Delaware's Experience with Data Validation of the Continuous PM2.5 BAM

OR
Job Security for QA Coordinators

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# Andersen Series FH62 C14 Continuous Ambient Particulate Monitor, aka BAM

- Delaware started operating BAMs in 2002
  - Currently operating at 4 sites, one collocated
- Original configuration:
  - SSC PM2.5 inlet
  - 35° C temp
- 2005 added seasonal inlet temp adjustment
- 2006 added collocated monitor and began beta testing "smart" heater

PM2.5 Monitors

Delaware is HERE

PM 2.5 Monitoring Sites in Delaware
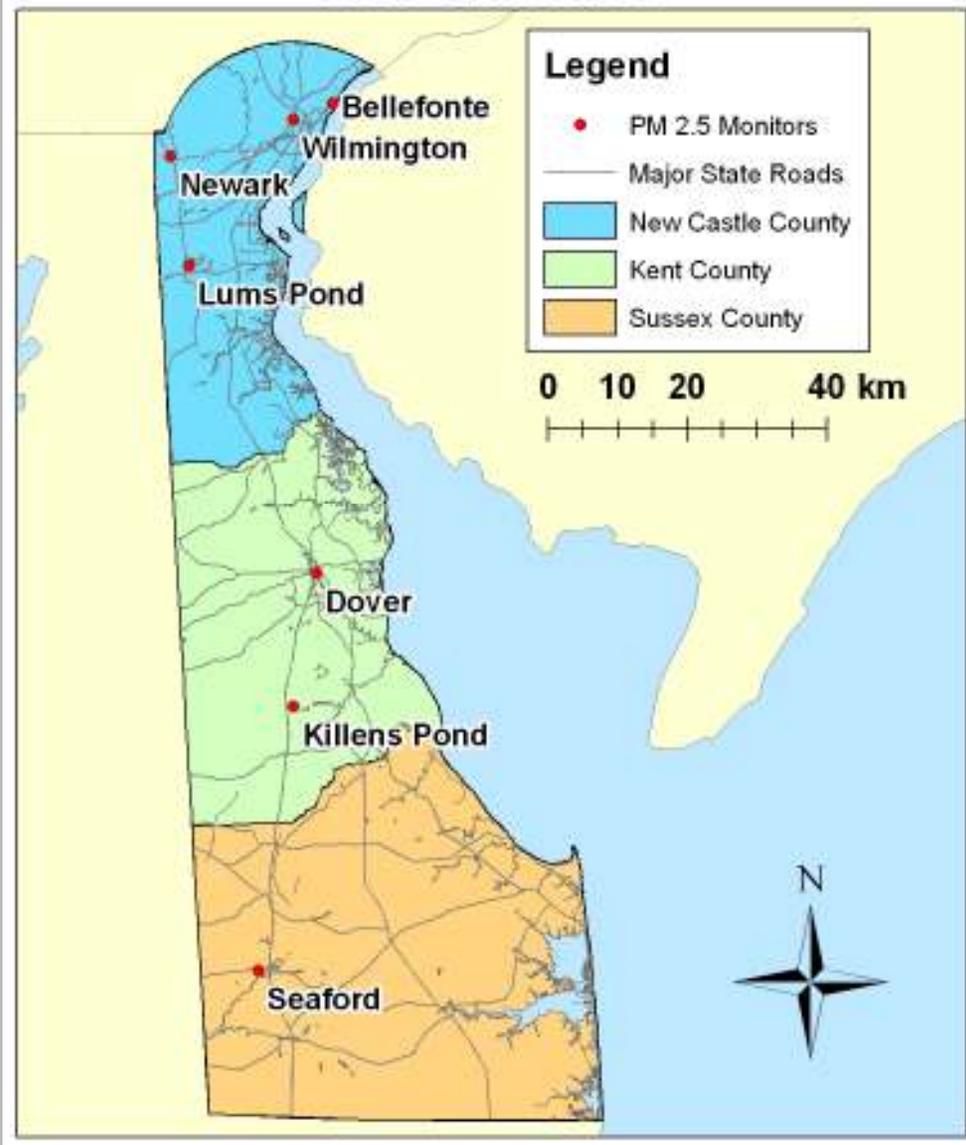
General Status

- 24-hour avg BAMs data correlate well with FRMs
- Summer vs winter linear correlations
- Can use various adjustments to deal with humidity issues

Overall, BAMs give reasonable correlation using site-specific regression calculations

But how do we do validate the hourly data?

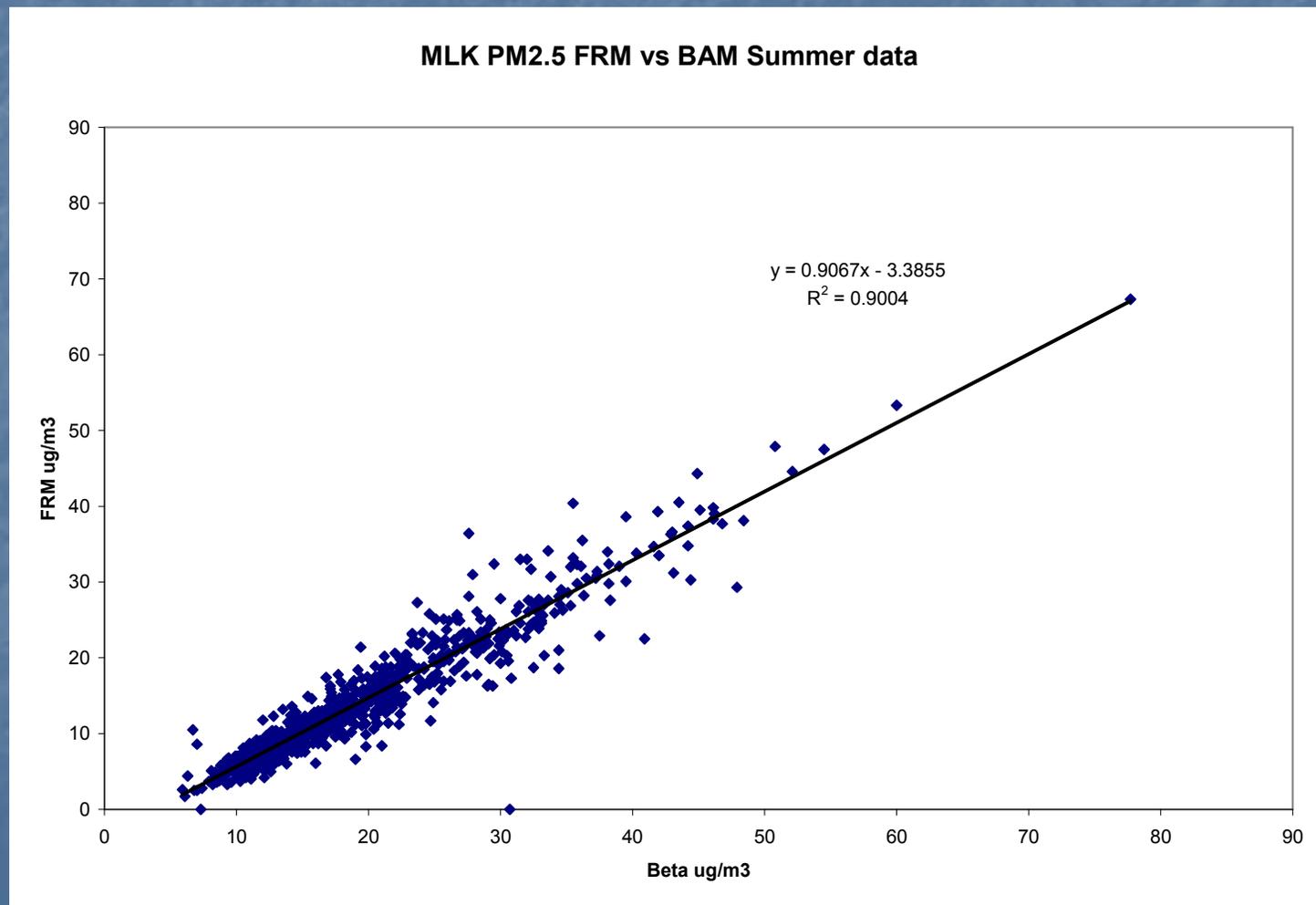| Day																	
1	27.2	18.5	19.1	14.5	15.7	19.5	11.4	0.1	0.1	5.2	9.2	0.1	0.1	0.6	14.1	34.9	36.3
2	10.1	20.5	18.4	19.2	16.2	12.3	17.7	3.2	4.4	12.8	10.2	25.9	22.1	11.3	19.3	38.6	45.6
3	32.2	33.7	26.4	26.1	25.1	28	14.8	18.8	12.3	33.7	7.7	0.5	5.4	2	6.8	0.1	2.1
4	3.4	7.4	3.8	4.9	7.3	1.5	0.1	3.8	7.8	8.5	2.4	1.7	10.4	1.4	4.5	20.4	20.5
5	14.4	29.3	33.3	16	7.9	4	5.9	2.3	9	22.6	0.4	0.6	5.5	8.2	35.3	16.3	15.8
6	26.9	42	24.4	29.1	26.7	30.9	29	2	10.1	10.2	15.3	21.2	5.6	14.8	2.4	12.4	18.1
7	0.2	9.5	0.6	10.2	12.6	11.1	24.1	15.6	10.2	16.1	9.5	10	9.3	28.1	15.7	18.8	16.7
8	3.9	8.5	1.5	5	5.1	2.3	0.1	5.4	10.3	9.9	16.5	4.1	6.1	14.6	17.7	25.7	24.1
9	6.2	17.2	13.3	9.9	6.7	10.3	20.8	4.7	12.6	8.2	8.1	19.9	11.3	8.1	17.6	61.2	3.2
10	5.7	16.4	4.6	11.7	7.9	1.2	0.1	19.7	0.4	9.3	19.2	1.3	11.6	11.5	12.3	14.4	12.5
11	10.6	12.2	15.6	15.4	5.3	0.5	10.4	12.9	13.2	8.9	8.2	6.3	8.8	9.8	15.3	1.3	6.2
12	6.6	1.1	12	12.2	18.1	12.7	14.5	16.2	9.9	10.2	0.7	11	7.3	6.8	13.7	11.7	21.5
13	4.4	4.2	8.5	18.1	28.8	19.9	0.4	0.1	9	7.8	13.9	9	19.5	6	6	2.8	20.5
14	36.2	32	34.2	28.4	36.8	44.4	37.7	24.8	18.1	0.2	22.7	19.1	35.4	16.1	16.9	15.9	20.5
15	15.9	25.3	15.3	17.8	6.4	3.5	1.3	4.1	14	0.1	9.9	3.3	10.6	8.6	14.6	26.6	27.3
16	9	2.1	18.1	10.1	7	1.5	0.2	13.1	4.8	20.7	5.8	2	4.2	3.4	17.9	13	20.5
17	5.6	10.1	4.8	6.3	15	6.9	4.1	16	1.6	4.5	0.1	12	12.2	20.1	35.1	32	15.7
18	9.7	14.4	12.4	7.9	16.9	4	7.2	7.4	22	15.5	26.7	21.8	40.8	34.3	32.4	56	53.7
19	63.9	57.5	58.7	41.8	35.6	40.8	17.8	13.2	9.6	1.8	8.8	17.3	18.3	37.2	37.8	26.5	38.5
20	38.1	10.9	11.4	21.4	11.3	34.3	49.4	5.3	2	27.4	20.8	11.8	8.6	10.3	28	9	29
21	13.1	28.8	33.5	31.9	32.2	15.9	0.1	0.1	0.1	5.3	4.8	11.1	18.8	14.6	28	24.3	34.4
22	36.8	54	62.4	54.2	57.3	66.4	43.7	26	1.2	7	6.3	23.9	18.4	38.4	18.9	0.1	11.1
23	84.9	33.1	31.4	35.1	7.5	0.1	0.1	2.7	8.2	16.6	13	7	20.6	72.6	36.7	43.9	41.2
24	19.9	18.5	12.4	27.2	22.2	19.3	21.4	5.1	0.1	0.1	1	10.1	11.7	32.9	0.4	0.9	6.8
25	26.1	8.9	0.1	3.1	13.1	1.9	15.6	13	5	6.6	13	4.1	0.4	6.2	9.6	0.1	0.1
26	5.2	20.9	14.5	6.4	22.5	10.7	3.1	0.8	14.2	19.3	4.7	0.4	6	28.3	5.3	0.1	7.8
27	3.4	7.5	4.8	14.2	16.6	14.8	8.2	4.4	4.9	1.9	15.3	0.1	0.1	0.1	6.1	9.2	27.3
28	9	5.3	17.3	4.4	0.7	5.7	6.2	1.8	0.7	0.1	2	4.8	4	4.4	12	11.5	22.1
29	30.7	25.9	34.1	32.5	27.4	39.3	36.7	0.1	0.1	5.1	14.9	8.7	41.4	39.6	35.2	42.6	31.5
30	5.1	29.6	26.1	28.9	28	32.3	10.5	0.1	12	16.1	8.1	1.7	4.8	1.5	14.7	25.7	18.6

Hourly data can look a bit wacky
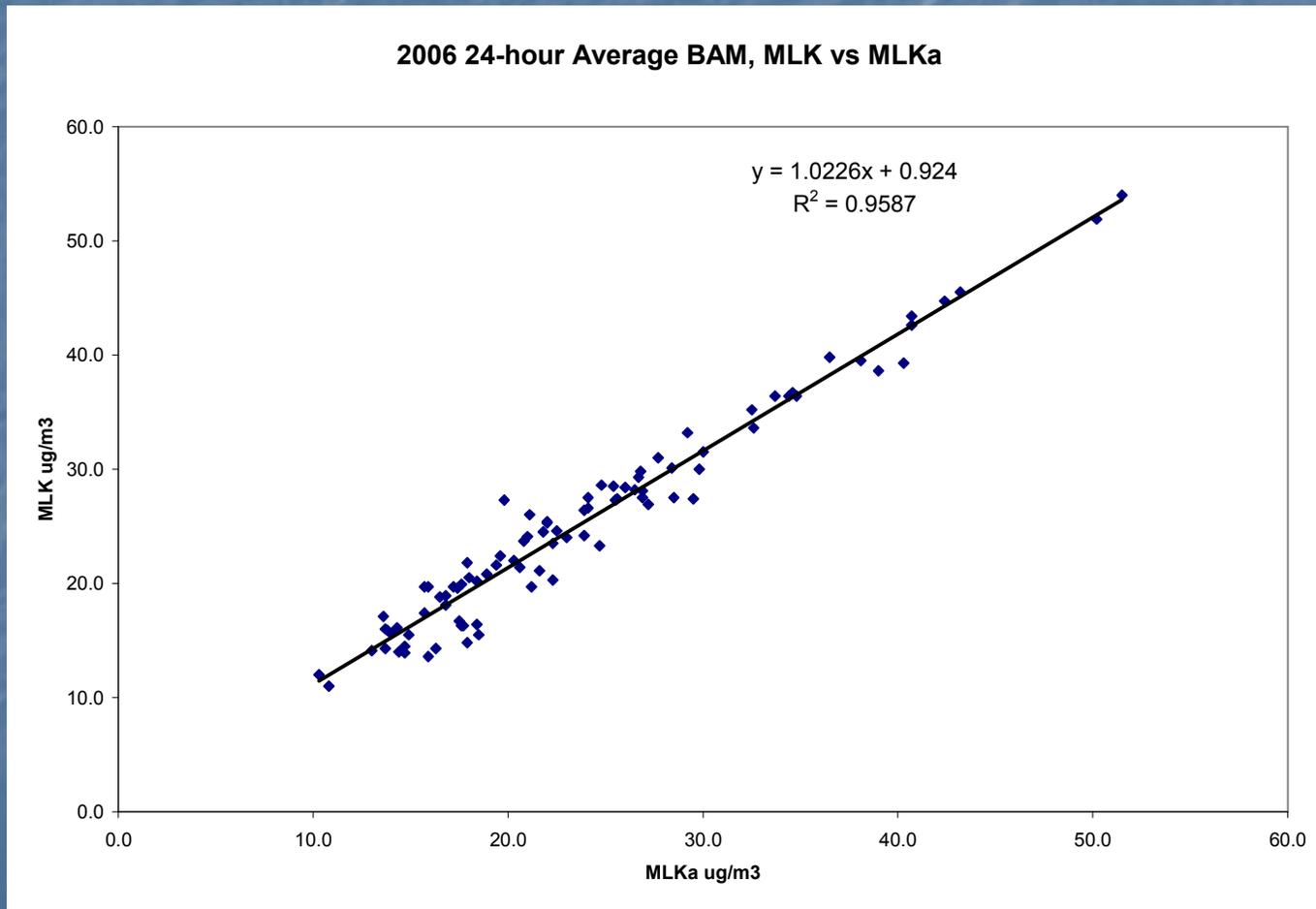

August 1-3, 2006
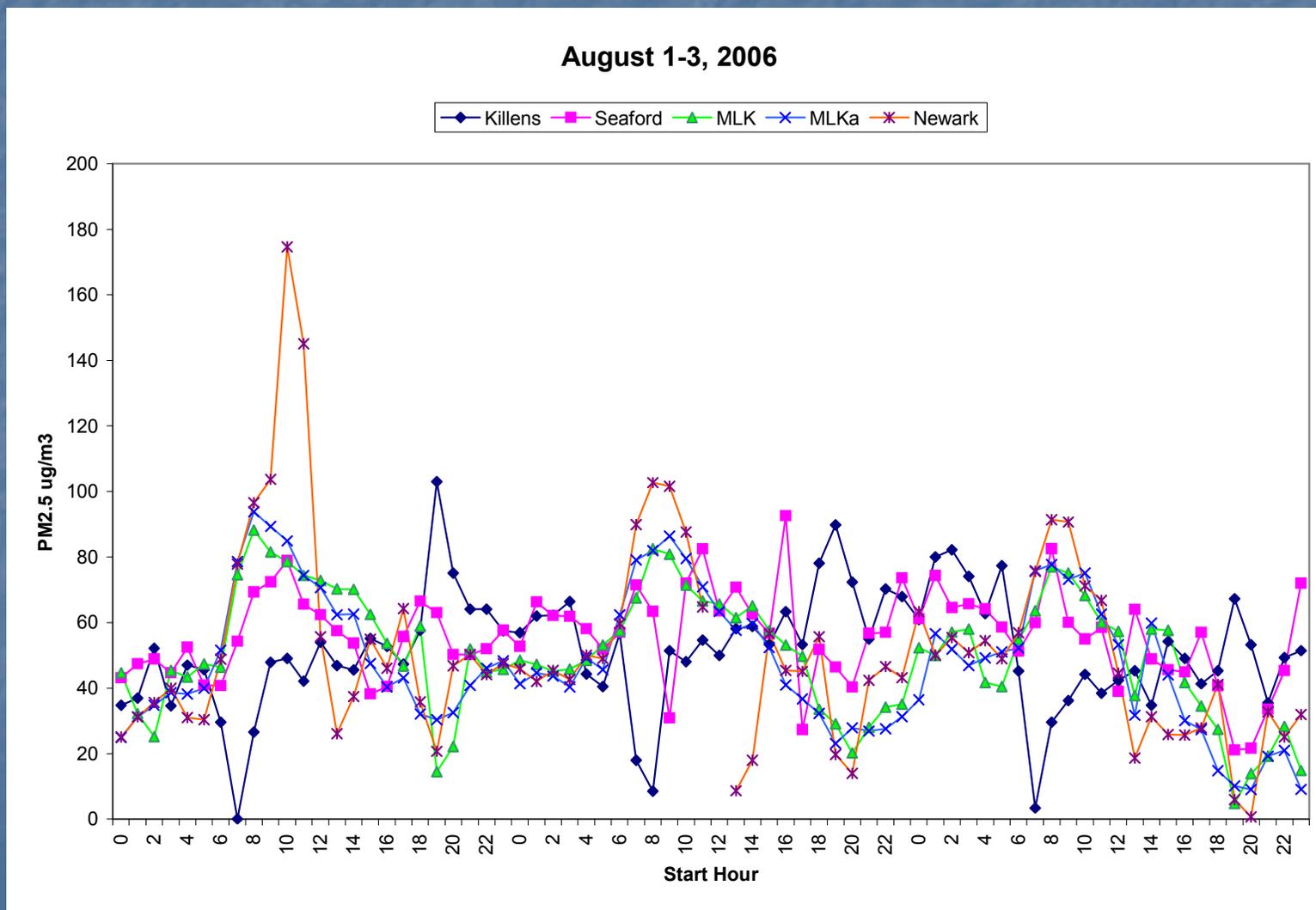
BAM Data Validation Tools

- Review measurement quality objectives
  - Operational parameter checks, monitor field records
  - Foil checks/audits, annual foil calibrations
- Use graphs to visualize data
- *Note: we do not have a digital data acquisition system and do not routinely download monitor status data*
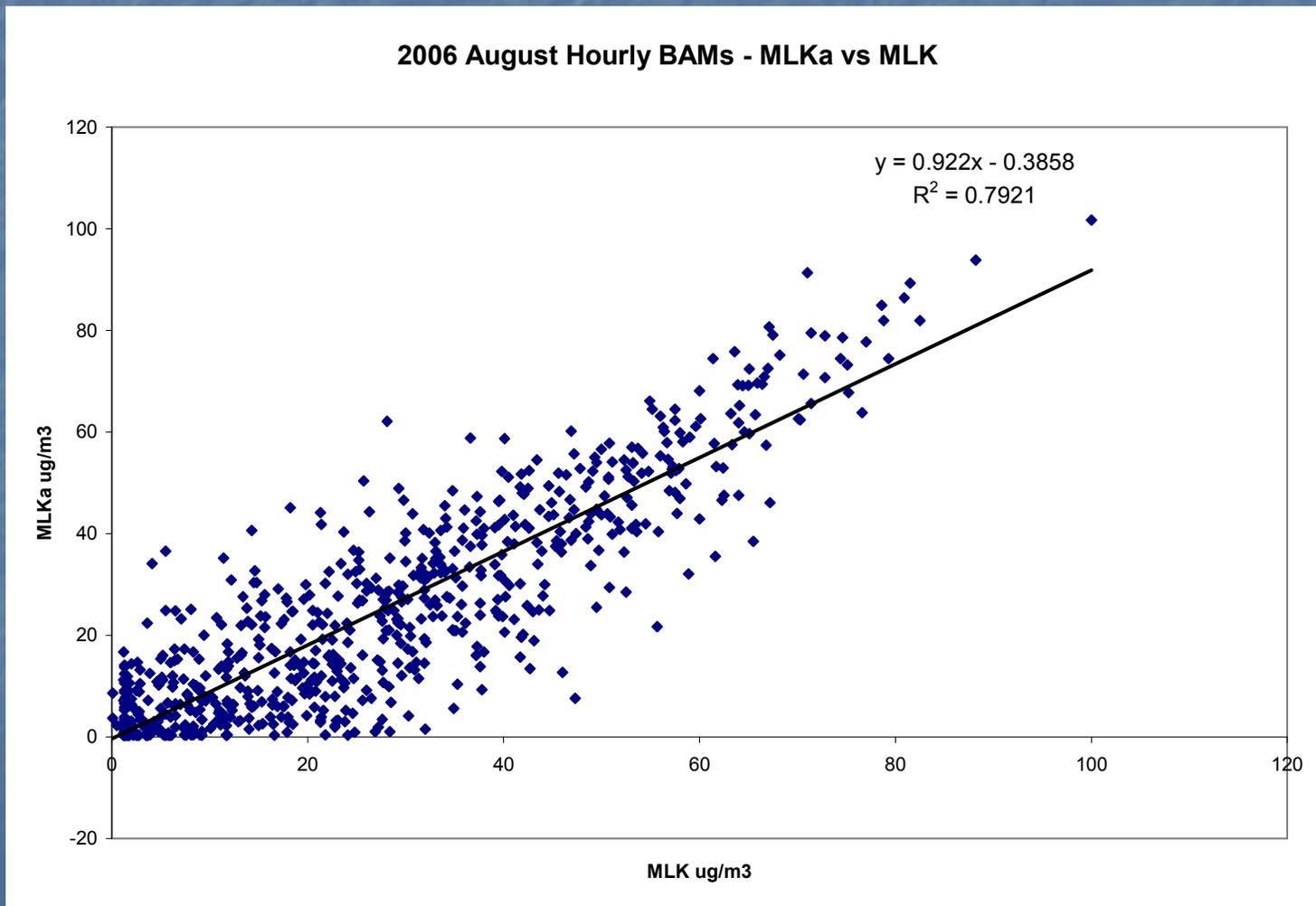
Hard Copy Records

Monthly Maintenance Checks – ThermoAndersen Particulate Tape Sampler FH 62 C14

Site _____   S/N _____   Month _____

Flow, Temp, and Press Checks – *Required at least once every two weeks*

Date	Parameter (Flow, Temp, or Press)	Ref. Device Value	Beta C-14 Value	% Difference
	Amb. Temp. T_1			
	Pressure P_3			
	Flow			
	Amb. Temp. T_1			
	Pressure P_3			
	Flow			
	Amb. Temp. T_1			
	Pressure P_3			
	Flow			

Criteria: Flow check ± 4%   Conversions: Pressure: mmHg = hPa x 0.75218
Temp check ± 6°C   hPa = mmHg x 1.33
Press check ± 10 mmHg   Flow: L/m = L/h / 60

Maintenance Checks – at least once per month (except inlet cleaning)

Date	Heated Inlet Temp-Control check *	Clean PM2.5	Clean PM10	Check Filter Tape	Clean inlet (quarterly)**
	T_s = T_4 = HL% =				
	T_s = T_4 = HL% =				

* Obtain real-time reading from theOperations Menu, Heater Control screen, display of current T1, T2, T4, and HL% .
** Caution! Remove front rack access plate above sampler, dismount heated tube from sampler input at threaded coupler and support to side before punching a cleaning patch through the inlet tube or it will be sucked into the instrument causing considerable inconvenience and potential for damage.

Comments:

Quality Control Audit
Thermo C-14 Beta Sampler
For Independent Audit Only

Site: _____   Monitor S/N: _____   Date: _____

Temperature Sensors

Service Screen – Step to Hardware Diagnostics submenu – find T_1 - T_4 display screen. Visually correlate the shown temperatures for T_1 thru T_4, and log these readings vs. reference standard temps in each category. Note: T_4 sensor located behind blank plate/panel above instrument and underneath insulation at the base of the inlet tube.

T_1 ambient sensor _____   Reference Ambient Temp _____   Criteria: ± 2 °C
T_2 upper head sens. _____ T_2 measured with reference _____
T_3 lower head sens. _____ T_3 measured with reference _____
T_4 heated tube sens. _____ T_4 measured with reference _____

Pressure Sensor

Same display screen as for Temperatures – find P_3.

P_3 ambient _____   Ref. Barometer _____   Criteria: ± 2 mmHg

hPa = mm.Hg * 1.33 ,   mm.Hg = hPa * .75218 (@20° C)

Flow Rate

Operations Menu – Step "next" three screens and see Air Flow read.

Flow Device Type _____   S/N _____   Calibration Due _____

Sampler Flow _____   Actual Flow _____   % Difference _____
Criteria: ± 5%

L/m = L/hr / 60

Conditions during flow calibration are Noted Above in the Temp/Pressure Checks

1-Point Foil Value Check

2. Operation Menu – Enable Keypad – step to Heater Control screen, set heater control to Off, let sampler run and wait for T_2 = T_1 although being within 2^0C seems to be sufficient. This cool-down period may take 30 min – 1hr.
3. Service Menu – Mechanical Control – "open head" screen - first turn pump off open head
4. Insert foil holder – close head – step two screens and Zero on this tape.
5. Watch for the value next to QLF to obtain an asterisk "*"indicating a zero and record.
6. Insert the span foil writing side down. See the value next to QLF again obtain an asterisk "*", indicating that it's found a relative span value. Record.
7. While still in Service Menu, go "back" to the Mechanical Control submenu and open the head. Return foil + holder to test kit, and reconnect the sample tape.
8. Step "next" to screen that lets you close the screen; pess "FC+Z" at this time. After the head closes, you should hear the pump start up on its own.
9. Operations Menu – Temp Ctrl screen - set heater control On. Note that the heated inlet tube T_4 should now be slowly rising above T_1 ambient temperature.
10. Back up in this menu to see Keypad Enabled, and use the command disable it.

Zero QLF Value	Span QLF Value	Span QLF - Zero QLF = Test Read	Span Foil Printed Value *g	% Diff. Test Read vs Printed Value

Comments:

Auditor:_____   Date:_____

QA Coordinator:_____   Date:_____

Prgm Mgr:_____   Date:_____

Data comparisons: 24-hr averages correlate well with FRM

MLK PM2.5 FRM vs BAM Summer data

$y = 0.9067x - 3.3855$
$R^2 = 0.9004$

24-hr averages also correlate well between collocated BAMs

2006 24-hour Average BAM, MLK vs MLKa

$y = 1.0226x + 0.924$
$R^2 = 0.9587$

MLK ug/m3 (y-axis) vs MLKa ug/m3 (x-axis)

But hourly BAM averages do not correlate as well

2006 August Hourly BAMs - MLKa vs MLK

$y = 0.922x - 0.3858$
$R^2 = 0.7921$

Times series collocated hourly BAMs

Hourly PM2.5 data MLK - Sep. 27, 2006

1-hour averages

- Do not correlate exactly, although follow similar diurnal patterns
  - Variance is high
- But still useful for:
  - Comparisons between monitors/sites to identify extreme outliers
  - Identify patterns indicating invalid data such as high rates of change, spikes, flat-lines

High Rate of Change/Spike

Hourly PM2.5 BAMs August 16, 2006

Legend: Killens, Seaford, MLK, MLKa, Newark

Y-axis: PM2.5 ug/m3

X-axis: Start Hour

High Rate of Change/Spike

Hourly PM2.5 BAM October 14, 2006
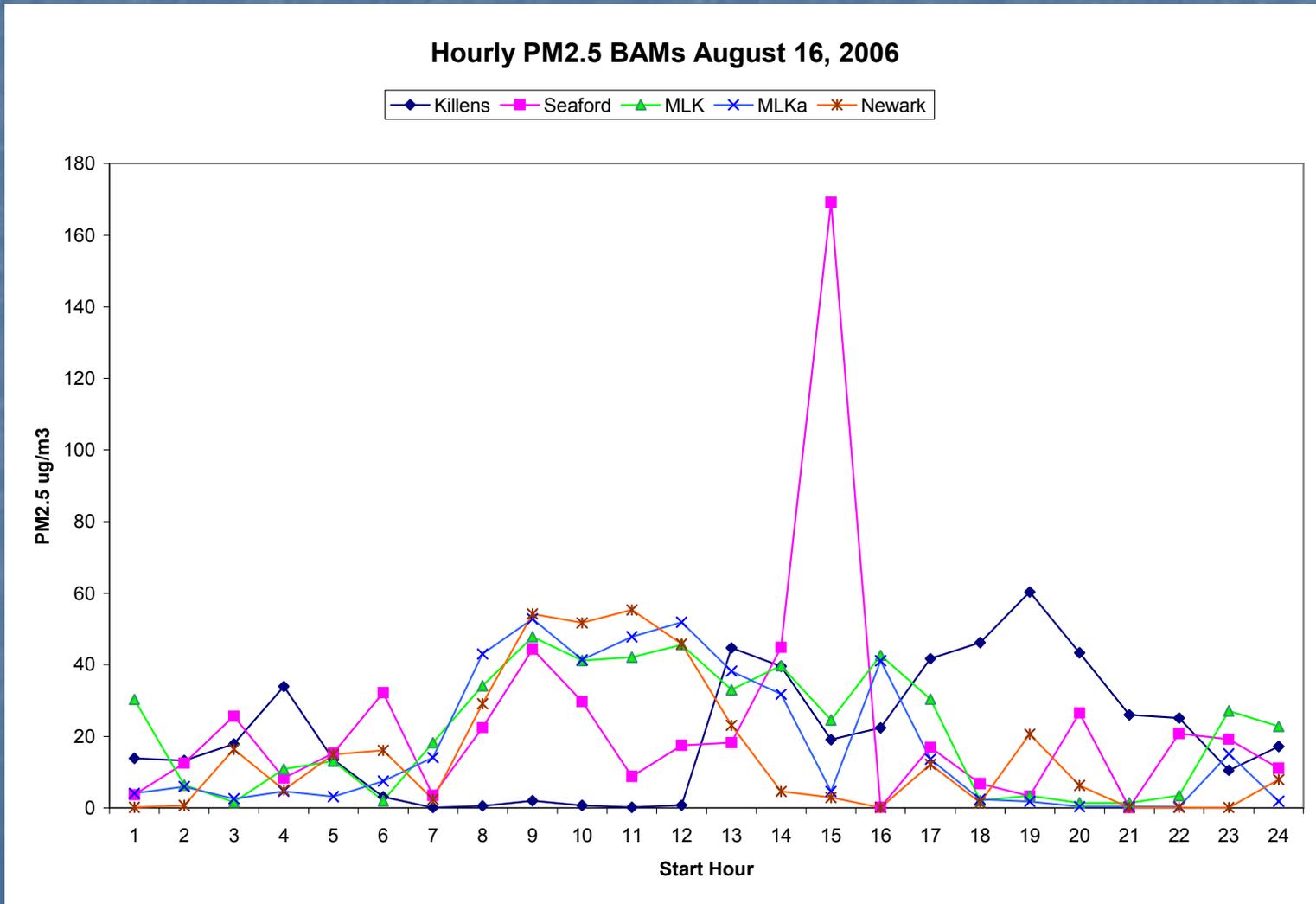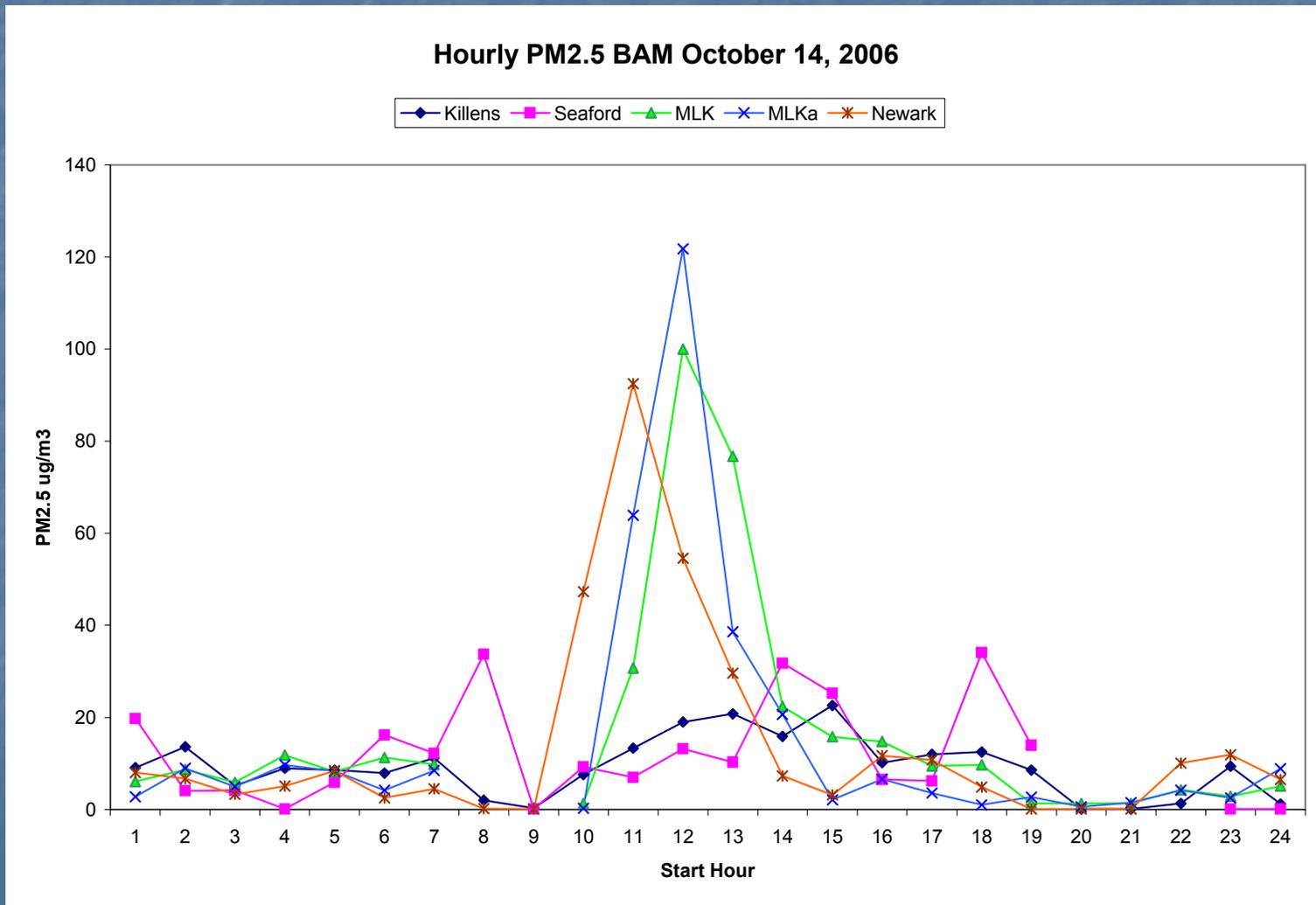
Time-series graphs can identify other issues

- Unstable hourly averages
  - Multiple causes, conditions
- Flat-line near zero
  - Often seen after monitor maintenance activities, or problems with high ambient RH
- Monitor malfunctions, example: temperature sensor loose connection
  - Extreme swings and negative averages

Instability due to electronic interference

Hourly PM2.5 BAMs Oct. 6-7, 2006
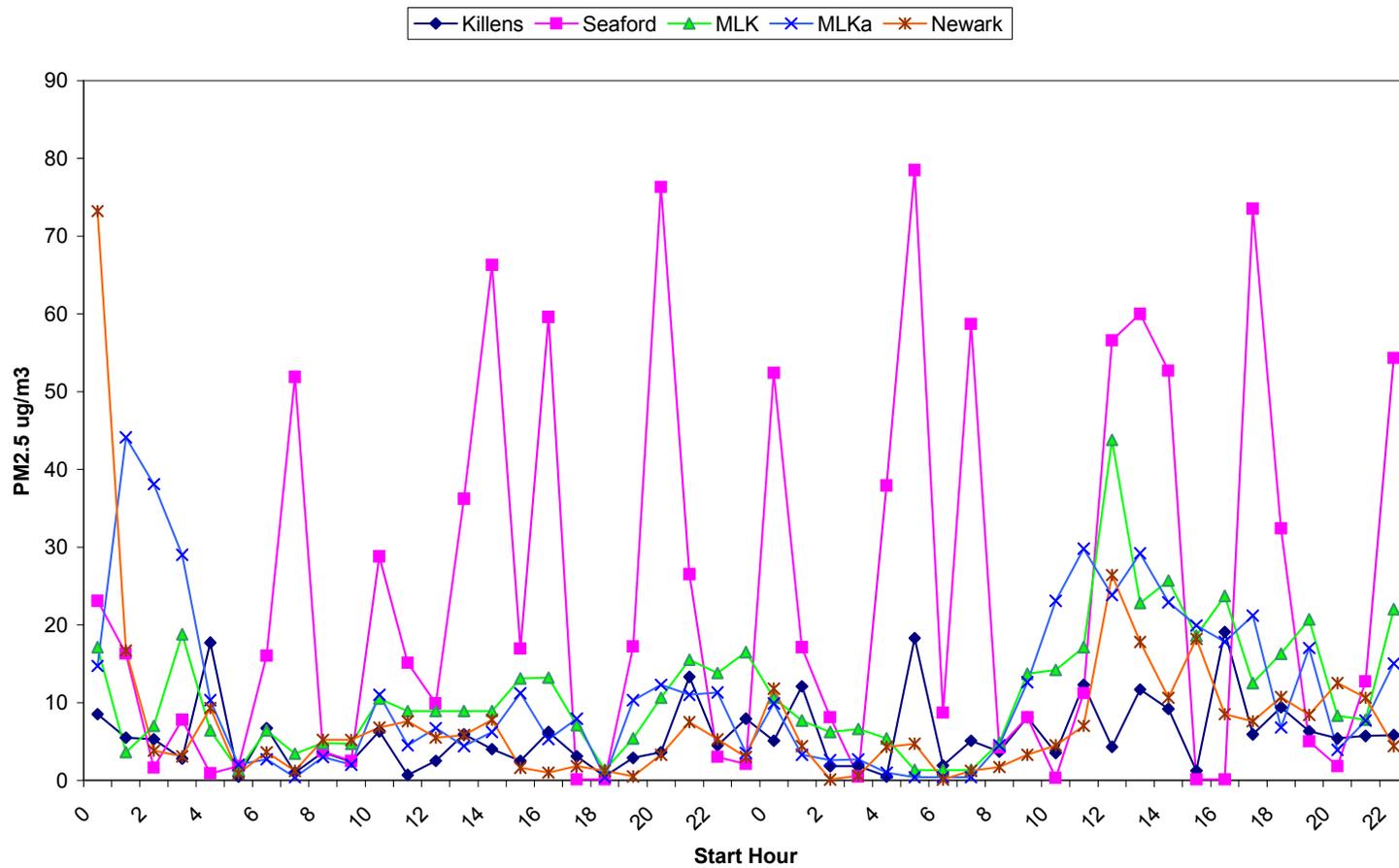
Instability –need to check other monitors

Oct. 17-20, 2006 Hourly Avg PM2.5
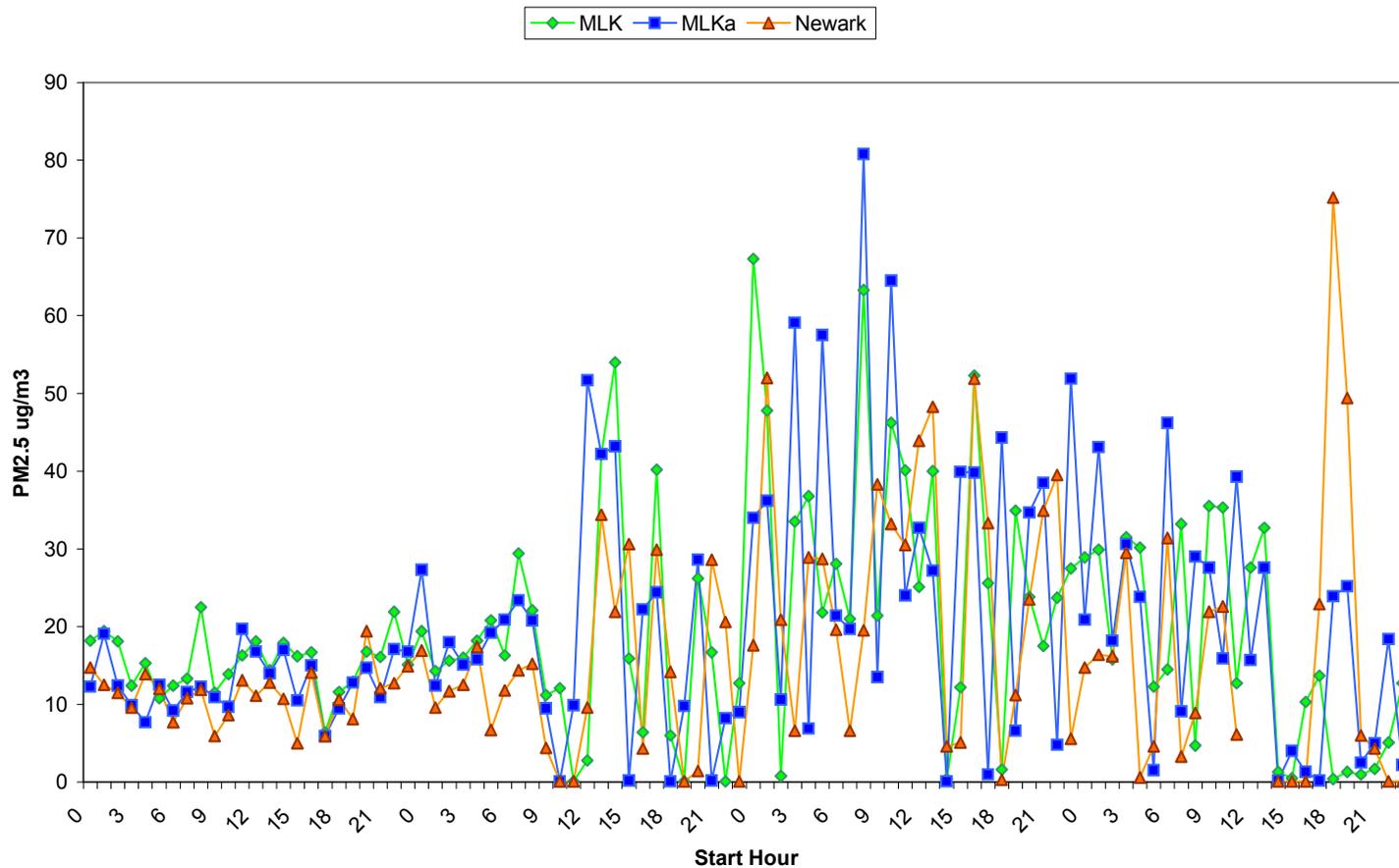
Flat line following maintenance

MLK Hourly PM2.5 Avg. Nov 1-6, 2005
raw data, including invalid data

Foil Calibration

PM2.5 ug/m3

Start Hour
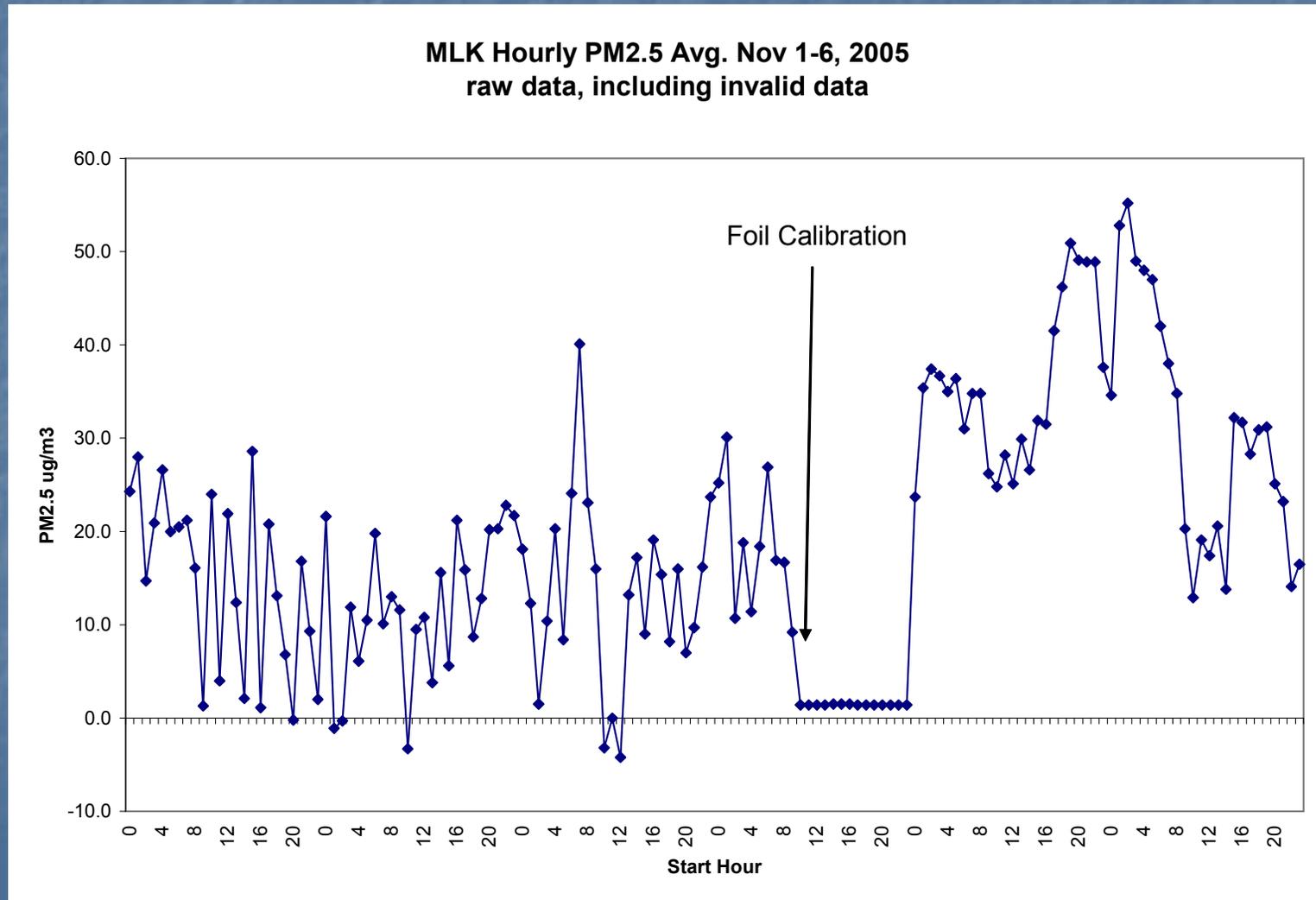
Monitor malfunction (temp. sensor)

Hourly Avg PM2.5 Seaford June 27-30, 2005
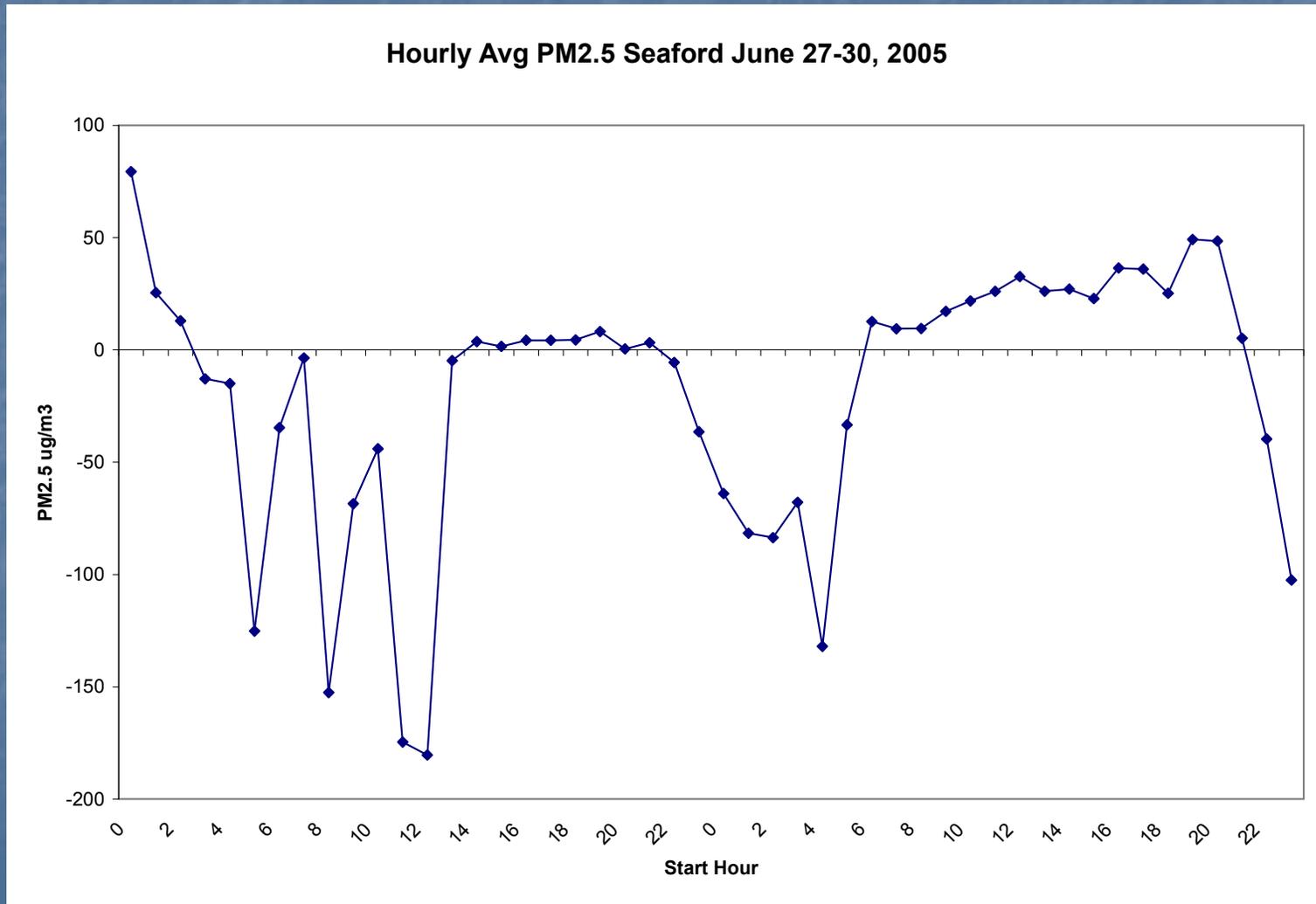
Additional tools for validation

- Can get regional continuous PM2.5 data from other states at AirNow Tech
  - Be careful of different types of monitors and operational parameters
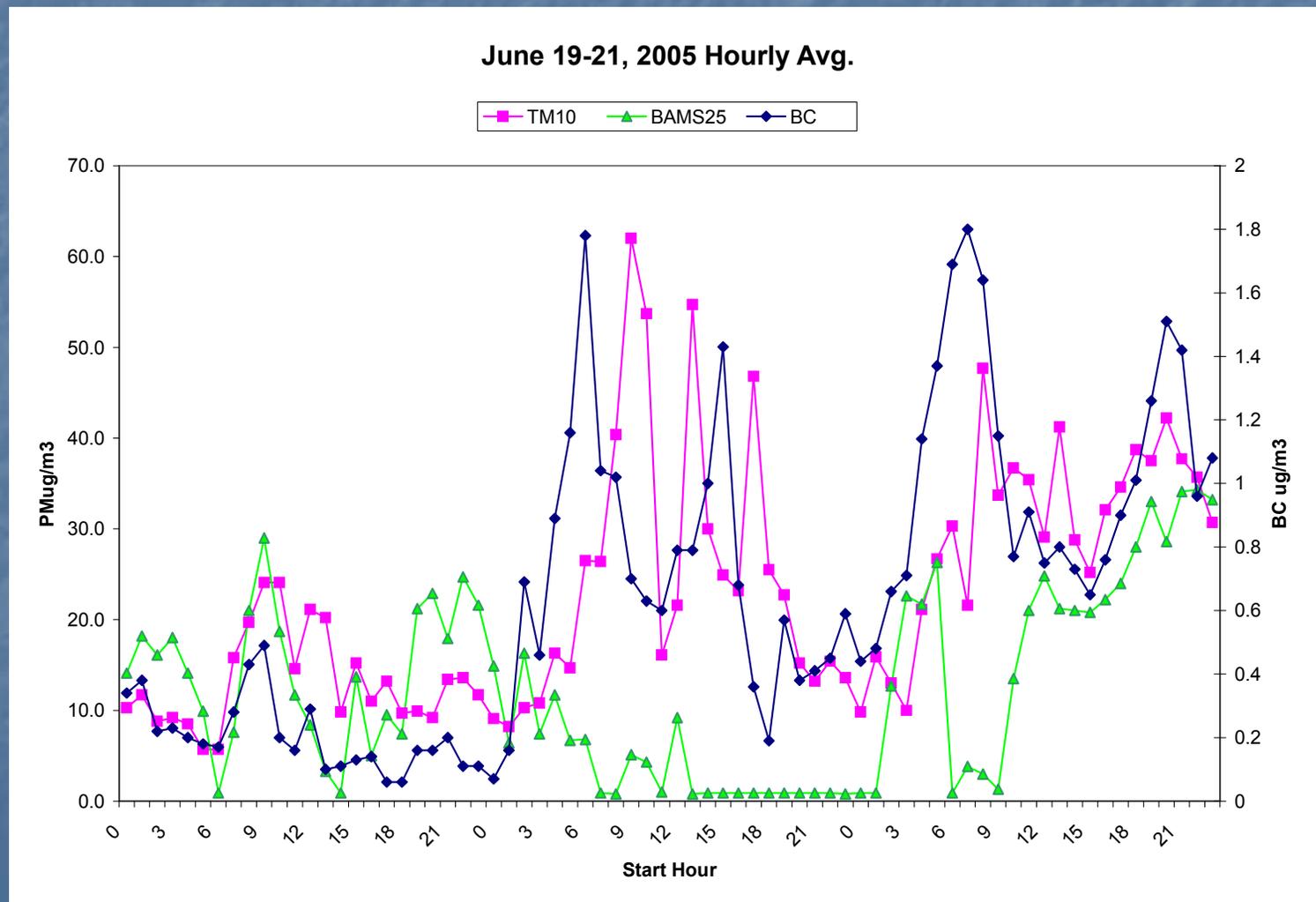 - More useful as general check, not as good for individual hourly values

Regional continuous PM2.5 data hourly averages

July 21, 2006 Hourly PM2.5 Averages
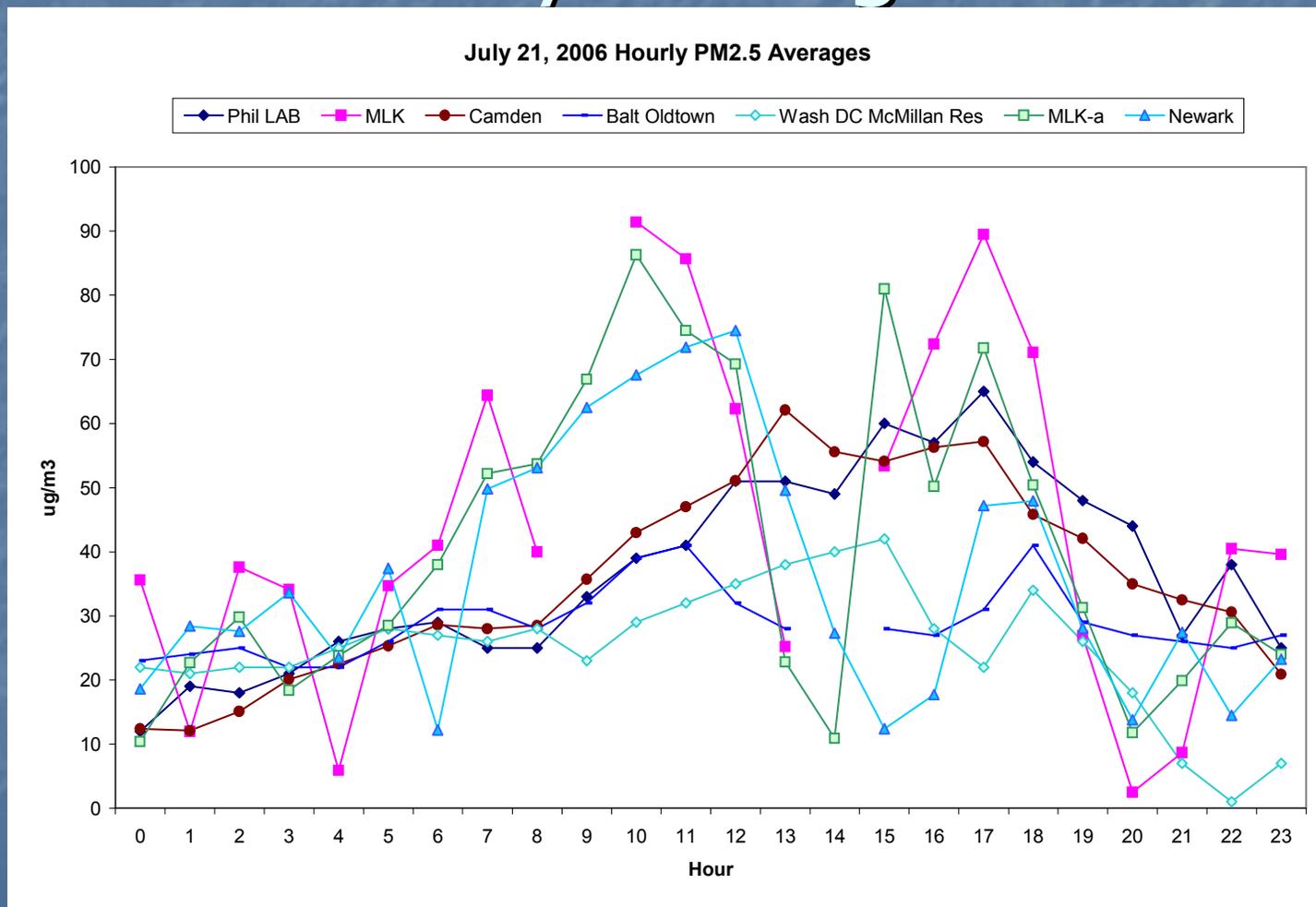
Regional continuous PM2.5 24-hour averages

Continuous PM2.5 24-hr Averages
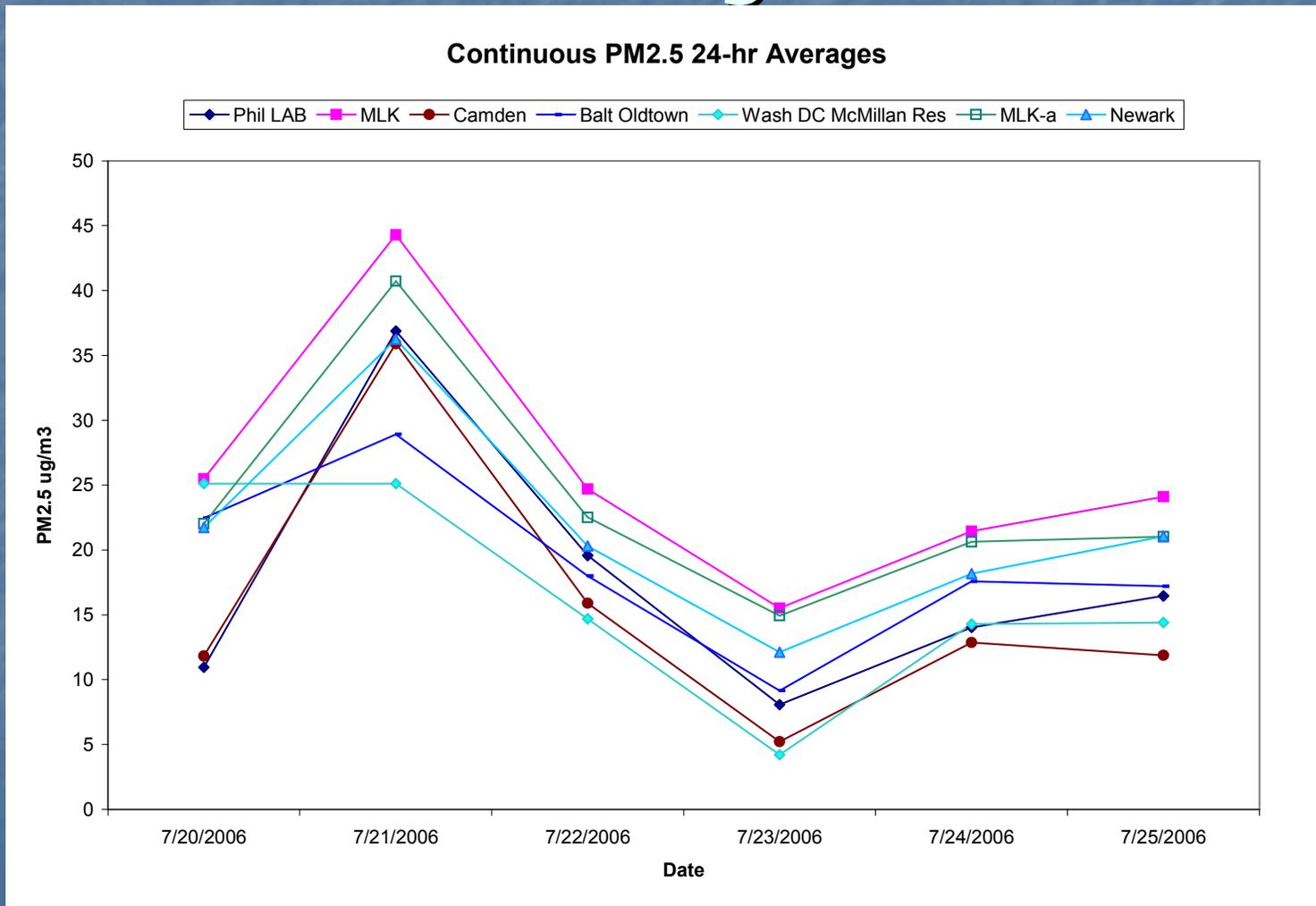
May be able to use hourly data from other pollutants

June 19-21, 2005 Hourly Avg.

Legend: TM10, BAMS25, BC

Conclusion

Use all tools available to validate data!

- Start with operational parameters and maintenance check records

- Look for extreme values and "flat lines"

- Time series graphs can highlight questionable data, identify valid episodes

  - Use comparisons with other monitors to look for patterns

Bottom line:

- May or may not have enough specific information for individual hourly data validation decision

- Need experience and familiarity with the data

Know your monitors and PM2.5 data!