Field Evaluation
Elitech Temtop PMD 351

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 04/23/2021 to 06/22/2021, three **Elitech Temtop PMD 351 (hereinafter Temtop PMD 351)** sensors were deployed at the South Coast AQMD stationary ambient monitoring site in Rubidoux and were run side-by-side with Federal Equivalent Method (FEM) instruments measuring the same pollutants

- Temtop PMD 351 (*3 units tested*):
  - Particle sensor: optical; non-FEM (Temtop PMS16)
  - Each unit reports: $PM_{1.0}$, $PM_{2.5}$ and PM_{10} ($\mu g/m^3$)
  - Also reports PM_4, and TSP ($\mu g/m^3$)
  - Unit cost: ~$960
  - Time resolution: 1-min
  - Units IDs: 10003, 60001, 80001

- GRIMM (*reference instrument*):
  - Optical particle counter (FEM $PM_{2.5}$)
  - Measures $PM_{1.0}$, $PM_{2.5}$, and PM_{10} ($\mu g/m^3$)
  - Cost: ~$25,000 and up
  - Time resolution: 1-min

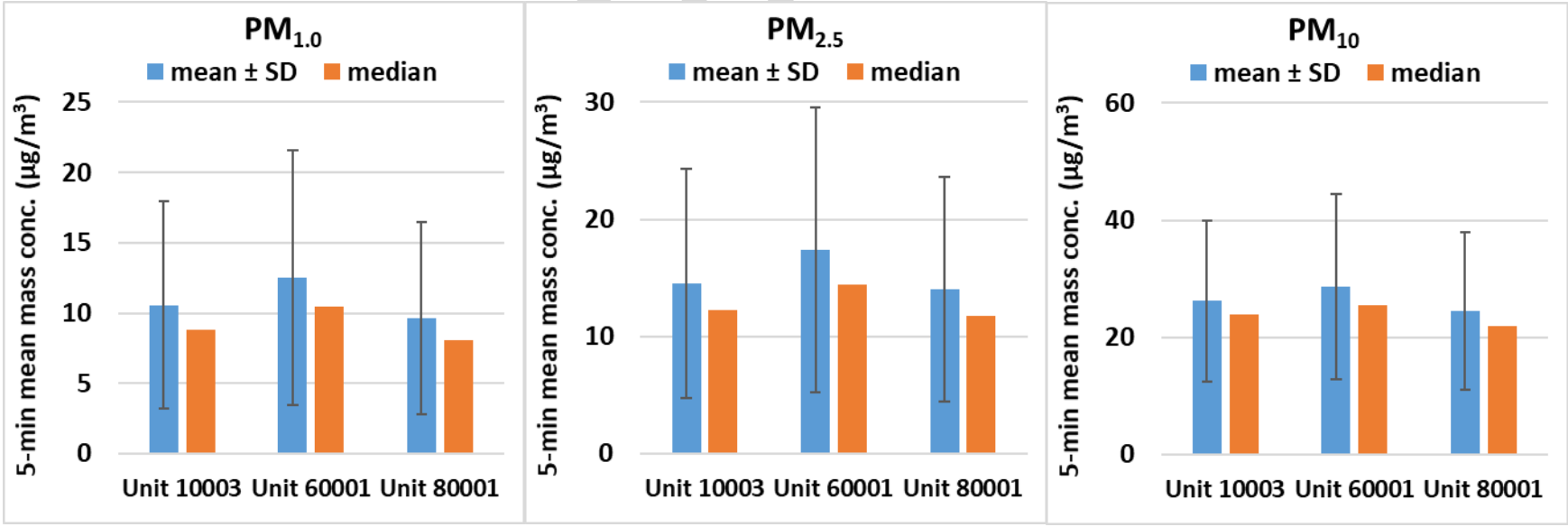
- Teledyne API T640 (*reference instrument*):
  - Optical particle counter (FEM $PM_{2.5}$)
  - Measures $PM_{1.0}$, $PM_{2.5}$ and PM_{10} ($\mu g/m^3$)
  - Cost: ~$21,000
  - Time resolution: 1-min

Data validation & recovery

- Basic QA/QC procedures were used to validate the collected data (i.e. obvious outliers, negative values and invalid data-points were eliminated from the data-set)
- Data recovery from all units was ~ 100% for all PM measurements

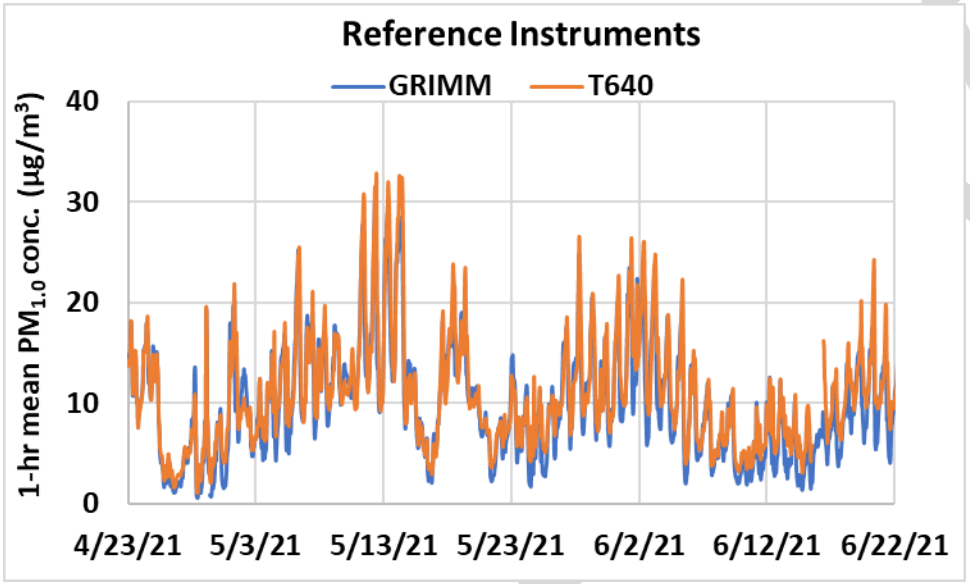
Temtop PMD 351; intra-model variability

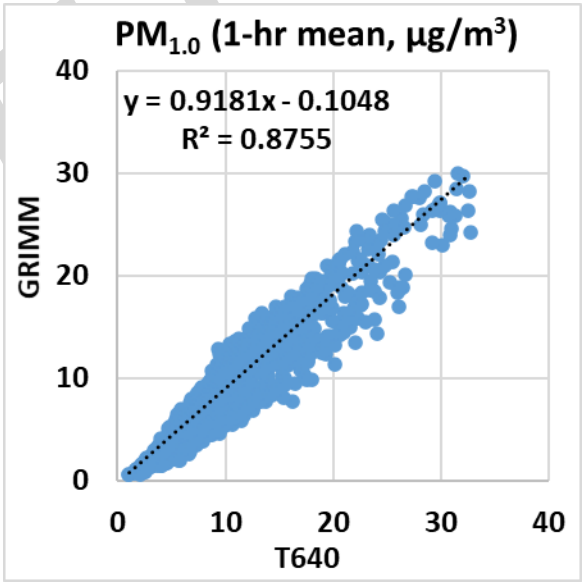
- Absolute intra-model variability was ~ 1.20, 1.48 and 1.68 µg/m^3 for $PM_{1.0}$, $PM_{2.5}$ and $PM_{10,}$ respectively (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 11.1%, 9.6% and 6.4% for $PM_{1.0}$, $PM_{2.5}$ and $PM_{10,}$ respectively (calculated as the absolute intra-model variability relative to the mean of the three sensor means)



Reference Instruments: $PM_{1.0}$ GRIMM and T640

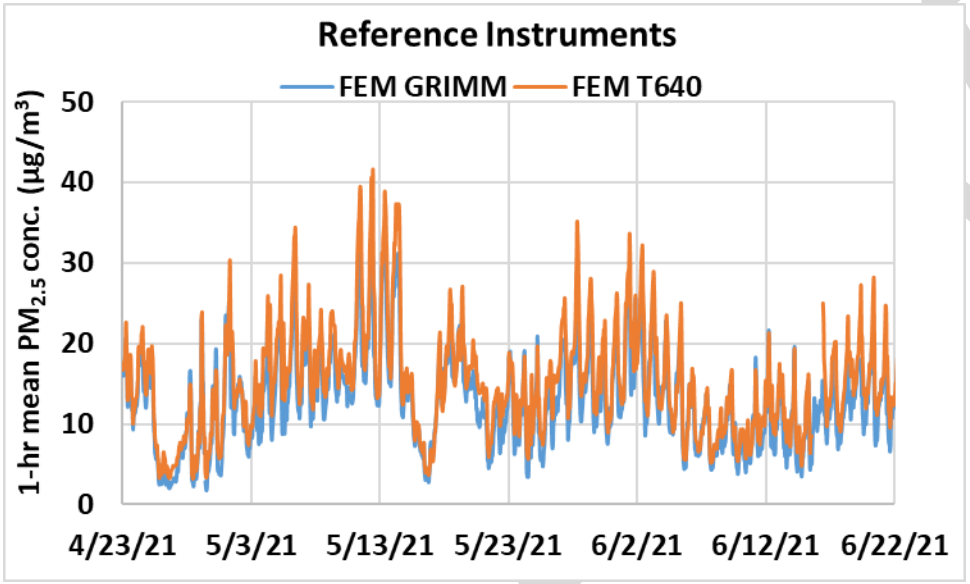
- Data recovery for $PM_{1.0}$ from GRIMM and T640 was ~ 100%.
- Strong correlations between the reference instruments for $PM_{1.0}$ measurements (R^2 ~ 0.88) were observed.

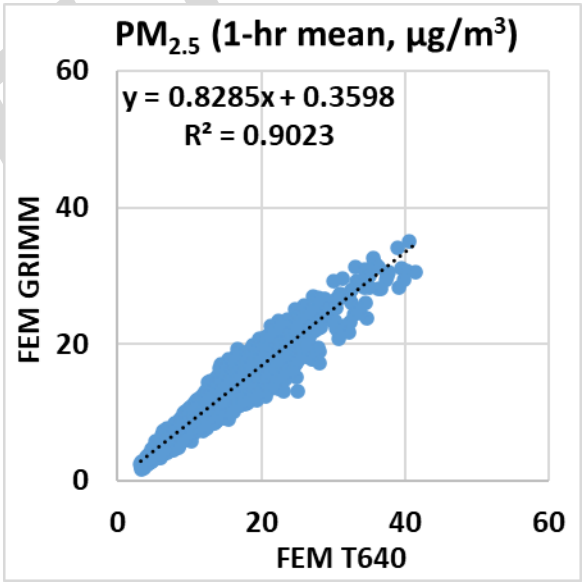




Reference Instruments: $PM_{2.5}$ FEM GRIMM and FEM T640

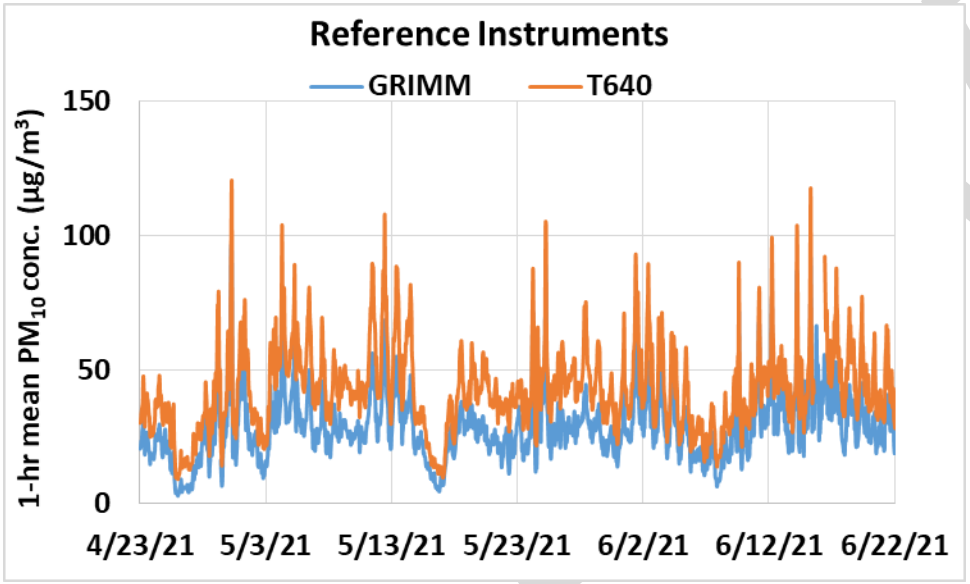
- Data recovery for $PM_{2.5}$ from FEM GRIMM and FEM T640 was ~ 100%.
- Very strong correlations between the reference instruments for $PM_{2.5}$ measurements (R^2 ~ 0.90) were observed.

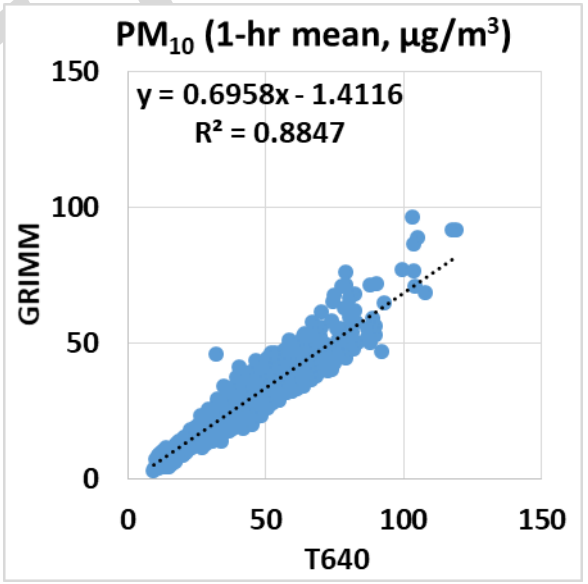




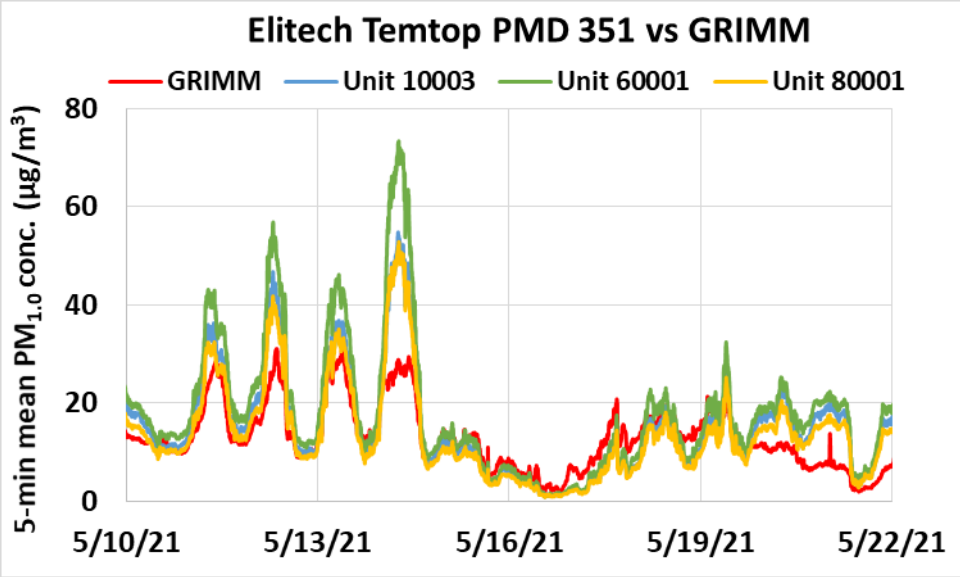
Reference Instruments: PM_{10} GRIMM and T640

- Data recovery for PM_{10} from GRIMM and T640 was ~ 100%.
- Strong correlations between the reference instruments for PM_{10} measurements (R^2 ~ 0.88) were observed.

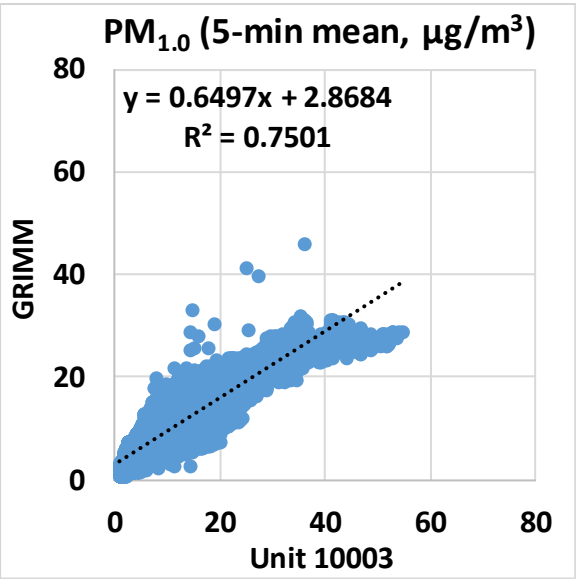


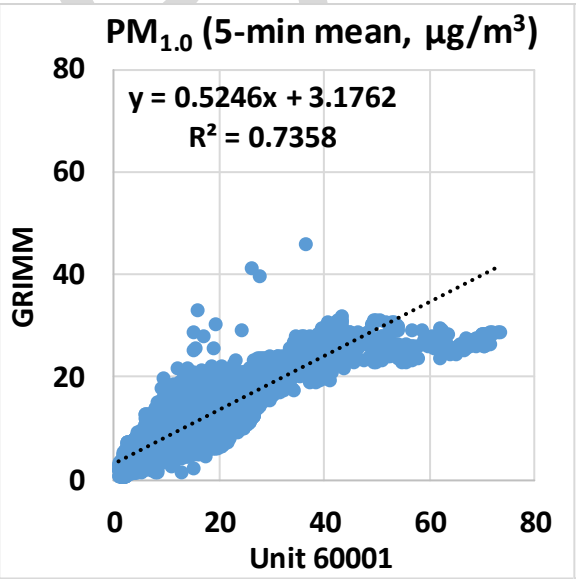


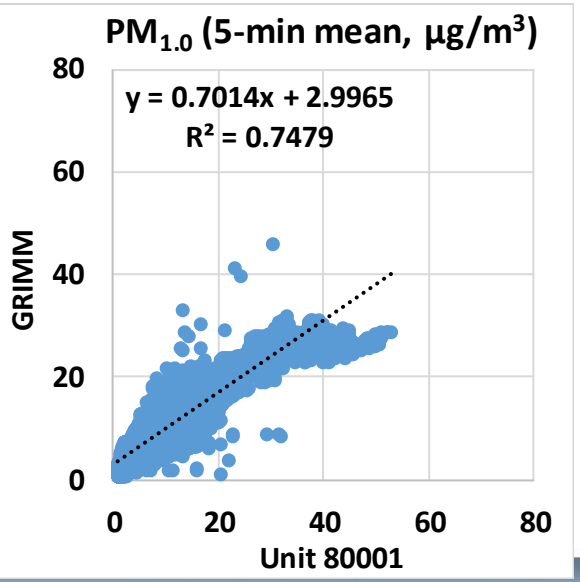
Temtop PMD 351 vs GRIMM ($PM_{1.0}$; 5-min mean)



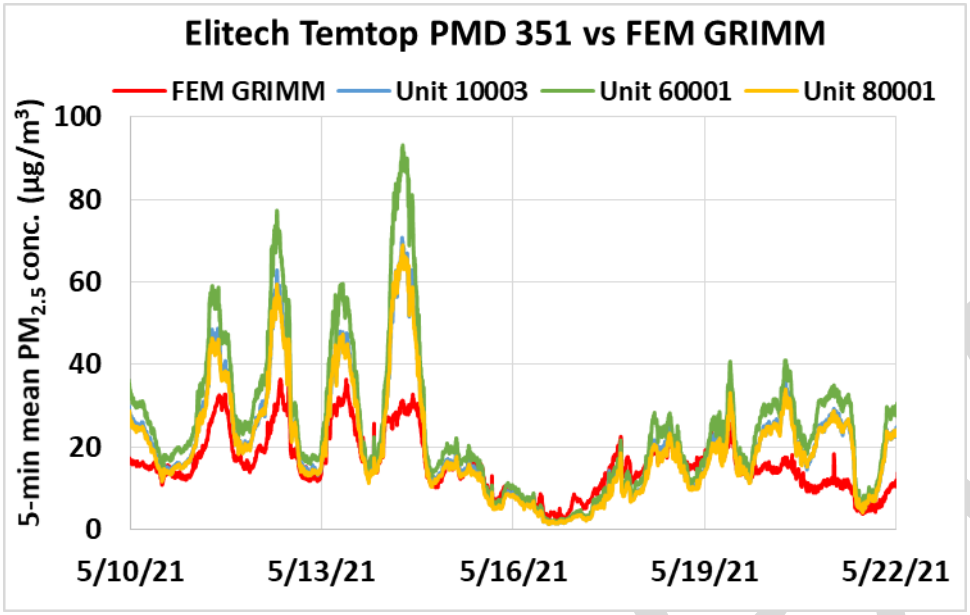
- The Temtop PMD 351 sensors showed strong correlations with the corresponding GRIMM data ($0.73 < R^2 < 0.76$)
- Overall, the Temtop PMD 351 sensors overestimated the $PM_{1.0}$ mass concentrations as measured by GRIMM
- The Temtop PMD 351 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by GRIMM



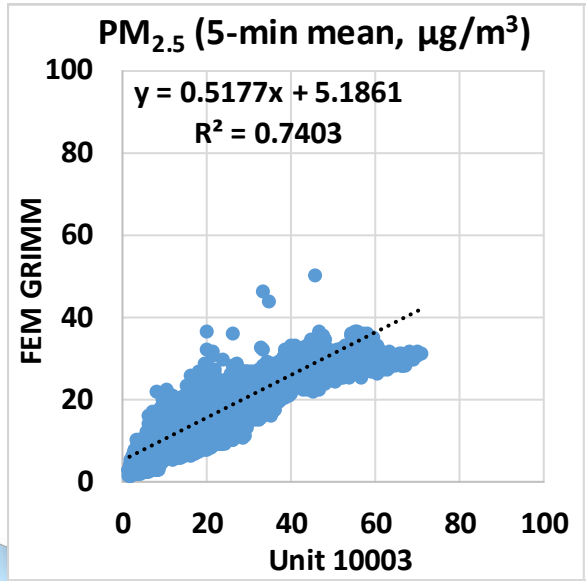


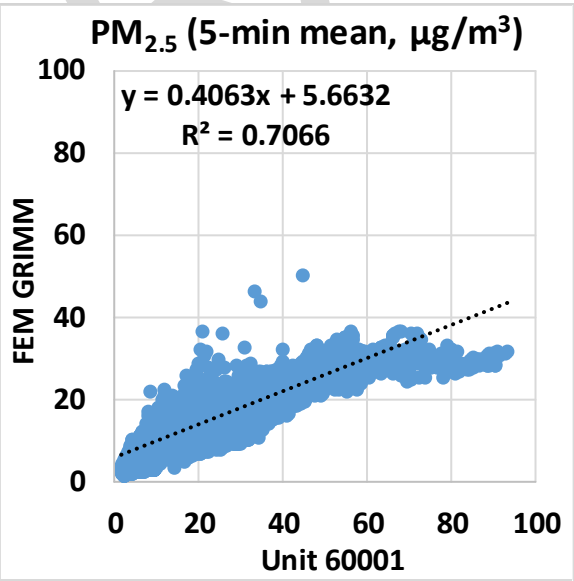


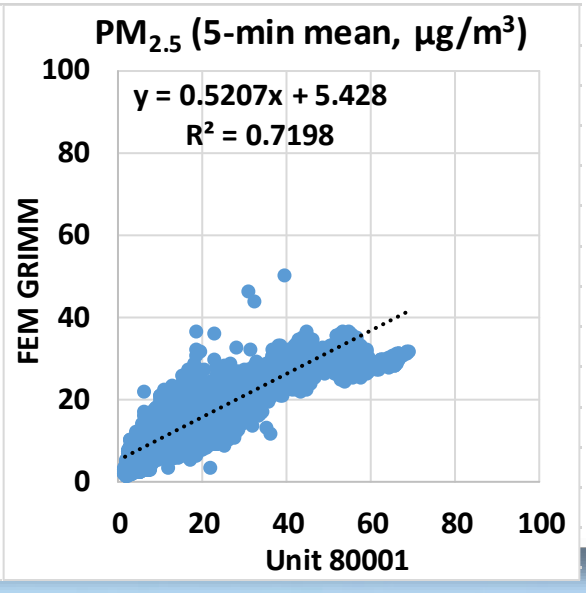
Temtop PMD 351 vs FEM GRIMM ($PM_{2.5}$; 5-min mean)



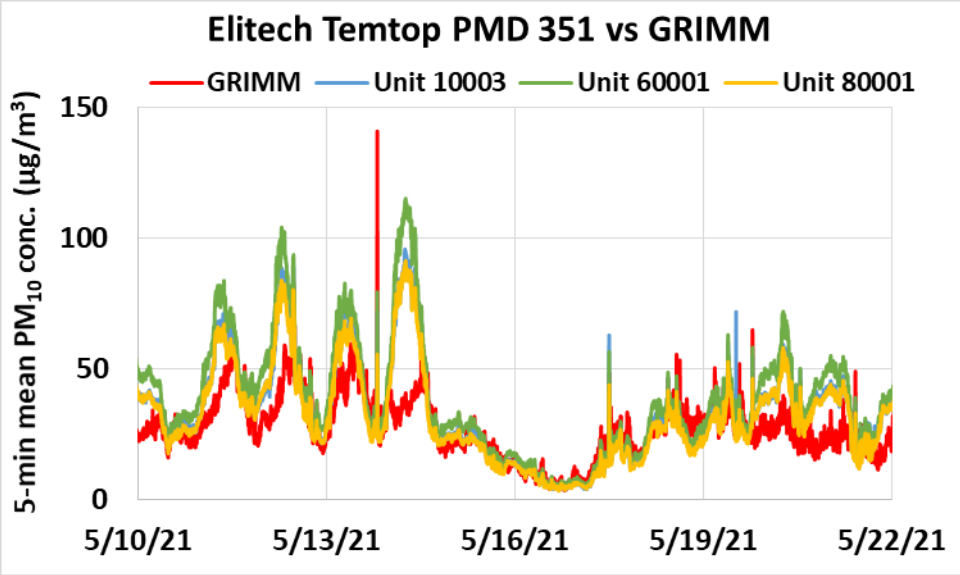
- The Temtop PMD 351 sensors showed strong correlations with the corresponding FEM GRIMM data ($0.70 < R^2 < 0.75$)
- Overall, the Temtop PMD 351 sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM GRIMM
- The Temtop PMD 351 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM



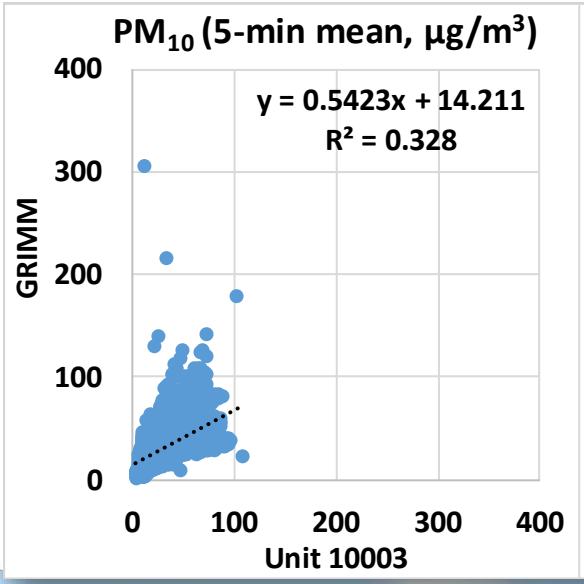


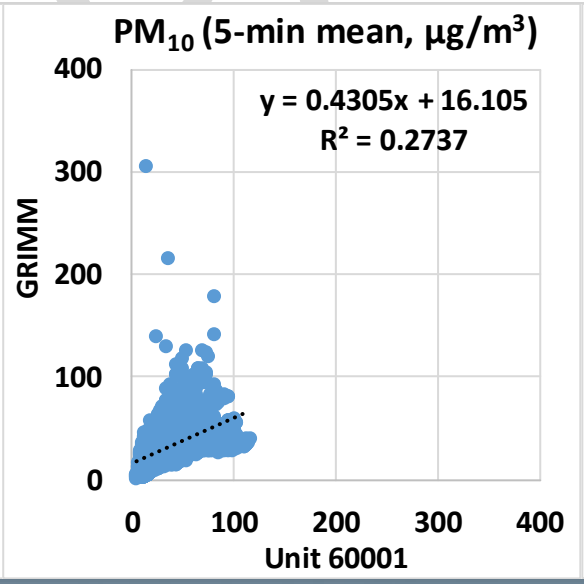


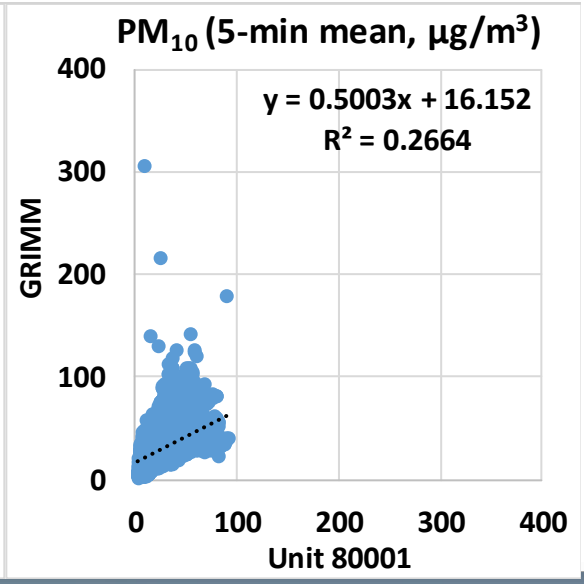
Temtop PMD 351 vs GRIMM (PM_{10}; 5-min mean)



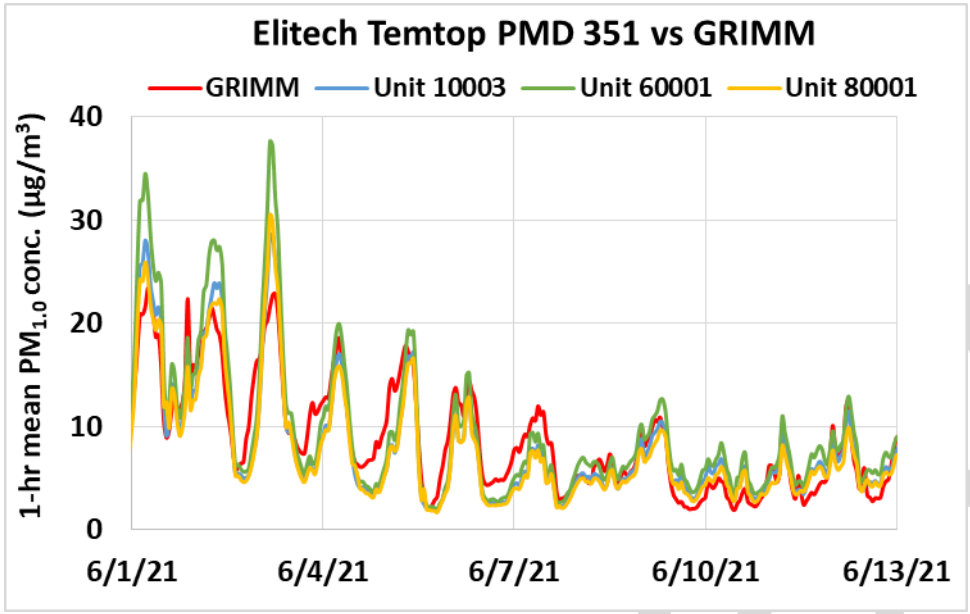
- The Temtop PMD 351 sensors showed very weak to weak correlations with the corresponding GRIMM data ($0.26 < R^2 < 0.33$)
- Overall, the Temtop PMD 351 sensors underestimated the PM_{10} mass concentrations as measured by GRIMM
- The Temtop PMD 351 sensors did not seem to track the PM_{10} diurnal variations as recorded by GRIMM



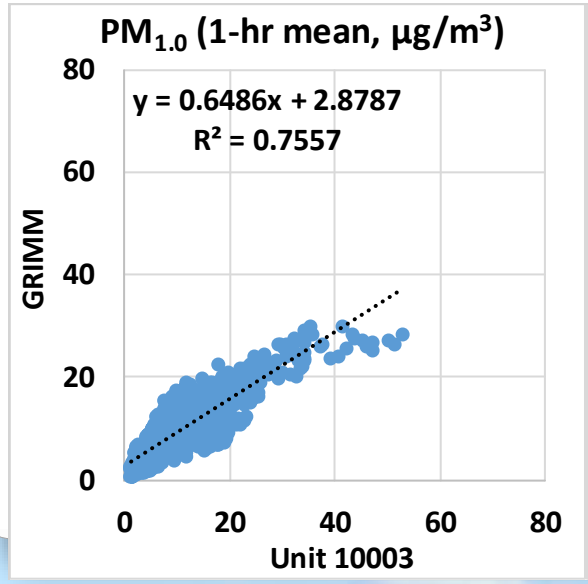


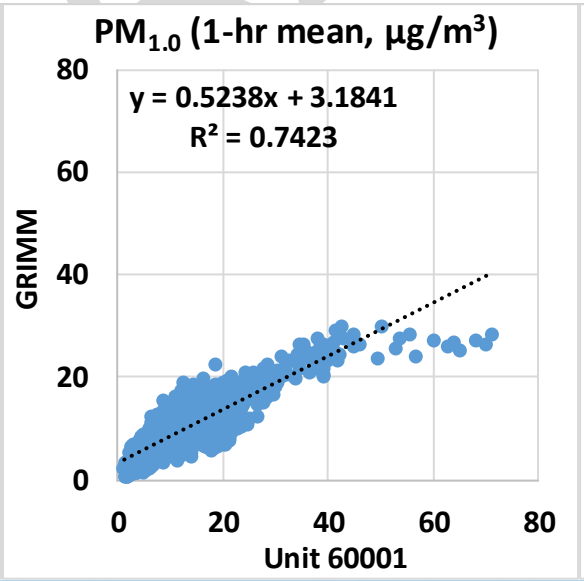


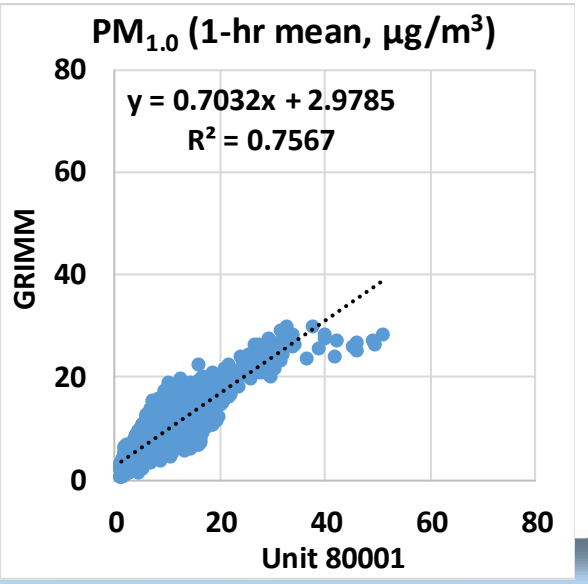
Temtop PMD 351 vs GRIMM ($PM_{1.0}$; 1-hr mean)



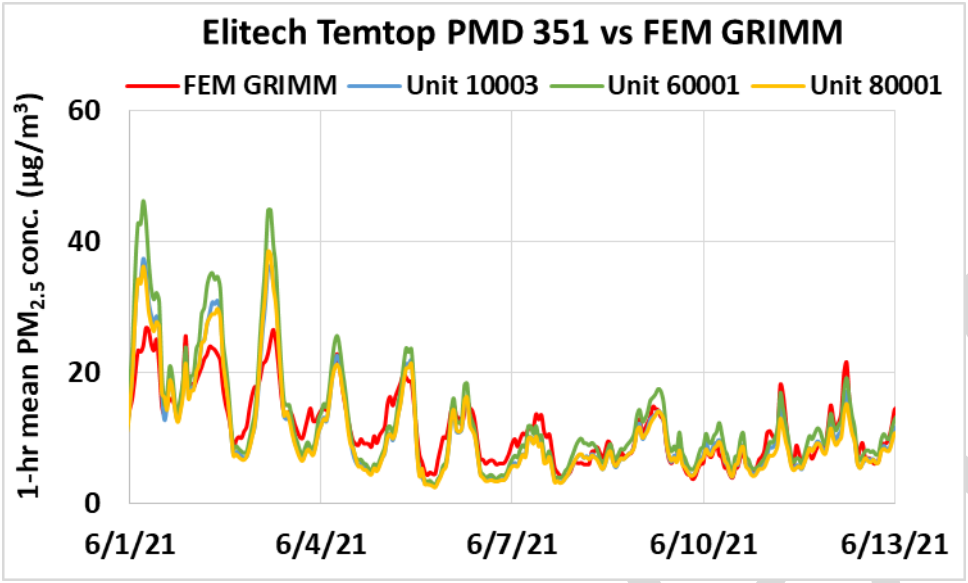
- The Temtop PMD 351 sensors showed strong correlations with the corresponding GRIMM data ($0.74 < R^2 < 0.76$)
- Overall, the Temtop PMD 351 sensors overestimated the $PM_{1.0}$ mass concentrations as measured by GRIMM
- The Temtop PMD 351 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by GRIMM



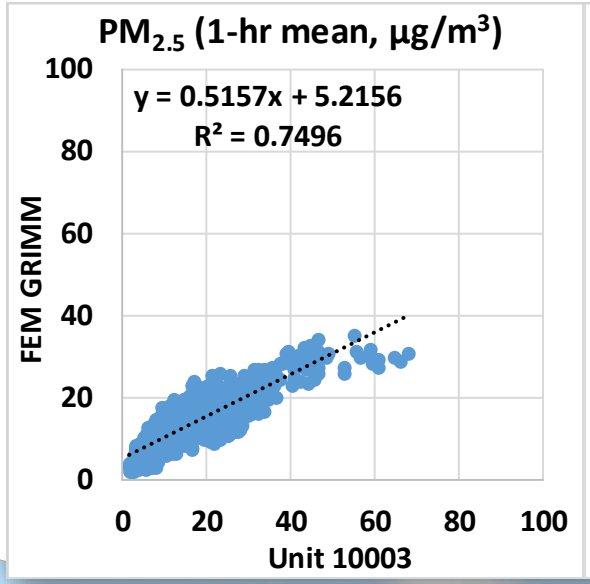


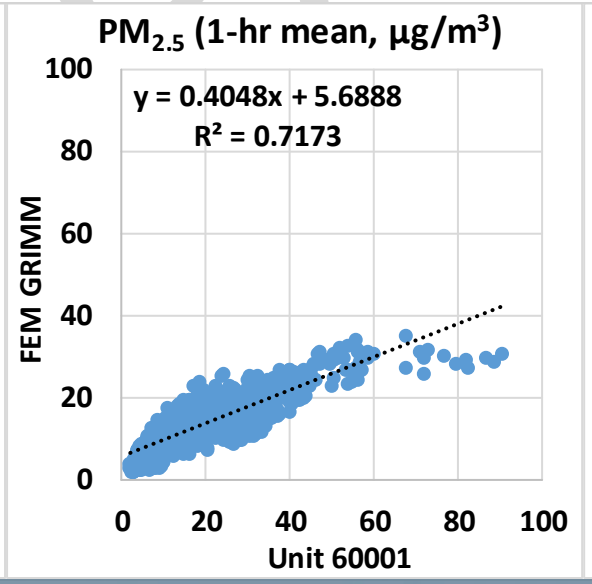


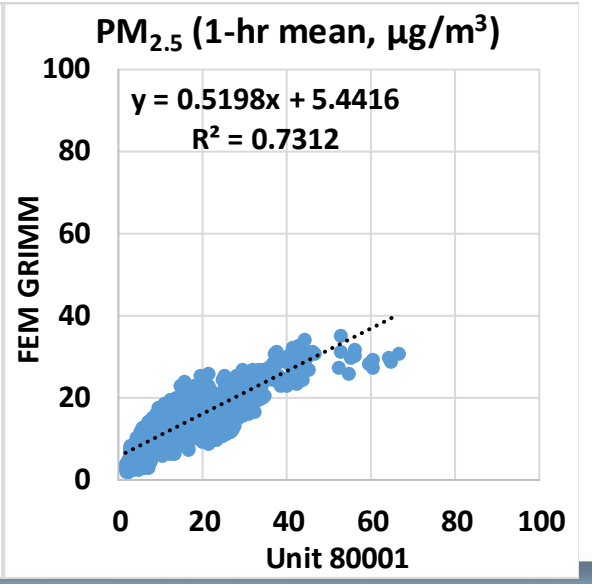
Temtop PMD 351 vs FEM GRIMM ($PM_{2.5}$; 1-hr mean)



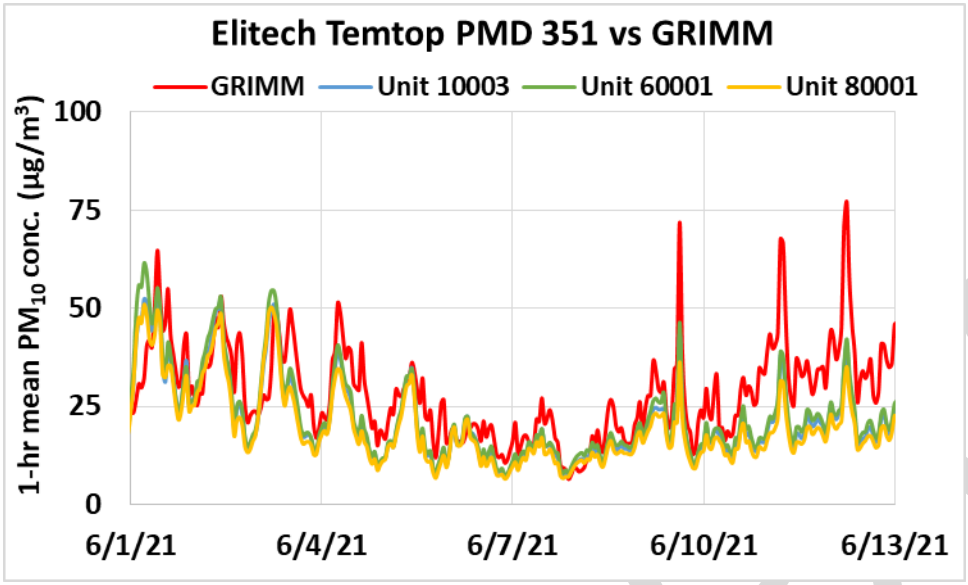
- The Temtop PMD 351 sensors showed strong correlations with the corresponding FEM GRIMM data ($0.71 < R^2 < 0.75$)
- Overall, the Temtop PMD 351 sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM GRIMM
- The Temtop PMD 351 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM



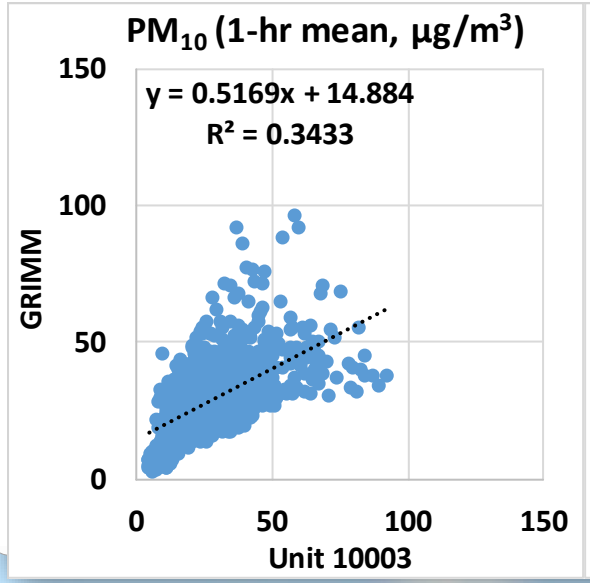


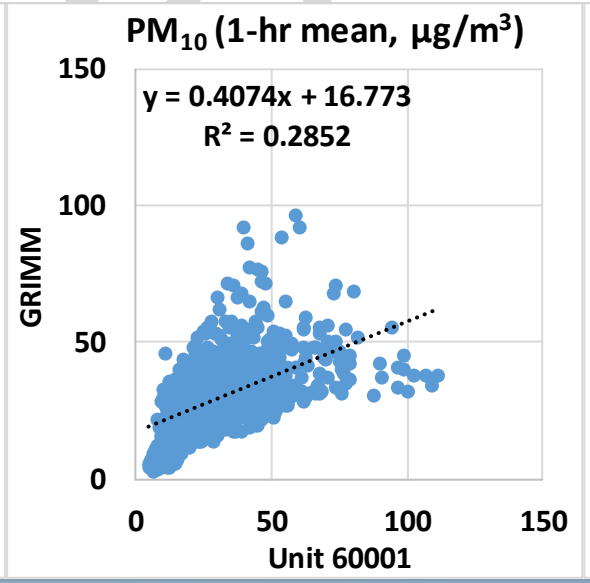


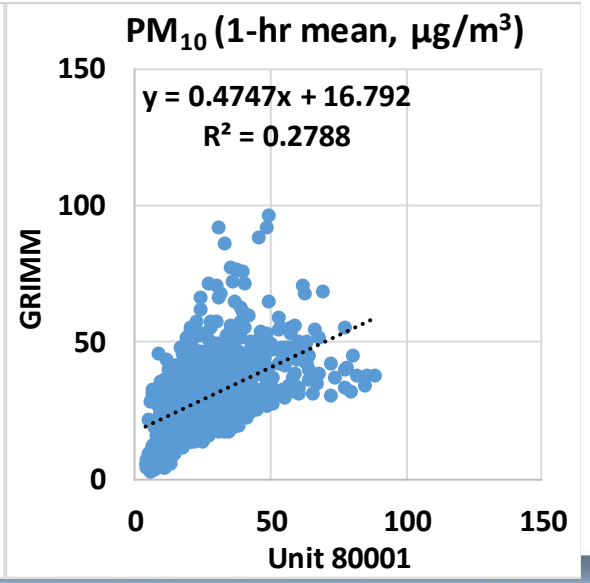
Temtop PMD 351 vs GRIMM (PM_{10}; 1-hr mean)



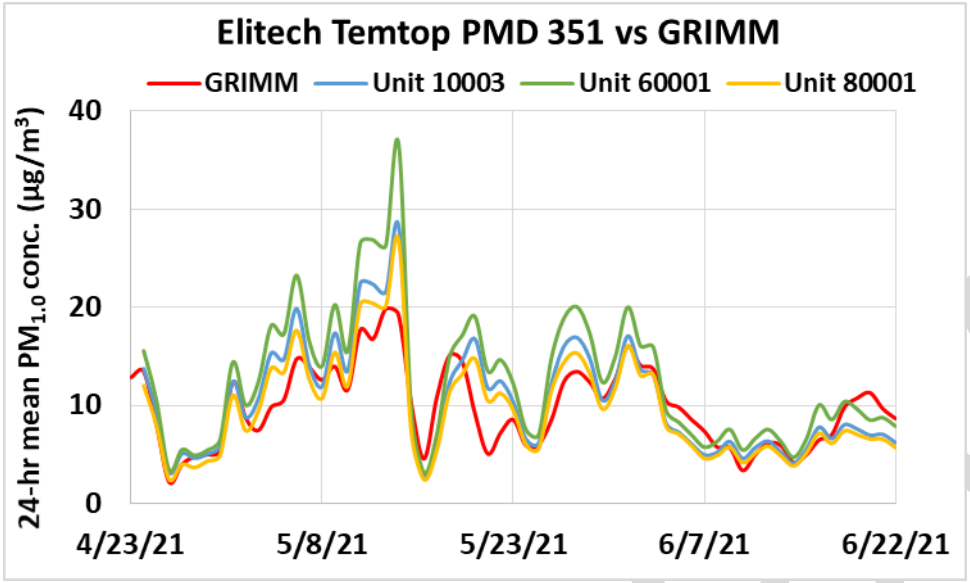
- The Temtop PMD 351 sensors showed very weak to weak correlations with the corresponding GRIMM data ($0.27 < R^2 < 0.35$)
- Overall, the Temtop PMD 351 sensors underestimated the PM_{10} mass concentrations as measured by GRIMM
- The Temtop PMD 351 sensors did not seem to track the PM_{10} diurnal variations as recorded by GRIMM



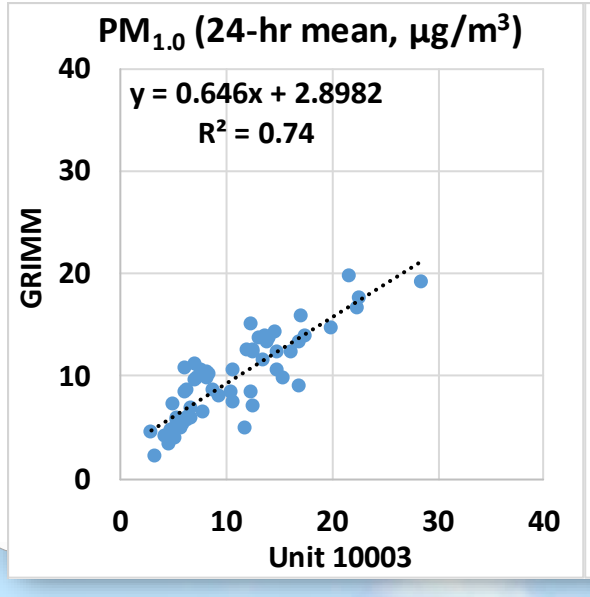


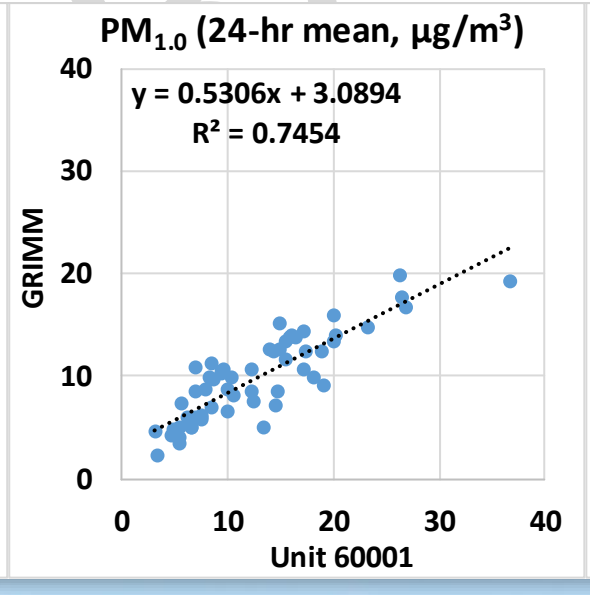


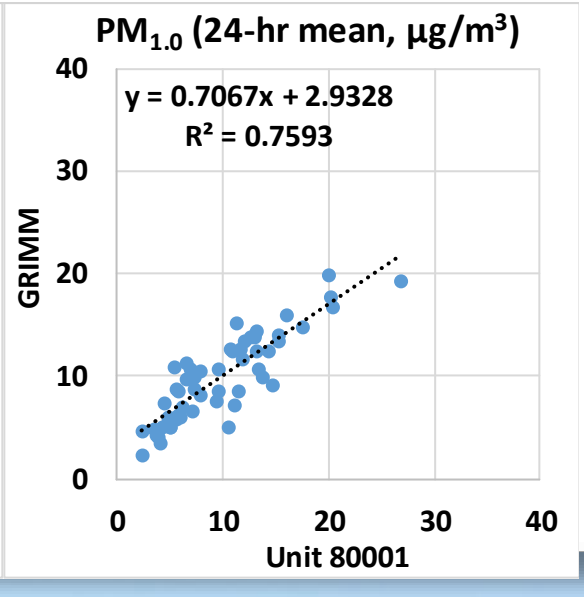
Temtop PMD 351 vs GRIMM ($PM_{1.0}$; 24-hr mean)



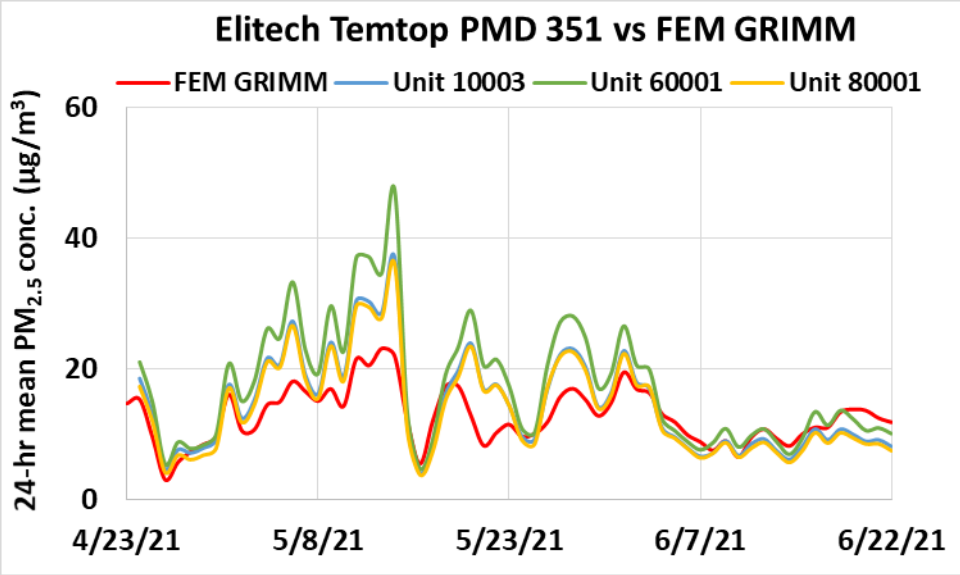
- The Temtop PMD 351 sensors showed strong correlations with the corresponding GRIMM data ($0.74 < R^2 < 0.76$)
- Overall, the Temtop PMD 351 sensors overestimated the $PM_{1.0}$ mass concentrations as measured by GRIMM
- The Temtop PMD 351 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by GRIMM



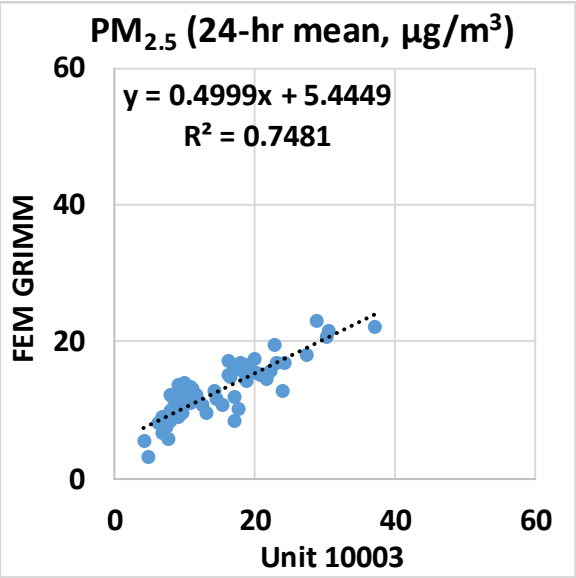


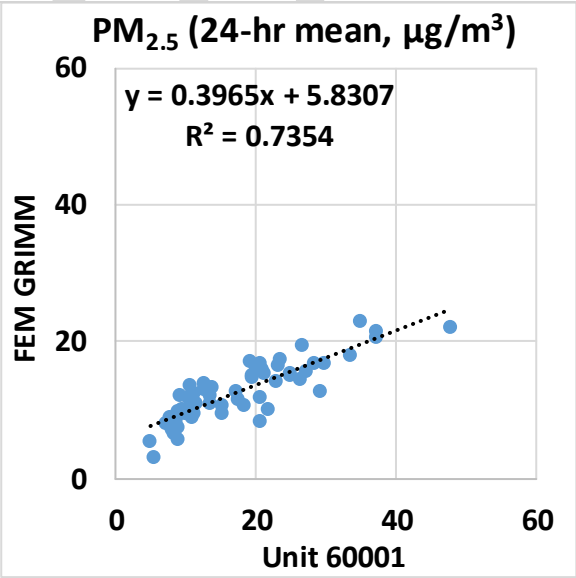


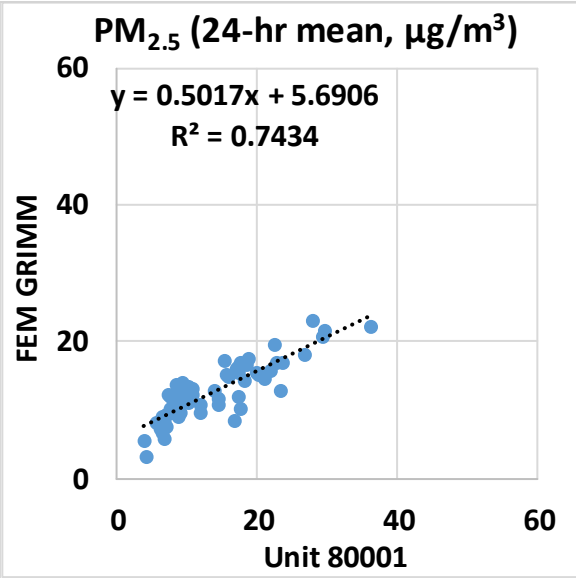
Temtop PMD 351 vs FEM GRIMM ($PM_{2.5}$; 24-hr mean)



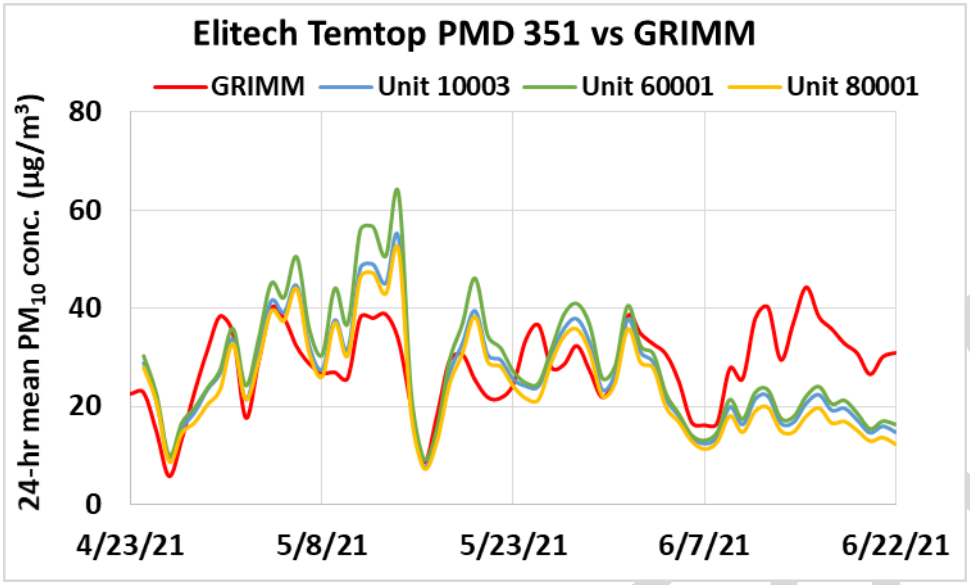
- The Temtop PMD 351 sensors showed strong correlations with the corresponding FEM GRIMM data ($0.73 < R^2 < 0.75$)
- Overall, the Temtop PMD 351 sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM GRIMM
- The Temtop PMD 351 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM



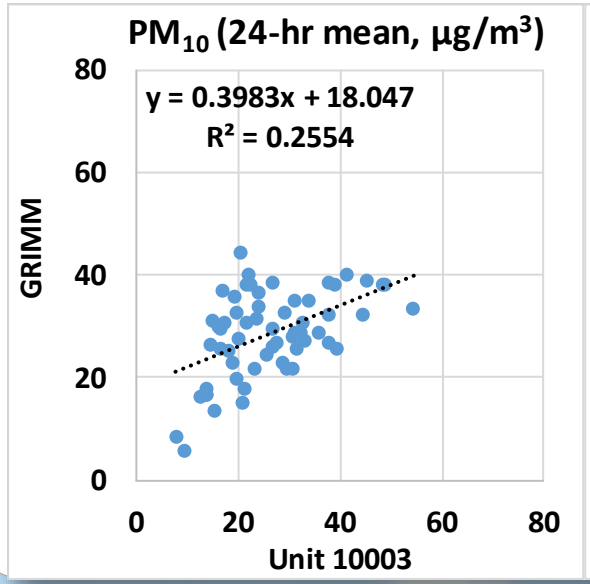


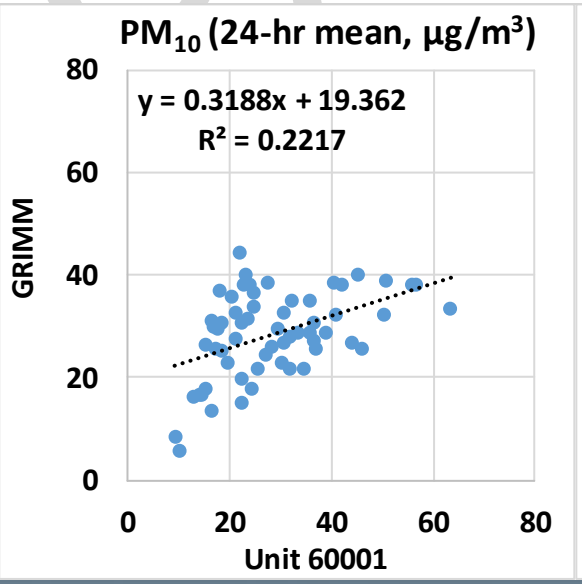


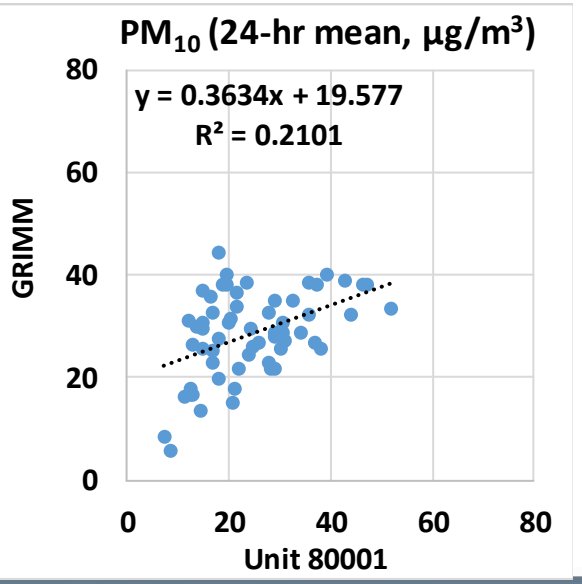
Temtop PMD 351 vs GRIMM (PM_{10}; 24-hr mean)



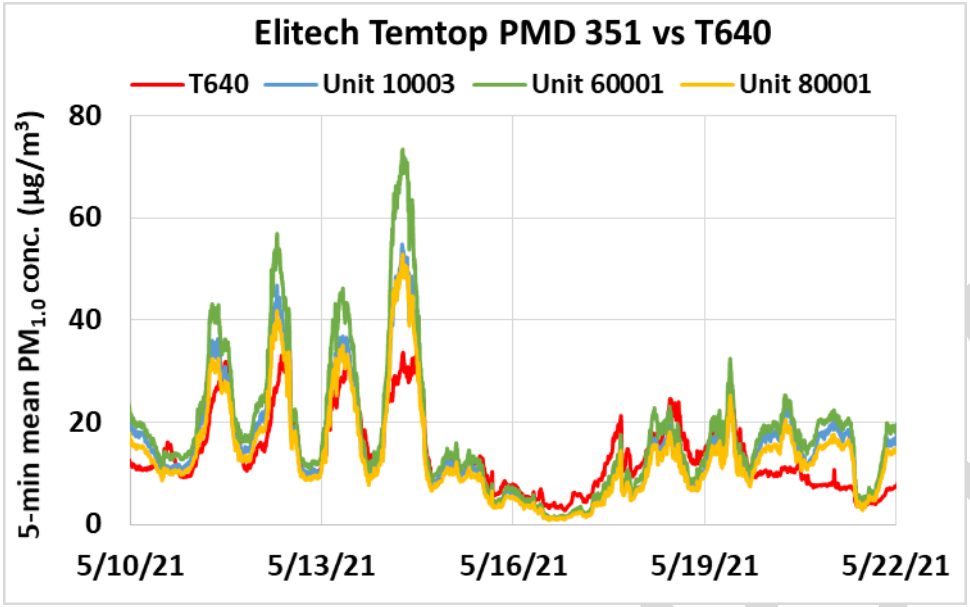
- The Temtop PMD 351 sensors showed very weak correlations with the corresponding GRIMM data ($0.21 < R^2 < 0.26$)
- Overall, the Temtop PMD 351 sensors underestimated the PM_{10} mass concentrations as measured by GRIMM
- The Temtop PMD 351 sensors did not seem to track the PM_{10} diurnal variations as recorded by GRIMM



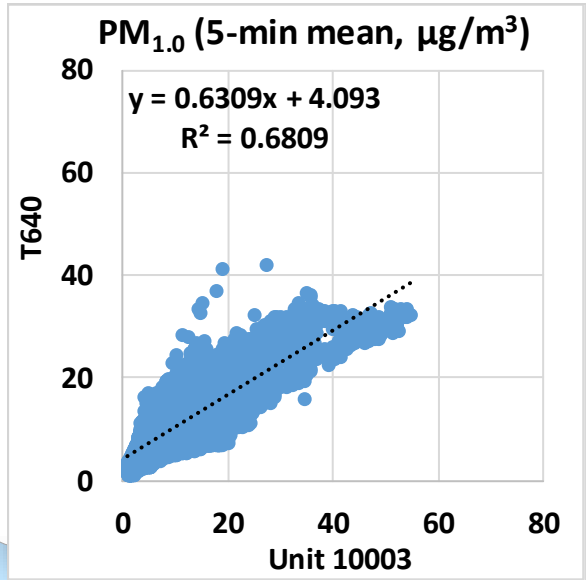


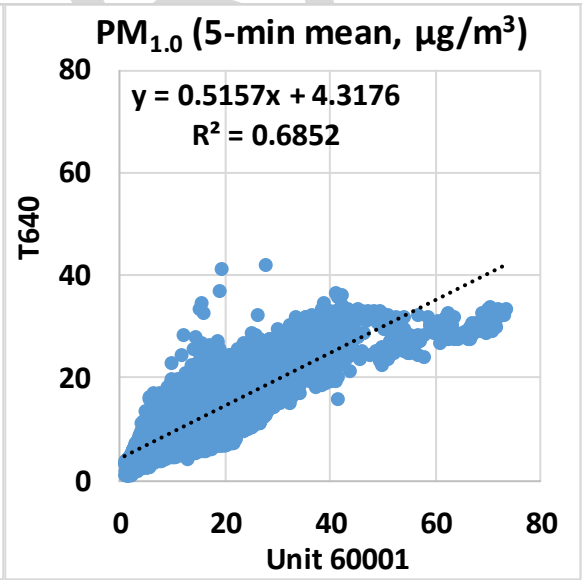


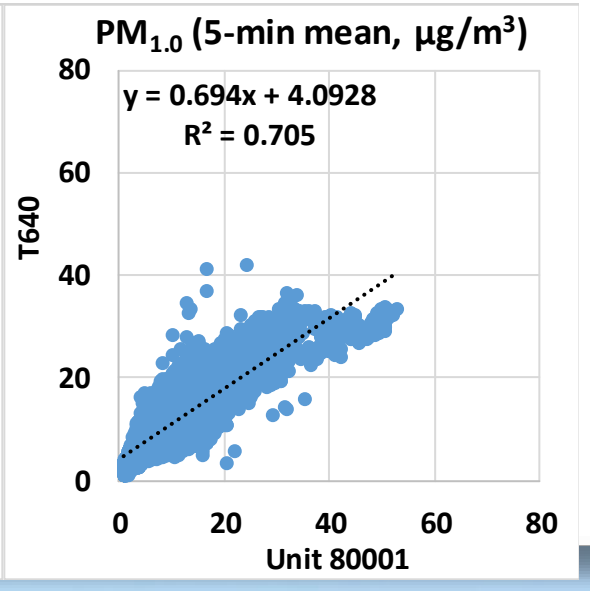
Temtop PMD 351 vs T640 ($PM_{1.0}$; 5-min mean)



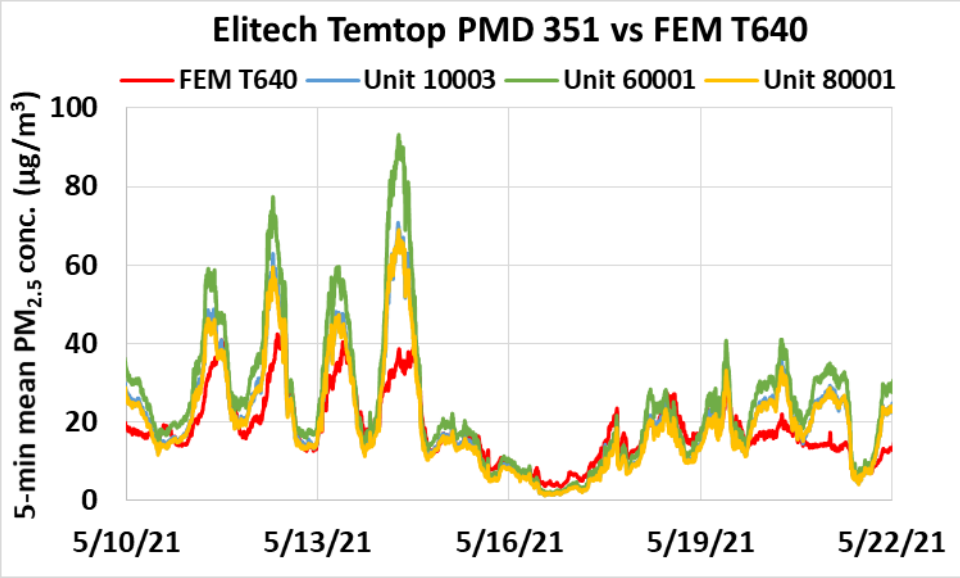
- The Temtop PMD 351 sensors showed moderate to strong correlations with the corresponding T640 data ($0.68 < R^2 < 0.71$)
- Overall, the Temtop PMD 351 sensors overestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The Temtop PMD 351 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640



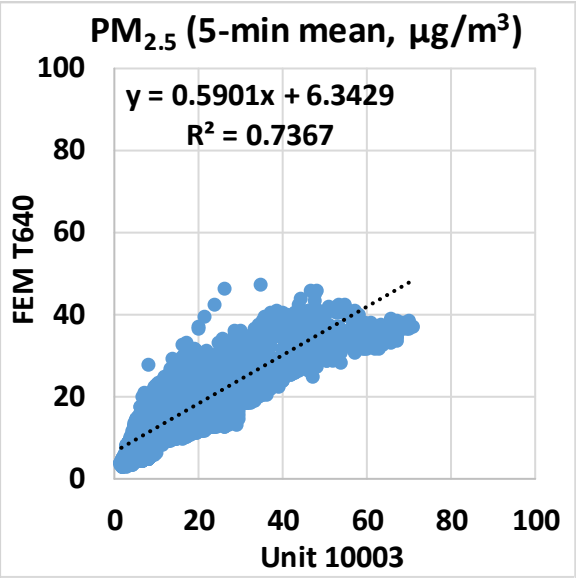


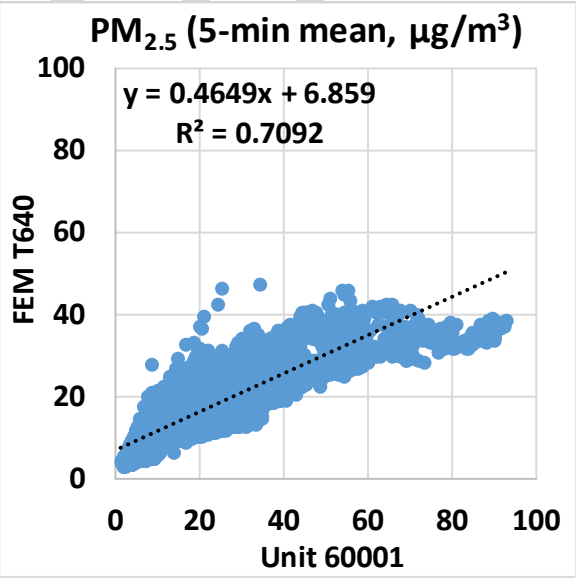


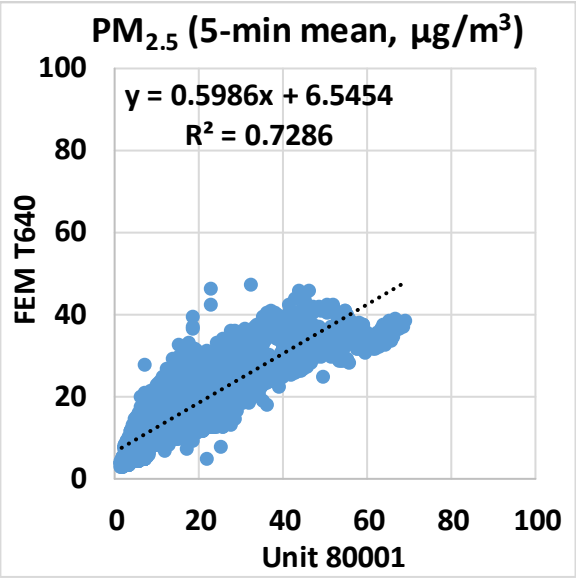
Temtop PMD 351 vs FEM T640 ($PM_{2.5}$; 5-min mean)



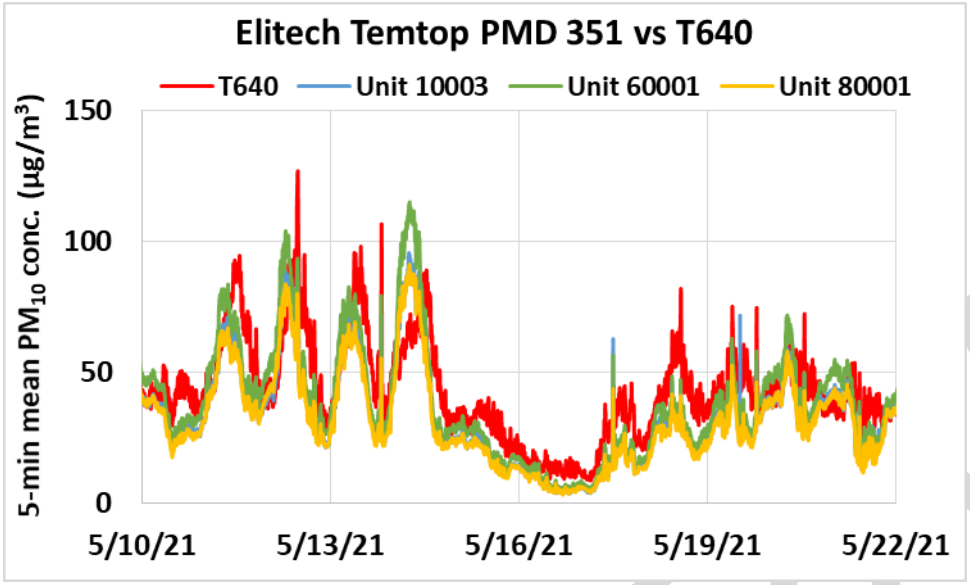
- The Temtop PMD 351 sensors showed strong correlations with the corresponding FEM T640 data ($0.70 < R^2 < 0.74$)
- Overall, the Temtop PMD 351 sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The Temtop PMD 351 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



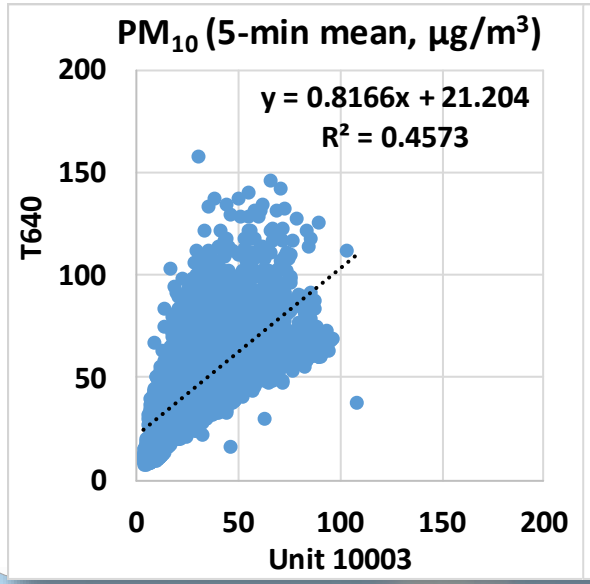


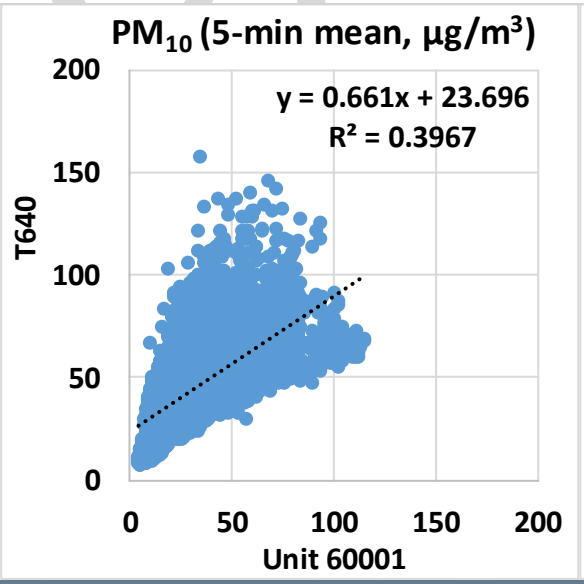


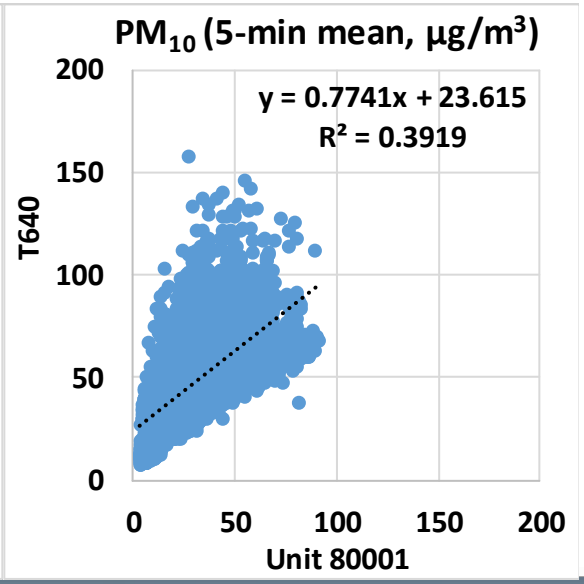
Temtop PMD 351 vs T640 (PM_{10}; 5-min mean)



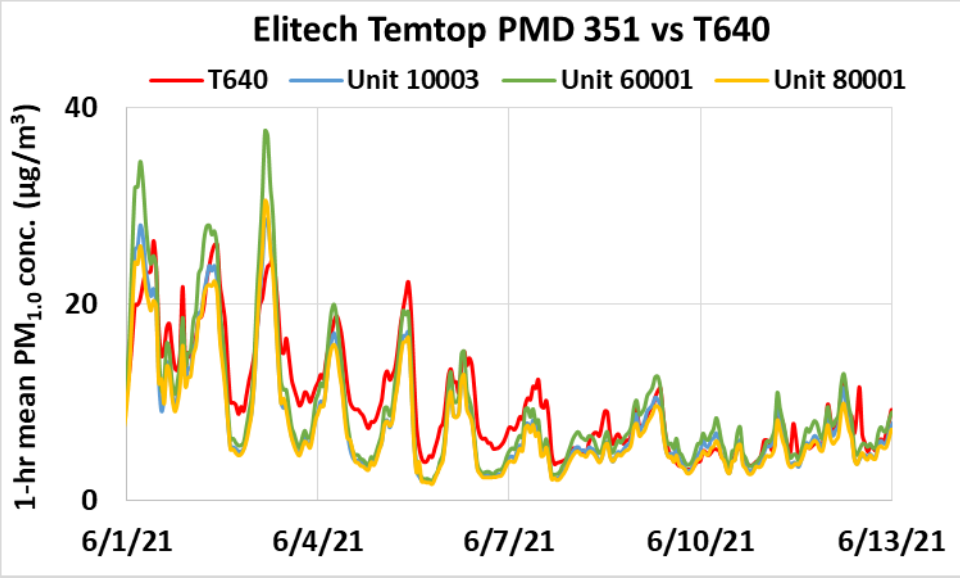
- Temtop PMD 351 sensors showed weak correlations with the corresponding T640 data ($0.39 < R^2 < 0.46$)
- Overall, the Temtop PMD 351 sensors underestimated the PM_{10} mass concentrations as measured by T640
- The Temtop PMD 351 sensors did not seem to track the PM_{10} diurnal variations as recorded by T640



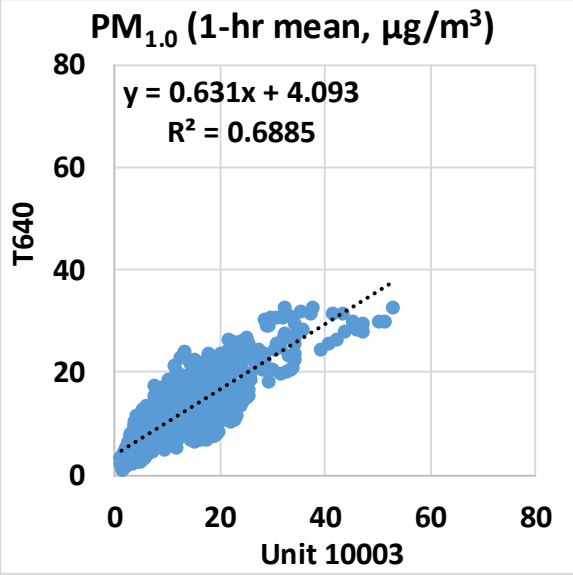


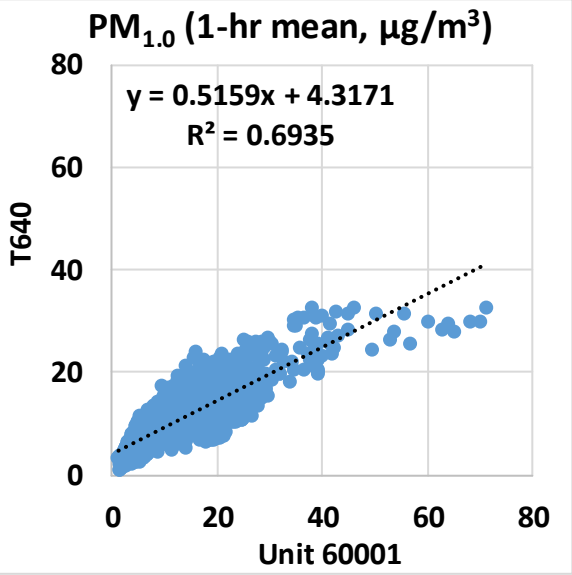


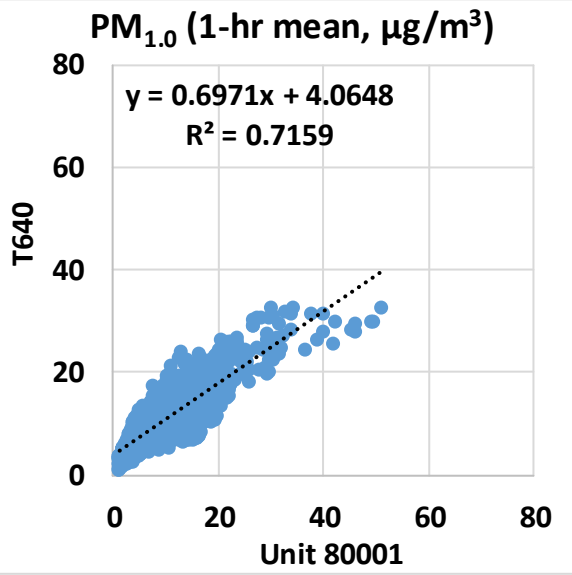
Temtop PMD 351 vs T640 ($PM_{1.0}$; 1-hr mean)



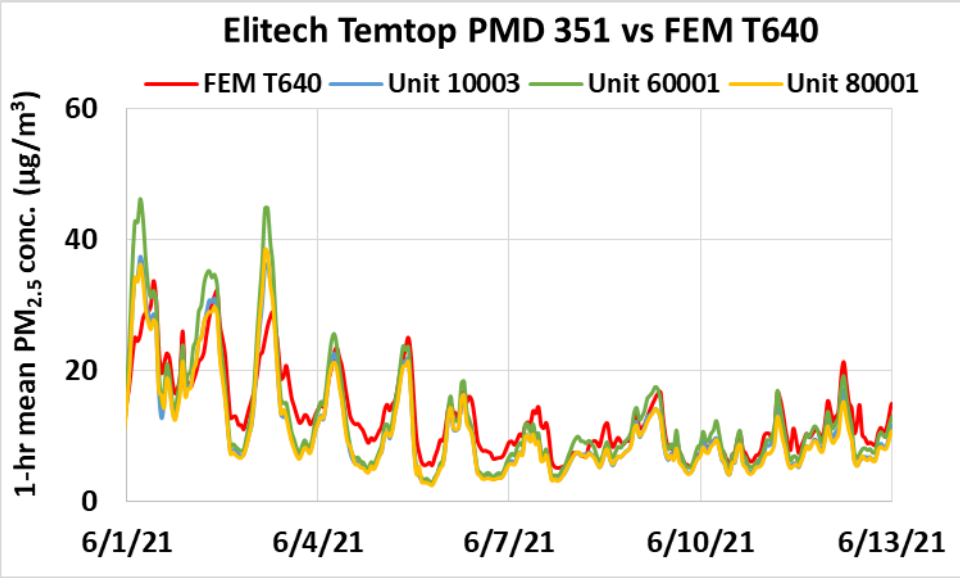
- The Temtop PMD 351 sensors showed moderate to strong correlations with the corresponding T640 data ($0.68 < R^2 < 0.72$)
- Overall, the Temtop PMD 351 sensors overestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The Temtop PMD 351 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640



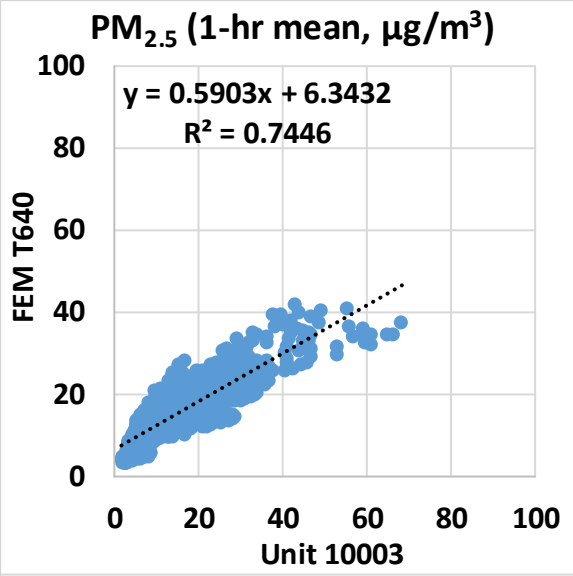


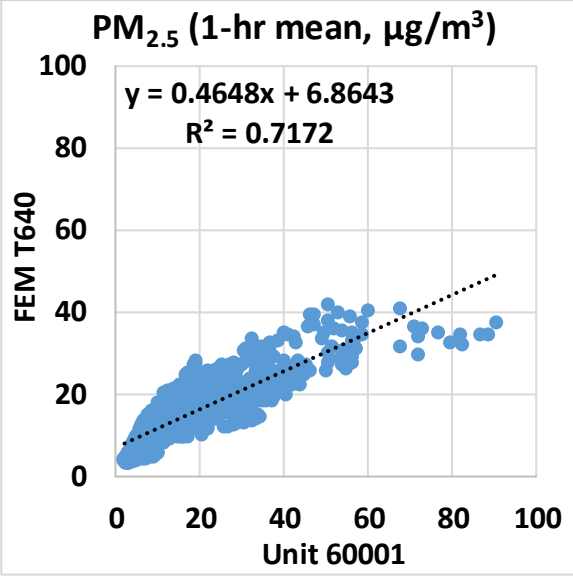


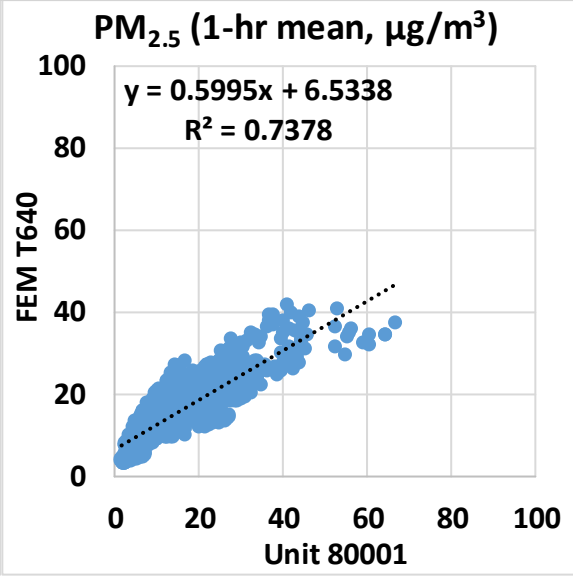
Temtop PMD 351 vs FEM T640 ($PM_{2.5}$; 1-hr mean)



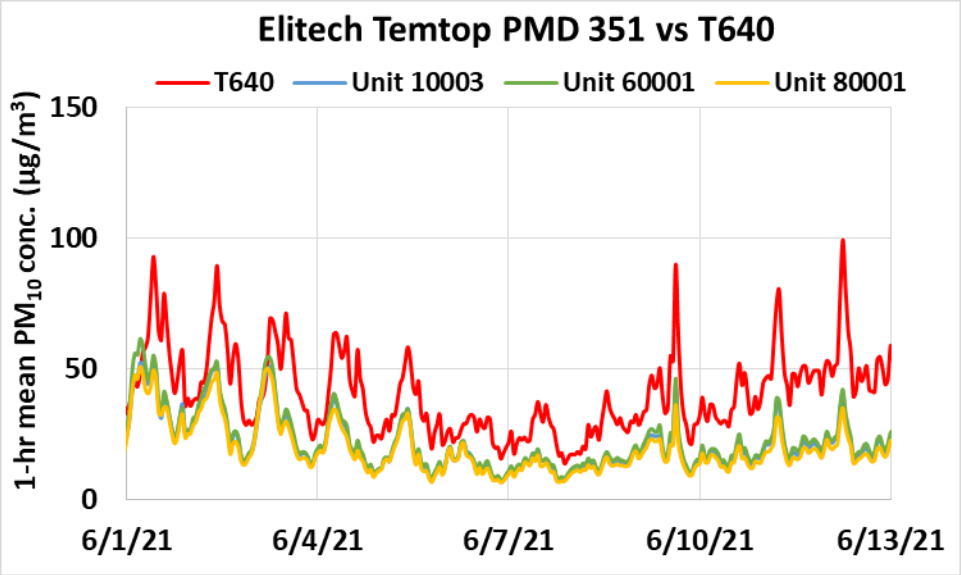
- The Temtop PMD 351 sensors showed strong correlations with the corresponding FEM T640 data ($0.71 < R^2 < 0.75$)
- Overall, the Temtop PMD 351 sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The Temtop PMD 351 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



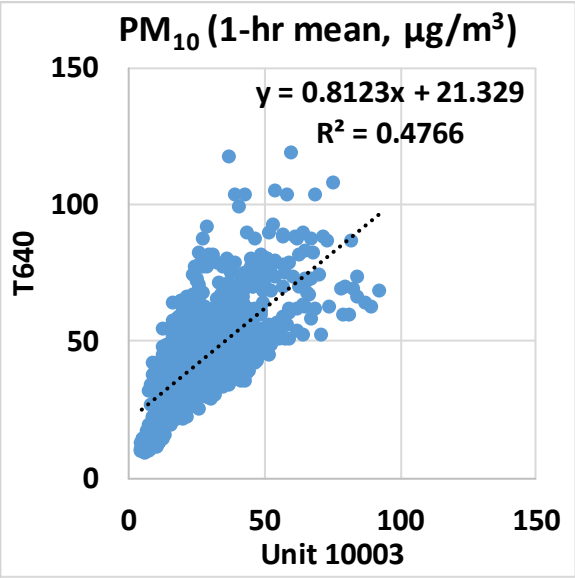


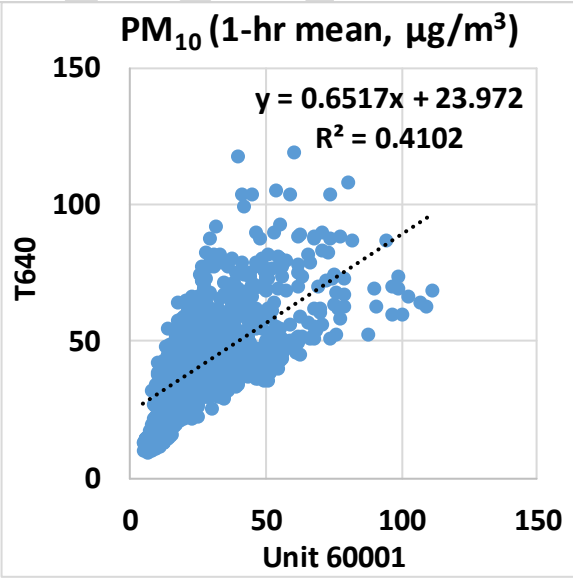


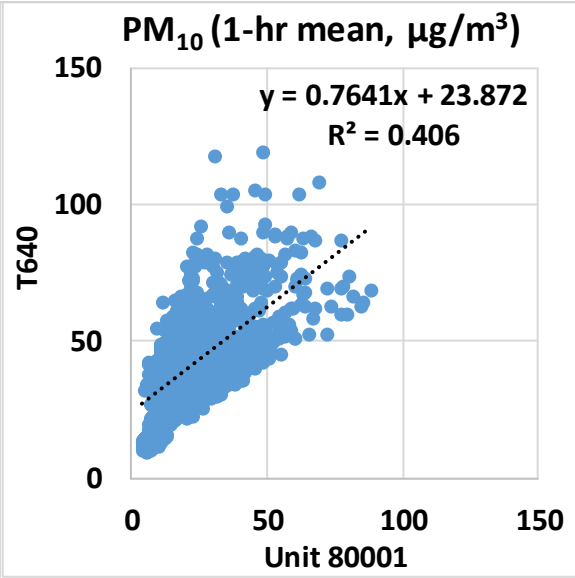
Temtop PMD 351 vs T640 (PM_{10}; 1-hr mean)



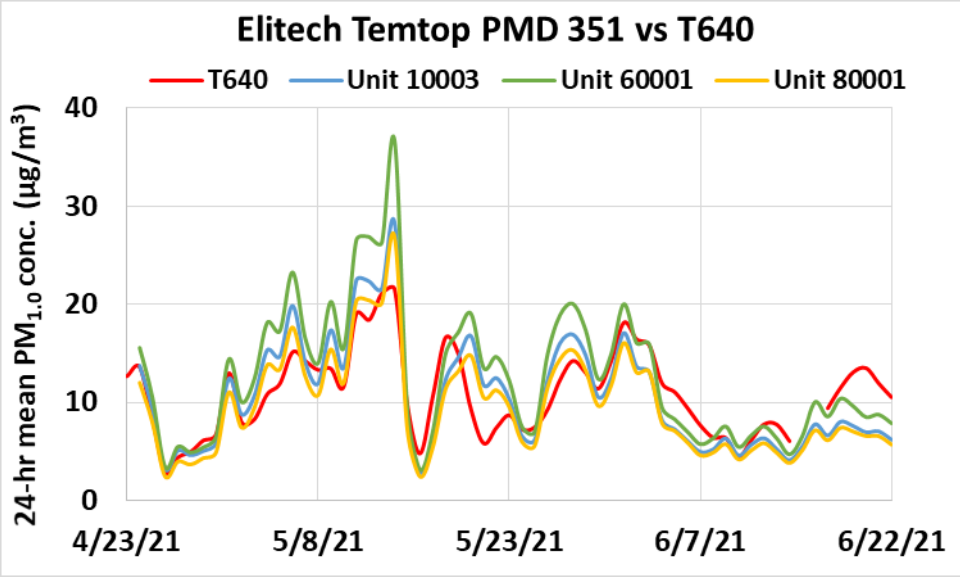
- The Temtop PMD 351 sensors showed weak correlations with the corresponding T640 data ($0.40 < R^2 < 0.48$)
- Overall, the Temtop PMD 351 sensors underestimated the PM_{10} mass concentrations as measured by T640
- The Temtop PMD 351 sensors did not seem to track the PM_{10} diurnal variations as recorded by T640



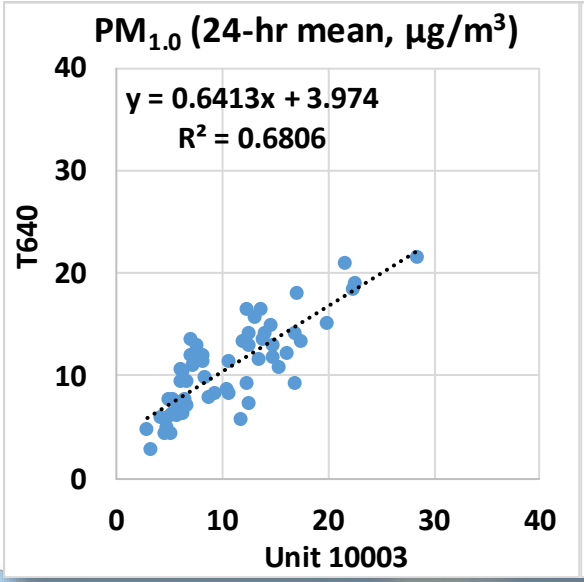


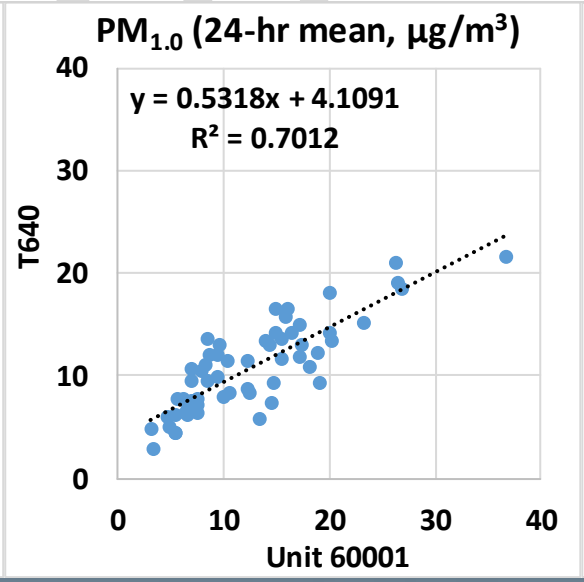


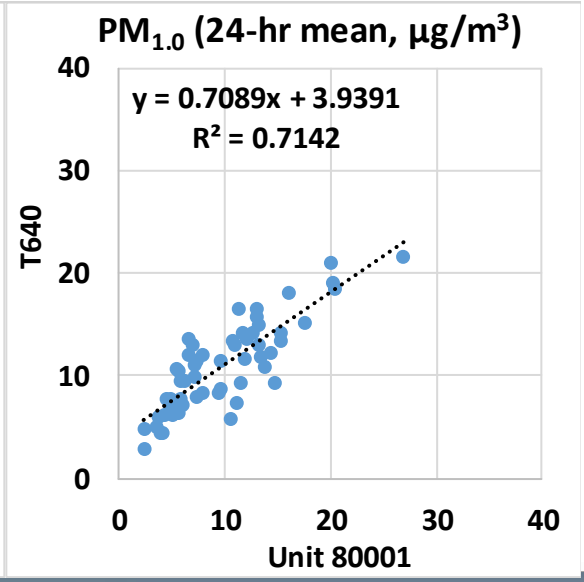
Temtop PMD 351 vs T640 ($PM_{1.0}$; 24-hr mean)



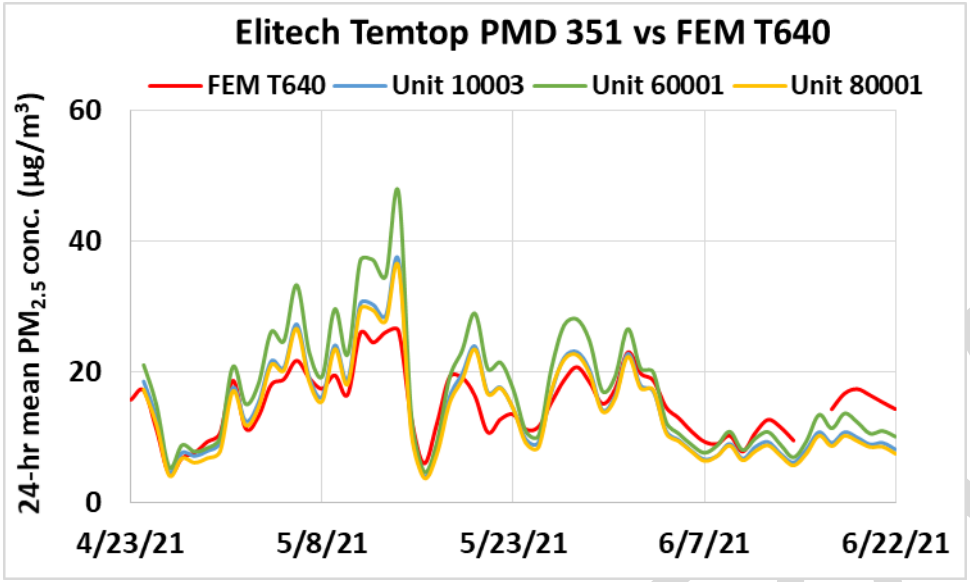
- The Temtop PMD 351 sensors showed moderate to strong correlations with the corresponding T640 data ($0.68 < R^2 < 0.72$)
- Overall, the Temtop PMD 351 sensors overestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The Temtop PMD 351 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640



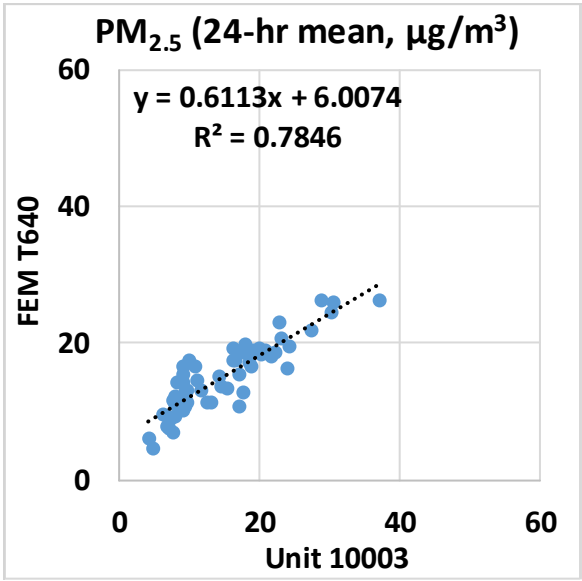


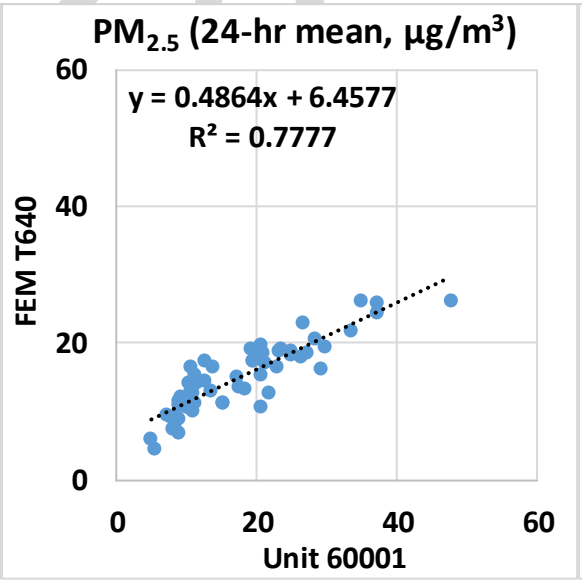


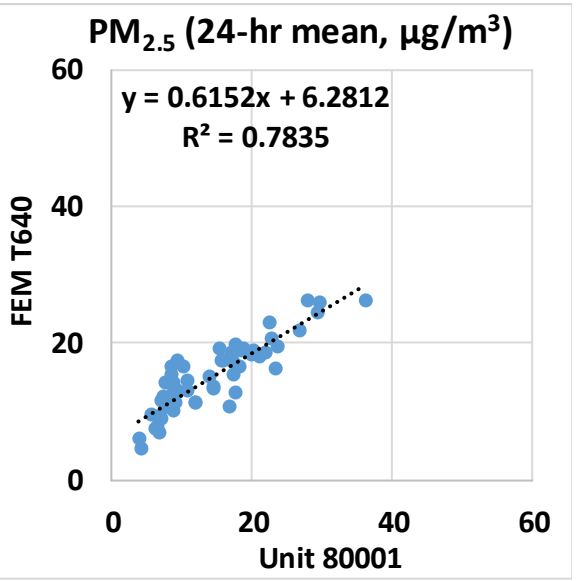
Temtop PMD 351 vs FEM T640 ($PM_{2.5}$; 24-hr mean)



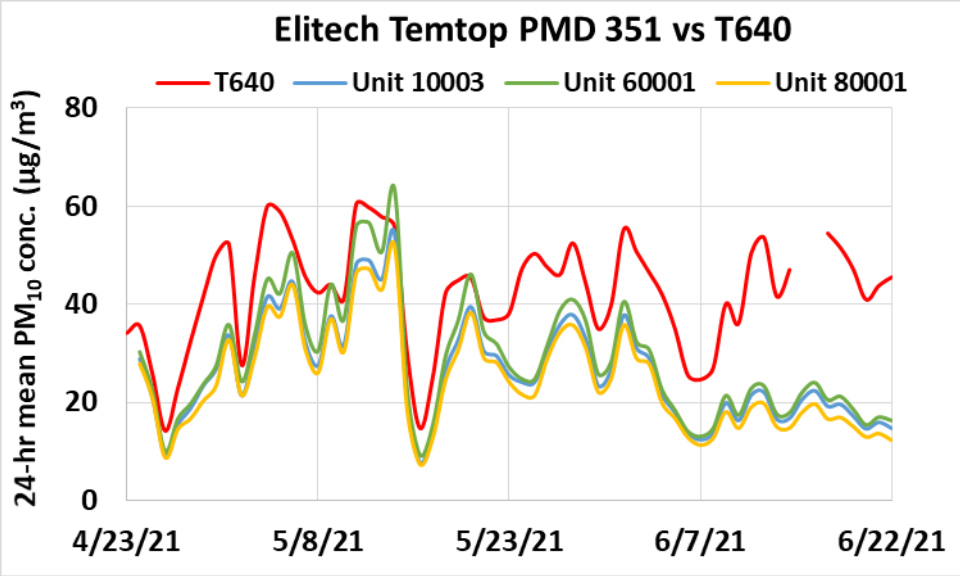
- The Temtop PMD 351 sensors showed strong correlations with the corresponding FEM T640 data ($0.77 < R^2 < 0.79$)
- Overall, the Temtop PMD 351 sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The Temtop PMD 351 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



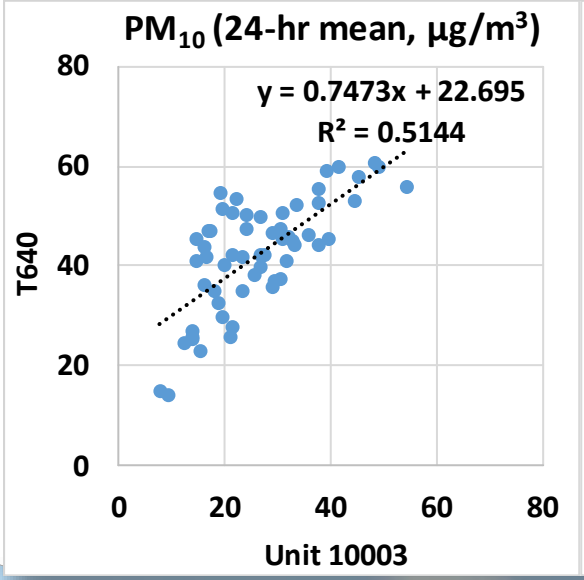


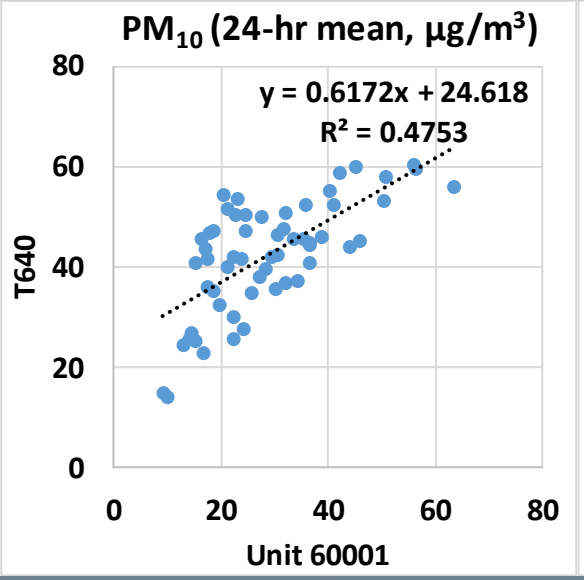


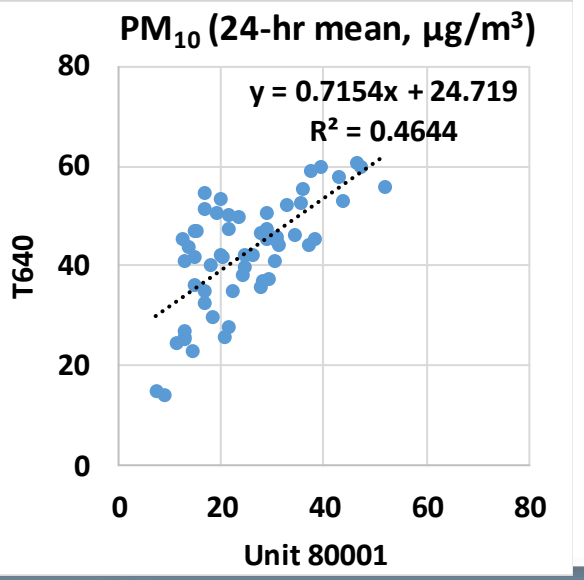
Temtop PMD 351 vs T640 (PM_{10}; 24-hr mean)



- The Temtop PMD 351 sensors showed weak to moderate correlations with the corresponding T640 data ($0.46 < R^2 < 0.52$)
- Overall, the Temtop PMD 351 sensors underestimated the PM_{10} mass concentrations as measured by T640
- The Temtop PMD 351 sensors did not seem to track the PM_{10} diurnal variations as recorded by T640







Summary

	Average of 3 Sensors, $PM_{1.0}$		Temtop PMD 351 vs GRIMM & T640, $PM_{1.0}$						GRIMM & T640 ($PM_{1.0}$, $\mu g/m^3$)		
	Average ($\mu g/m^3$)	SD ($\mu g/m^3$)	R^2	Slope	Intercept	MBE[1] ($\mu g/m^3$)	MAE[2] ($\mu g/m^3$)	RMSE[3] ($\mu g/m^3$)	Ref. Average	Ref. SD	Range during the field evaluation
5-min	10.9	7.8	0.68 to 0.75	0.52 to 0.70	2.9 to 4.3	-1.1 to 2.8	2.4 to 3.8	3.5 to 5.9	9.8 to 10.8	5.5 to 5.7	0.4 to 45.8
1-hr	10.9	7.7	0.69 to 0.76	0.52 to 0.70	2.9 to 4.3	-1.1 to 2.8	2.4 to 3.7	3.4 to 5.8	9.8 to 10.8	5.5 to 5.6	0.6 to 32.7
24-hr	10.9	5.8	0.68 to 0.76	0.53 to 0.71	2.9 to 4.1	-1.1 to 2.8	1.9 to 3.4	2.5 to 4.7	9.8 to 10.9	4.1 to 4.3	2.2 to 21.5
	Average of 3 Sensors, $PM_{2.5}$		Temtop PMD 351 vs FEM GRIMM & FEM T640, $PM_{2.5}$						FEM GRIMM & FEM T640 ($PM_{2.5}$, $\mu g/m^3$)		
	Average ($\mu g/m^3$)	SD ($\mu g/m^3$)	R^2	Slope	Intercept	MBE[1] ($\mu g/m^3$)	MAE[2] ($\mu g/m^3$)	RMSE[3] ($\mu g/m^3$)	Ref. Average	Ref. SD	Range during the field evaluation
5-min	15.3	10.5	0.71 to 0.74	0.41 to 0.60	5.2 to 6.9	-0.9 to 4.7	3.8 to 5.8	5.3 to 9.2	12.8 to 15.0	5.9 to 6.7	1.3 to 49.9
1-hr	15.3	10.5	0.72 to 0.75	0.40 to 0.60	5.2 to 6.9	-0.9 to 4.7	3.8 to 5.7	5.2 to 9.1	12.8 to 15.0	5.8 to 6.7	1.7 to 41.5
24-hr	15.3	7.9	0.74 to 0.78	0.40 to 0.62	5.4 to 6.5	-0.8 to 4.7	3.0 to 5.3	3.7 to 7.5	12.8 to 15.0	4.2 to 5.0	3.1 to 26.3
	Average of 3 Sensors, PM_{10}		Temtop PMD 351 vs GRIMM & T640, PM_{10}						GRIMM & T640 (PM_{10}, $\mu g/m^3$)		
	Average ($\mu g/m^3$)	SD ($\mu g/m^3$)	R^2	Slope	Intercept	MBE[1] ($\mu g/m^3$)	MAE[2] ($\mu g/m^3$)	RMSE[3] ($\mu g/m^3$)	Ref. Average	Ref. SD	Range during the field evaluation
5-min	26.5	14.3	0.27 to 0.46	0.43 to 0.82	14.2 to 23.7	-18.1 to -0.2	9.1 to 18.6	12.6 to 22.5	28.4 to 42.6	13.0 to 16.7	2.1 to 306.4
1-hr	26.5	14.1	0.28 to 0.48	0.41 to 0.81	14.9 to 24.0	-18.1 to -0.2	8.9 to 18.6	11.9 to 22.1	28.4 to 42.6	11.9 to 15.9	3.0 to 119.0
24-hr	26.5	10.9	0.21 to 0.51	0.32 to 0.75	18.0 to 24.7	-17.7 to -0.2	7.7 to 17.7	9.7 to 19.6	28.4 to 42.3	8.2 to 10.9	3.5 to 53.4

[1] Mean Bias Error (MBE): the difference between the sensors and the reference instruments. MBE indicates the tendency of the sensors to underestimate (negative MBE values) or overestimate (positive MBE values).

[2] Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.

[3] Root Mean Square Error (RMSE): another metric to calculate measurement errors.

Discussion

- The three **Temtop PMD 351** sensors' data recovery from all units was ~ 100% for all PM measurements
- The absolute intra-model variability was ~ 1.20, 1.48 and 1.68 µg/m^3 for $PM_{1.0}$, $PM_{2.5}$ and $PM_{10,}$ respectively
- Strong correlations between GRIMM and T640 for $PM_{1.0}$ (R^2 ~ 0.88, 1-hr mean); very strong correlations between FEM GRIMM and FEM T640 for $PM_{2.5}$ (R^2 ~ 0.90, 1-hr mean) and strong correlations between GRIMM and T640 for PM_{10} (R^2 ~ 0.88, 1-hr mean) mass concentration measurements
- $PM_{1.0}$ mass concentrations measured by the Temtop PMD 351 sensors showed moderate to strong correlations with the corresponding GRIMM and T640 data ($0.68 < R^2 < 0.76$, 1-hr mean). The sensors overestimated $PM_{1.0}$ mass concentrations as measured by GRIMM and T640
- $PM_{2.5}$ mass concentrations measured by the Temtop PMD 351 sensors showed strong correlations with the corresponding FEM GRIMM and FEM T640 data ($0.71 < R^2 < 0.75$, 1-hr mean). The sensors overestimated $PM_{2.5}$ mass concentrations as measured by FEM GRIMM and FEM T640
- PM_{10} mass concentrations measured by the Temtop PMD 351 sensors showed very weak to weak correlations with the corresponding GRIMM and T640 data ($0.27 < R^2 < 0.48$; 1-hr mean). The sensors underestimated PM_{10} mass concentrations as measured by GRIMM and T640
- No sensor calibration was performed by South Coast AQMD Staff prior to the beginning of this test
- Laboratory chamber testing is necessary to fully evaluate the performance of these sensors under known aerosol concentrations and controlled temperature and relative humidity conditions

- All results are still preliminary