Field Evaluation
HabitatMap AirBeam3

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 02/02/2022 to 04/03/2022, three **HabitatMap AirBeam3 (hereinafter AirBeam3)** 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
- AirBeam3 (*3 units tested*):
  - Particle sensor: optical; non-FEM (Plantower PMS7003)
  - Each unit reports: $PM_{1.0}$, $PM_{2.5}$ and PM_{10} ($\mu g/m^3$)
  - Also measures: internal temperature (°F) and internal relative humidity (%)
  - Unit cost: $249
  - Time resolution: 1-min
  - Units IDs: A350, 86B4, 9FF0

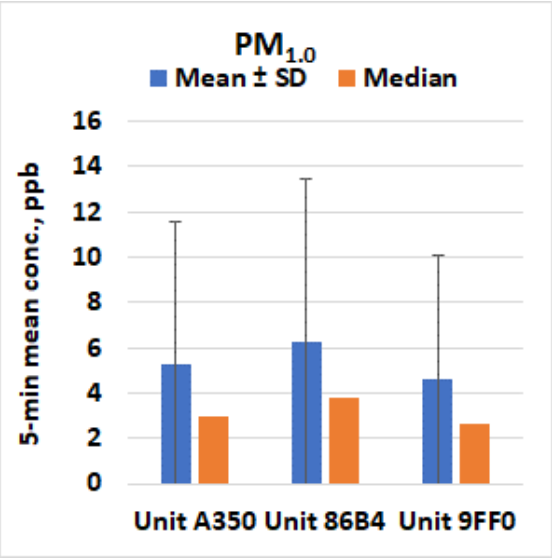
- South Coast AQMD Reference Instruments:
- GRIMM EDM 180 (*hereinafter FEM GRIMM for $PM_{2.5}$, GRIMM otherwise*):
  - Optical particle counter (FEM $PM_{2.5}$)
  - Measures $PM_{1.0}$, $PM_{2.5}$, and PM_{10} ($\mu g/m^3$)
  - Cost: ~$25,000 and up
  - Time resolution: 1-min
- Teledyne API T640 (*hereinafter FEM T640 for $PM_{2.5}$, T640 otherwise*):
  - Optical particle counter (FEM $PM_{2.5}$)
  - Measures $PM_{1.0}$, $PM_{2.5}$ and PM_{10} ($\mu g/m^3$)
  - Unit cost: ~$21,000
  - Time resolution: 1-min

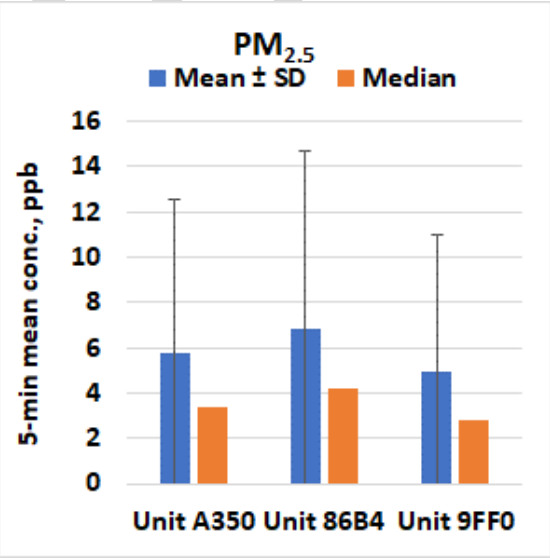
Data validation & recovery

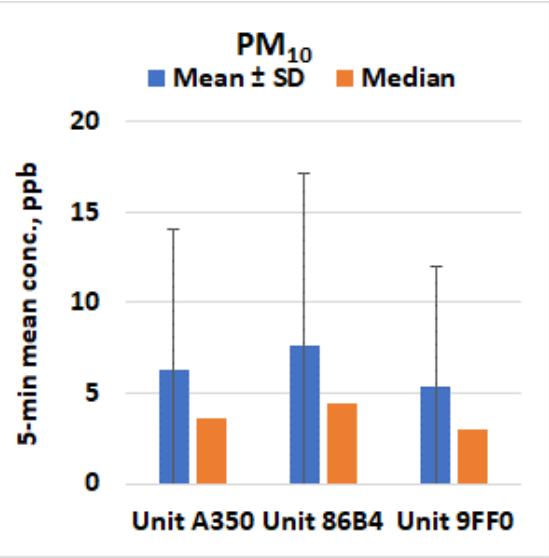
- Basic QA/QC procedures were used to validate the collected data (i.e. obvious outliers, negative values and invalid data-points were eliminated from the data-set)
- Data recovery from all units was 99% for all PM measurements

AirBeam3; intra-model variability

- Absolute intra-model variability was ~ 0.86, ~ 0.94 and ~ 1.14 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 ~ 16.0%, ~ 16.0% and ~ 17.9% 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)

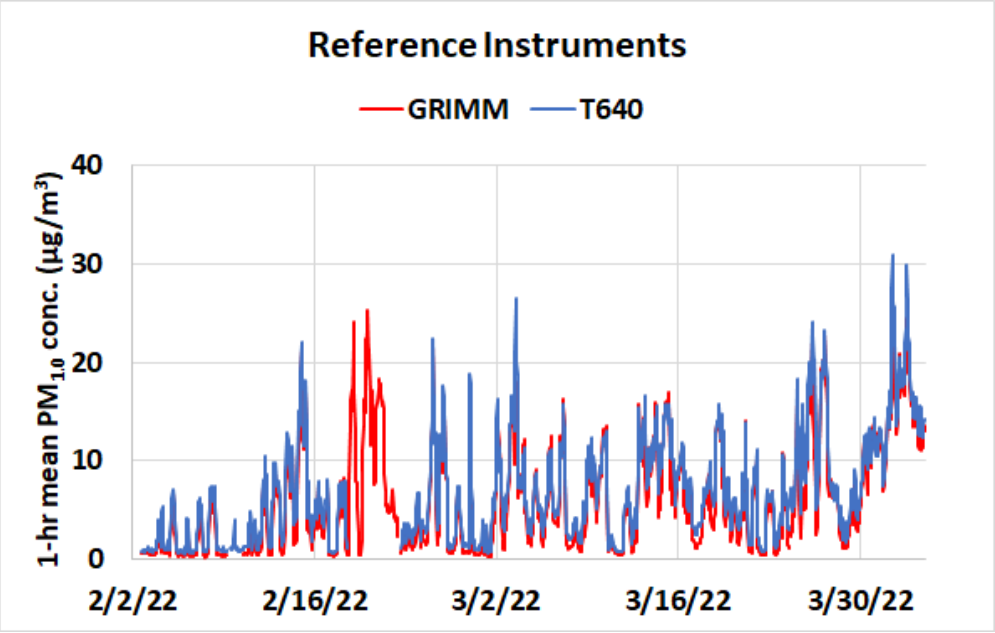


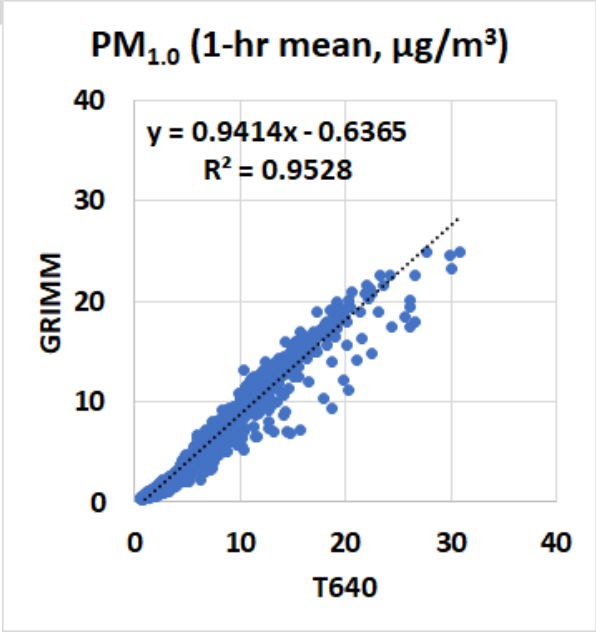




Reference Instruments: $PM_{1.0}$ GRIMM and T640

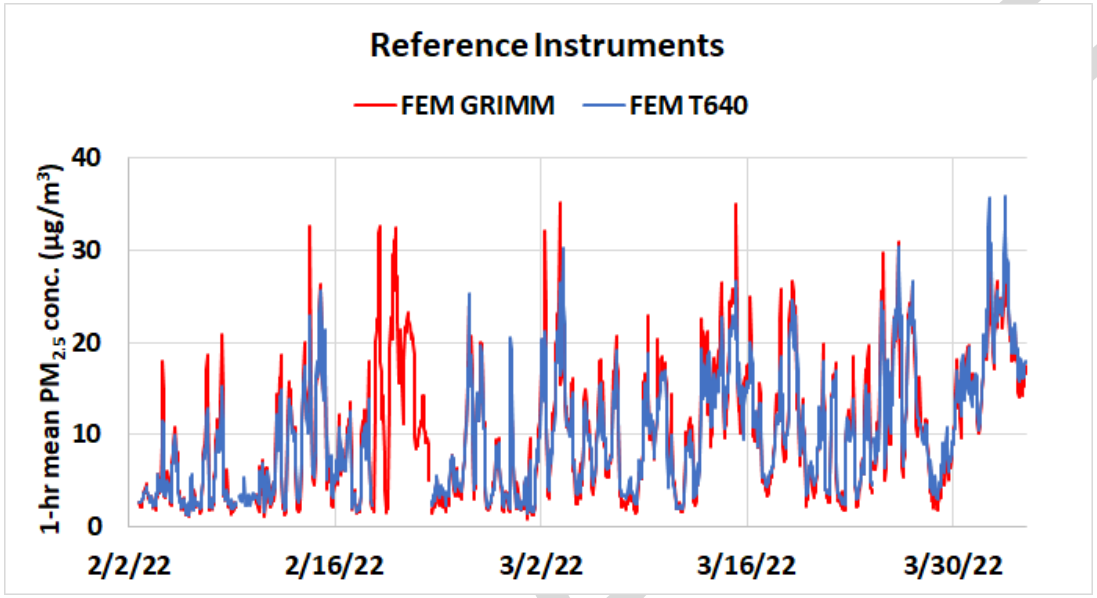
- Data recovery for $PM_{1.0}$ from GRIMM and T640 was ~ 98% and ~ 93%, respectively.
- Very strong correlations between the reference instruments for $PM_{1.0}$ measurements ($R^2 > 0.95$) were observed.

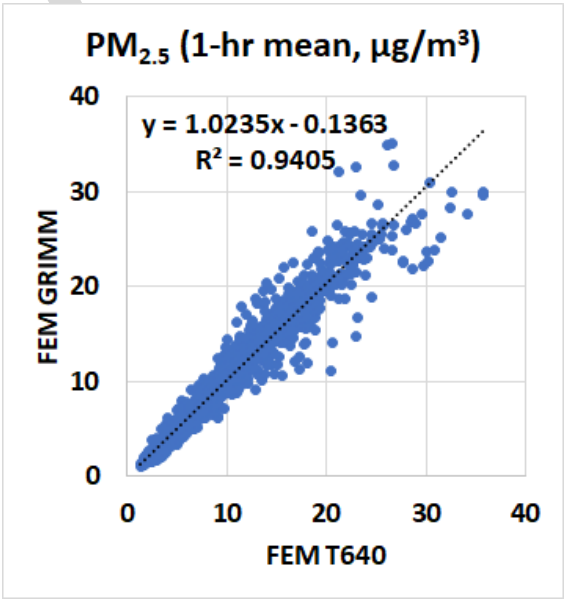




Reference Instruments: $PM_{2.5}$ FEM GRIMM and FEM T640

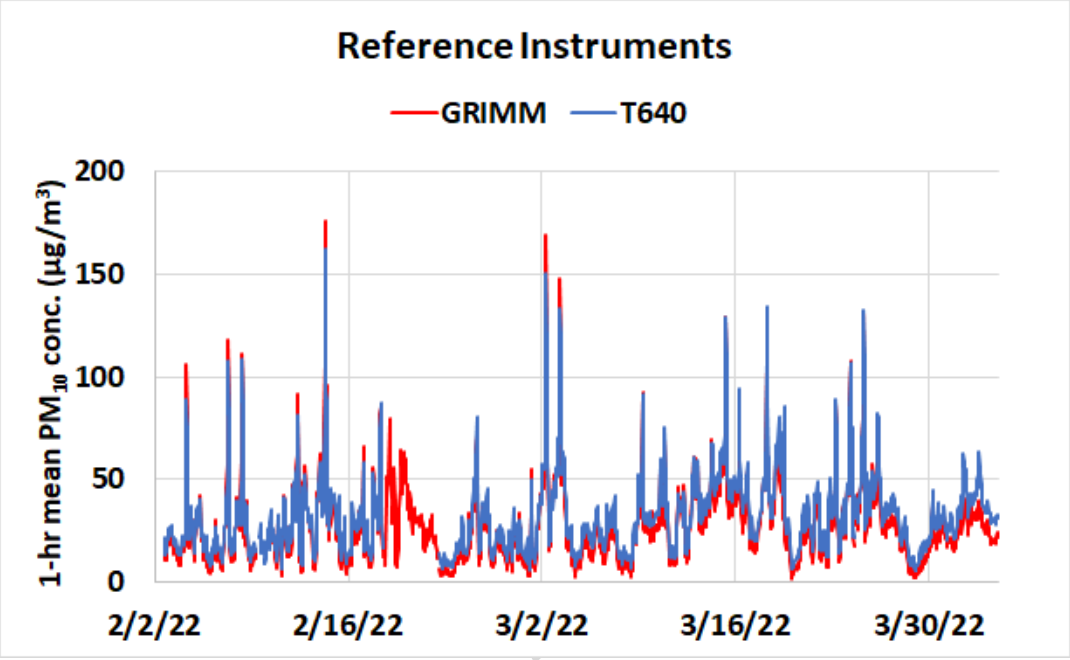
- Data recovery for $PM_{2.5}$ from FEM GRIMM and FEM T640 was ~ 98% and ~ 93%, respectively.
- Very strong correlations between the reference instruments for $PM_{2.5}$ measurements ($R^2 > 0.94$) were observed.

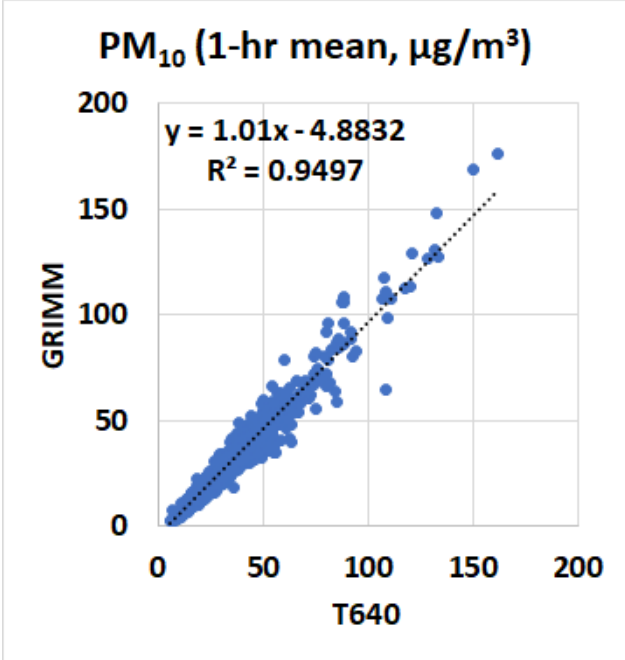




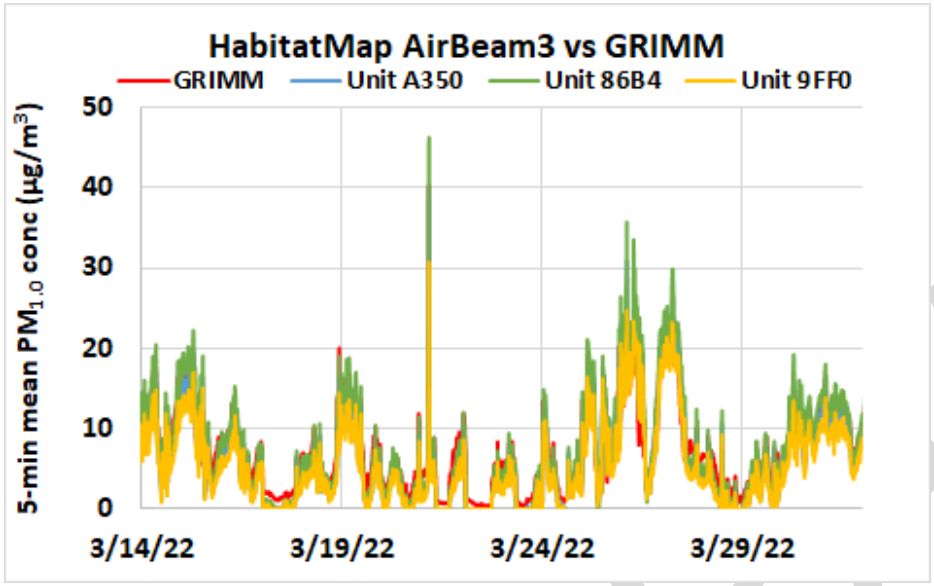
Reference Instruments: PM_{10} GRIMM and T640

- Data recovery for PM_{10} from GRIMM and T640 was ~ 98% and ~ 93%, respectively.
- Very strong correlations between the reference instruments for PM_{10} measurements ($R^2 > 0.94$) were observed.

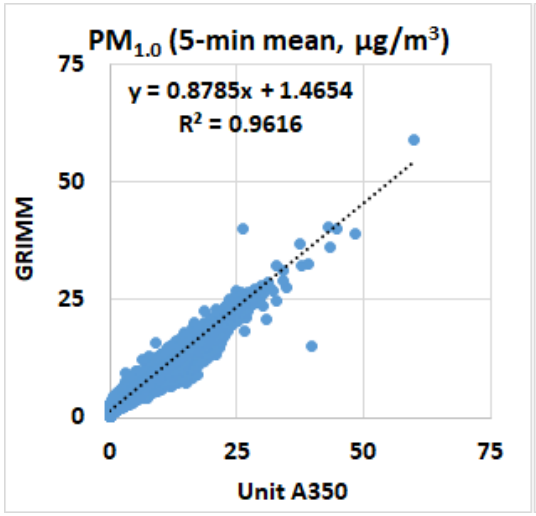


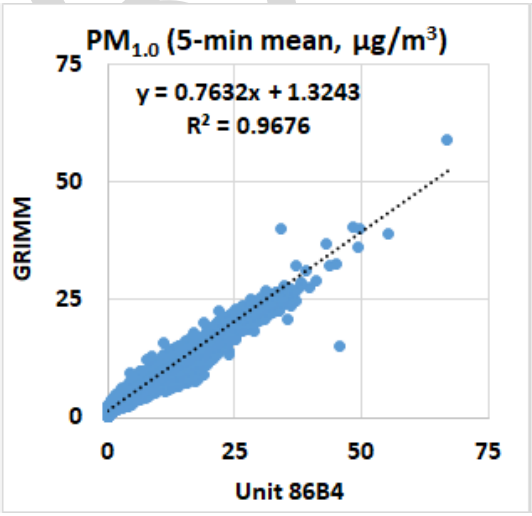


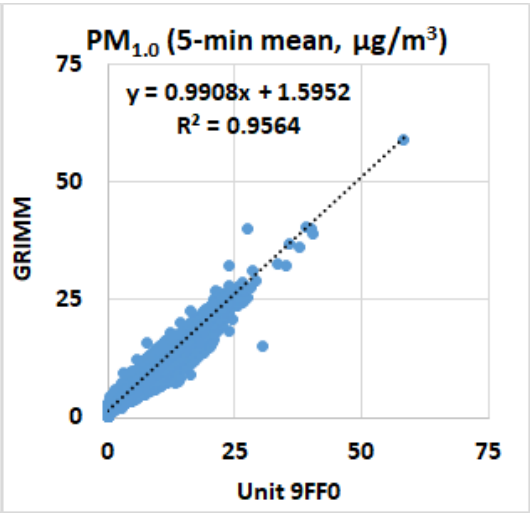
AirBeam3 vs GRIMM ($PM_{1.0}$; 5-min mean)



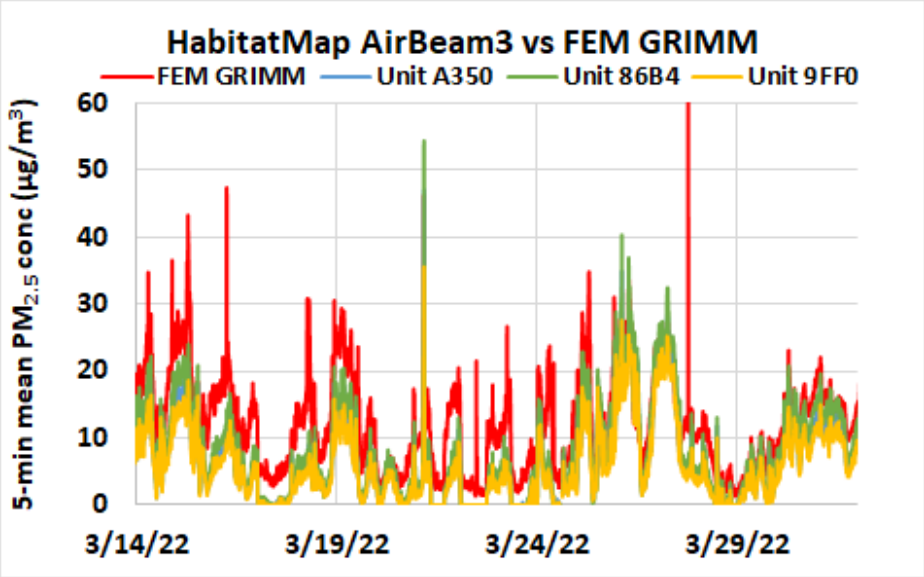
- The AirBeam3 sensors showed very strong correlations with the corresponding GRIMM data ($0.95 < R^2 < 0.97$)
- Overall, the AirBeam3 sensors underestimated the $PM_{1.0}$ mass concentrations as measured by GRIMM
- The AirBeam3 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by GRIMM



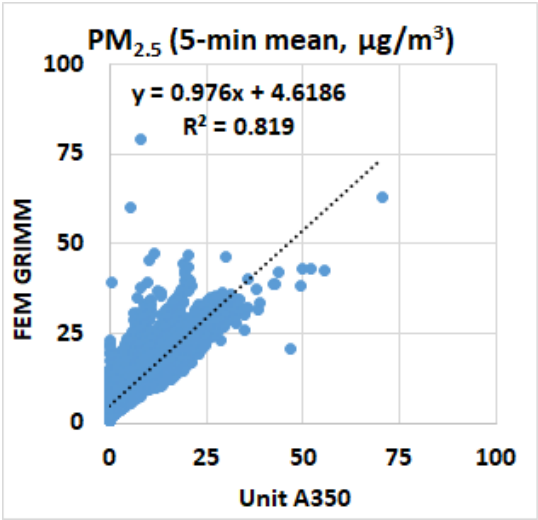


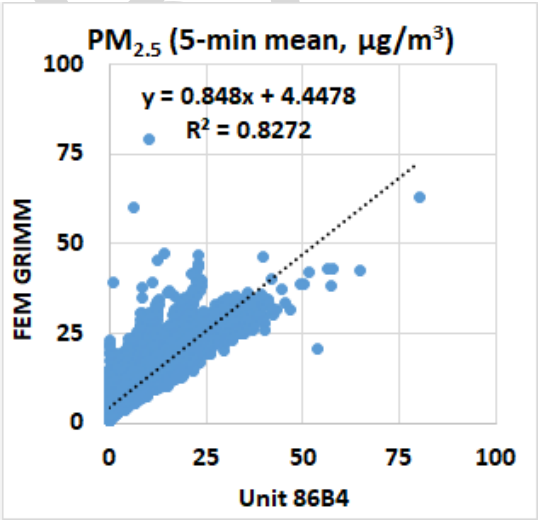


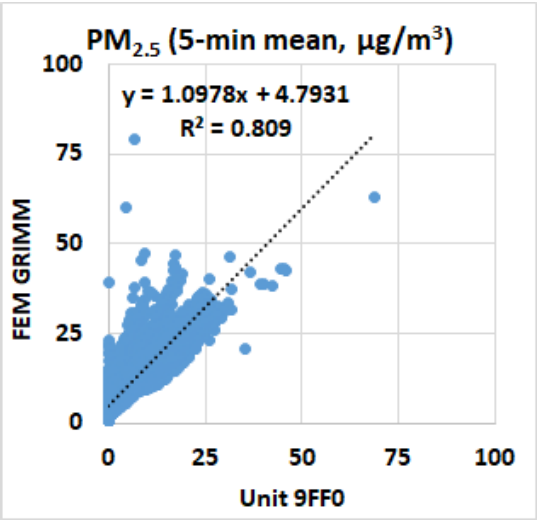
AirBeam3 vs FEM GRIMM ($PM_{2.5}$; 5-min mean)



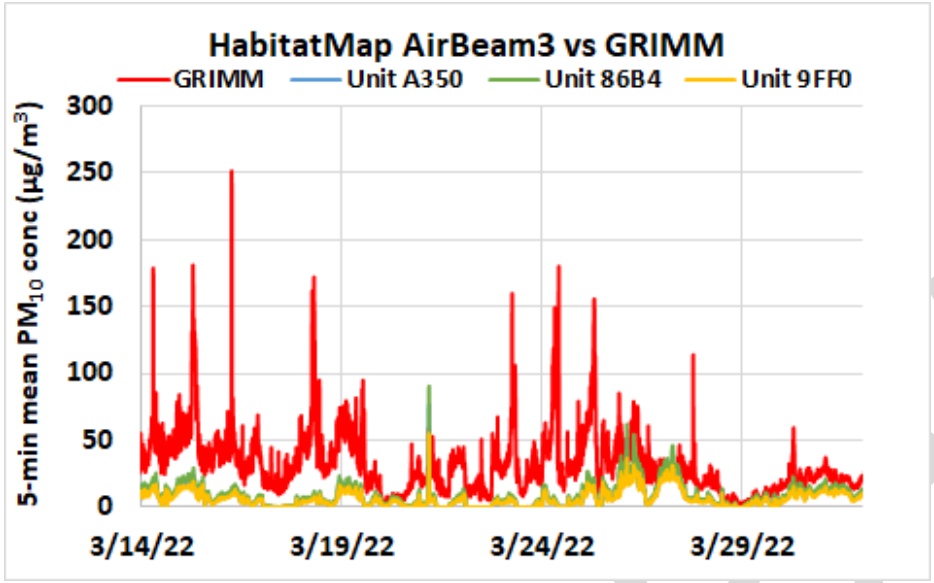
- The AirBeam3 sensors showed strong correlations with the corresponding FEM GRIMM data ($0.80 < R^2 < 0.83$)
- Overall, the AirBeam3 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM GRIMM
- The AirBeam3 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM



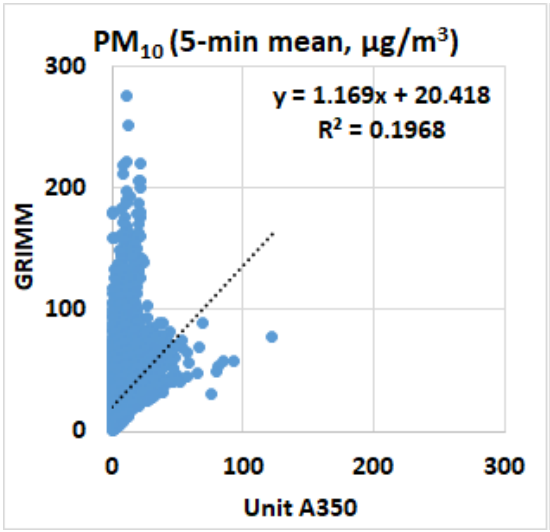


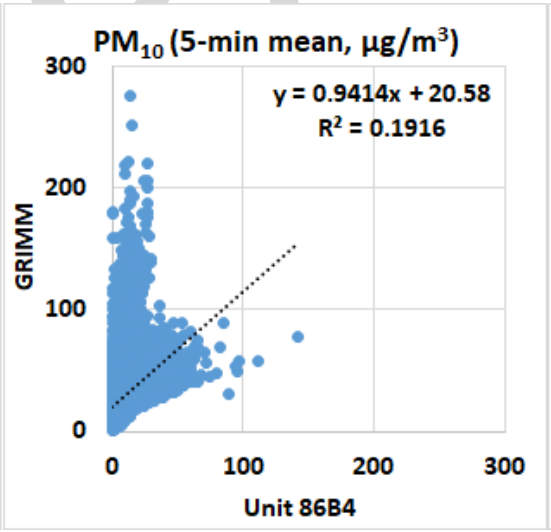


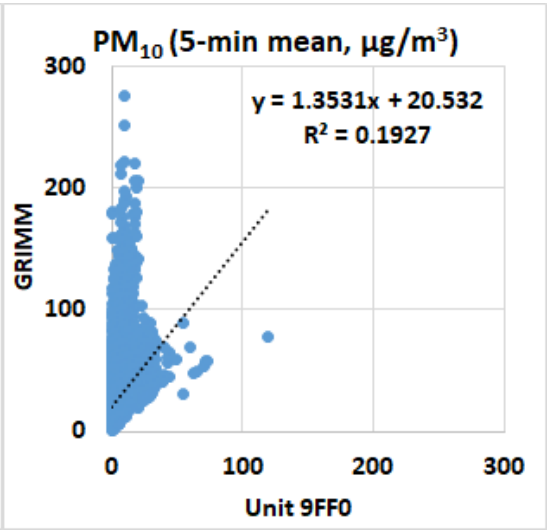
AirBeam3 vs GRIMM (PM_{10}; 5-min mean)



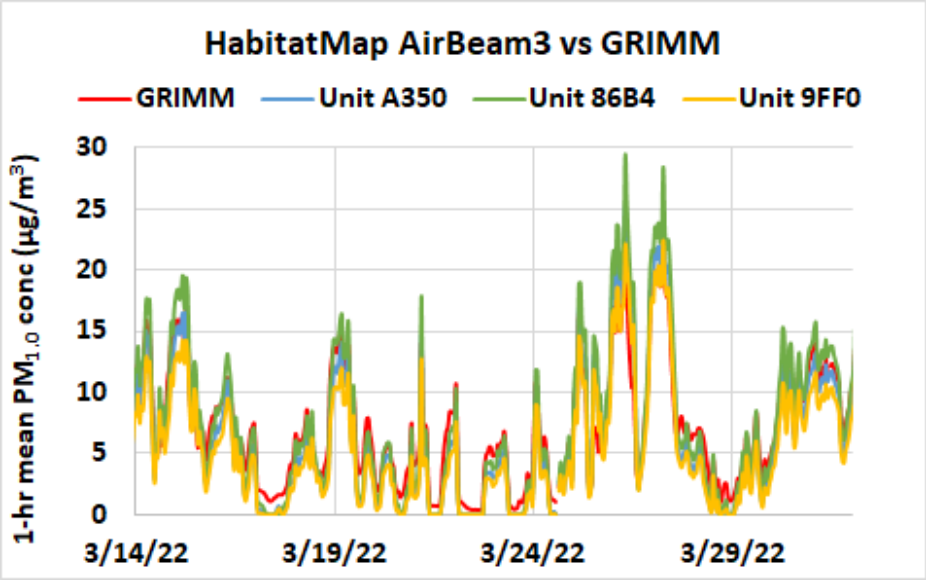
- The AirBeam3 sensors showed very weak correlations with the corresponding GRIMM data ($0.19 < R^2 < 0.20$)
- Overall, the AirBeam3 sensors underestimated the PM_{10} mass concentrations as measured by GRIMM
- The AirBeam3 sensors seemed to track the PM_{10} diurnal variations as recorded by GRIMM



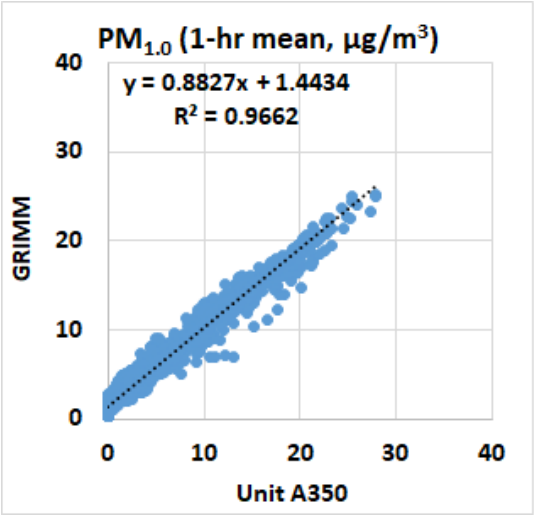


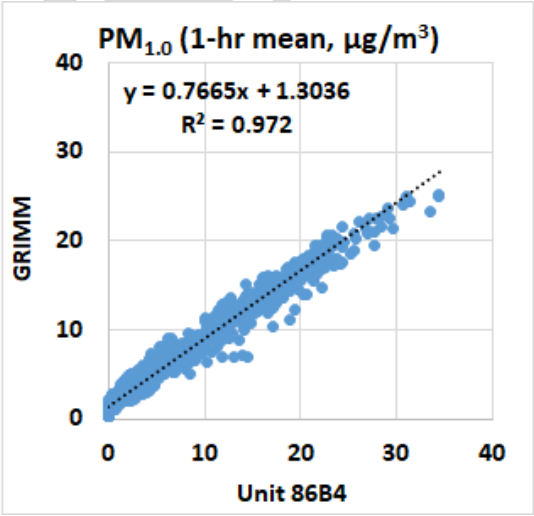


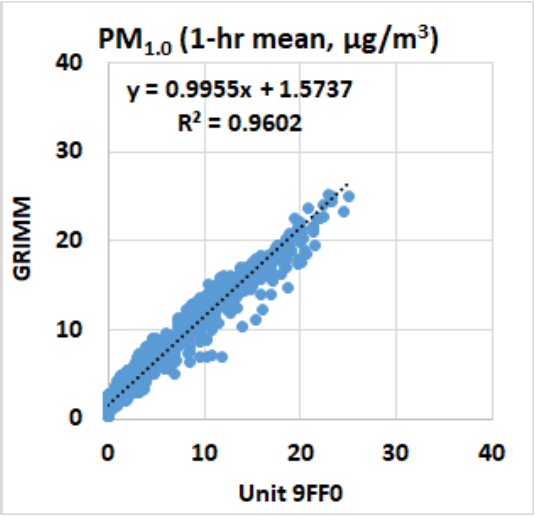
AirBeam3 vs GRIMM ($PM_{1.0}$; 1-hr mean)



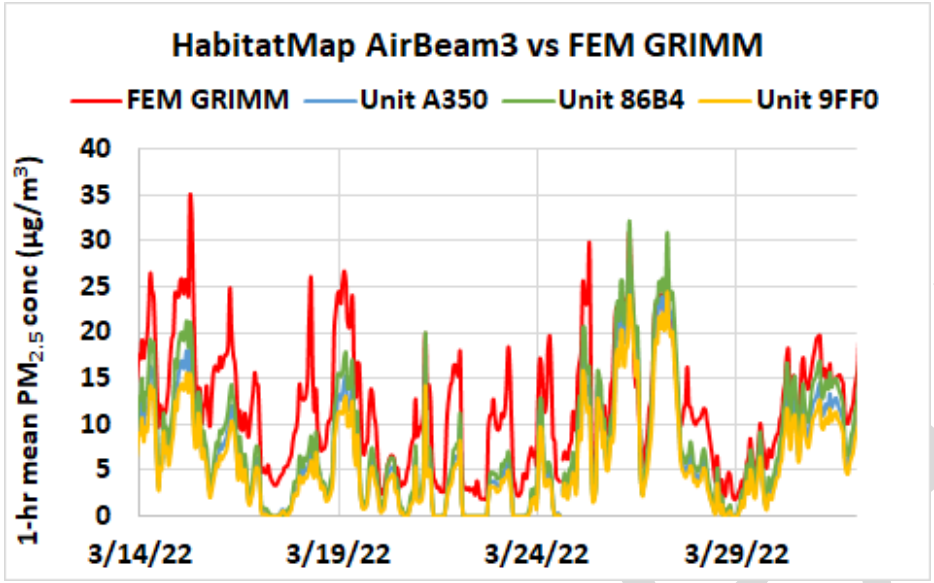
- The AirBeam3 sensors showed very strong correlations with the corresponding GRIMM data ($0.96 < R^2 < 0.98$)
- Overall, the AirBeam3 sensors underestimated the $PM_{1.0}$ mass concentrations as measured by GRIMM
- The AirBeam3 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by GRIMM



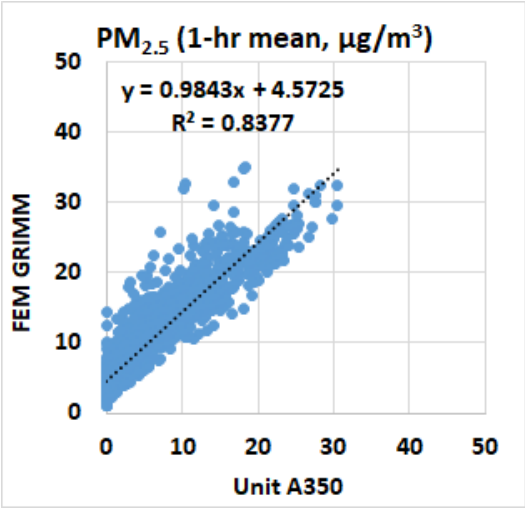


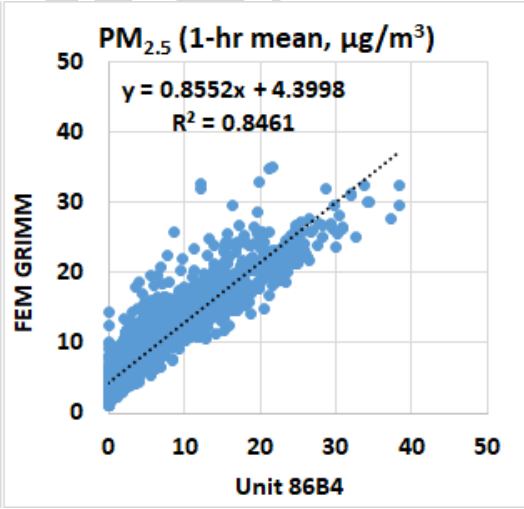


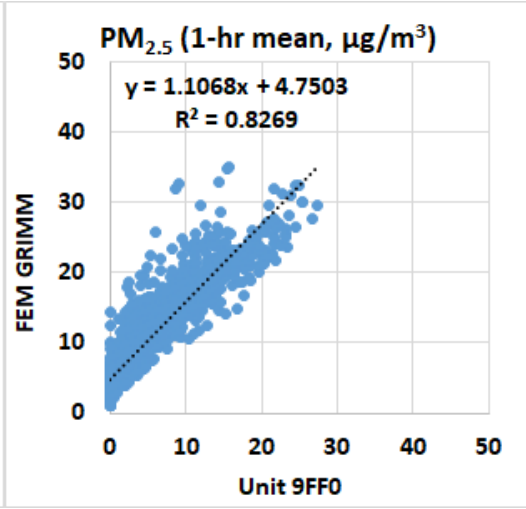
AirBeam3 vs FEM GRIMM ($PM_{2.5}$; 1-hr mean)



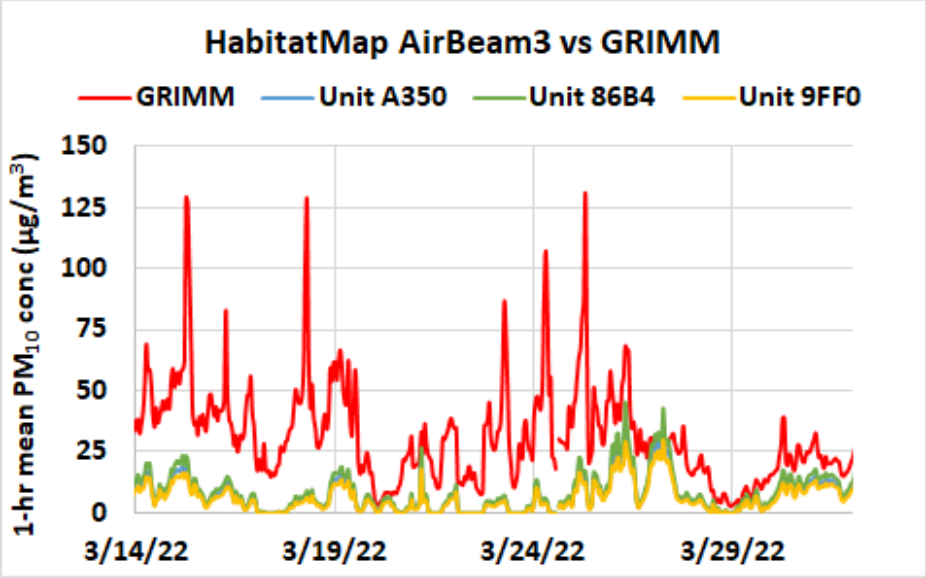
- The AirBeam3 sensors showed strong correlations with the corresponding FEM GRIMM data ($0.82 < R^2 < 0.85$)
- Overall, the AirBeam3 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM GRIMM
- The AirBeam3 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM



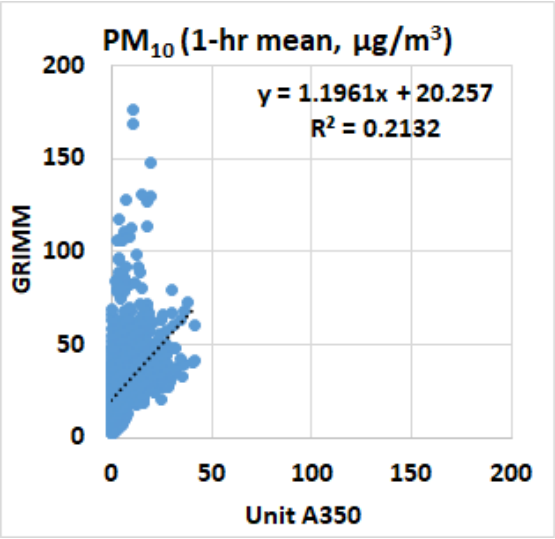


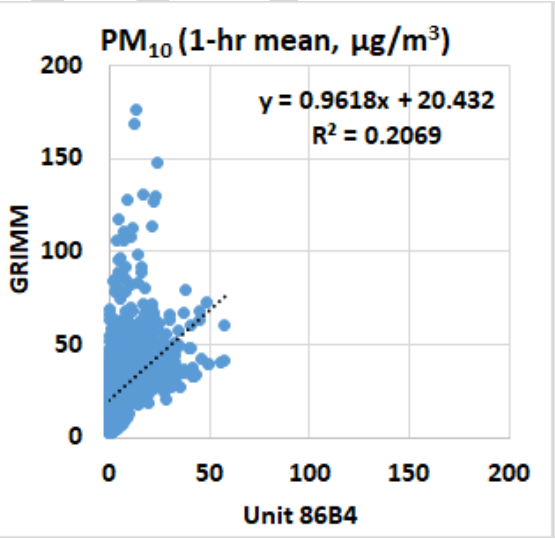


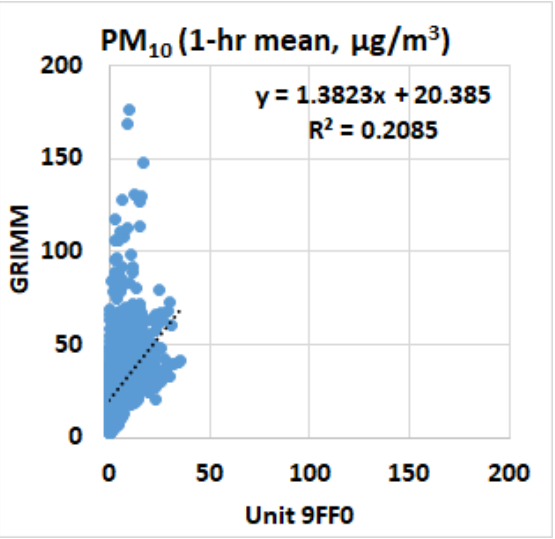
AirBeam3 vs GRIMM (PM_{10}; 1-hr mean)



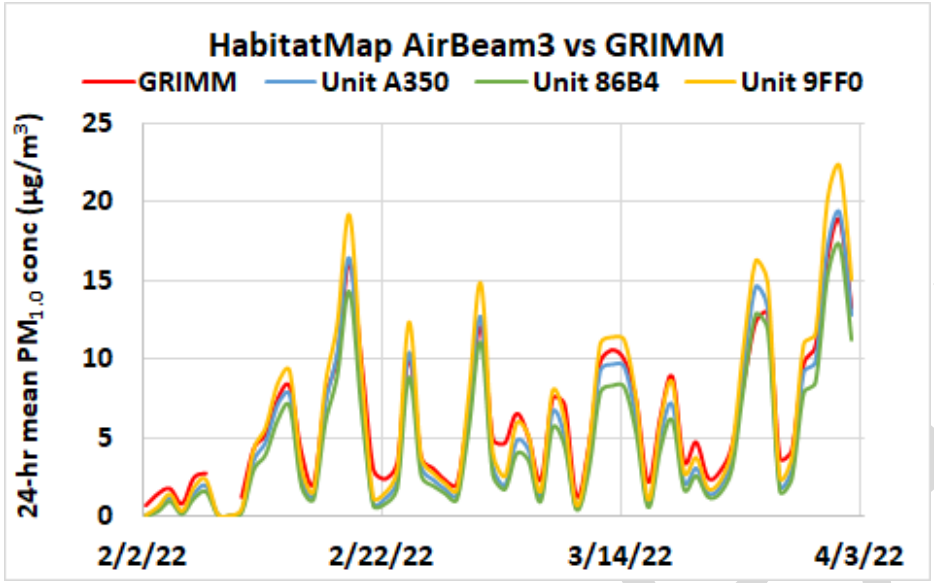
- The AirBeam3 sensors showed very weak correlations with the corresponding GRIMM data ($0.20 < R^2 < 0.22$)
- Overall, the AirBeam3 sensors underestimated the PM_{10} mass concentrations as measured by GRIMM
- The AirBeam3 sensors seemed to track the PM_{10} diurnal variations as recorded by GRIMM



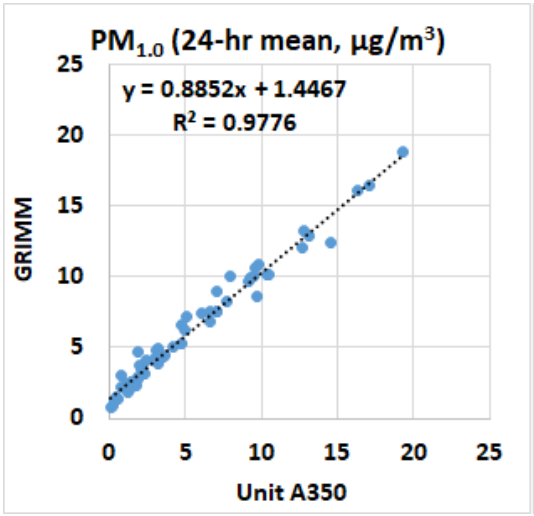


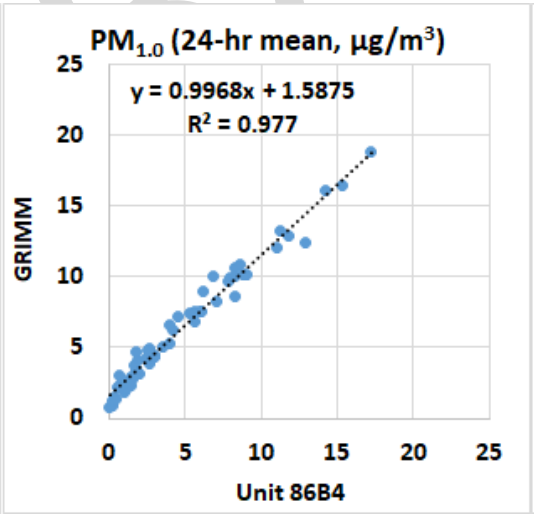


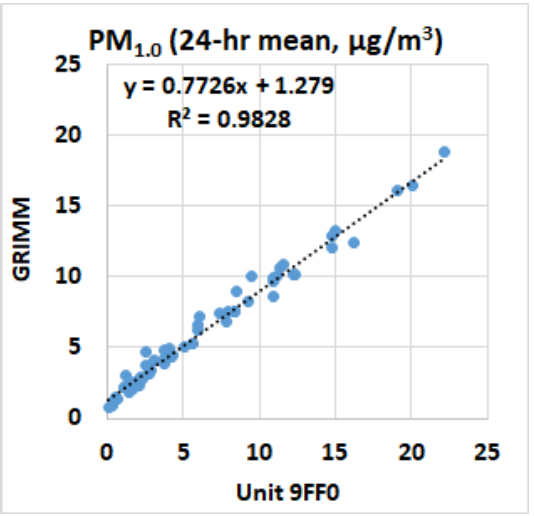
AirBeam3 vs GRIMM ($PM_{1.0}$; 24-hr mean)



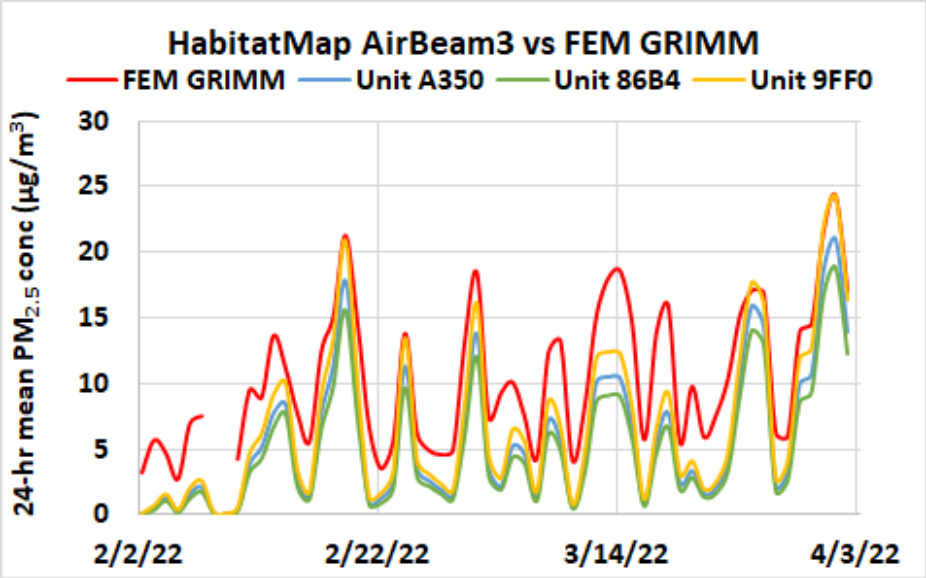
- The AirBeam3 sensors showed very strong correlations with the corresponding GRIMM data ($0.97 < R^2 < 0.99$)
- Overall, the AirBeam3 sensors underestimated the $PM_{1.0}$ mass concentrations as measured by GRIMM
- The AirBeam3 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by GRIMM



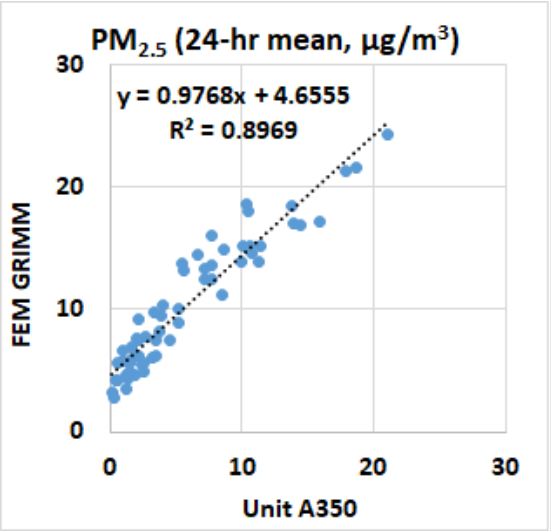


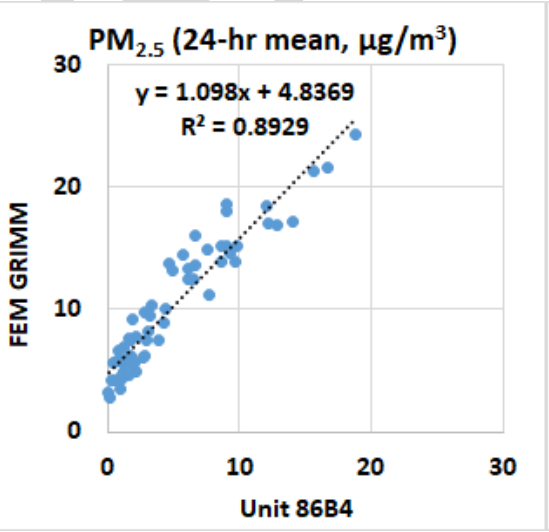


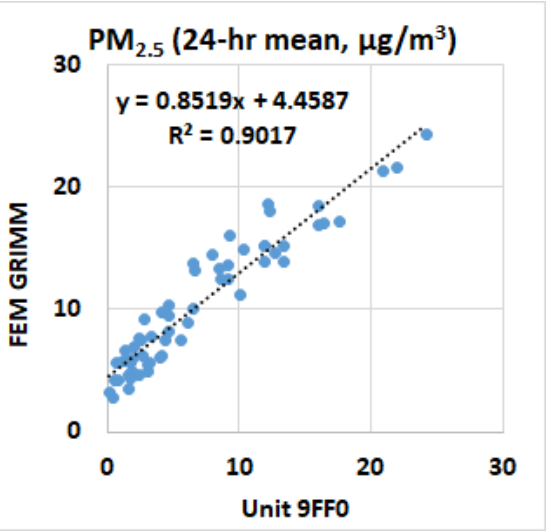
AirBeam3 vs FEM GRIMM ($PM_{2.5}$; 24-hr mean)



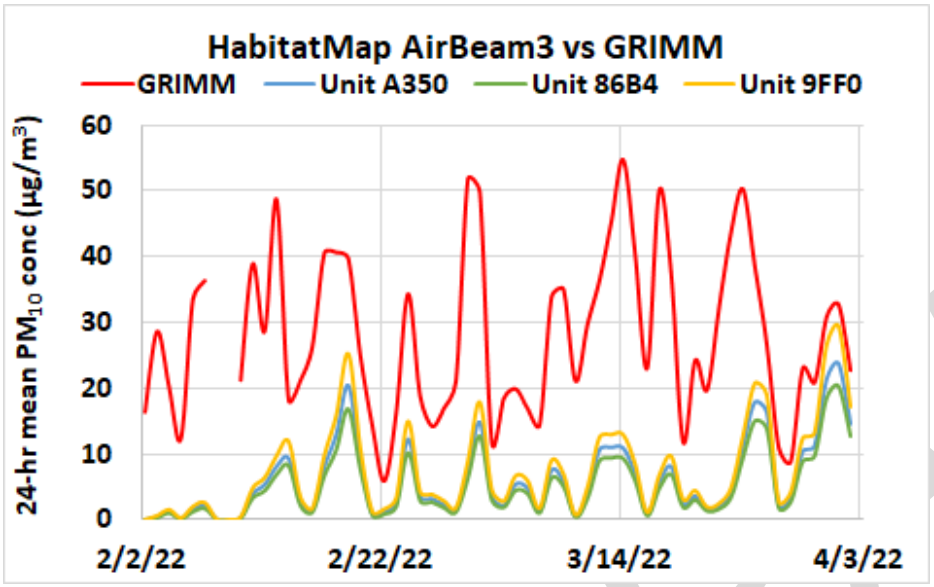
- The AirBeam3 sensors showed strong to very strong correlations with the corresponding FEM GRIMM data ($0.89 < R^2 < 0.91$)
- Overall, the AirBeam3 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM GRIMM
- The AirBeam3 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM



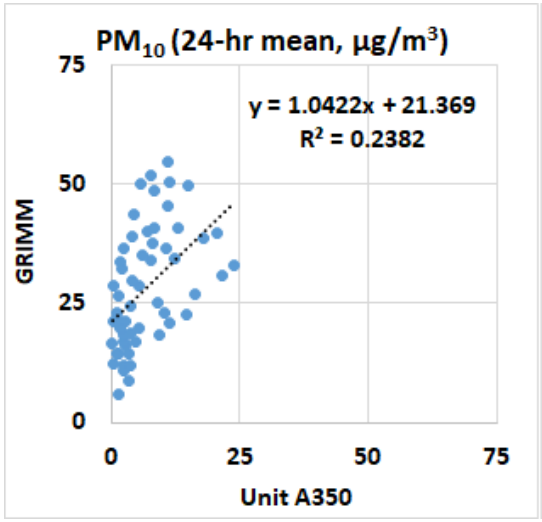


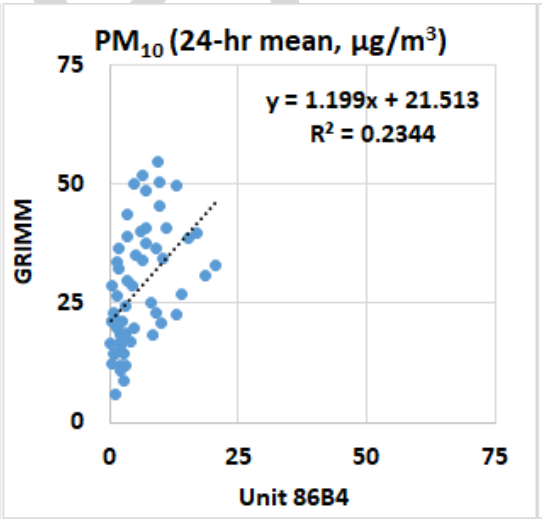


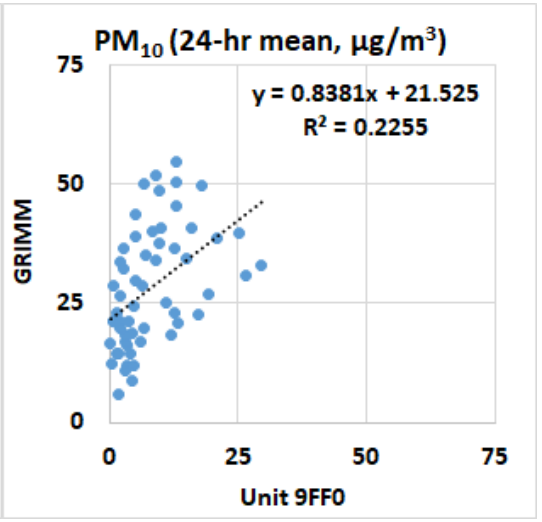
AirBeam3 vs GRIMM (PM_{10}; 24-hr mean)



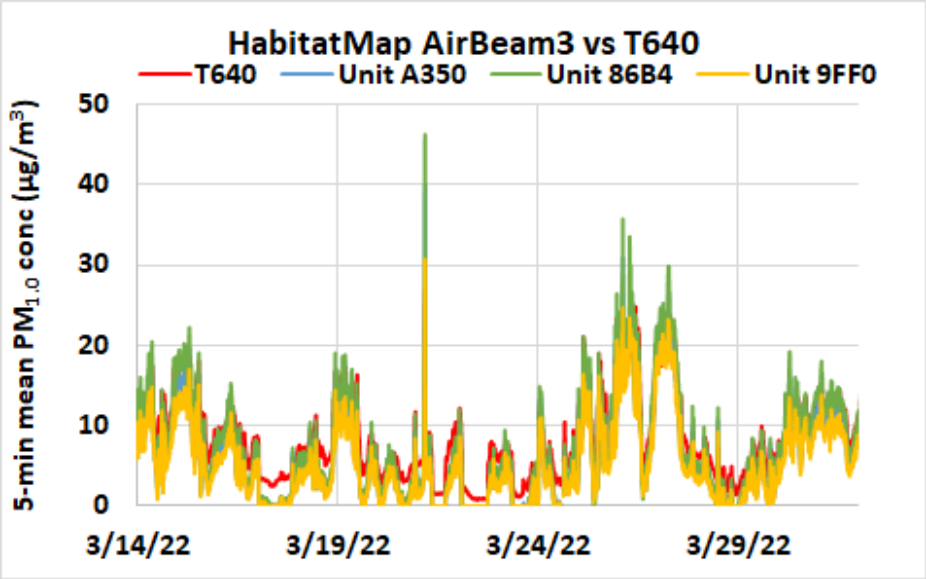
- The AirBeam3 sensors showed very weak correlations with the corresponding GRIMM data ($0.22 < R^2 < 0.24$)
- Overall, the AirBeam3 sensors underestimated the PM_{10} mass concentrations as measured by GRIMM
- The AirBeam3 sensors seemed to track the PM_{10} diurnal variations as recorded by GRIMM



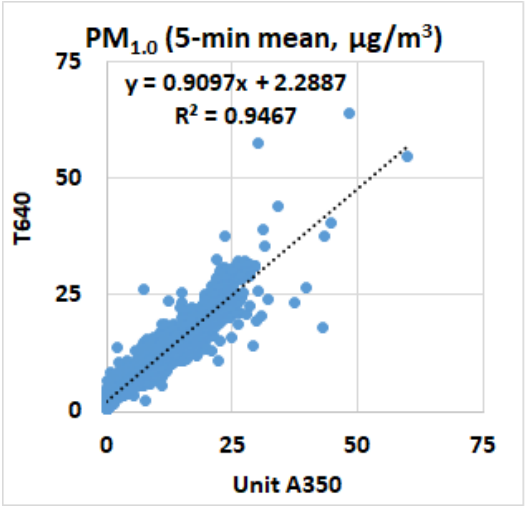


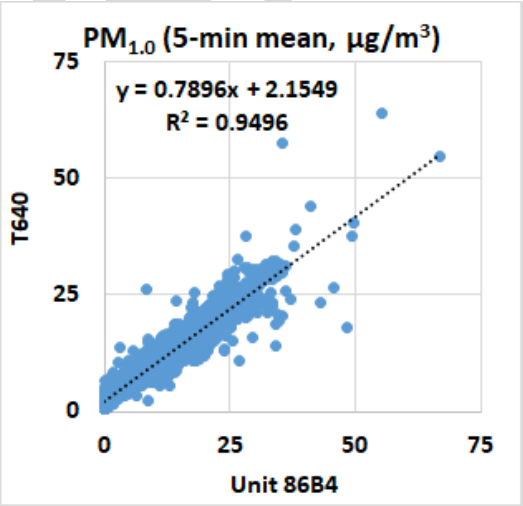


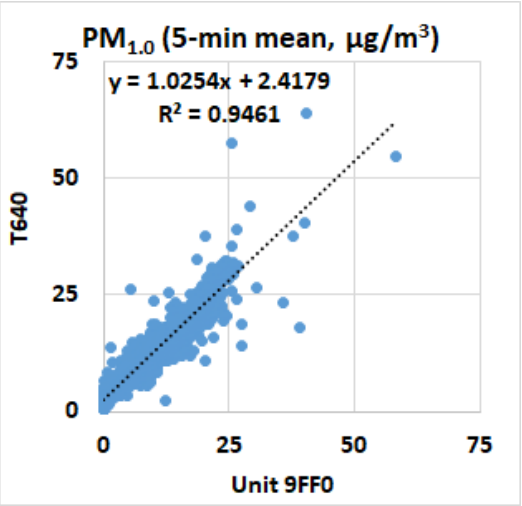
AirBeam3 vs T640 ($PM_{1.0}$; 5-min mean)



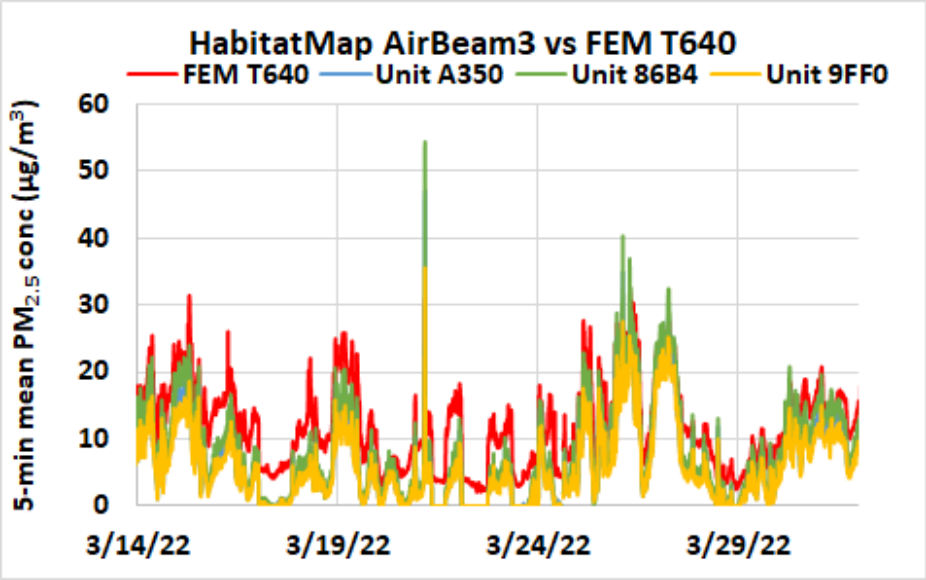
- The AirBeam3 sensors showed very strong correlations with the corresponding T640 data ($0.94 < R^2 < 0.95$)
- Overall, the AirBeam3 sensors underestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The AirBeam3 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640



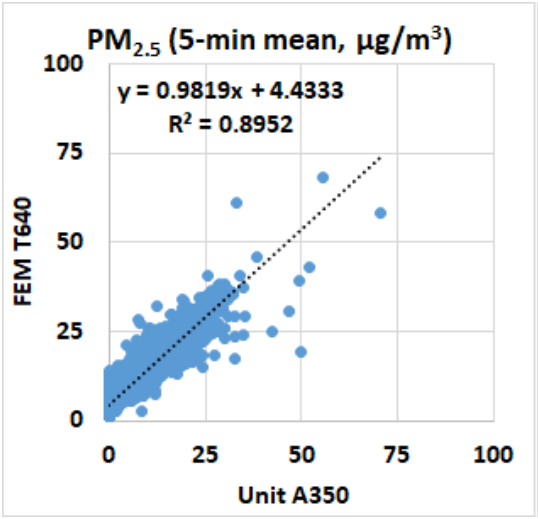


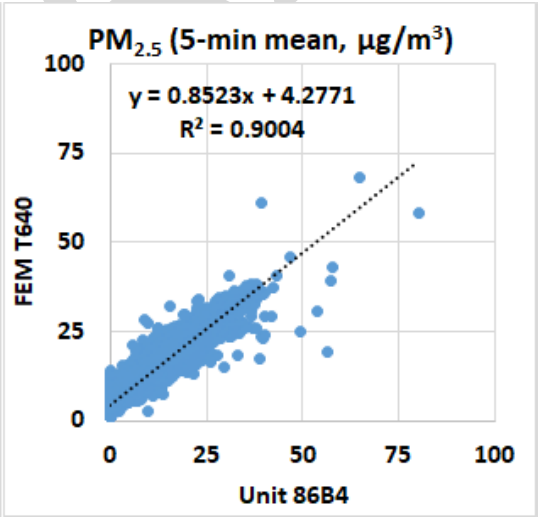


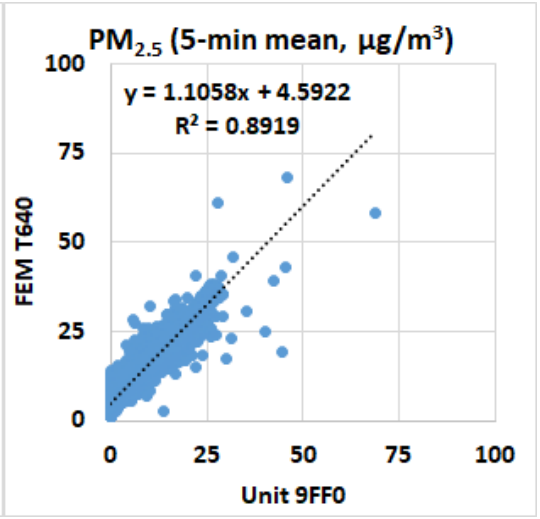
AirBeam3 vs FEM T640 ($PM_{2.5}$; 5-min mean)



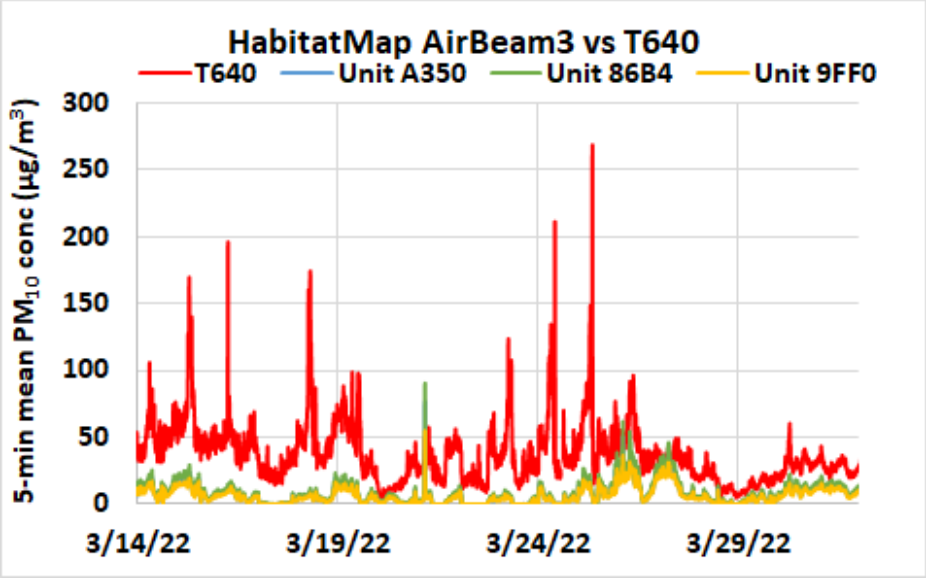
- The AirBeam3 sensors showed strong to very strong correlations with the corresponding FEM T640 data ($0.89 < R^2 < 0.91$)
- Overall, the AirBeam3 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The AirBeam3 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



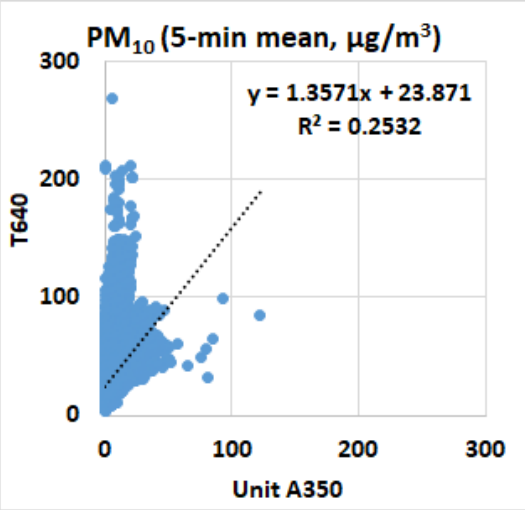


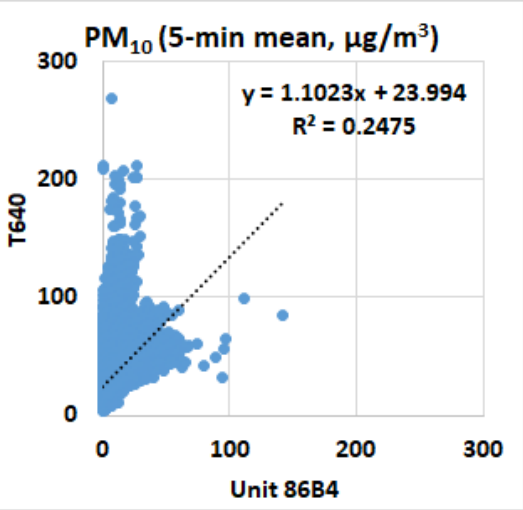


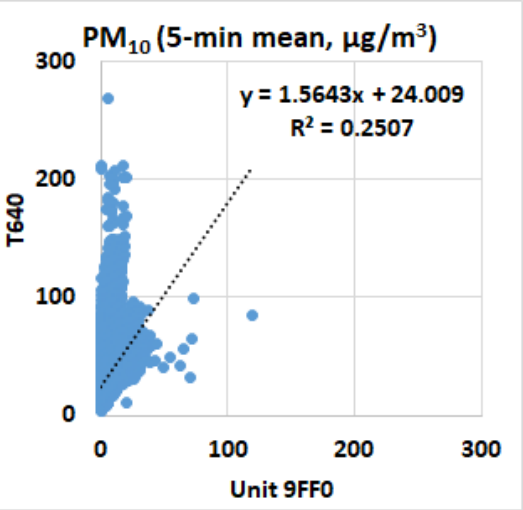
AirBeam3 vs T640 (PM_{10}; 5-min mean)



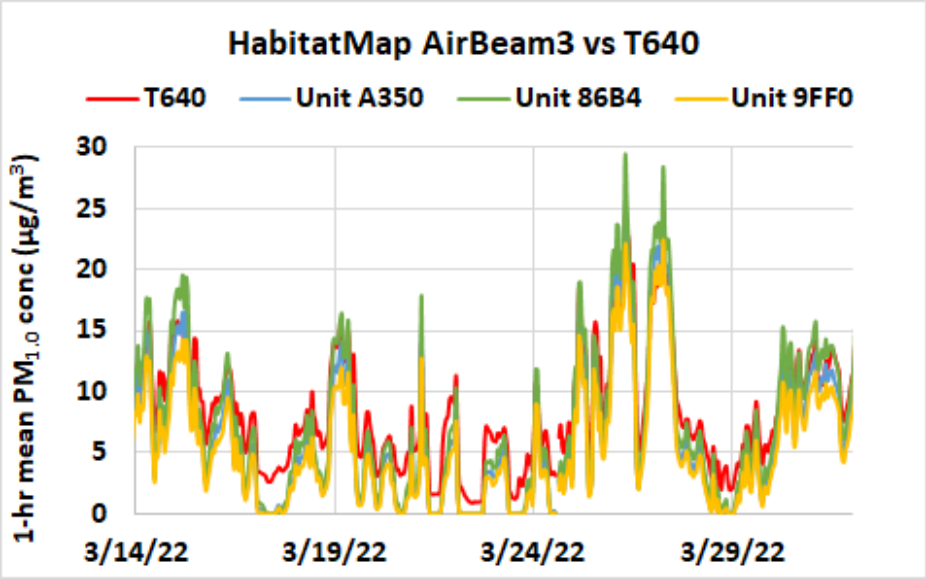
- AirBeam3 sensors showed very weak correlations with the corresponding T640 data ($0.24 < R^2 < 0.26$)
- Overall, the AirBeam3 sensors underestimated the PM_{10} mass concentrations as measured by T640
- The AirBeam3 sensors seemed to track the PM_{10} diurnal variations as recorded by T640



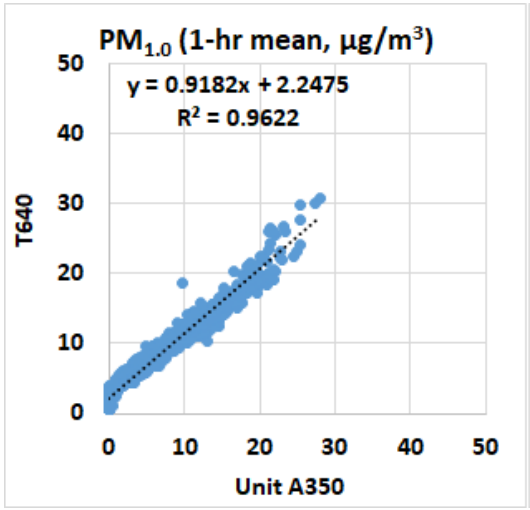


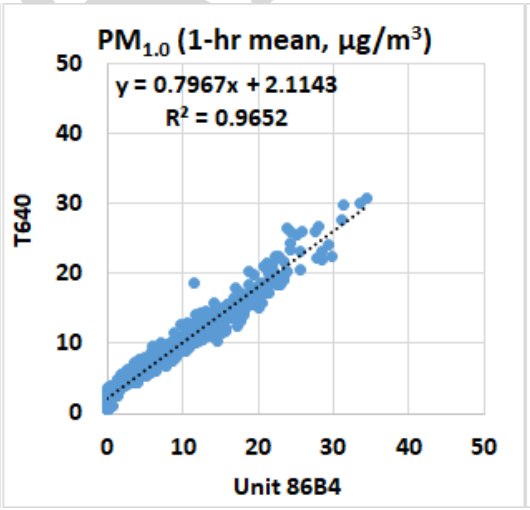


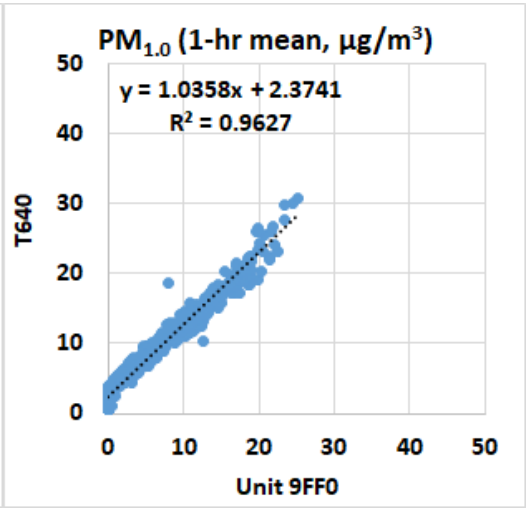
AirBeam3 vs T640 ($PM_{1.0}$; 1-hr mean)



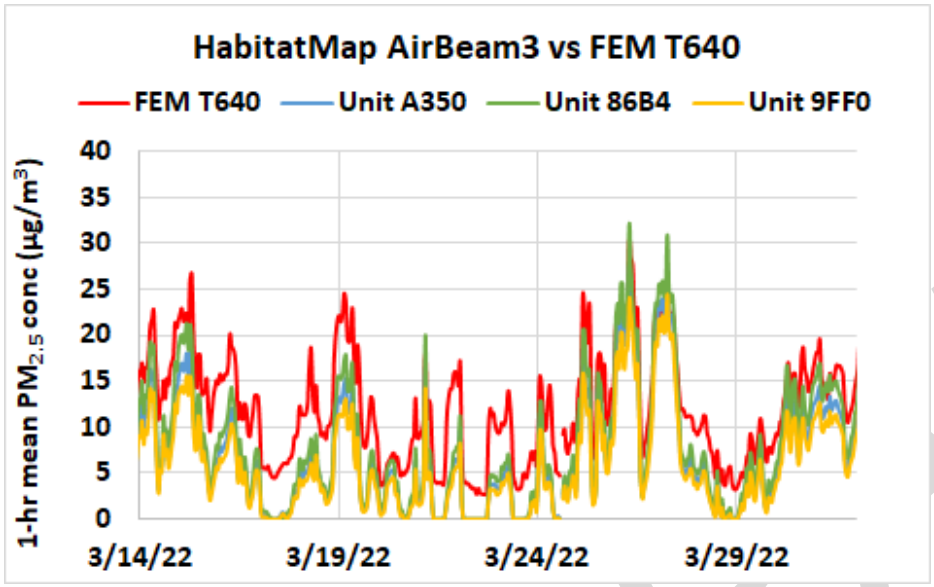
- The AirBeam3 sensors showed very strong correlations with the corresponding T640 data ($0.96 < R^2 < 0.97$)
- Overall, the AirBeam3 sensors underestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The AirBeam3 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640



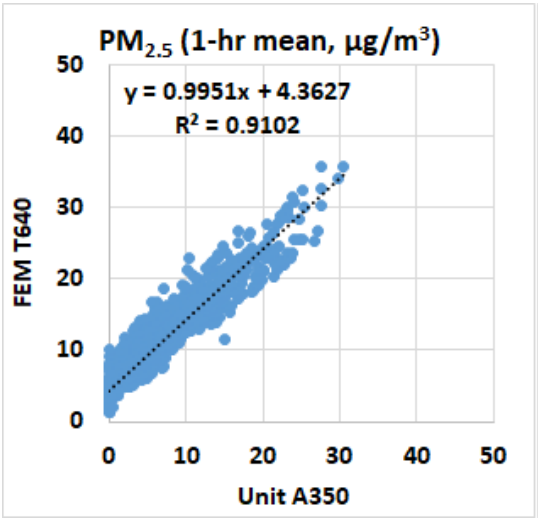


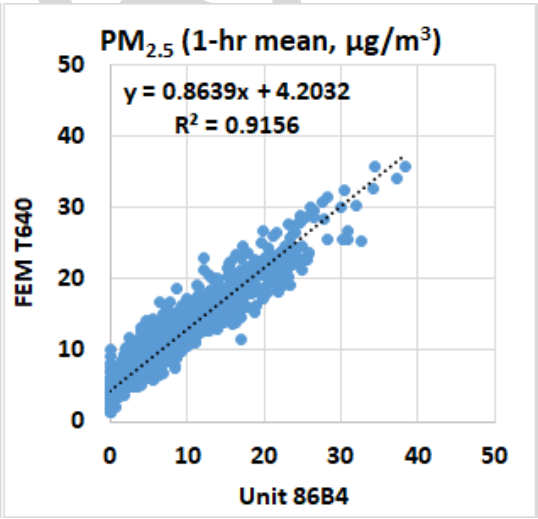


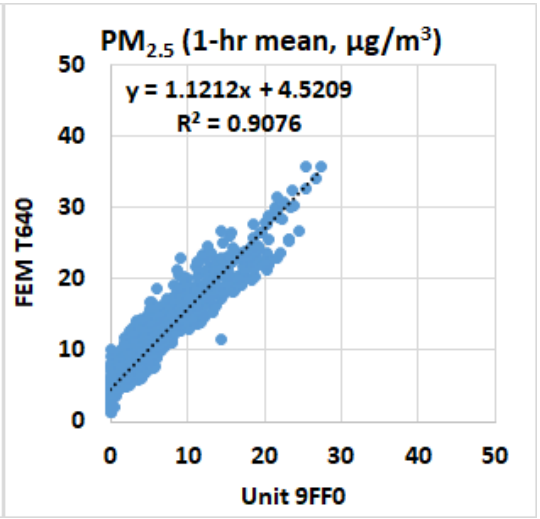
AirBeam3 vs FEM T640 ($PM_{2.5}$; 1-hr mean)



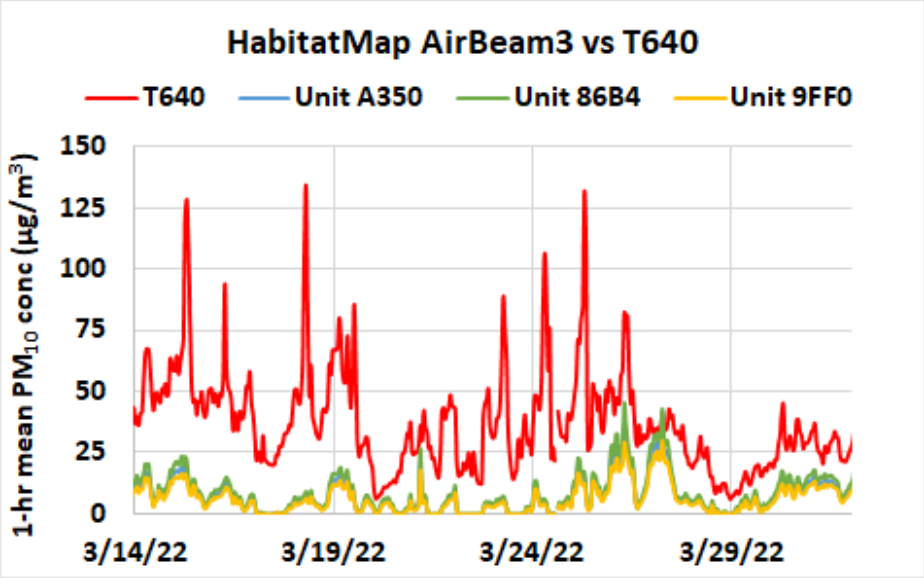
- The AirBeam3 sensors showed very strong correlations with the corresponding FEM T640 data ($0.90 < R^2 < 0.92$)
- Overall, the AirBeam3 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The AirBeam3 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



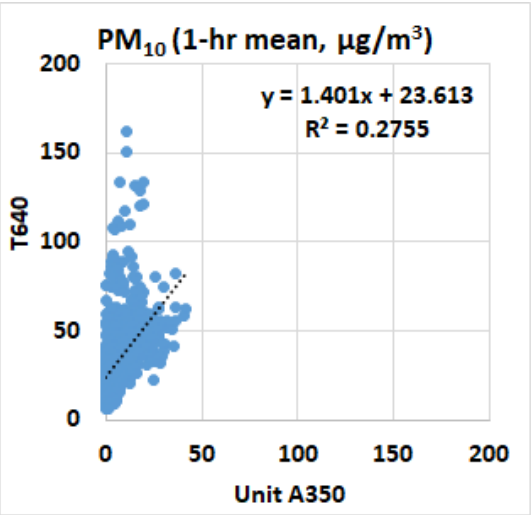


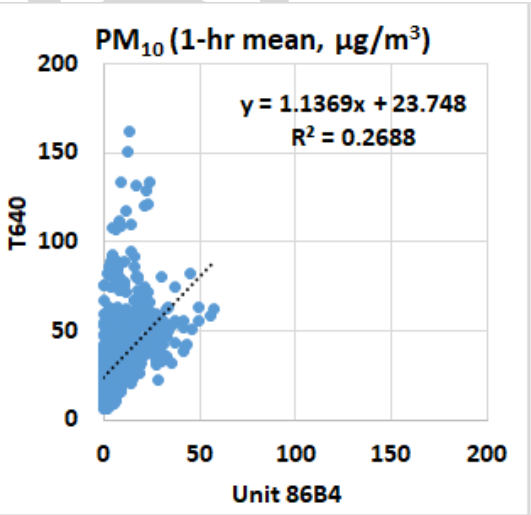


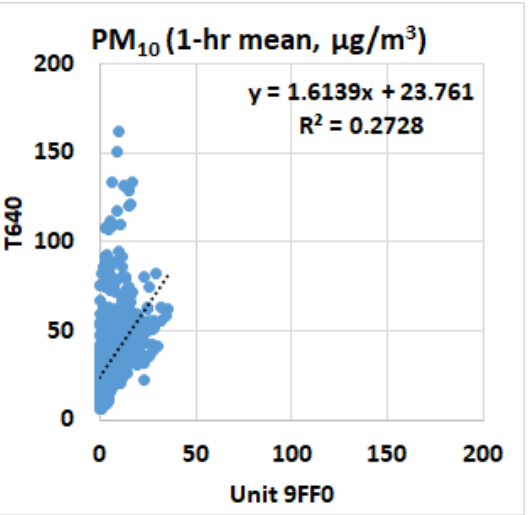
AirBeam3 vs T640 (PM_{10}; 1-hr mean)



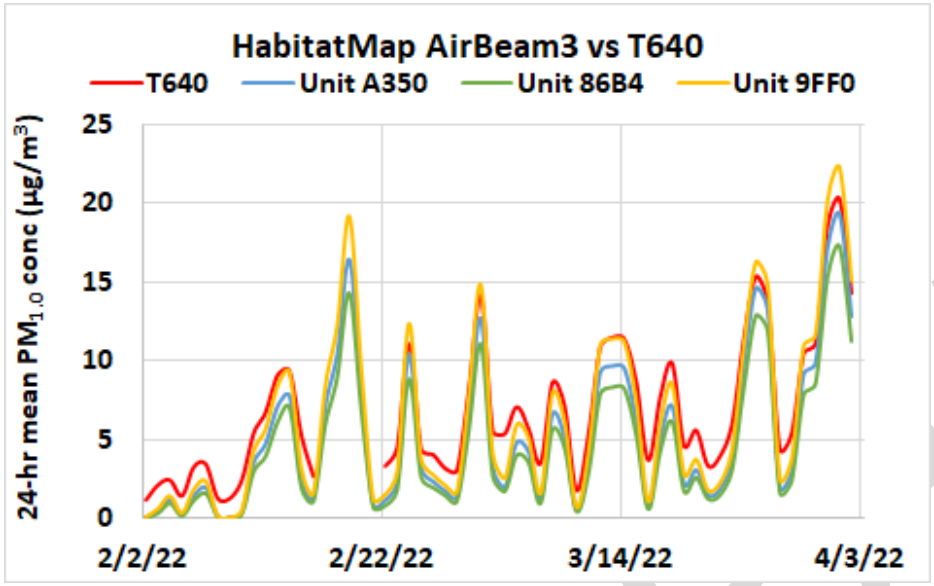
- The AirBeam3 sensors showed very weak correlations with the corresponding T640 data ($0.26 < R^2 < 0.28$)
- Overall, the AirBeam3 sensors underestimated the PM_{10} mass concentrations as measured by T640
- The AirBeam3 sensors seemed to track the PM_{10} diurnal variations as recorded by T640



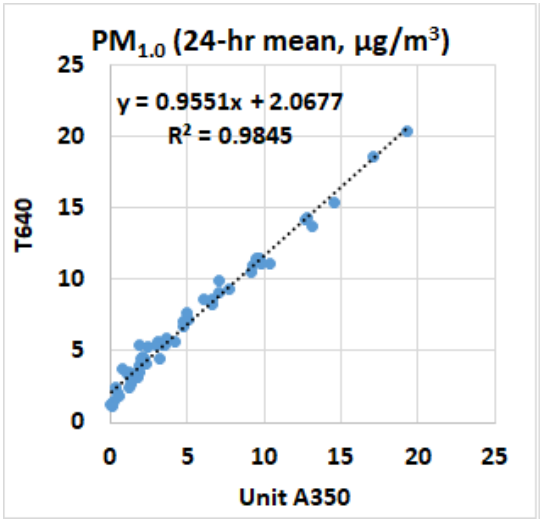


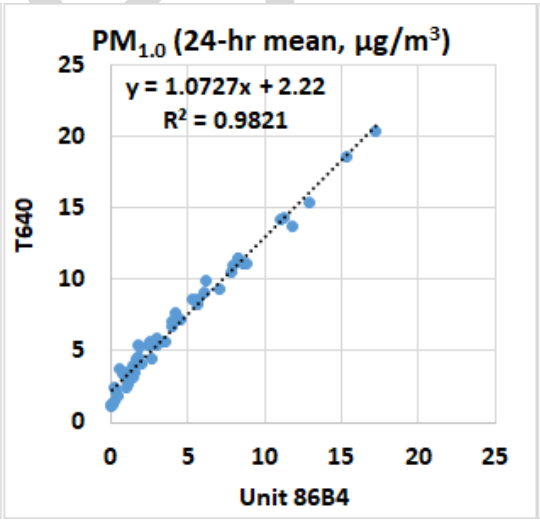


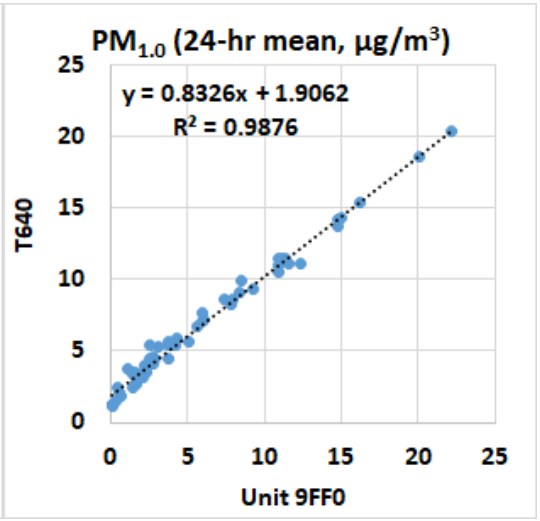
AirBeam3 vs T640 ($PM_{1.0}$; 24-hr mean)



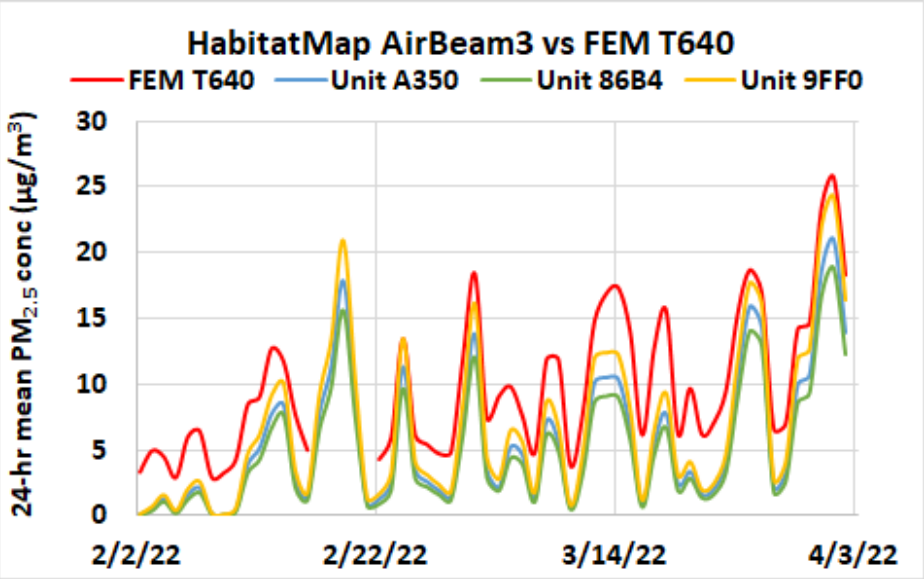
- The AirBeam3 sensors showed very strong correlations with the corresponding T640 data ($0.98 < R^2 < 0.99$)
- Overall, the AirBeam3 sensors underestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The AirBeam3 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640



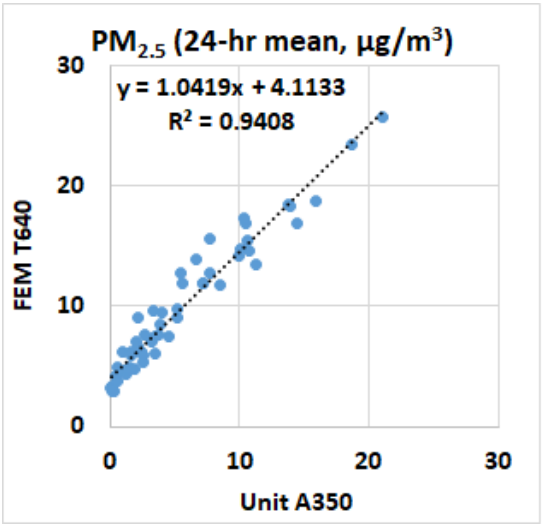


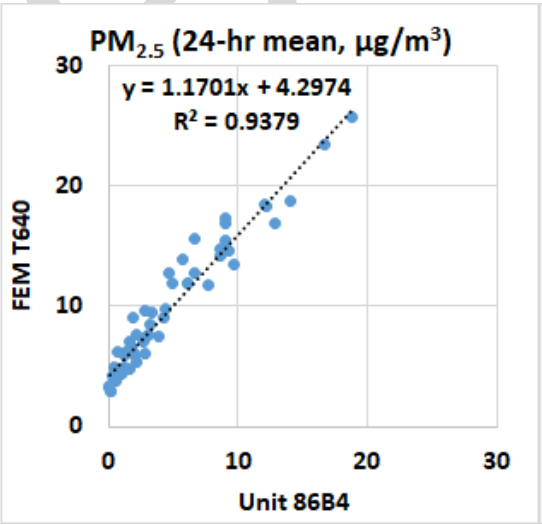


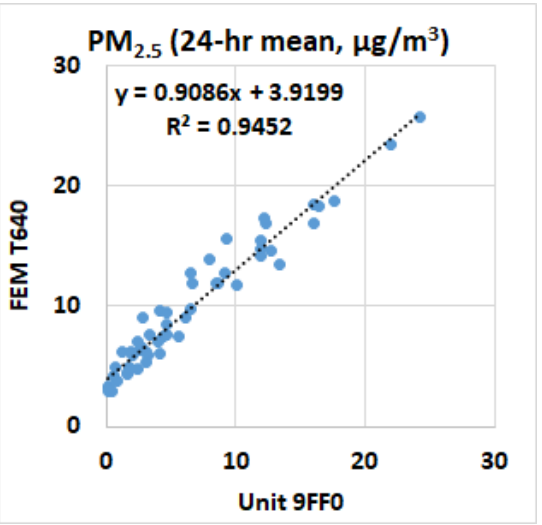
AirBeam3 vs FEM T640 ($PM_{2.5}$; 24-hr mean)



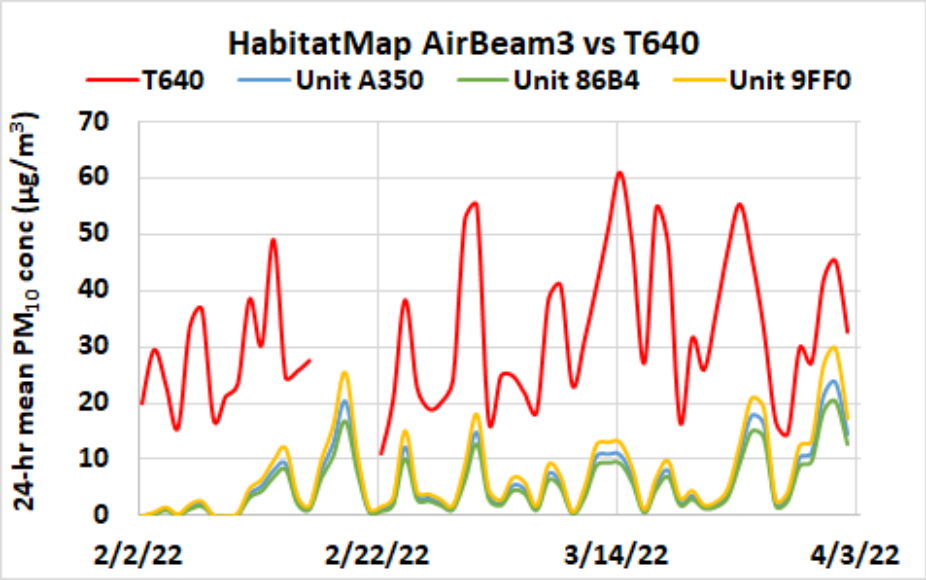
- The AirBeam3 sensors showed very strong correlations with the corresponding FEM T640 data ($0.93 < R^2 < 0.95$)
- Overall, the AirBeam3 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The AirBeam3 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



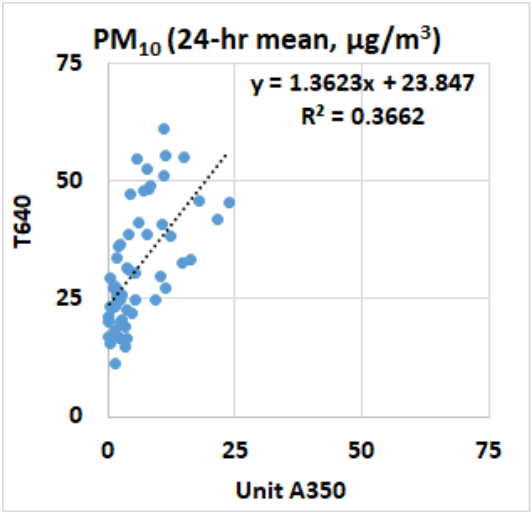


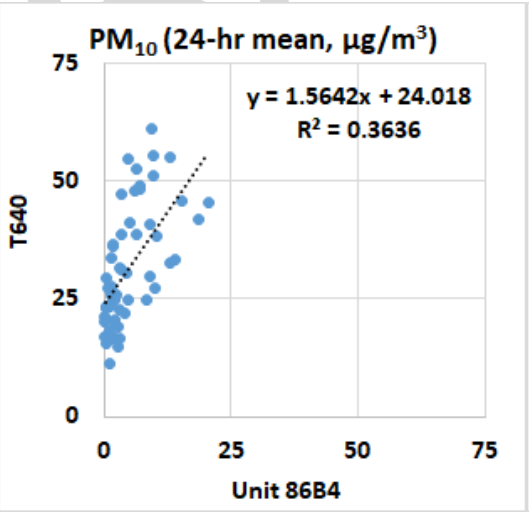


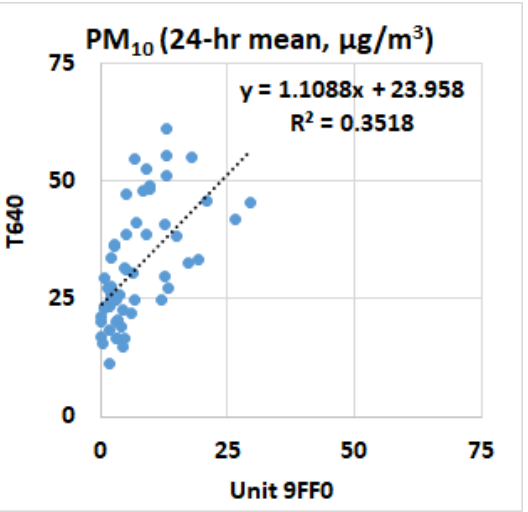
AirBeam3 vs T640 (PM_{10}; 24-hr mean)



- The AirBeam3 sensors showed weak correlations with the corresponding T640 data ($0.35 < R^2 < 0.37$)
- Overall, the AirBeam3 sensors underestimated the PM_{10} mass concentrations as measured by T640
- The AirBeam3 sensors seemed to track the PM_{10} diurnal variations as recorded by T640







Summary

	Average of 3 Sensors, $PM_{1.0}$		AirBeam3 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	5.4	6.4	0.95 to 0.97	0.76 to 1.03	1.3 to 2.4	-2.5 to 0.2	1.3 to 2.6	1.6 to 2.8	6.2 to 6.8	5.5 to 5.6	0.3 to 64.1
1-hr	5.4	6.2	0.96 to 0.97	0.77 to 1.04	1.3 to 2.4	-2.5 to 0.2	1.2 to 2.5	1.5 to 2.7	6.2 to 6.8	5.4 to 5.5	0.3 to 30.9
24-hr	5.4	4.9	0.98 to 0.99	0.77 to 1.07	1.3 to 2.2	-2.5 to 0.2	1.0 to 2.5	1.2 to 2.6	6.3 to 6.9	4.3 to 4.5	0.8 to 20.3
	Average of 3 Sensors, $PM_{2.5}$		AirBeam3 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	5.9	7.0	0.81 to 0.90	0.85 to 1.11	4.3 to 4.8	-5.3 to -3.3	3.6 to 5.3	4.1 to 6.2	9.7 to 10.3	6.7 to 7.3	0.7 to 79.3
1-hr	5.9	6.8	0.83 to 0.92	0.86 to 1.12	4.2 to 4.8	-5.3 to -3.3	3.5 to 5.3	4.0 to 6.1	9.7 to 10.4	6.6 to 7.1	1.0 to 35.8
24-hr	5.9	5.4	0.89 to 0.95	0.85 to 1.17	3.9 to 4.8	-5.3 to -3.3	3.3 to 5.3	3.6 to 5.6	9.8 to 10.5	5.4 to 5.5	2.7 to 25.7
	Average of 3 Sensors, PM_{10}		AirBeam3 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	6.4	8.2	0.19 to 0.25	0.94 to 1.56	20.4 to 24.0	-26.8 to -20.1	20.4 to 26.8	27.4 to 32.1	27.8 to 31.8	19.9 to 20.7	1.4 to 276.2
1-hr	6.4	7.8	0.21 to 0.28	0.96 to 1.61	20.3 to 23.8	-26.8 to -20.1	20.3 to 26.8	26.6 to 31.5	27.9 to 31.8	18.9 to 19.5	2.3 to 175.9
24-hr	6.4	6.1	0.23 to 0.37	0.84 to 1.56	21.4 to 24.0	-26.8 to -20.3	20.3 to 26.8	23.0 to 28.8	28.1 to 31.9	12.4 to 12.7	6.0 to 61.0

[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 **AirBeam3** sensors' data recovery from all units was 99% for all PM measurements
- The absolute intra-model variability was ~ 0.86, ~ 0.94 and ~ 1.14 µg/m^3 for $PM_{1.0}$, $PM_{2.5}$ and $PM_{10,}$ respectively
- Regulatory-grade instruments: Very strong correlations between GRIMM and T640 for $PM_{1.0}$, $PM_{2.5}$, and PM_{10} ($R^2 > 0.95$, $R^2 > 0.94$, and $R^2 > 0.94$, respectively, 1-hr mean)
- $PM_{1.0}$ mass concentrations measured by AirBeam3 sensors showed very strong correlations with the corresponding GRIMM and T640 data ($0.96 < R^2 < 0.98$, 1-hr mean). The sensors underestimated $PM_{1.0}$ mass concentrations as measured by GRIMM and T640
- $PM_{2.5}$ mass concentrations measured by AirBeam3 sensors showed strong to very strong correlations with the corresponding FEM GRIMM and FEM T640 data ($0.82 < R^2 < 0.92$, 1-hr mean). The sensors underestimated $PM_{2.5}$ mass concentrations as measured by FEM GRIMM and FEM T640
- PM_{10} mass concentrations measured by AirBeam3 sensors showed very weak correlations with the corresponding GRIMM and T640 ($0.20 < R^2 < 0.28$; 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 for this evaluation
- 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