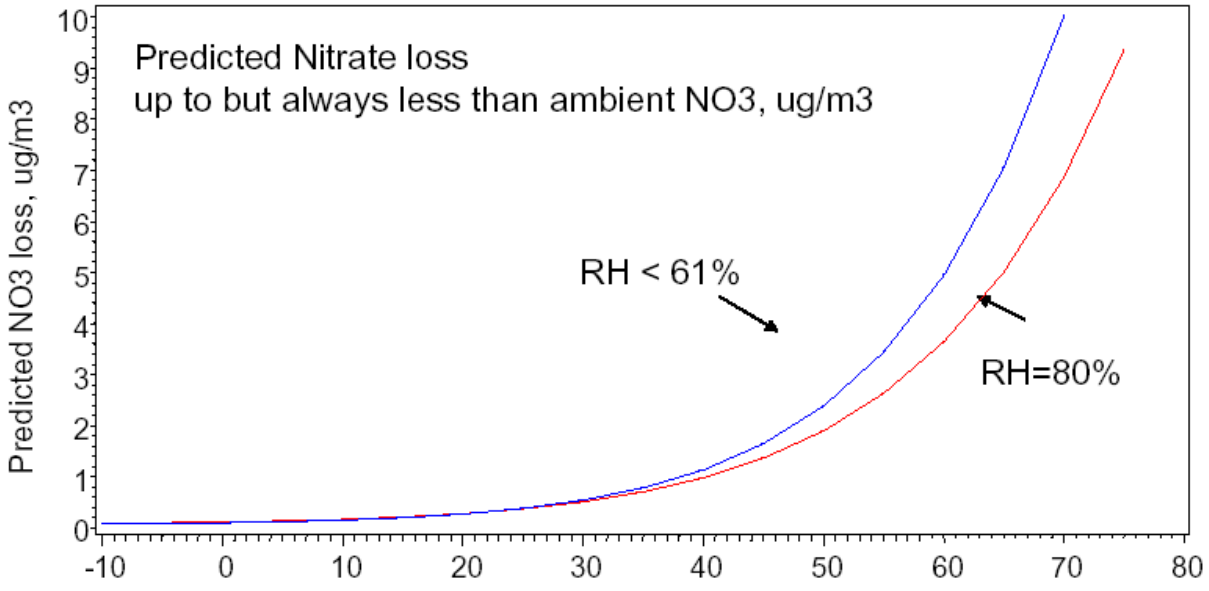


The red shaded area represents mass that is not retained by a 50 Deg C TEOM but is retained by the FRM.



The NYSDEC participated in a study sponsored by the EPA to examine Nitrate retention on FRM filters.

FRM filters for calendar year 2003 were analyzed for Nitrate and the results were compared to the STN sampler.



The results helped in the development of a model to predict the %retention of Nitrate on the FRM Teflon filters vs the STN Nylon filters (with denuder).

References: Zhang and McMurray (1992), Mozurkewich (1993), Hering and Cass (1999), Chang et al (2000)

Estimate Water using a thermodynamic model (AIM)

Water is approximately 25% of the sulfate + ammonium concentration

Less during periods with high nitrates