Field Evaluation
Wicked Device – Air Quality Egg
2022 Model

South Coast AQMD

AQ-SPEC

Air Quality Sensor Performance Evaluation Center

Background

- From 11/20/2021 to 1/19/2022, three **Wicked Device – Air Quality Egg 2022 Model (hereinafter Air Quality Egg 2022 Model)** 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) and Federal Reference Method (FRM) instruments measuring the same pollutants

- Air Quality Egg 2022 Model (*3 units tested*):
  - Particle sensor: optical; non-FEM (dual Plantower PMS5003)
  - Gas-phase sensor: Electrochemical; non-FEM (Winsen ZE12A)
  - Each unit reports: CO (ppm), $PM_{1.0}$, $PM_{2.5}$ and PM_{10} ($\mu g/m^3$)
  - Unit cost: $671 (with offline data logging option)
  - Time resolution: 1-min
  - Units IDs: 582f, 6c91, 6108

- South Coast AQMD Reference instruments:
  - Horiba APMA 370 (FRM CO); cost: ~$10,000
    - Time resolution; 1-min
  - MetOne BAM (FEM $PM_{2.5}$ & FEM PM_{10}); cost: ~$20,000
    - Time resolution: 1-hr
  - Teledyne API T640 (FEM $PM_{2.5}$); cost: $21,000
    - Time resolution: 1-min
  - GRIMM EDM 180 (FEM $PM_{2.5}$); cost: $25,000
    - Time resolution: 1-min
  - Met station (T, RH, P, WS, WD); cost: ~$5,000
    - Time resolution: 1-min

Carbon Monoxide (CO) in Air Quality Egg 2022 Model

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 for CO from all units was ~ 99%

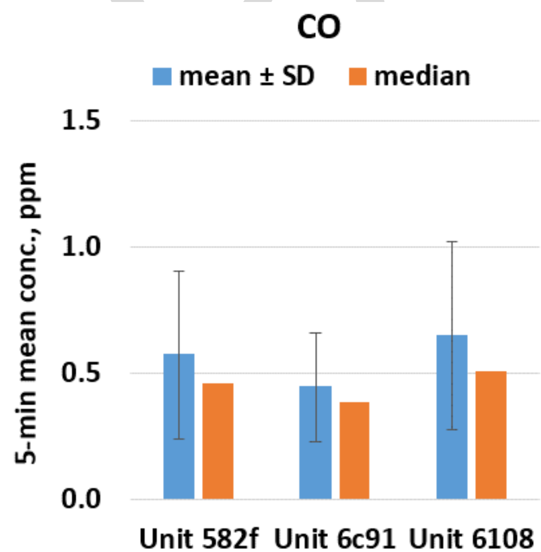
Air Quality Egg 2022 Model; Intra-model variability

- Absolute intra-model variability was ~ 0.10 ppm for the CO measurements

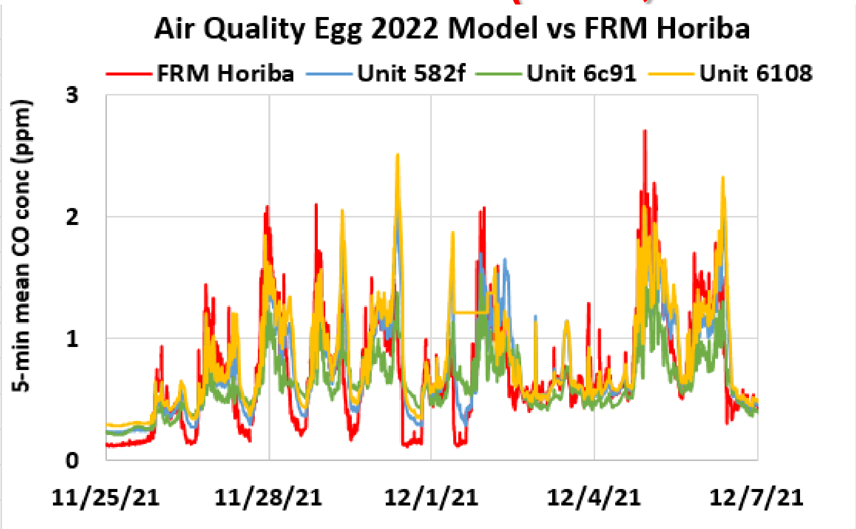
(calculated as the standard deviation of the three sensor means)

- Relative intra-model variability was ~ 18.7% for the CO measurements

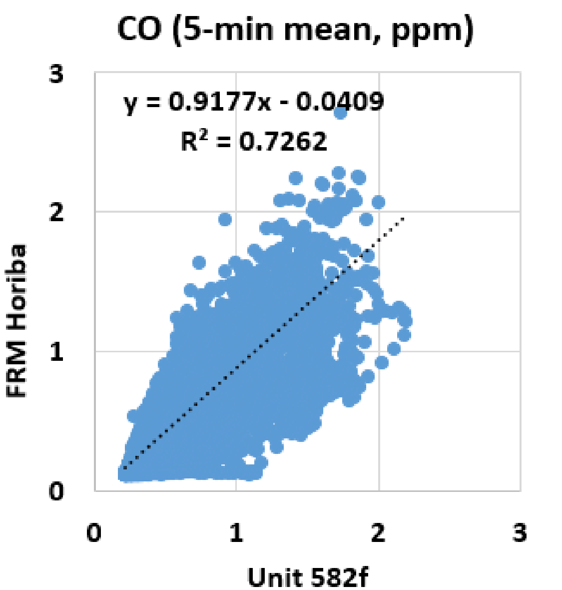
(calculated as the absolute intra-model variability relative to the mean of the three sensor means)

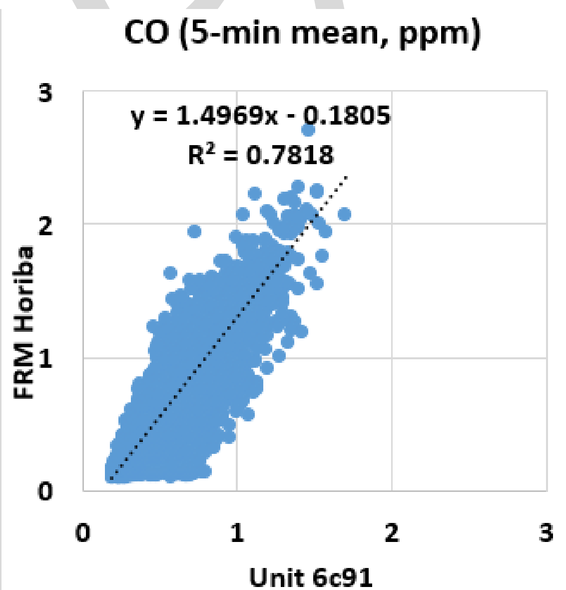


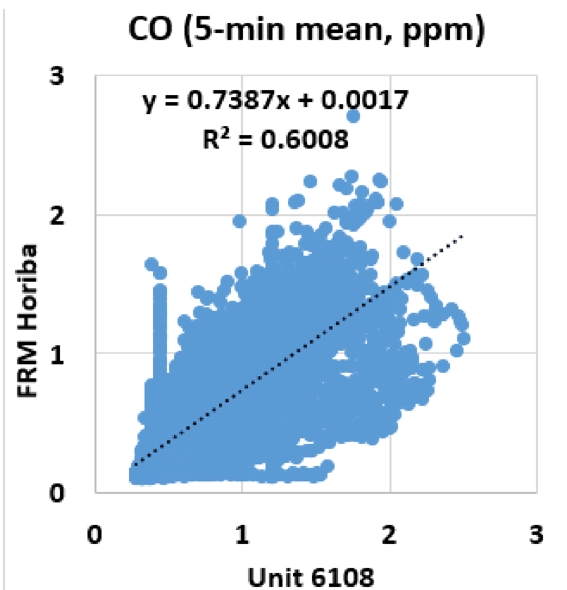
Air Quality Egg 2022 Model vs FRM Horiba (CO; 5-min mean)



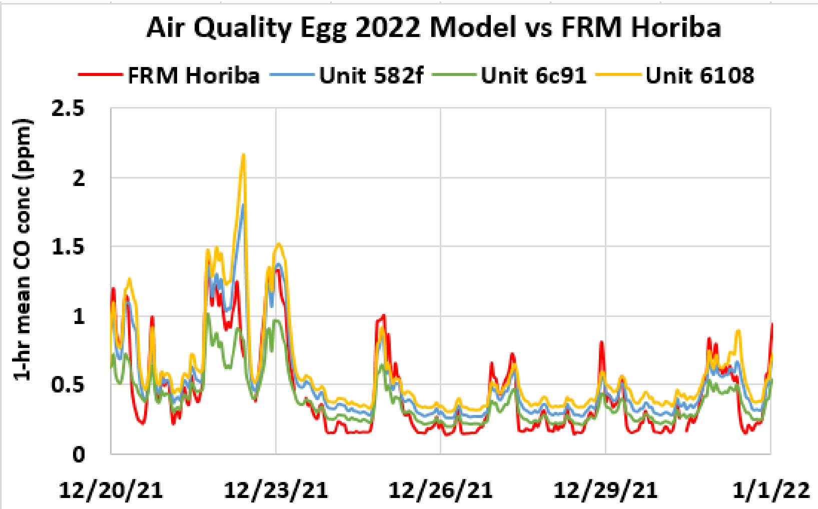
- The Air Quality Egg 2022 Model sensors showed moderate to strong correlations with the corresponding FRM Horiba CO data (0.60 < R^2 < 0.79)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the CO concentration as measured by the FRM Horiba instrument
- The Air Quality Egg 2022 Model sensors seemed to track the diurnal CO variations as recorded by the FRM Horiba instrument



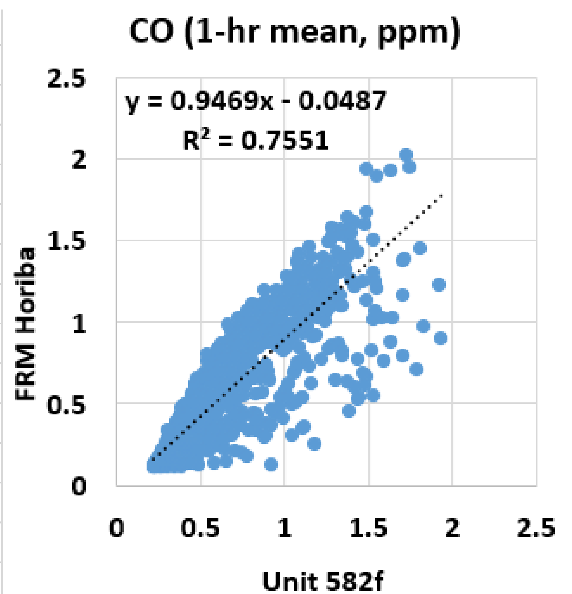


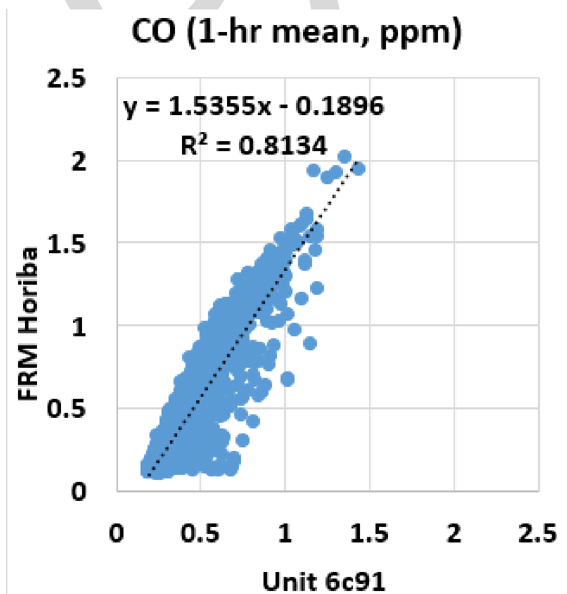


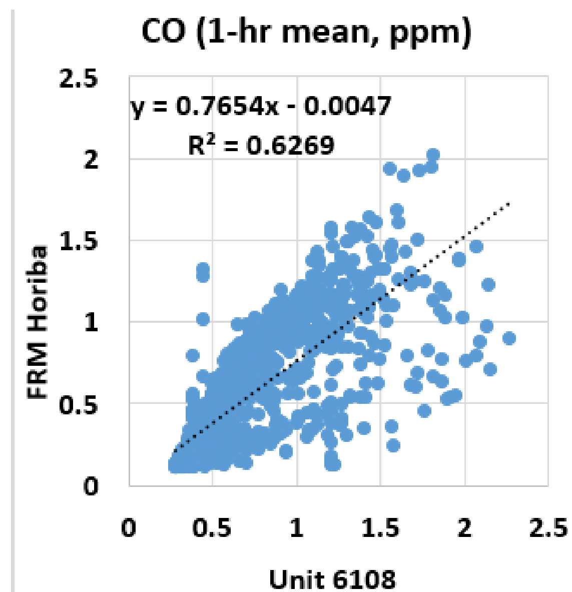
Air Quality Egg 2022 Model vs FRM Horiba (CO; 1-hr mean)



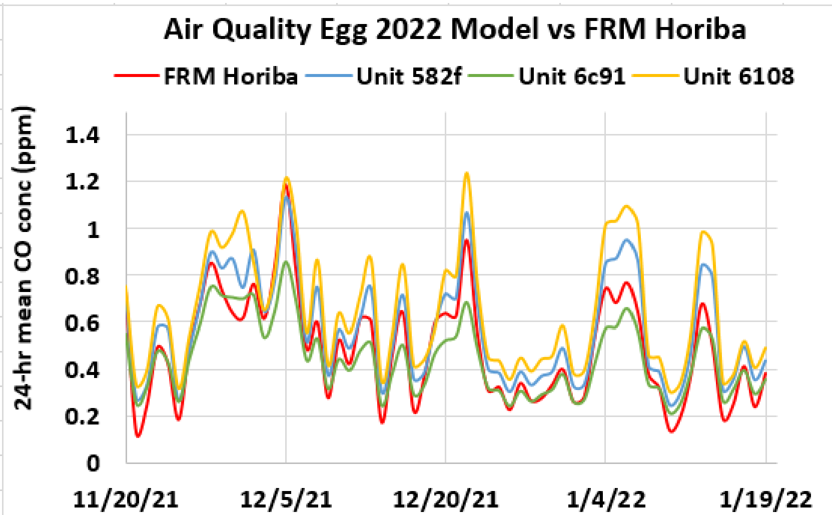
- The Air Quality Egg 2022 Model sensors showed moderate to strong correlations with the corresponding FRM Horiba CO data ($0.62 < R^2 < 0.82$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the CO concentration as measured by the FRM Horiba instrument
- The Air Quality Egg 2022 Model sensors seemed to track the diurnal CO variations as recorded by the FRM Horiba instrument



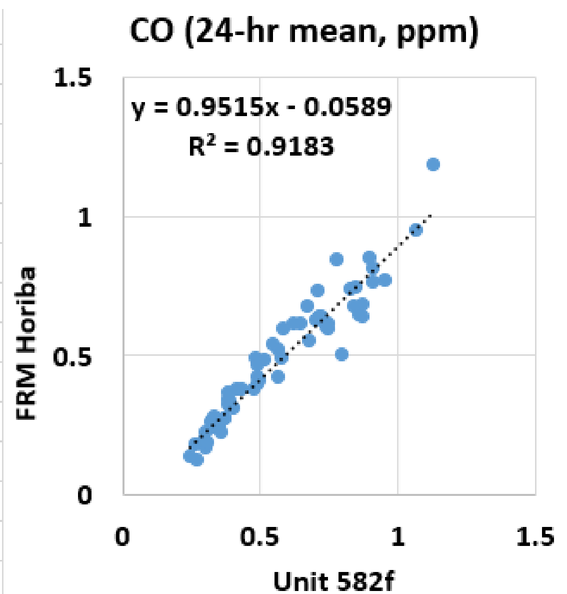


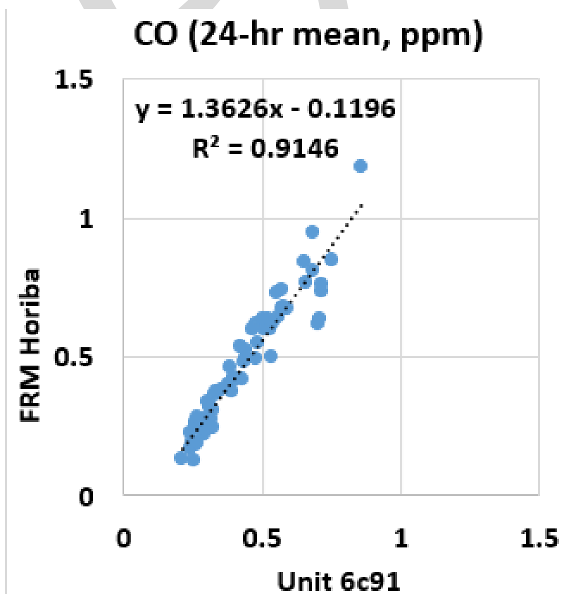


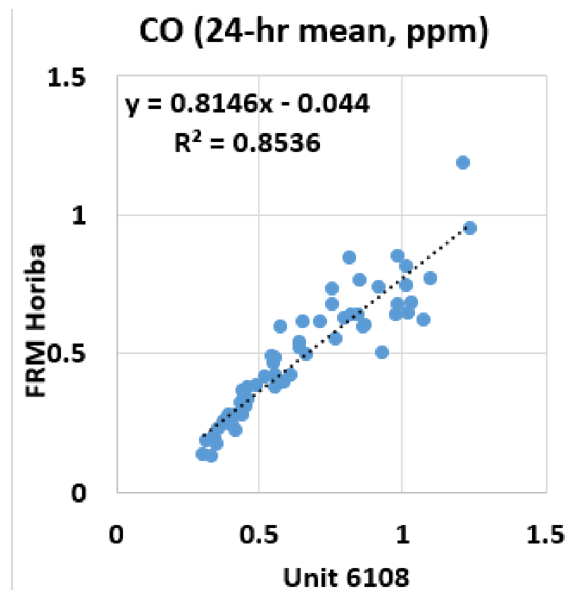
Air Quality Egg 2022 Model vs FRM Horiba (CO; 24-hr mean)



- The Air Quality Egg 2022 Model sensors showed strong to very strong correlations with the corresponding FRM Horiba CO data (0.85 < R^2 < 0.92)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the CO concentration as measured by the FRM Horiba instrument
- The Air Quality Egg 2022 Model sensors seemed to track the diurnal CO variations as recorded by the FRM Horiba instrument







Summary: CO

	Average of 3 Sensors CO		Air Quality Egg 2022 Model vs FRM Horiba, CO						FRM Horiba, CO (ppm)		
	Average (ppm)	SD (ppm)	R^2	Slope	Intercept	MBE[1] (ppm)	MAE[2] (ppm)	RMSE[3] (ppm)	Ref. Average	Ref. SD	Range during the field evaluation
5-min	0.56	0.31	0.60 to 0.78	0.74 to 1.50	-0.18 to 0.00	-0.04 to 0.17	0.15 to 0.21	0.20 to 0.30	0.48	0.36	0.10 to 2.70
1-hr	0.56	0.30	0.63 to 0.81	0.77 to 1.54	-0.19 to 0.00	-0.05 to 0.16	0.14 to 0.20	0.19 to 0.28	0.49	0.36	0.11 to 2.02
24-hr	0.56	0.22	0.85 to 0.92	0.81 to 1.36	-0.12 to -0.04	-0.04 to 0.16	0.07 to 0.17	0.10 to 0.19	0.49	0.23	0.13 to 1.19

[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.

Particulate Matter (PM) in Air Quality Egg 2022 Model

PM Data Handling

- The Wicked Device – Air Quality Egg 2022 Model sensor uses a combination of two Plantower PMS5003 nephelometric optical particle sensors (OPS) to characterize $PM_{1.0}$, $PM_{2.5}$, and PM_{10}. As of this writing, the data download web portal only allows users to download the PM value from the aggregation of the two OPS, and not data from an individual OPS.

- Manufacturer statement:

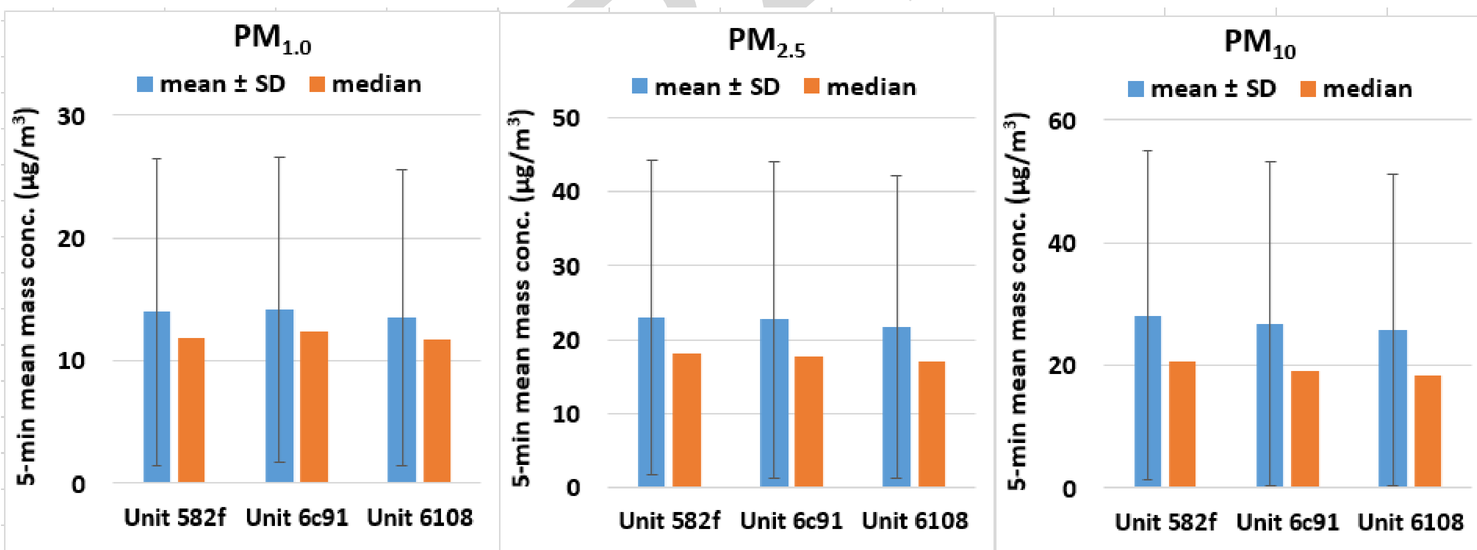
  "The Air Quality Eggs [2022 Model] use an aggregate value of two PMS 5003 nephelometers to characterize PM1.0, PM2.5 and PM10. The average mean value of the two nephelometers is used if both sensors are reporting reliably, otherwise the aggregate value reflects the value of the single working sensor. The AQI calculation is also based on the aggregate."

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

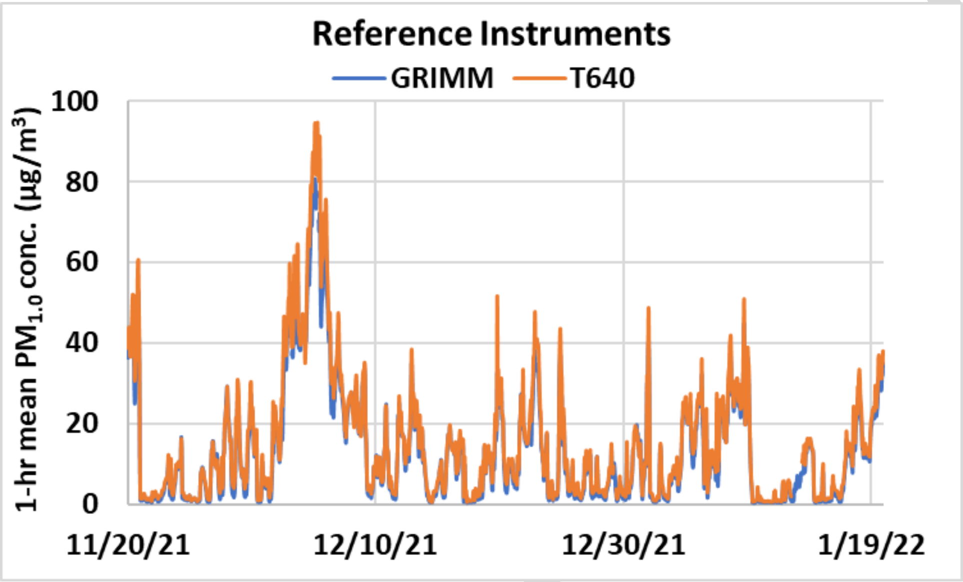
Air Quality Egg 2022 Model; intra-model variability

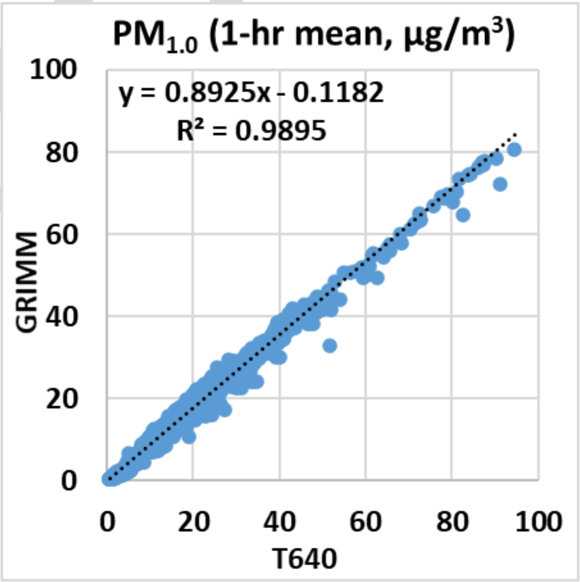
- Absolute intra-model variability was ~ 0.29, 0.63, and 1.14 µg/m^3 for $PM_{1.0}$, $PM_{2.5}$ and PM_{10}, respectively (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 2.1%, 2.8%, and 4.2% for $PM_{1.0}$, $PM_{2.5}$ and PM_{10}, respectively (calculated as the absolute intra-model variability relative to the mean of the three sensor means)



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

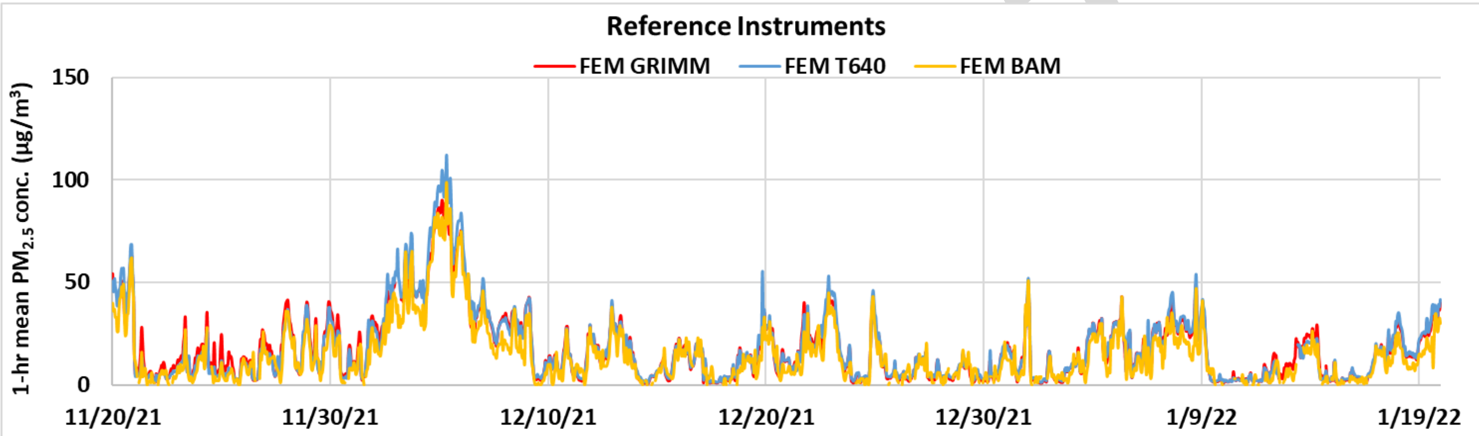
- Data recovery for $PM_{1.0}$ from GRIMM and T640 was ~98% and 98%, respectively.
- Very strong correlations between the reference instruments for $PM_{1.0}$ measurements (R^2 ~ 0.99) were observed.

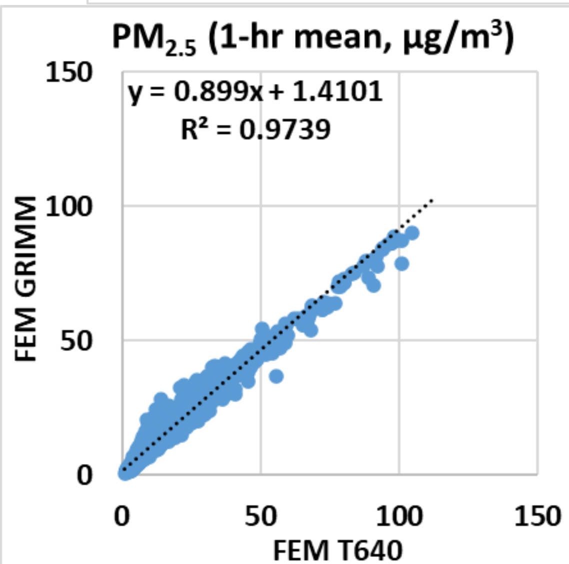


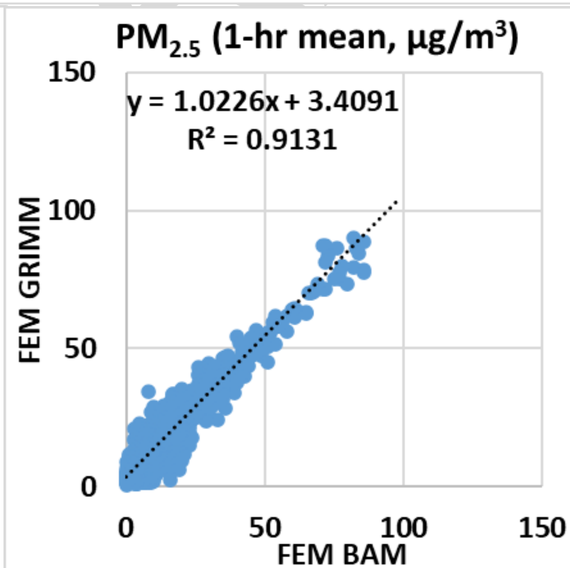


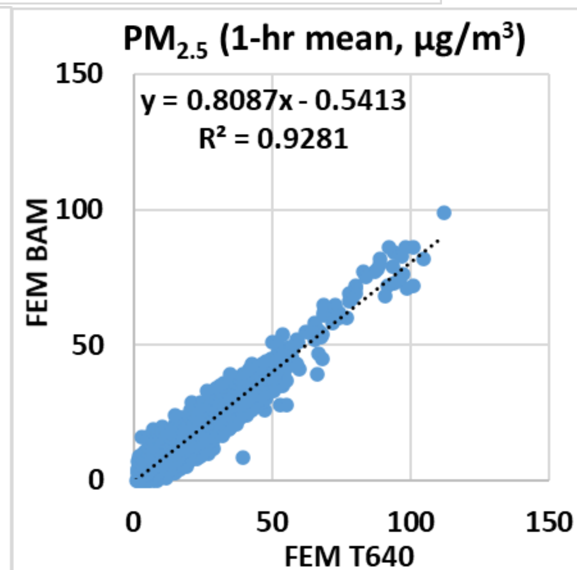
Reference Instruments: $PM_{2.5}$
FEM BAM, FEM GRIMM and FEM T640

- Data recovery for $PM_{2.5}$ from FEM BAM, FEM GRIMM and FEM T640 was ~ 90%, 98% and 98%, respectively.
- Very strong correlations between the reference instruments for $PM_{2.5}$ measurements ($0.91 < R^2 < 0.98$) were observed.



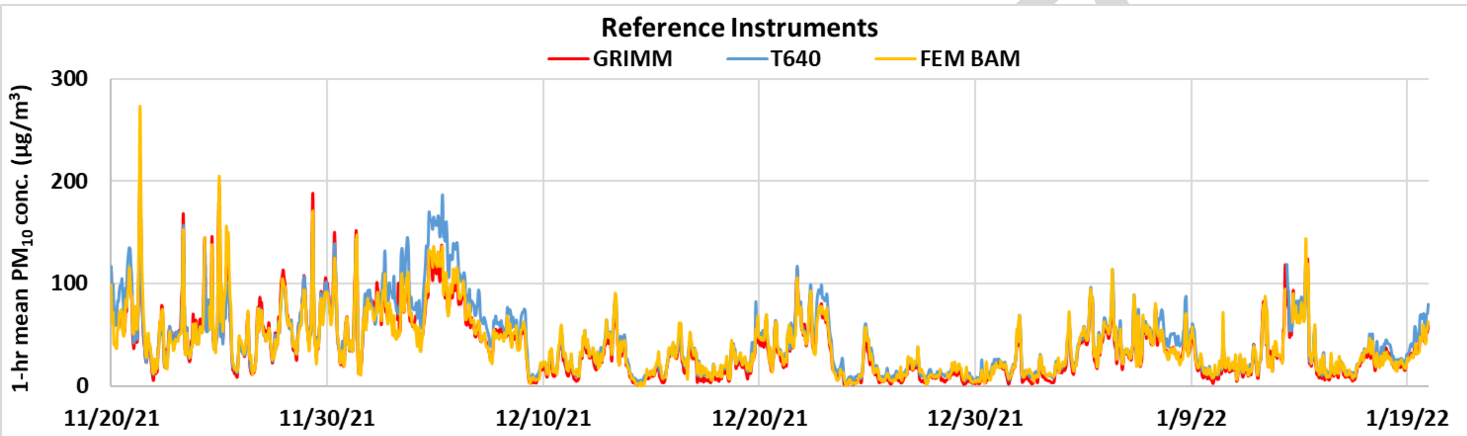


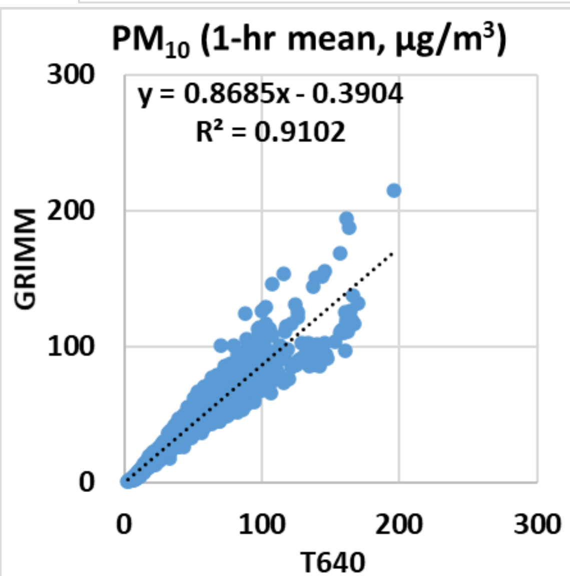


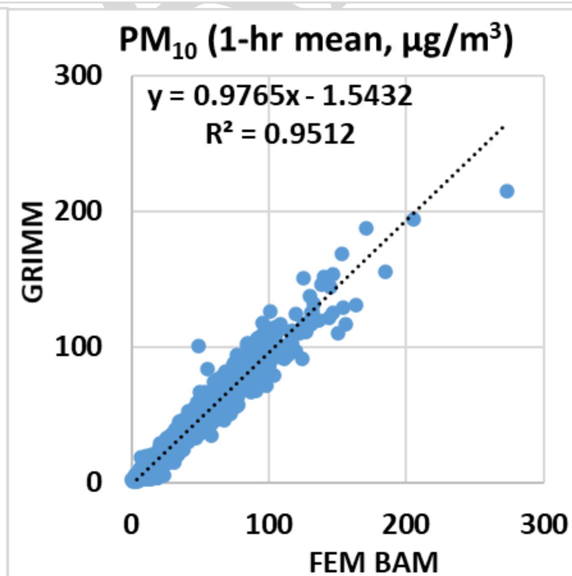


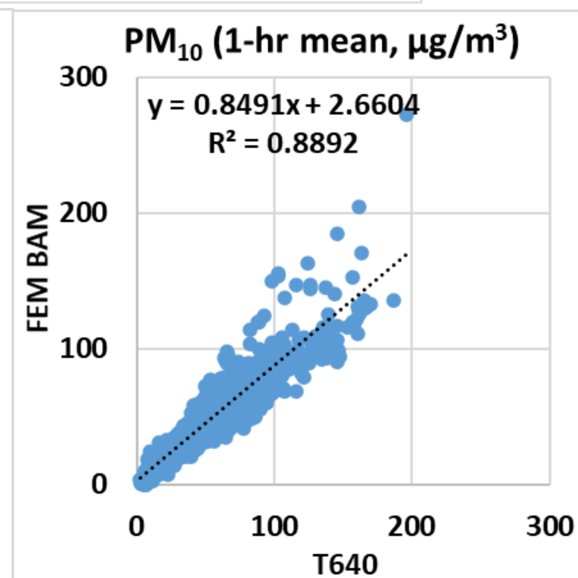
Reference Instruments: PM_{10}
FEM BAM, GRIMM and T640

- Data recovery for PM_{10} from FEM BAM, GRIMM and T640 was ~ 99%, 98% and 98%, respectively.
- Strong to very strong correlations between the reference instruments for PM_{10} measurements ($0.88 < R^2 < 0.96$) were observed.

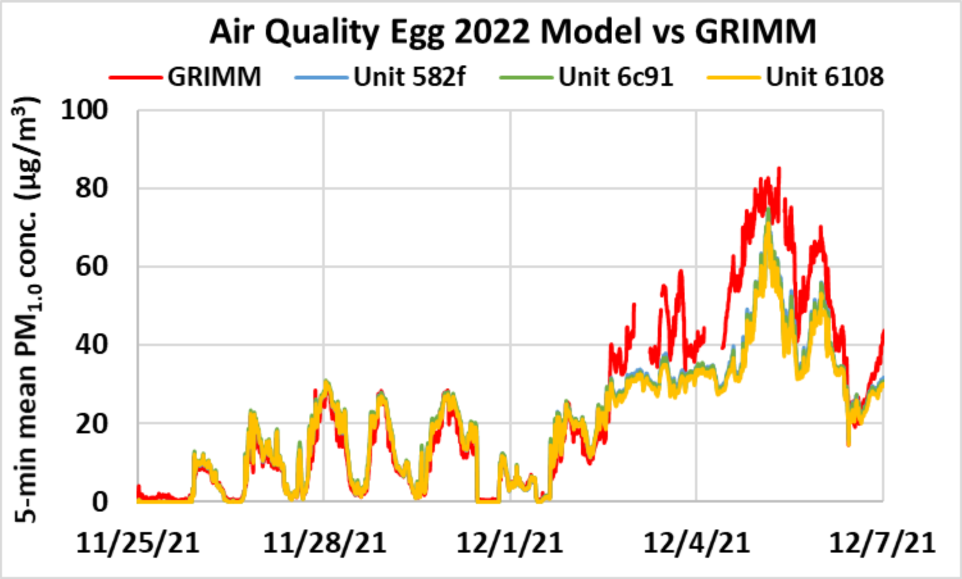




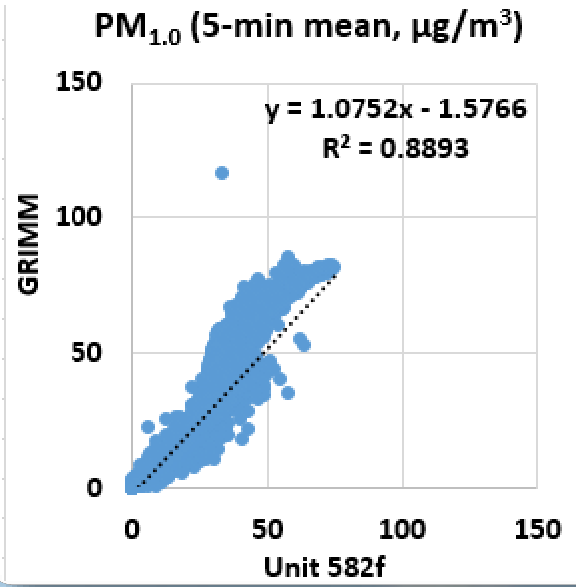


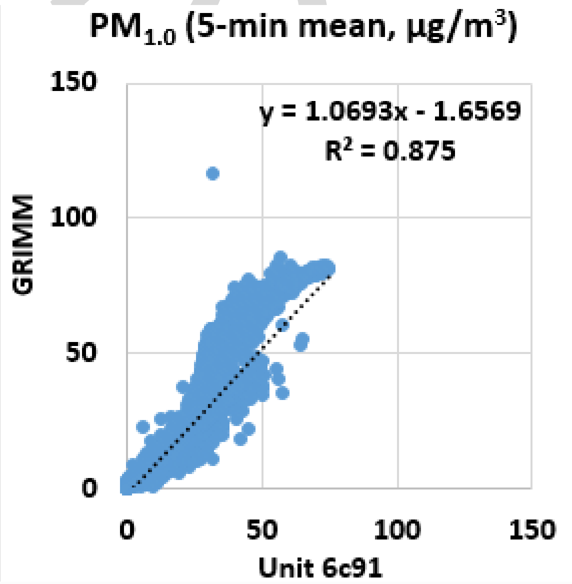


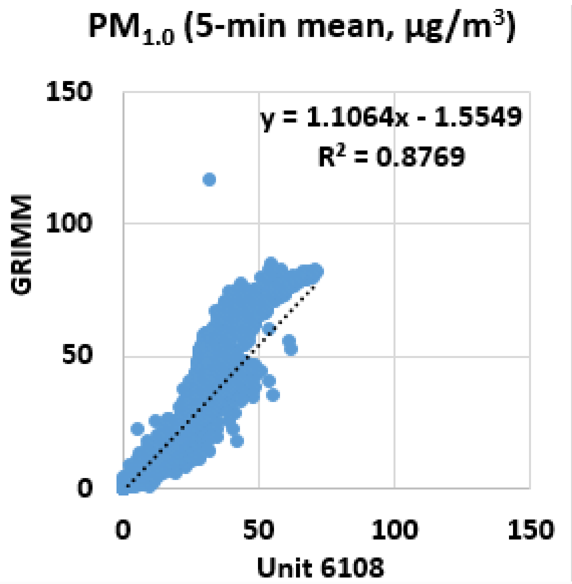
Air Quality Egg 2022 Model vs GRIMM ($PM_{1.0}$; 5-min mean)



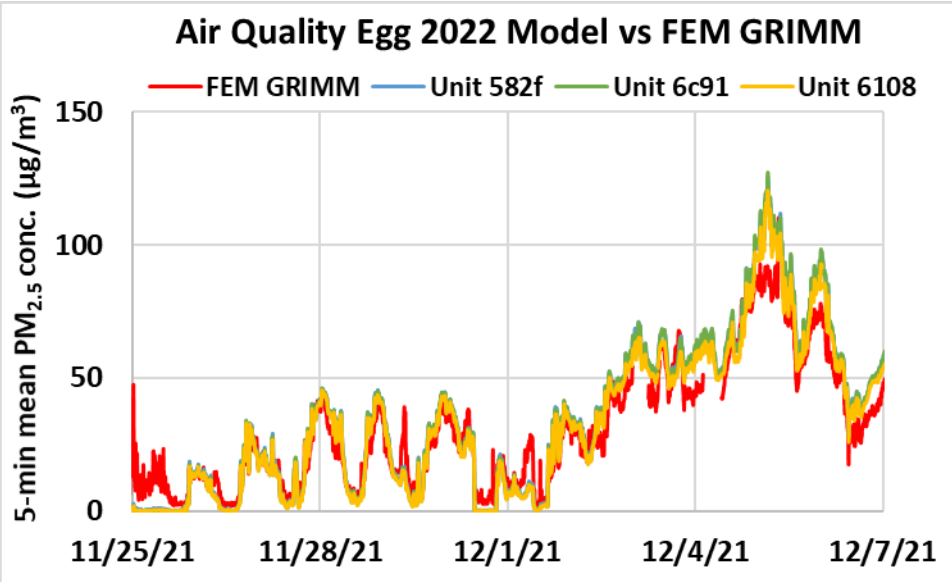
- The Air Quality Egg 2022 Model sensors showed strong correlations with the corresponding GRIMM data ($0.87 < R^2 < 0.89$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the $PM_{1.0}$ mass concentrations as measured by GRIMM
- The Air Quality Egg 2022 Model sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by GRIMM



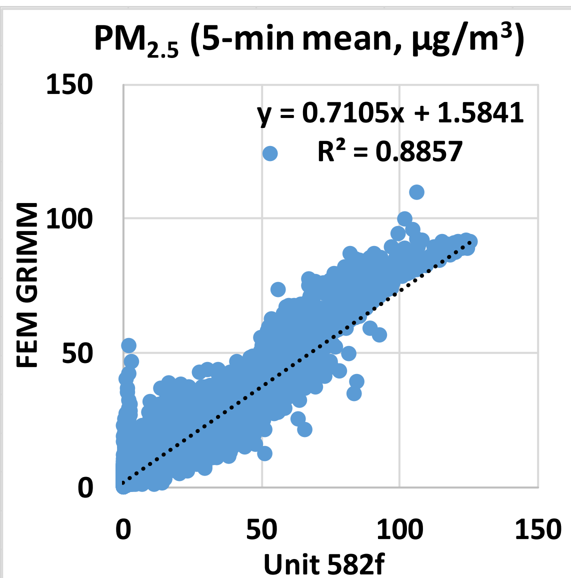


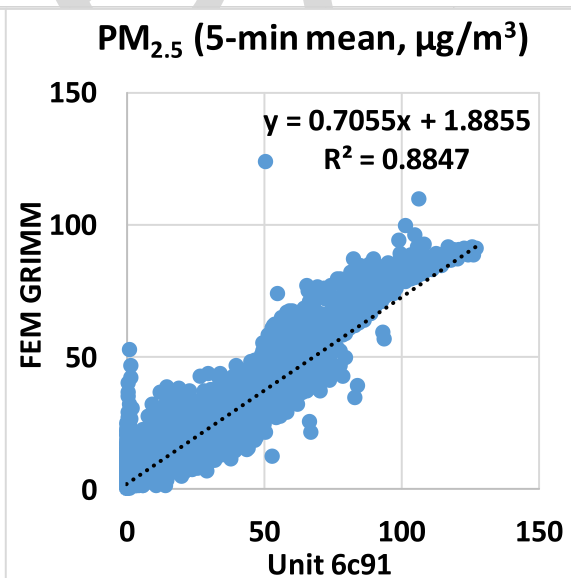


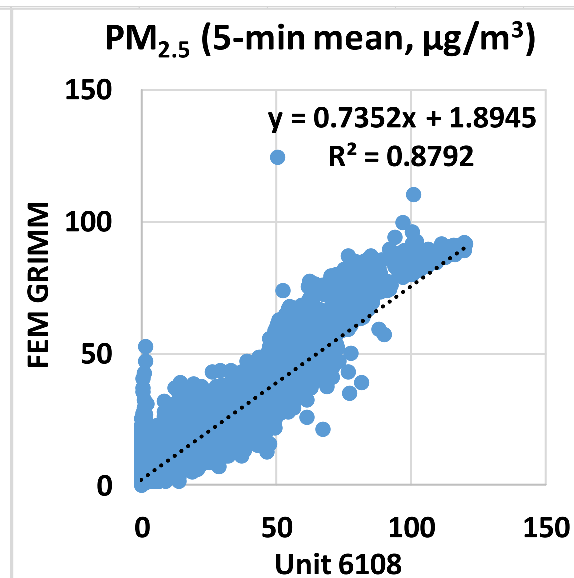
Air Quality Egg 2022 Model vs FEM GRIMM ($PM_{2.5}$; 5-min mean)



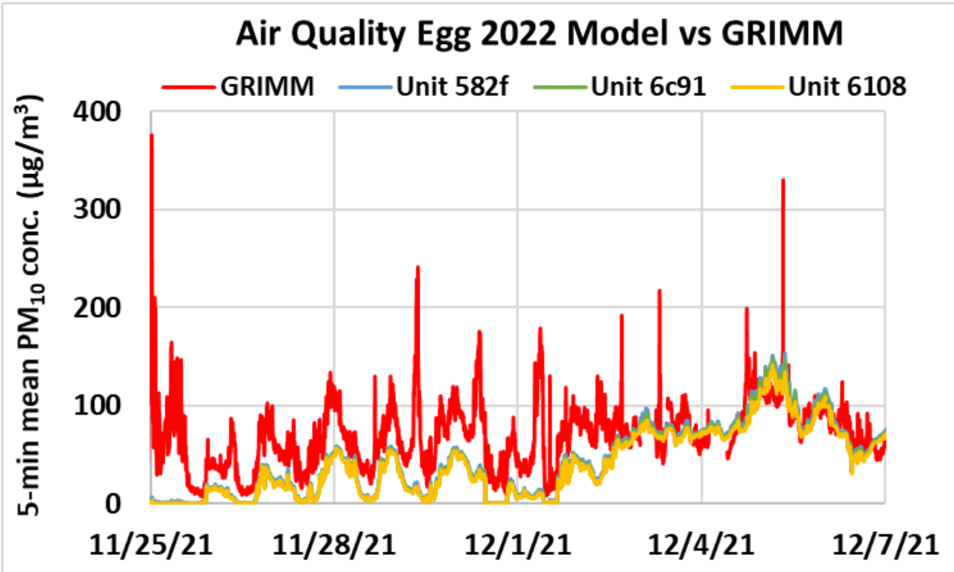
- The Air Quality Egg 2022 Model sensors showed strong correlations with the corresponding FEM GRIMM data ($0.87 < R^2 < 0.89$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM GRIMM
- The Air Quality Egg 2022 Model sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM



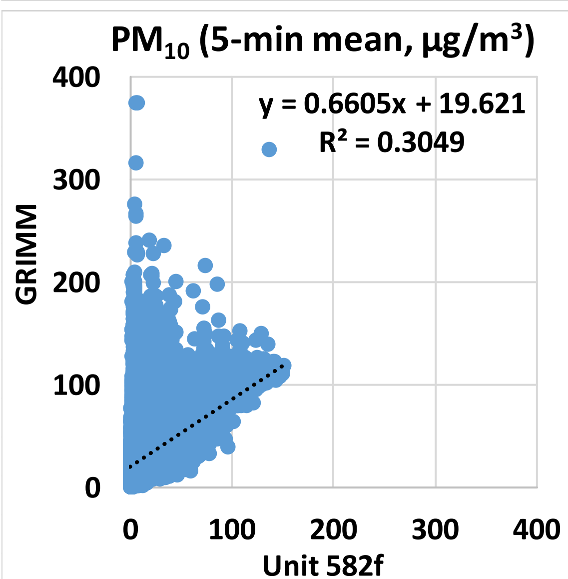


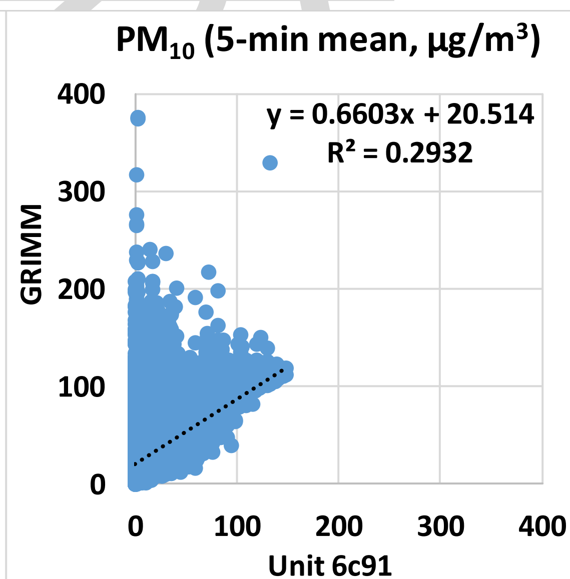


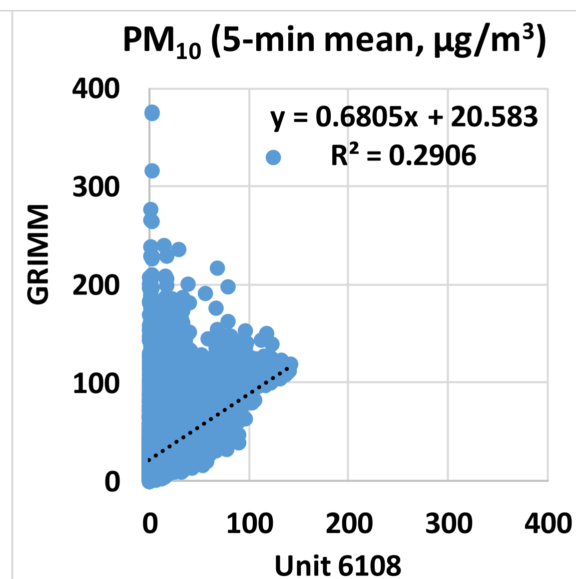
Air Quality Egg 2022 Model vs GRIMM (PM_{10}; 5-min mean)



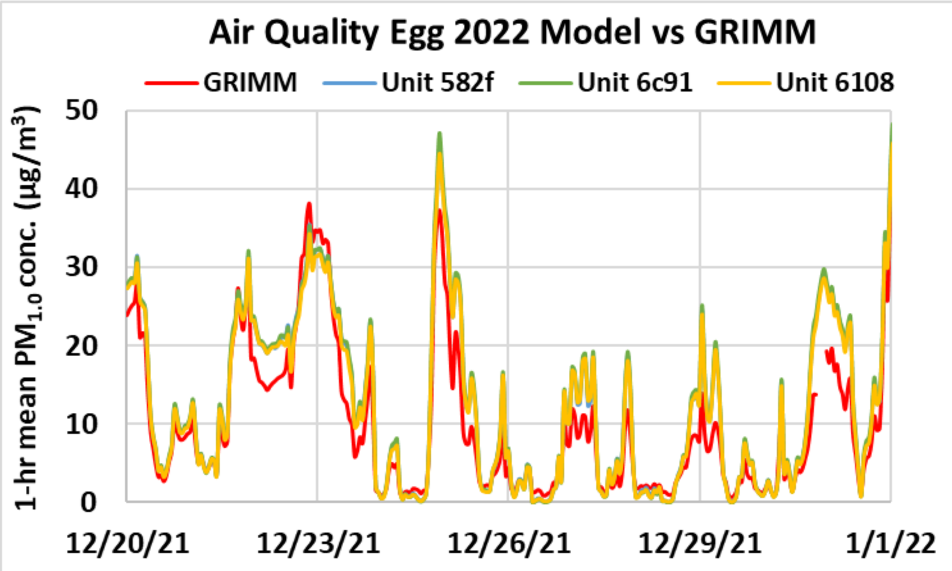
- The Air Quality Egg 2022 Model sensors showed very weak to weak correlations with the corresponding GRIMM data ($0.29 < R^2 < 0.31$)
- Overall, the Air Quality Egg 2022 Model sensors underestimated the PM_{10} mass concentrations as measured by GRIMM
- The Air Quality Egg 2022 Model sensors did not seem to track the PM_{10} diurnal variations as recorded by GRIMM



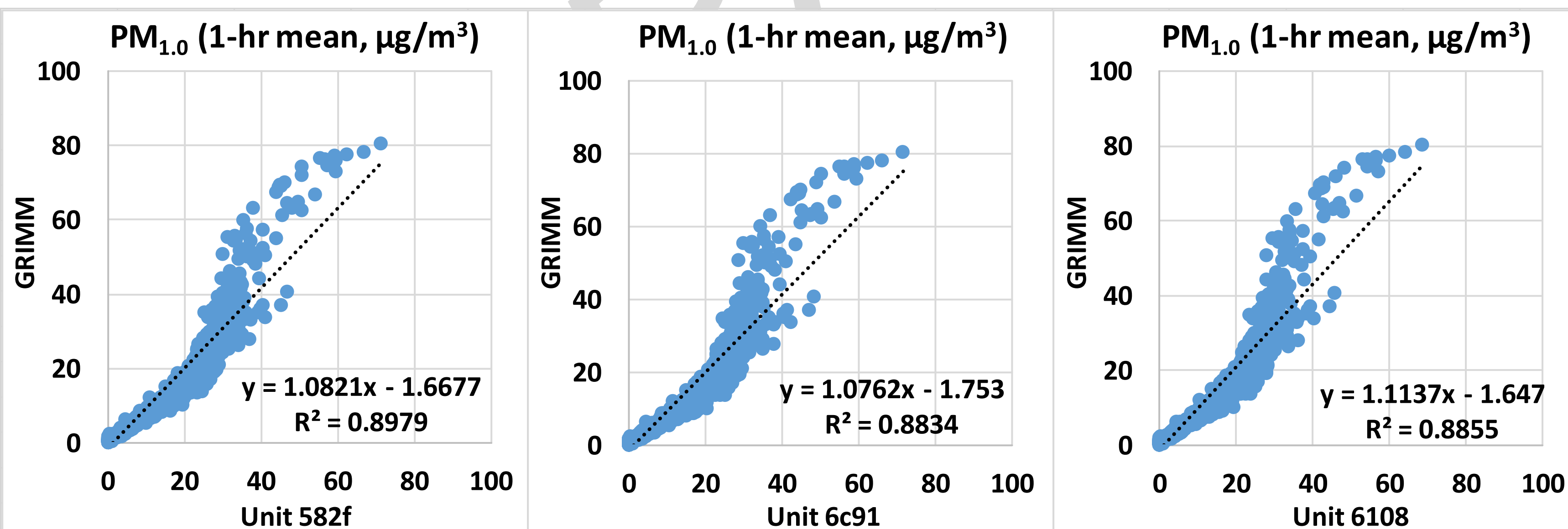




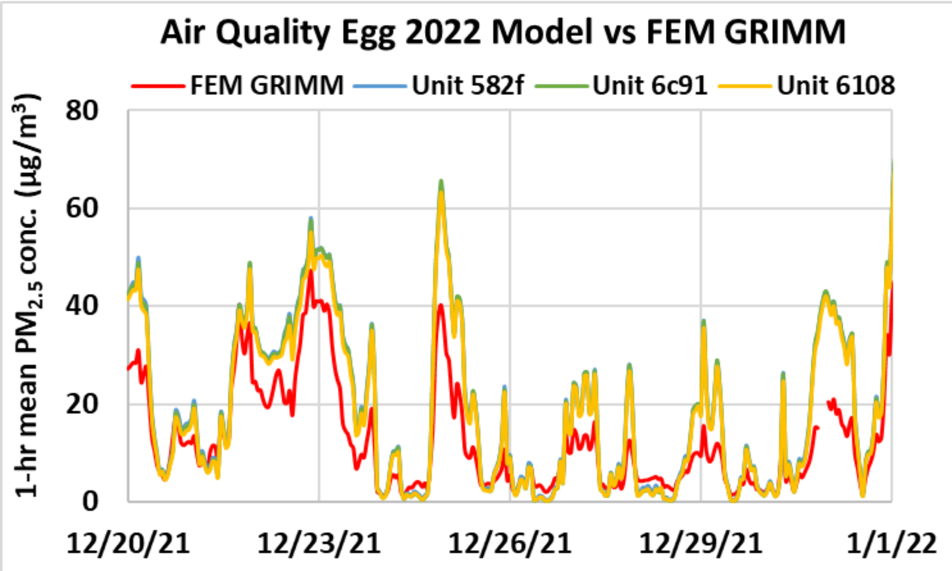
Air Quality Egg 2022 Model vs GRIMM ($PM_{1.0}$; 1-hr mean)



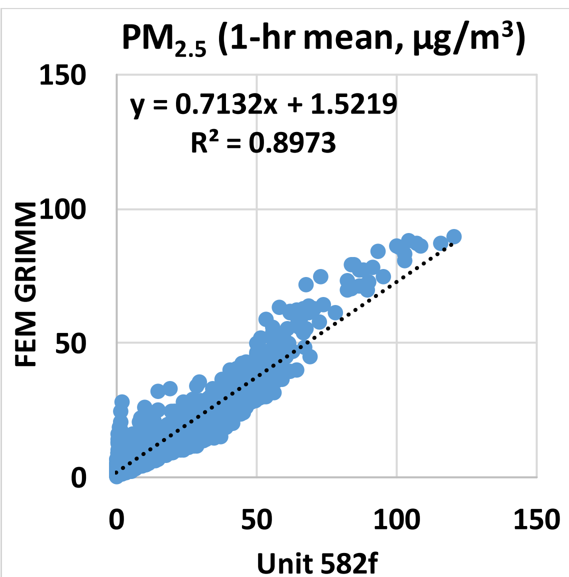
- The Air Quality Egg 2022 Model sensors showed strong correlations with the corresponding GRIMM data ($0.88 < R^2 < 0.90$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the $PM_{1.0}$ mass concentrations as measured by GRIMM
- The Air Quality Egg 2022 Model sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by GRIMM

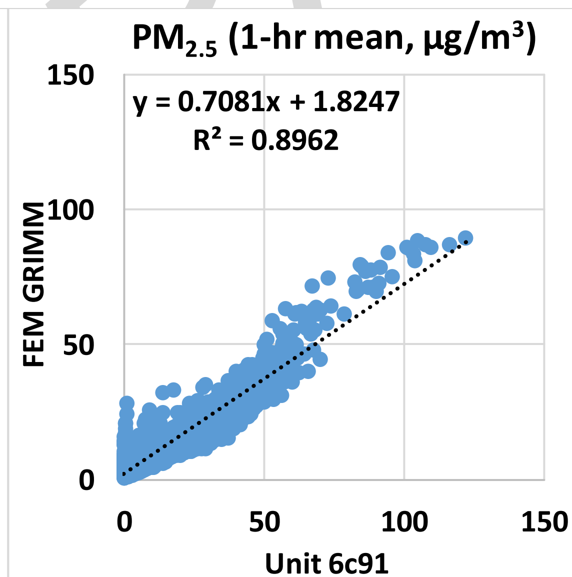


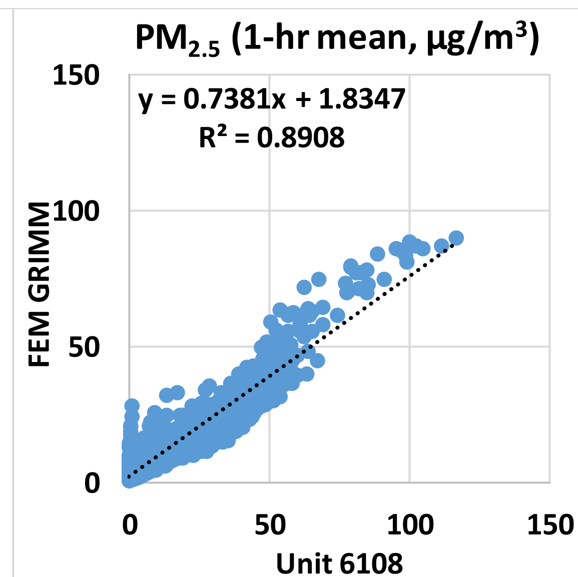
Air Quality Egg 2022 Model vs FEM GRIMM ($PM_{2.5}$; 1-hr mean)



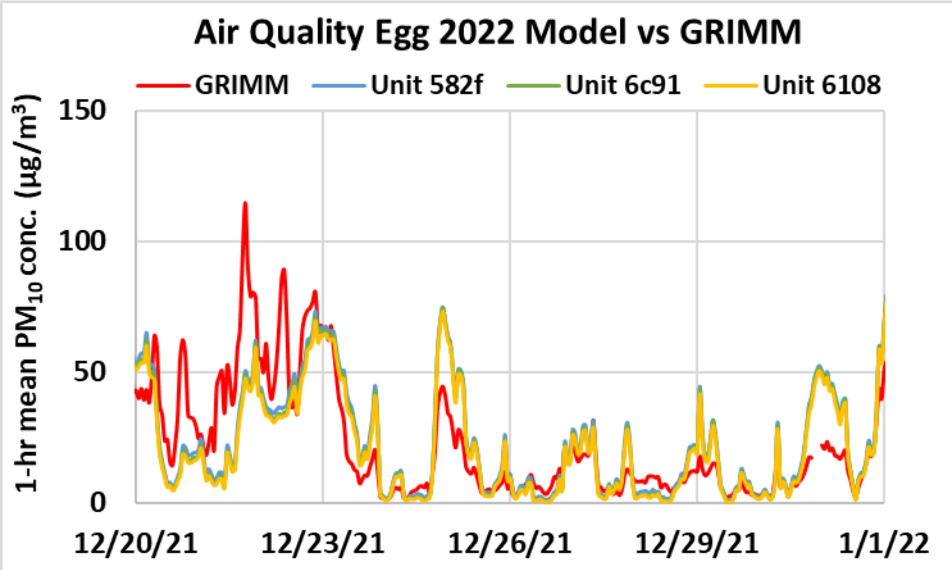
- The Air Quality Egg 2022 Model sensors showed strong correlations with the corresponding FEM GRIMM data ($0.89 < R^2 < 0.90$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM GRIMM
- The Air Quality Egg 2022 Model sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM



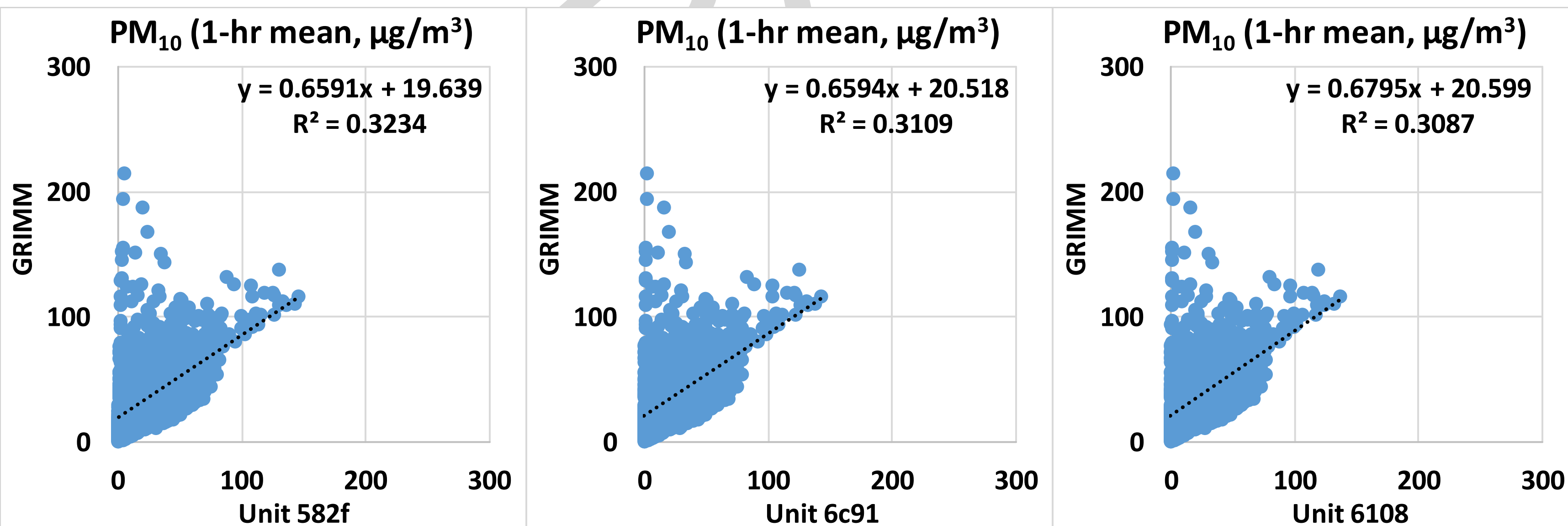




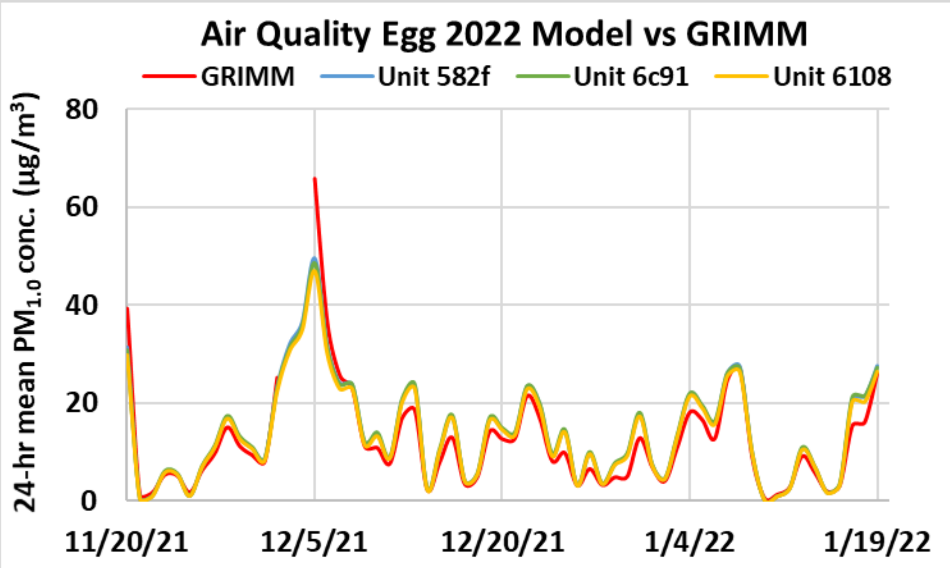
Air Quality Egg 2022 Model vs GRIMM (PM_{10}; 1-hr mean)



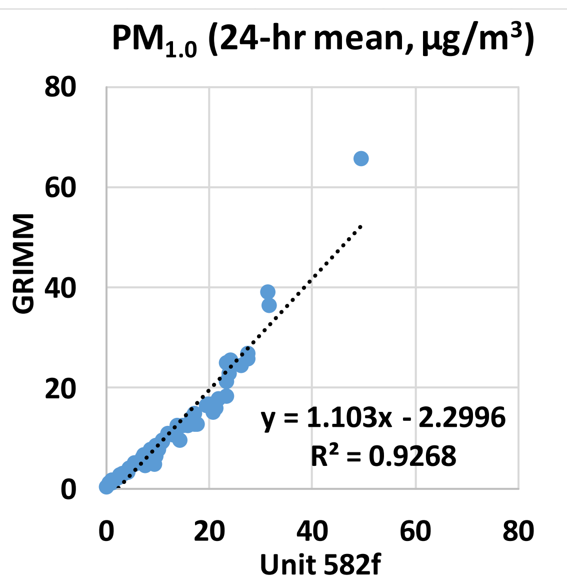
- The Air Quality Egg 2022 Model sensors showed weak correlations with the corresponding GRIMM data ($0.30 < R^2 < 0.33$)
- Overall, the Air Quality Egg 2022 Model sensors underestimated the PM_{10} mass concentrations as measured by GRIMM
- The Air Quality Egg 2022 Model sensors did not seem to track the PM_{10} diurnal variations as recorded by GRIMM

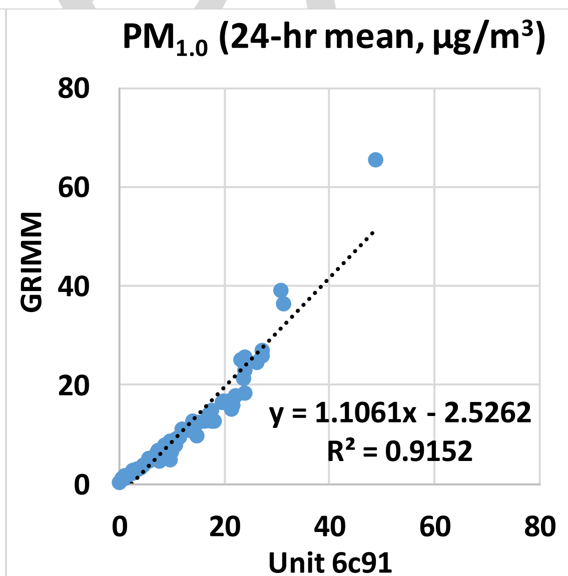


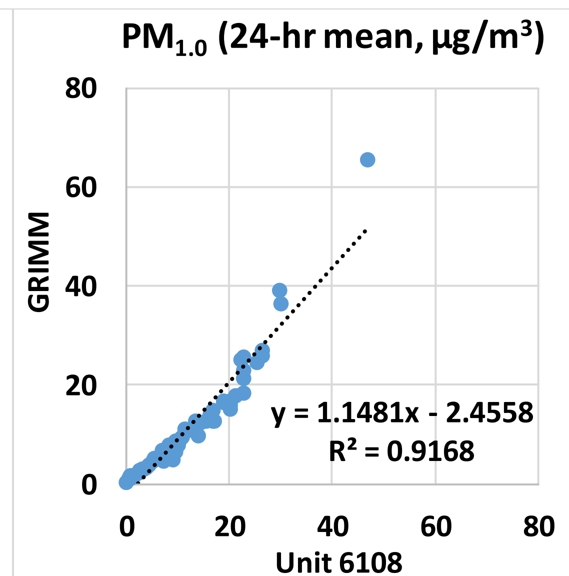
Air Quality Egg 2022 Model vs GRIMM ($PM_{1.0}$; 24-hr mean)



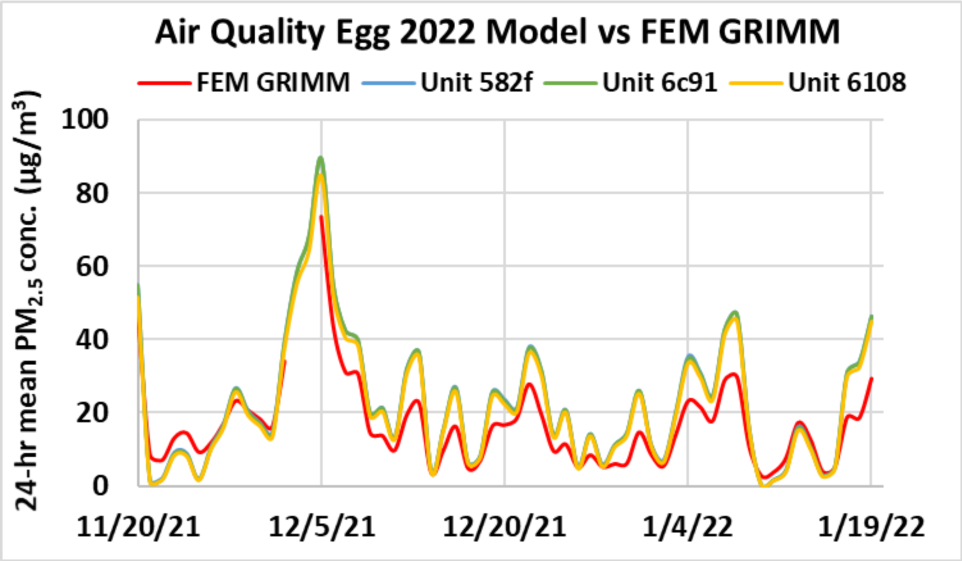
- The Air Quality Egg 2022 Model sensors showed very strong correlations with the corresponding GRIMM data ($0.91 < R^2 < 0.93$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the $PM_{1.0}$ mass concentrations as measured by GRIMM
- The Air Quality Egg 2022 Model sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by GRIMM



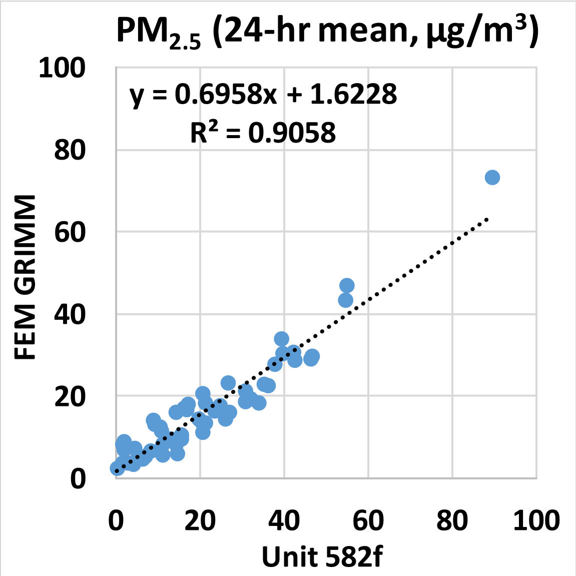


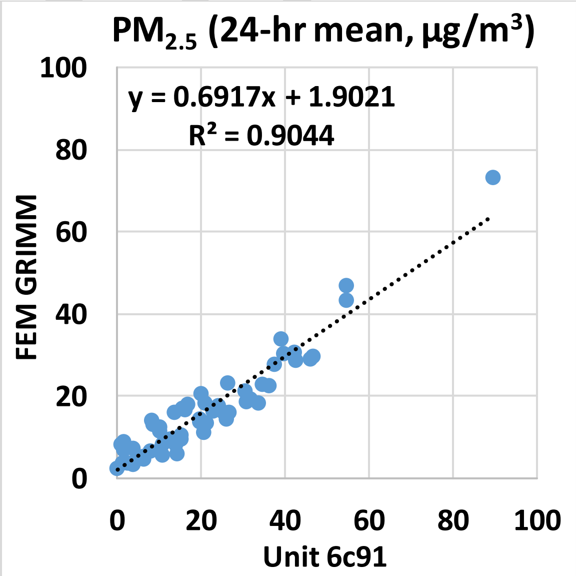


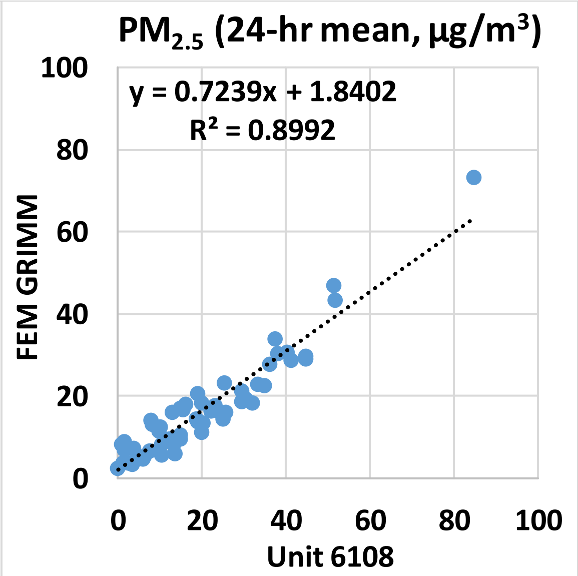
Air Quality Egg 2022 Model vs FEM GRIMM ($PM_{2.5}$; 24-hr mean)



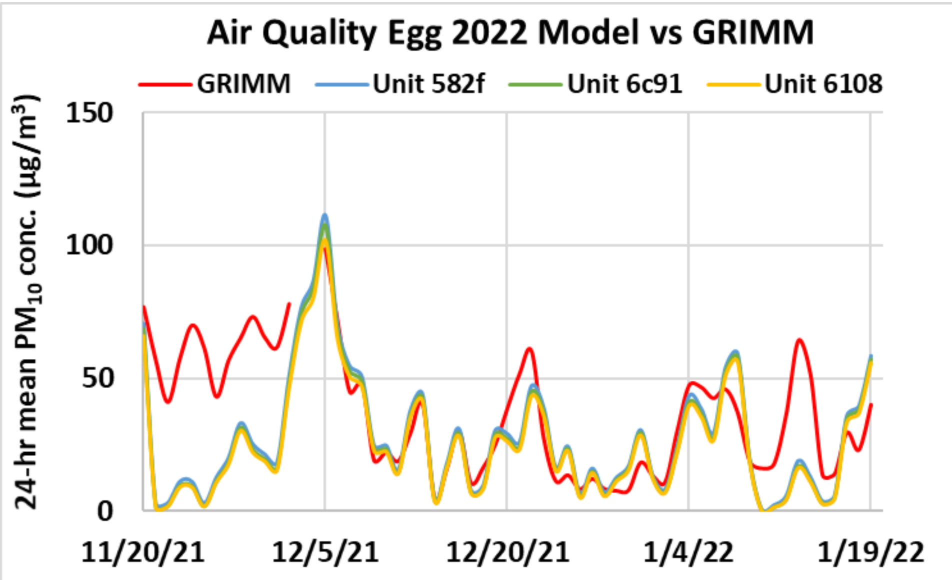
- The Air Quality Egg 2022 Model sensors showed strong to very strong correlations with the corresponding FEM GRIMM data ($0.89 < R^2 < 0.91$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM GRIMM
- The Air Quality Egg 2022 Model sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM



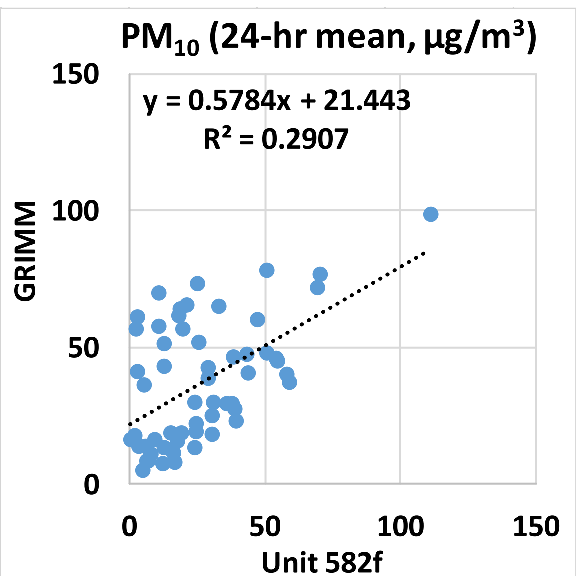


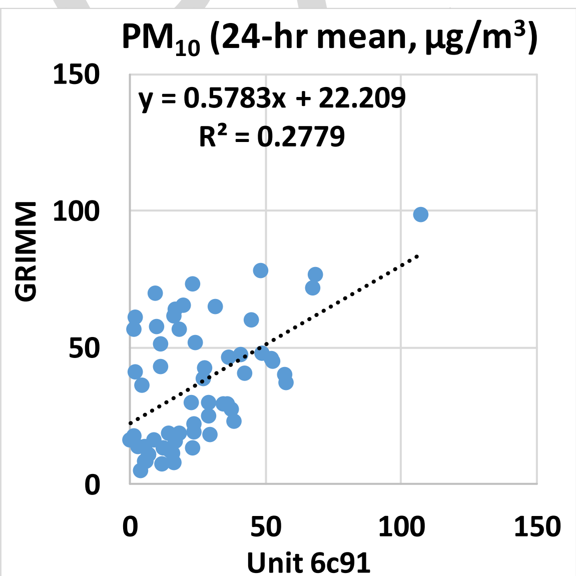


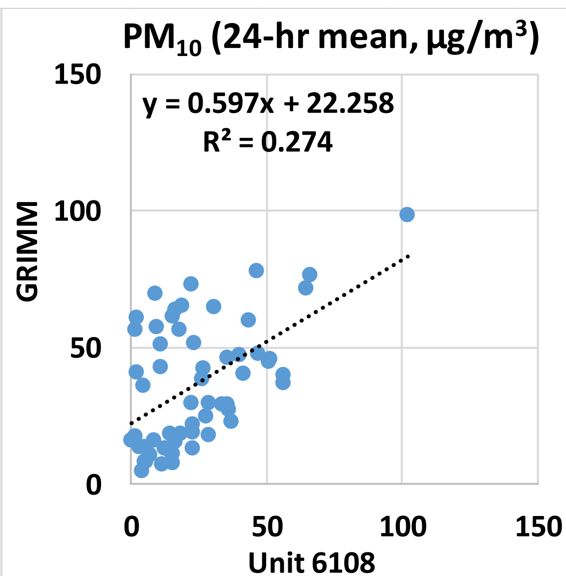
Air Quality Egg 2022 Model vs GRIMM (PM_{10}; 24-hr mean)



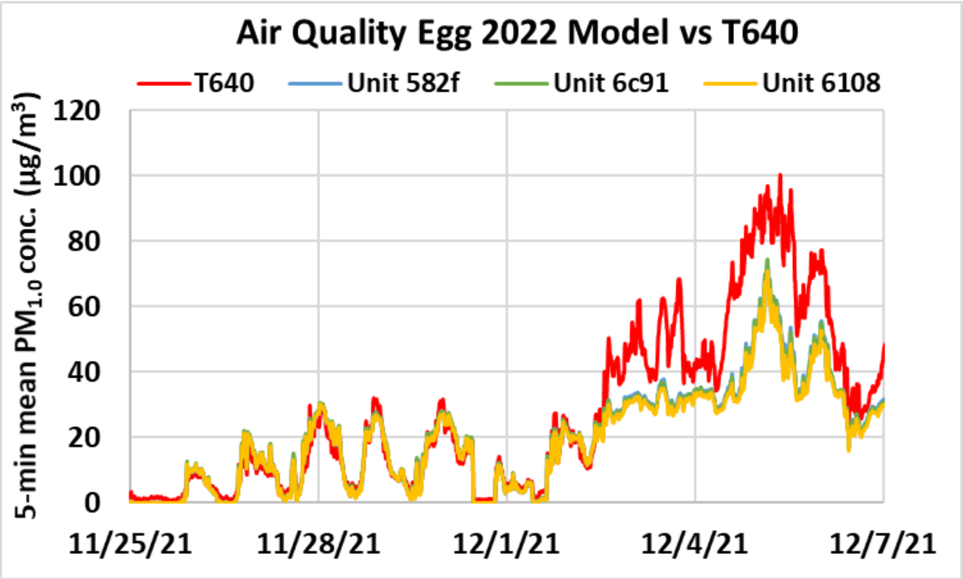
- The Air Quality Egg 2022 Model sensors showed very weak correlations with the corresponding GRIMM data (0.27 < R^2 < 0.30)
- Overall, the Air Quality Egg 2022 Model sensors underestimated the PM_{10} mass concentrations as measured by GRIMM
- The Air Quality Egg 2022 Model sensors did not seem to track the PM_{10} diurnal variations as recorded by GRIMM



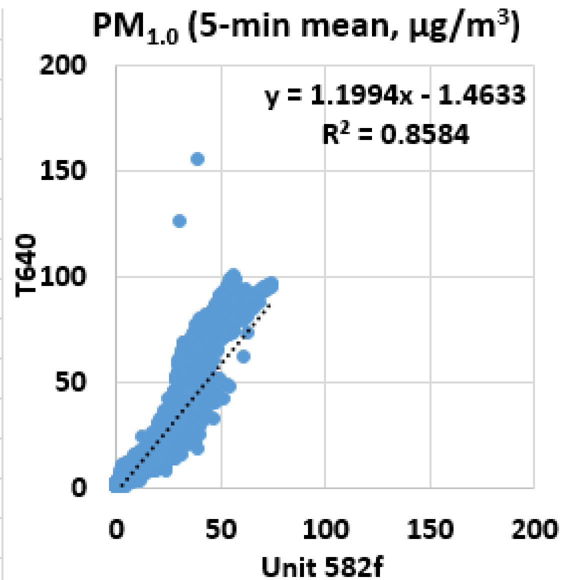


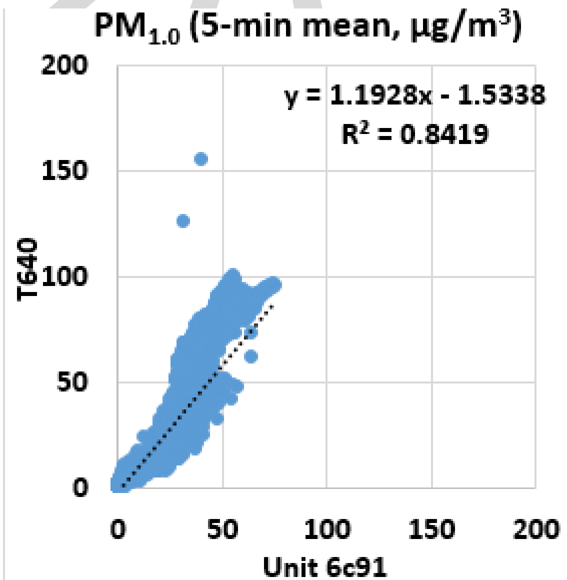


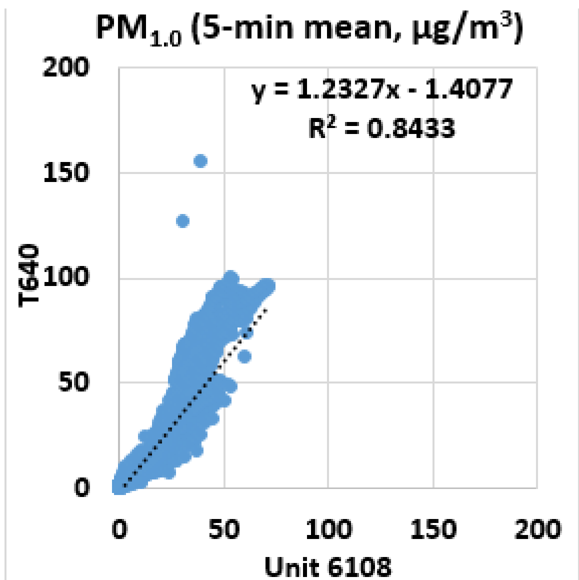
Air Quality Egg 2022 Model vs T640 ($PM_{1.0}$; 5-min mean)



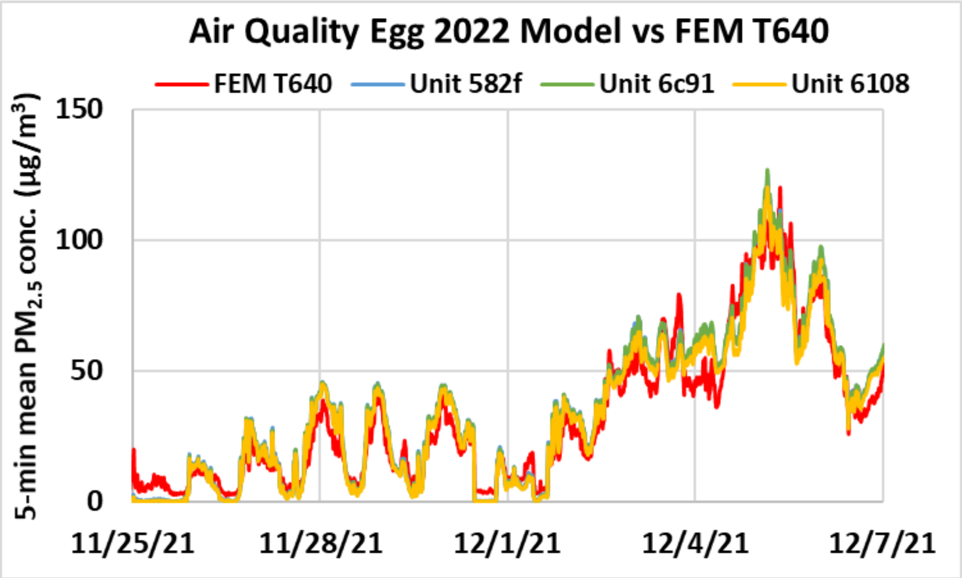
- The Air Quality Egg 2022 Model sensors showed strong correlations with the corresponding T640 data ($0.84 < R^2 < 0.86$)
- Overall, the Air Quality Egg 2022 Model sensors underestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The Air Quality Egg 2022 Model sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640



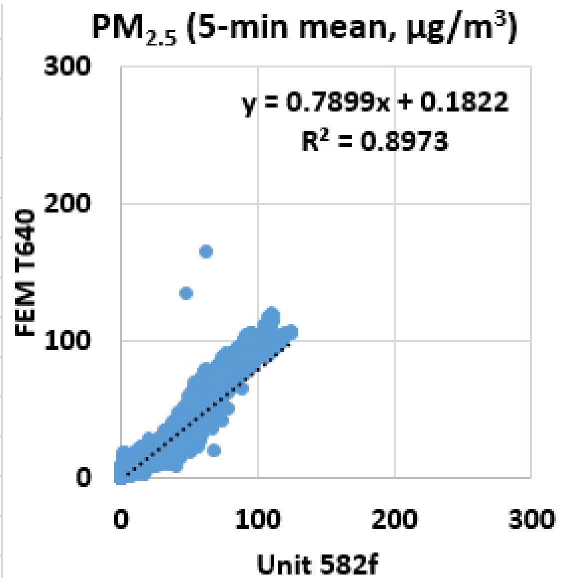


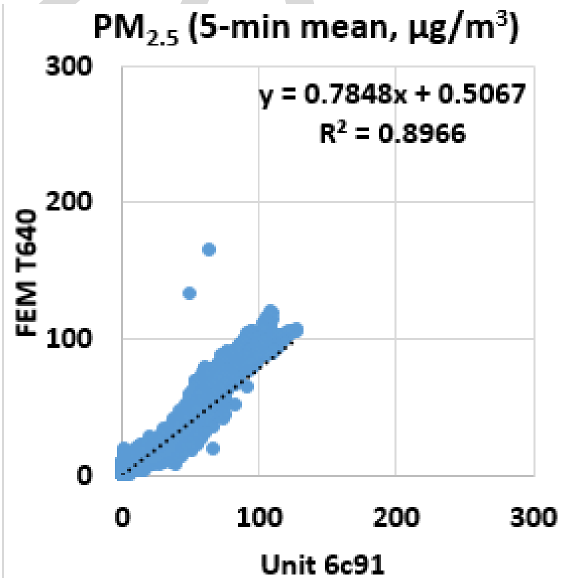


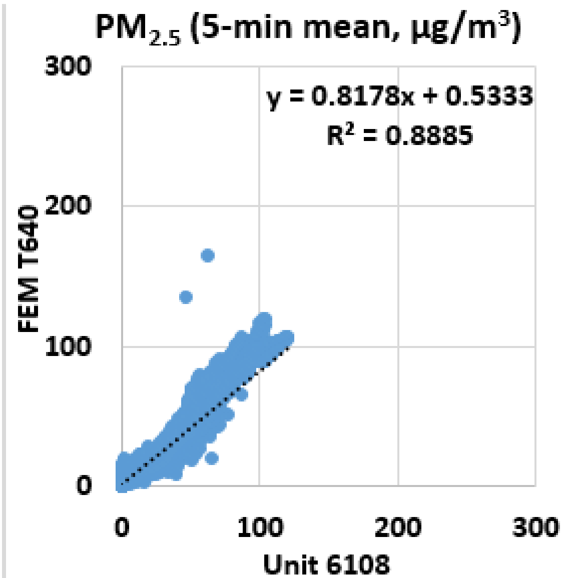
Air Quality Egg 2022 Model vs FEM T640 ($PM_{2.5}$; 5-min mean)



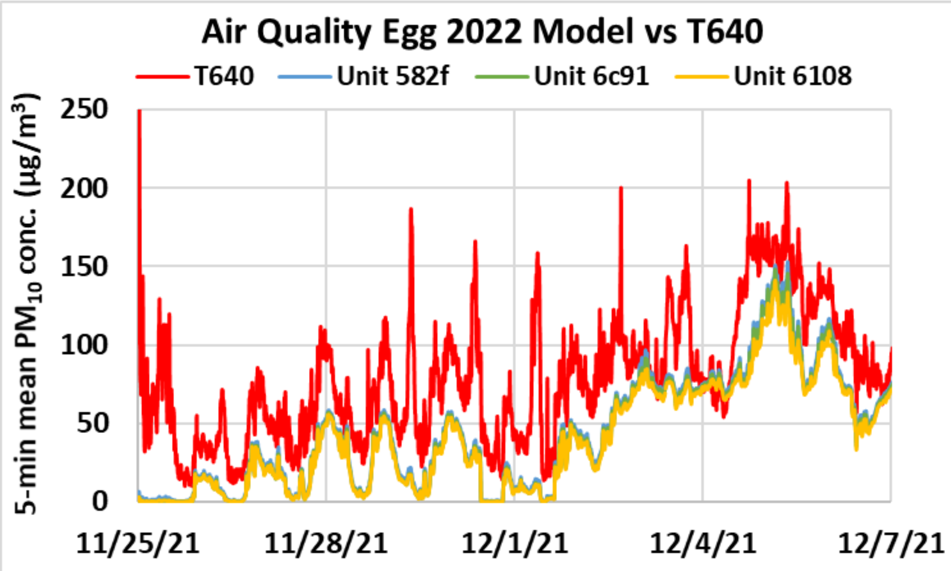
- The Air Quality Egg 2022 Model sensors showed strong correlations with the corresponding FEM T640 data ($0.88 < R^2 < 0.90$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The Air Quality Egg 2022 Model sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



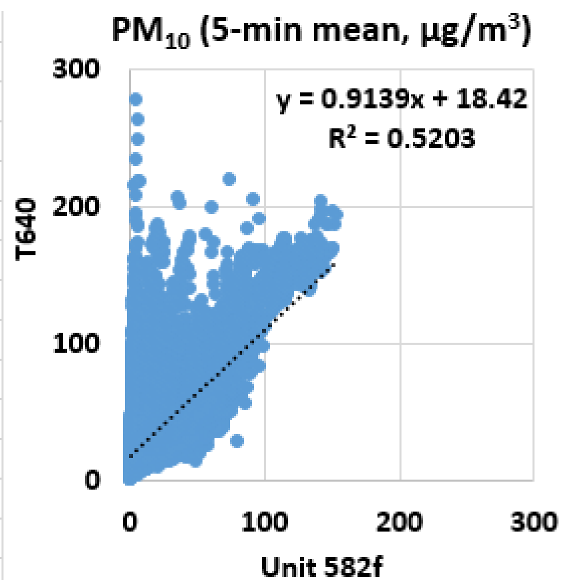


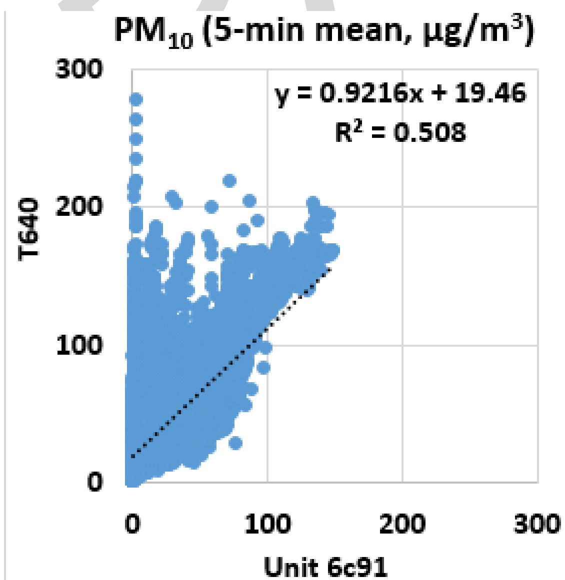


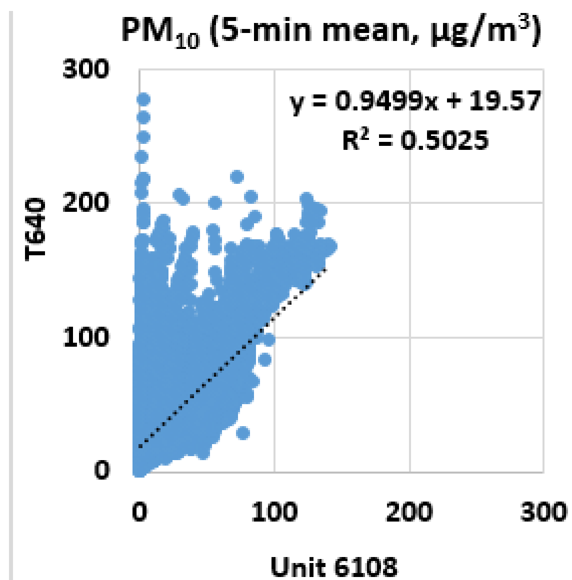
Air Quality Egg 2022 Model vs T640 (PM_{10}; 5-min mean)



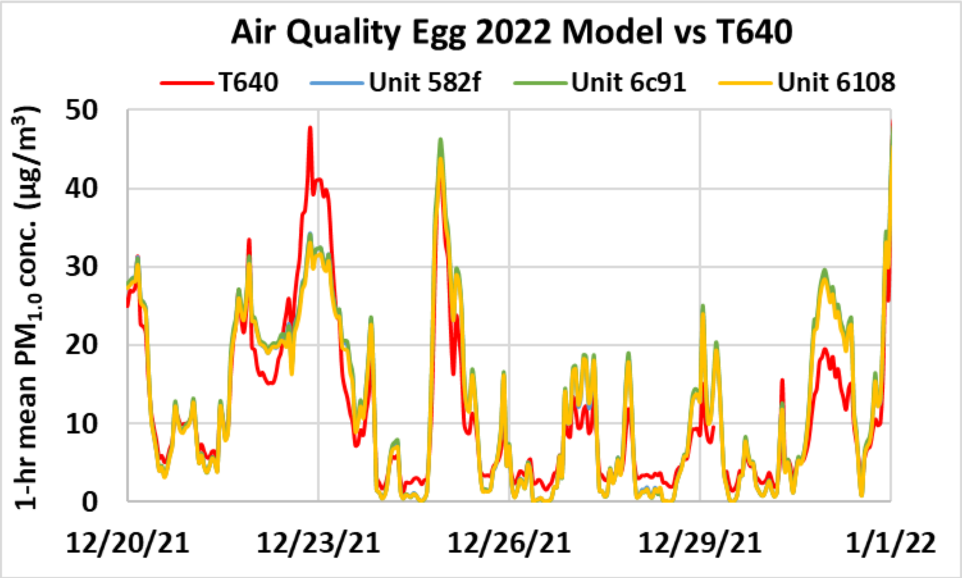
- Air Quality Egg 2022 Model sensors showed moderate correlations with the corresponding T640 data ($0.50 < R^2 < 0.53$)
- Overall, the Air Quality Egg 2022 Model sensors underestimated the PM_{10} mass concentrations as measured by T640
- The Air Quality Egg 2022 Model sensors seemed to track the PM_{10} diurnal variations as recorded by T640



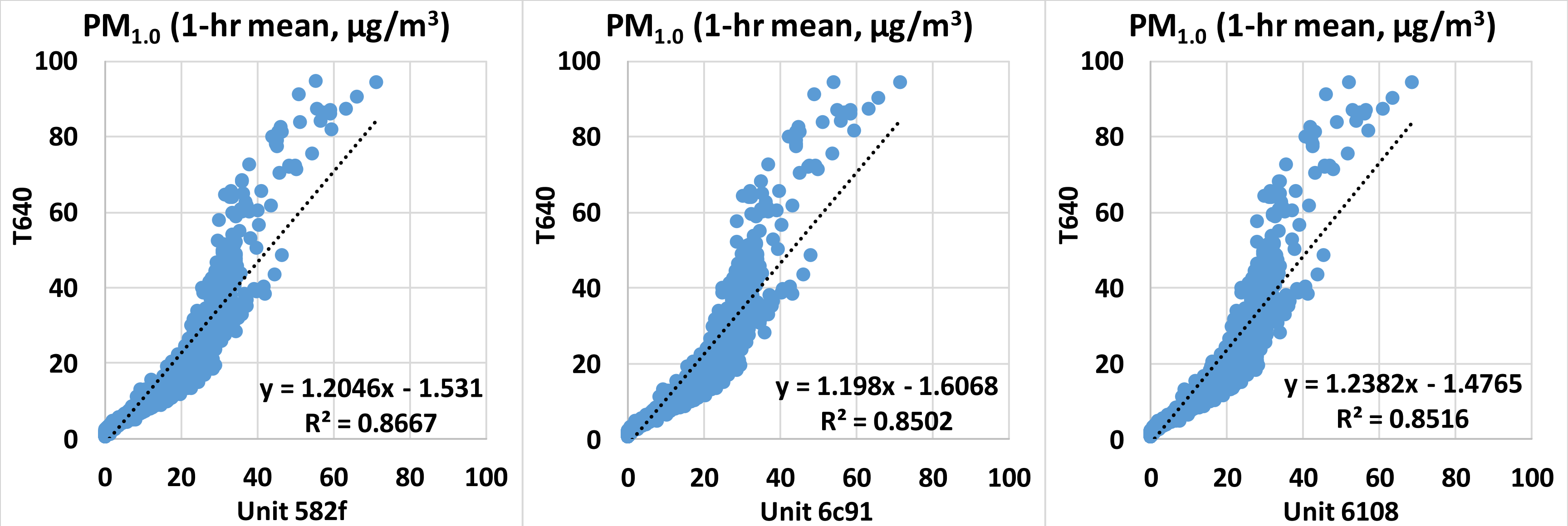




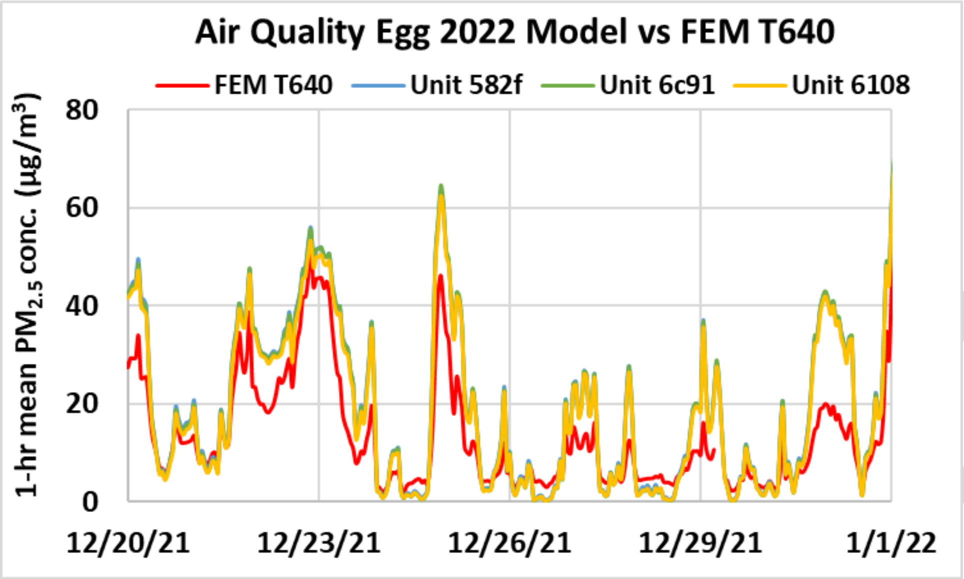
Air Quality Egg 2022 Model vs T640 ($PM_{1.0}$; 1-hr mean)



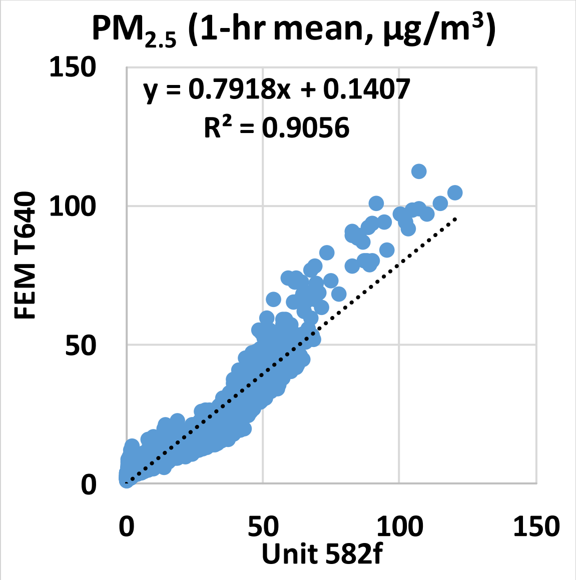
- The Air Quality Egg 2022 Model sensors showed strong correlations with the corresponding T640 data ($0.85 < R^2 < 0.87$)
- Overall, the Air Quality Egg 2022 Model sensors underestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The Air Quality Egg 2022 Model sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640

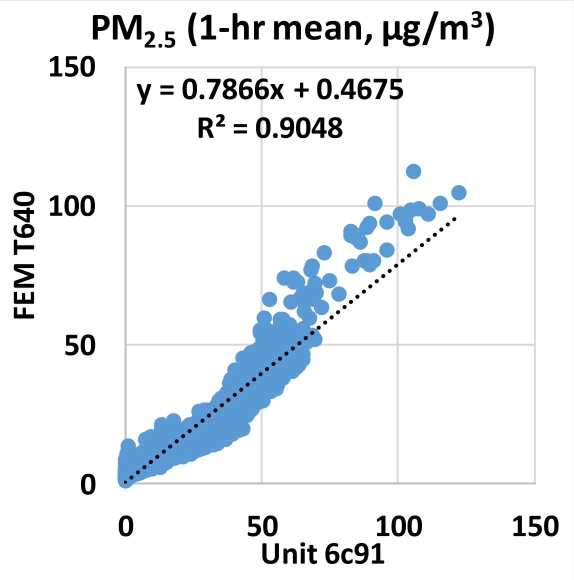


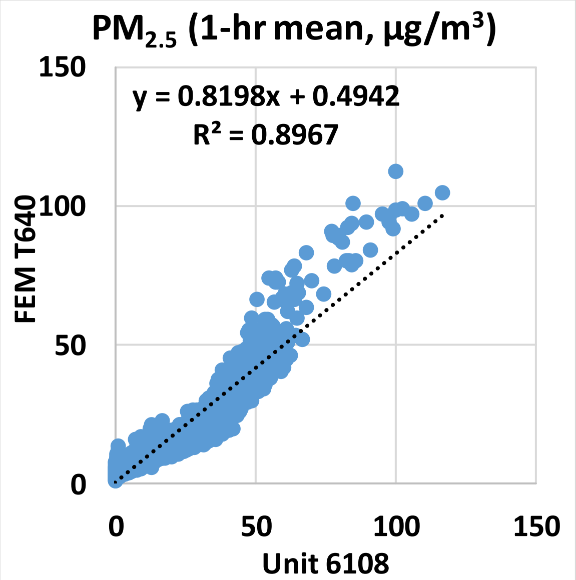
Air Quality Egg 2022 Model vs FEM T640 ($PM_{2.5}$; 1-hr mean)



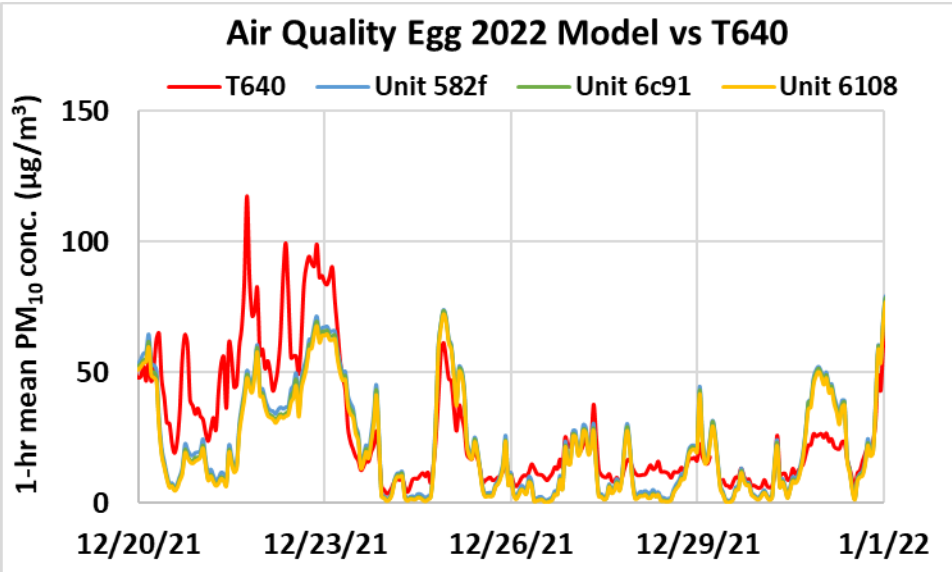
- The Air Quality Egg 2022 Model sensors showed strong to very strong correlations with the corresponding FEM T640 data ($0.89 < R^2 < 0.91$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The Air Quality Egg 2022 Model sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



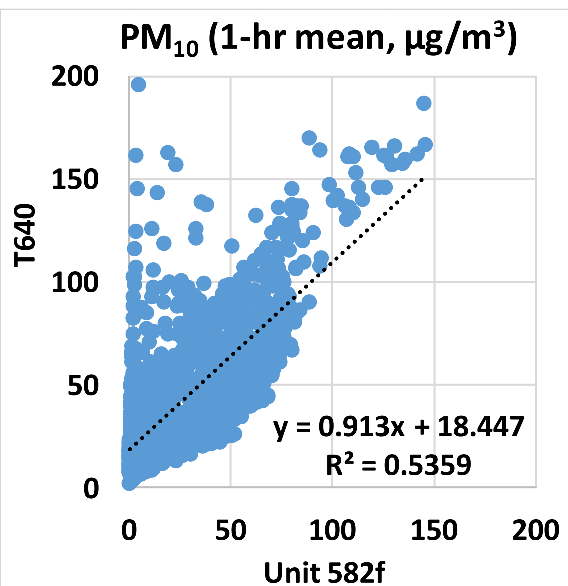


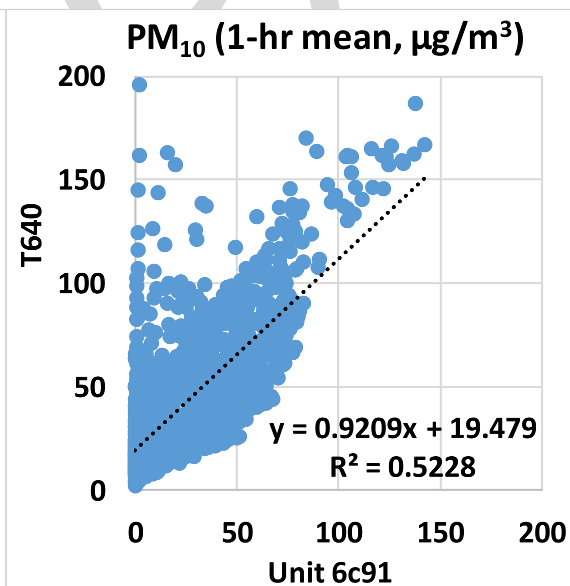


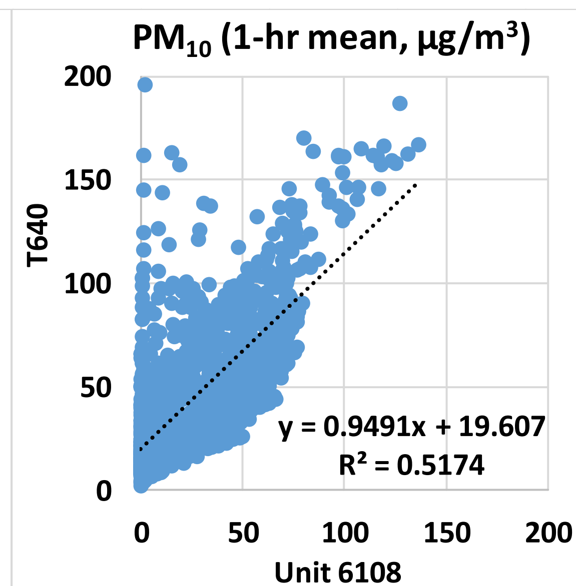
Air Quality Egg 2022 Model vs T640 (PM_{10}; 1-hr mean)



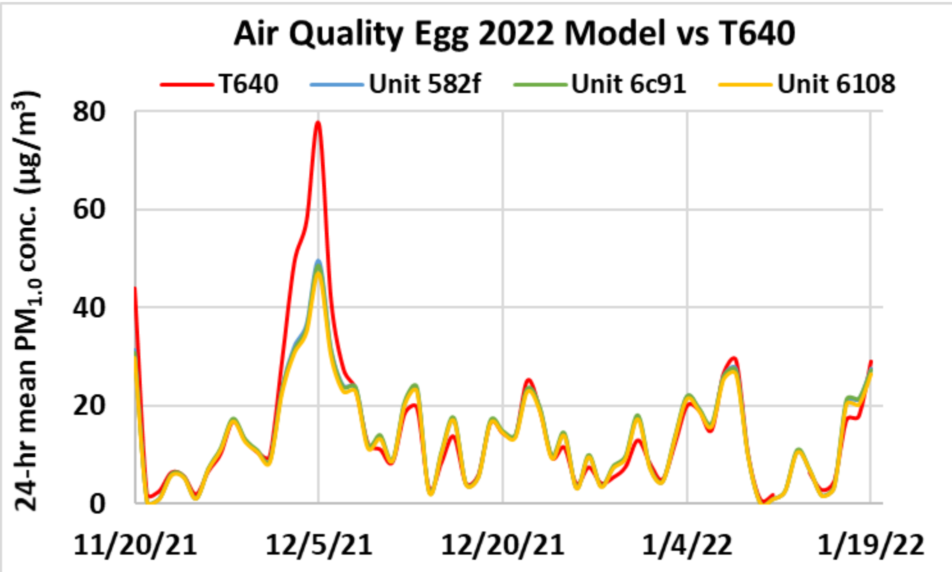
- The Air Quality Egg 2022 Model sensors showed moderate correlations with the corresponding T640 data ($0.51 < R^2 < 0.54$)
- Overall, the Air Quality Egg 2022 Model sensors underestimated the PM_{10} mass concentrations as measured by T640
- The Air Quality Egg 2022 Model sensors seemed to track the PM_{10} diurnal variations as recorded by T640



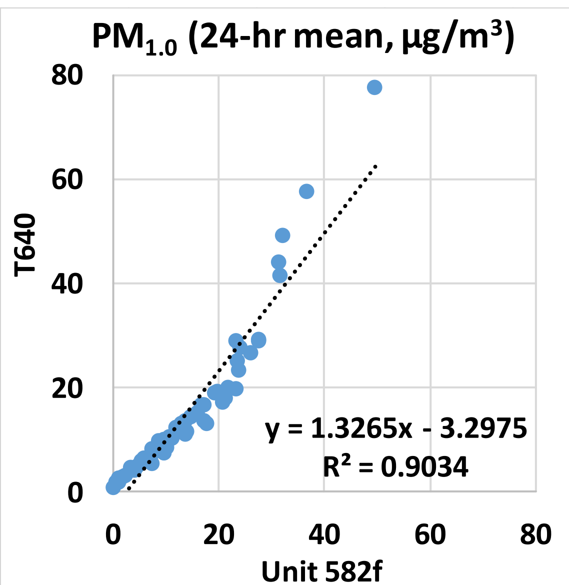


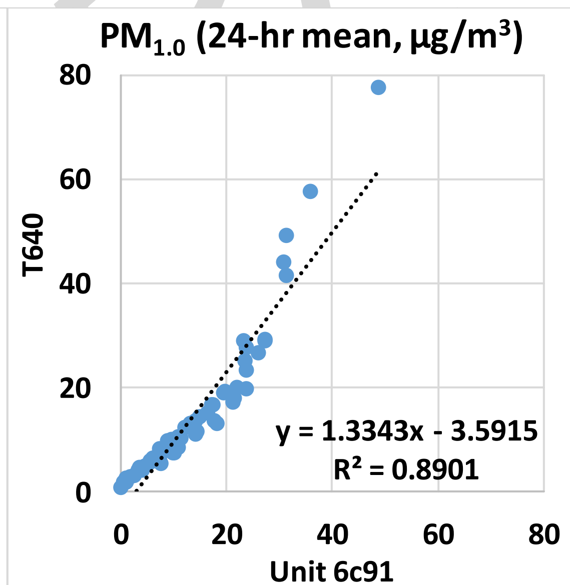


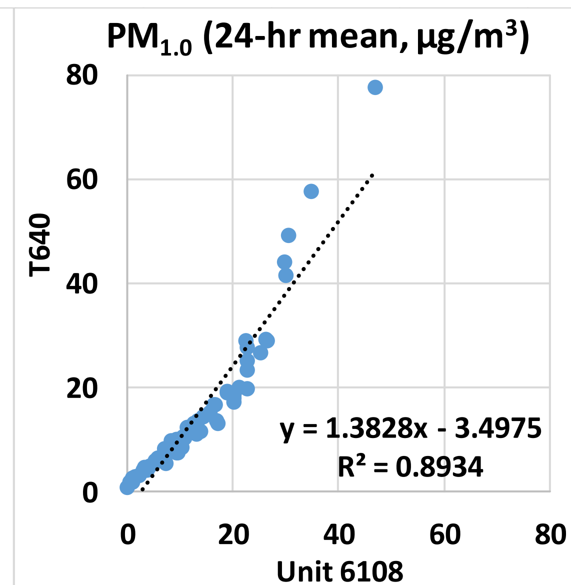
Air Quality Egg 2022 Model vs T640 ($PM_{1.0}$; 24-hr mean)



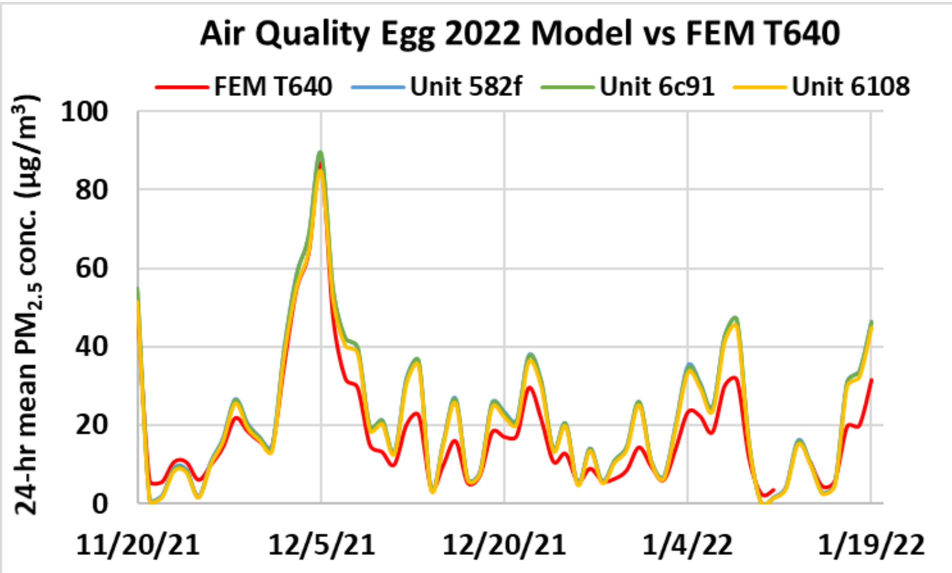
- The Air Quality Egg 2022 Model sensors showed strong to very strong correlations with the corresponding T640 data ($0.89 < R^2 < 0.91$)
- Overall, the Air Quality Egg 2022 Model sensors underestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The Air Quality Egg 2022 Model sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640



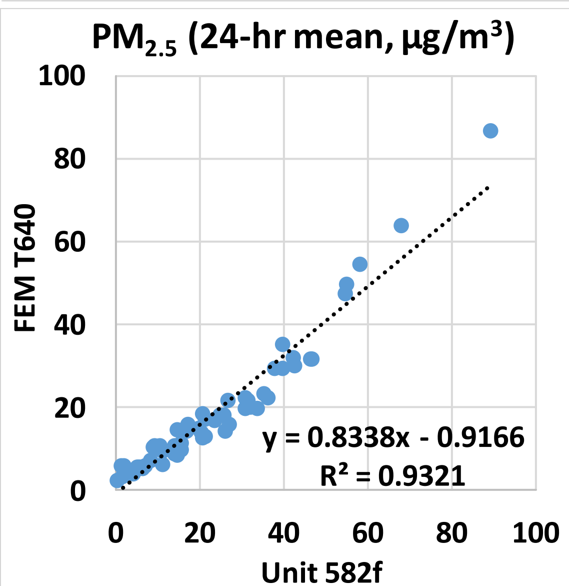


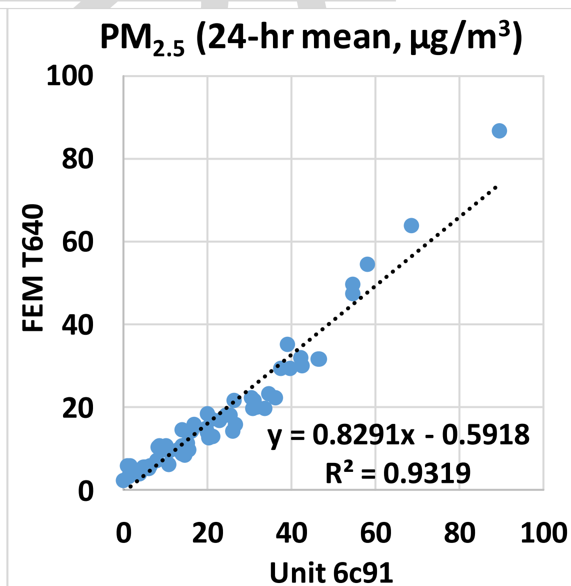


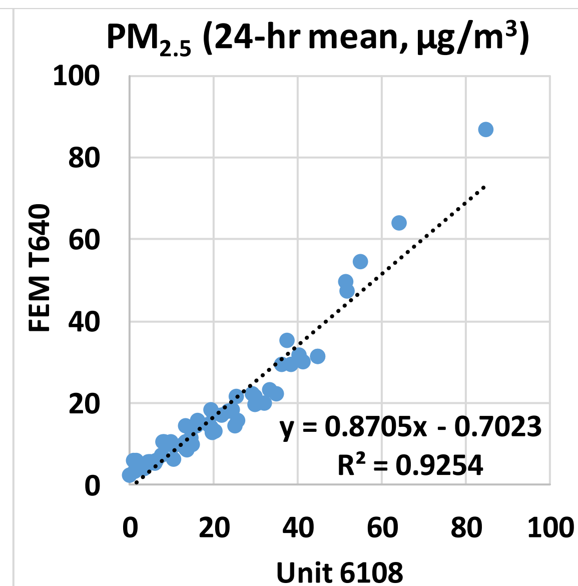
Air Quality Egg 2022 Model vs FEM T640 ($PM_{2.5}$; 24-hr mean)



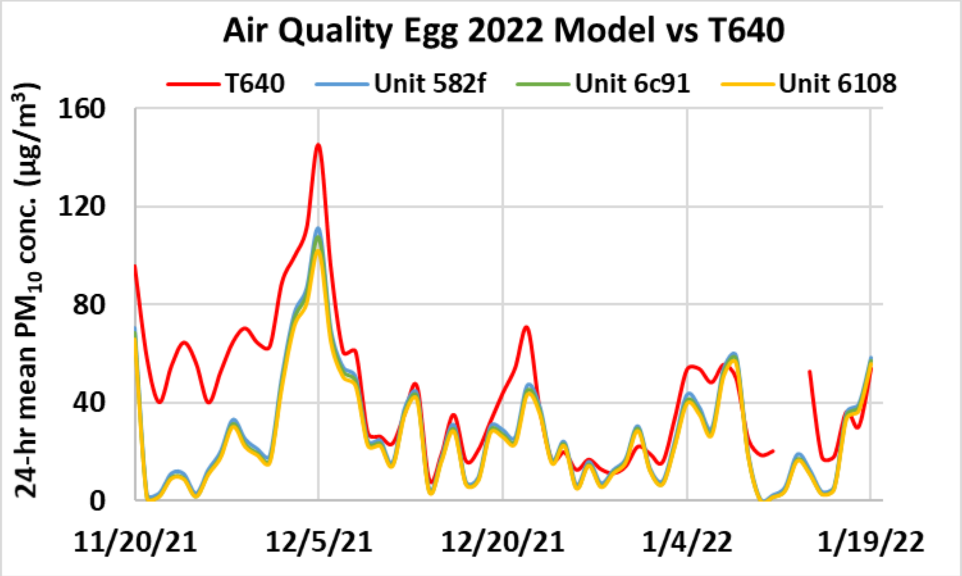
- The Air Quality Egg 2022 Model sensors showed very strong correlations with the corresponding FEM T640 data ($0.92 < R^2 < 0.94$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The Air Quality Egg 2022 Model sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



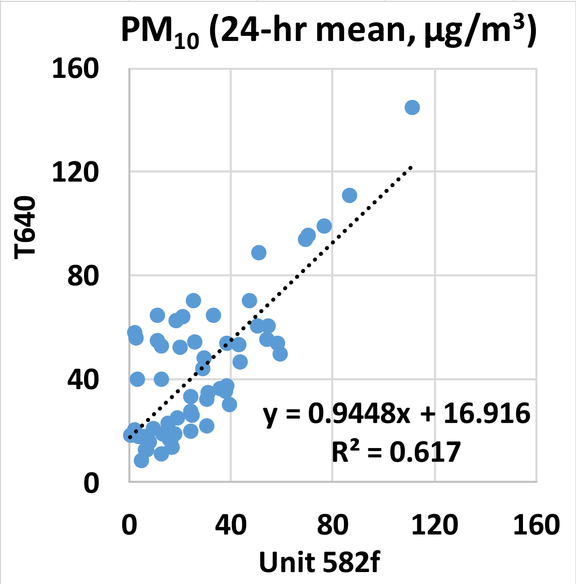


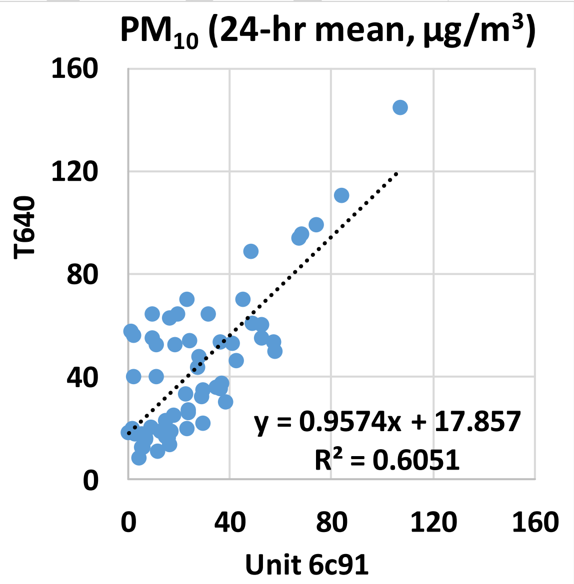


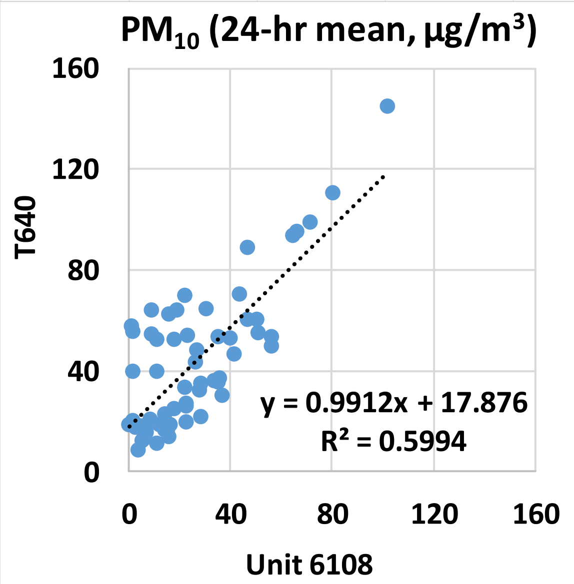
Air Quality Egg 2022 Model vs T640 (PM_{10}; 24-hr mean)



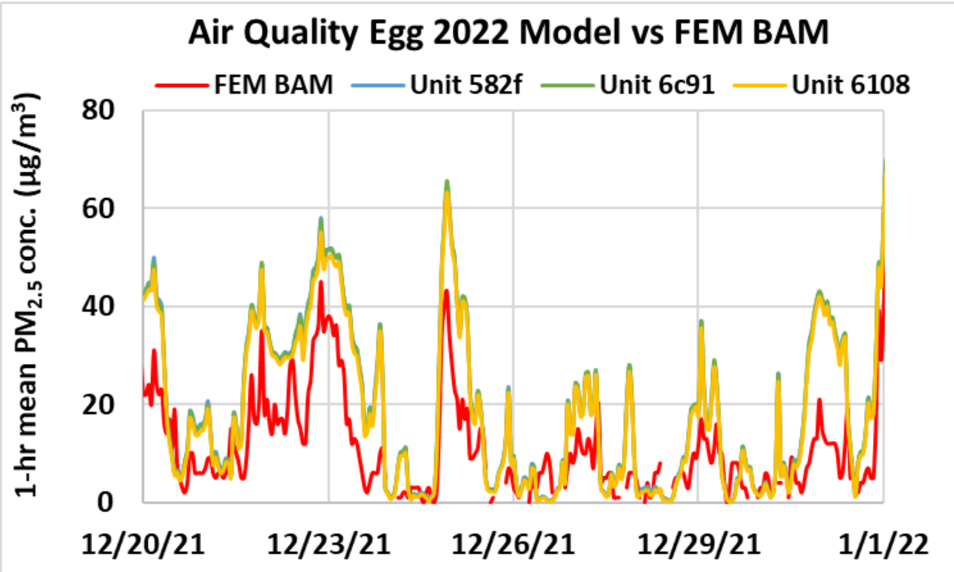
- The Air Quality Egg 2022 Model sensors showed moderate correlations with the corresponding T640 data ($0.59 < R^2 < 0.62$)
- Overall, the Air Quality Egg 2022 Model sensors underestimated the PM_{10} mass concentrations as measured by T640
- The Air Quality Egg 2022 Model sensors seemed to track the PM_{10} diurnal variations as recorded by T640



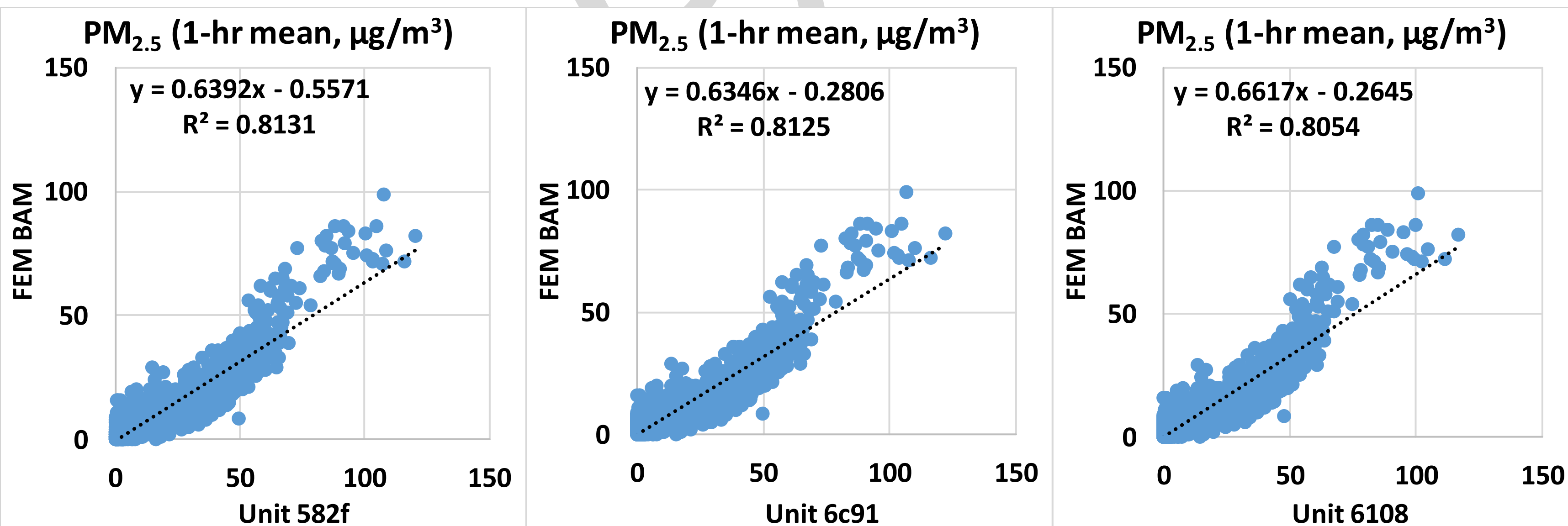




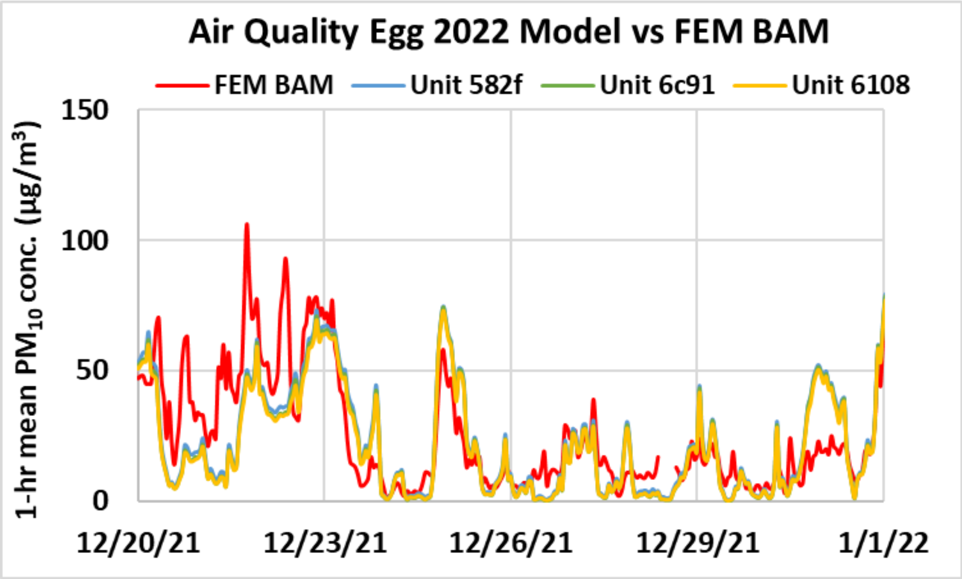
Air Quality Egg 2022 Model vs FEM BAM ($PM_{2.5}$; 1-hr mean)



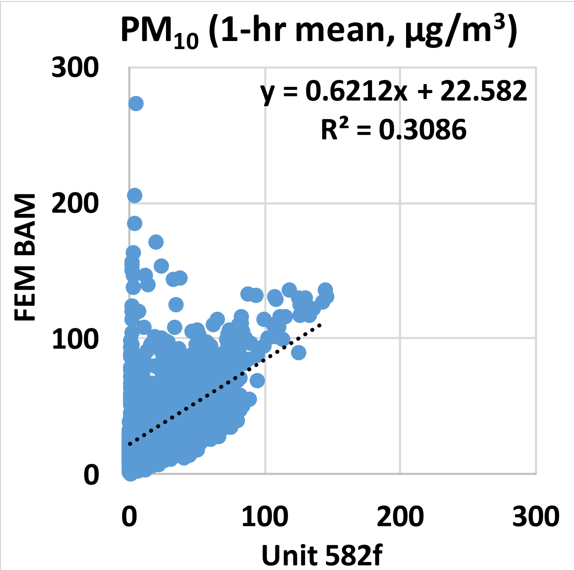
- The Air Quality Egg 2022 Model sensors showed strong correlations with the corresponding FEM BAM data (0.80 < R^2 < 0.82)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM BAM
- The Air Quality Egg 2022 Model sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM BAM

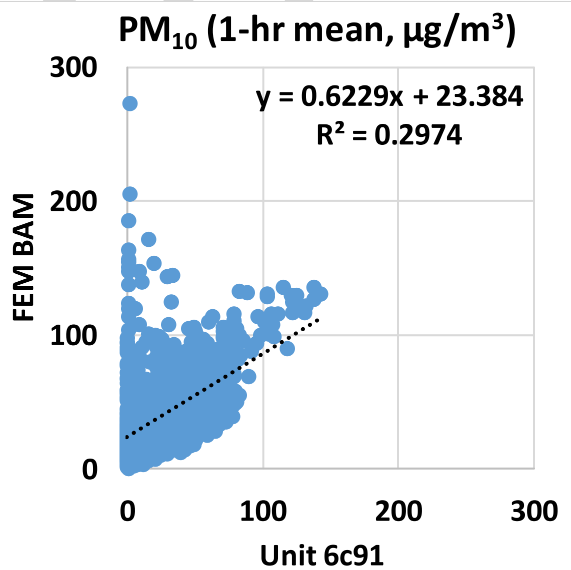


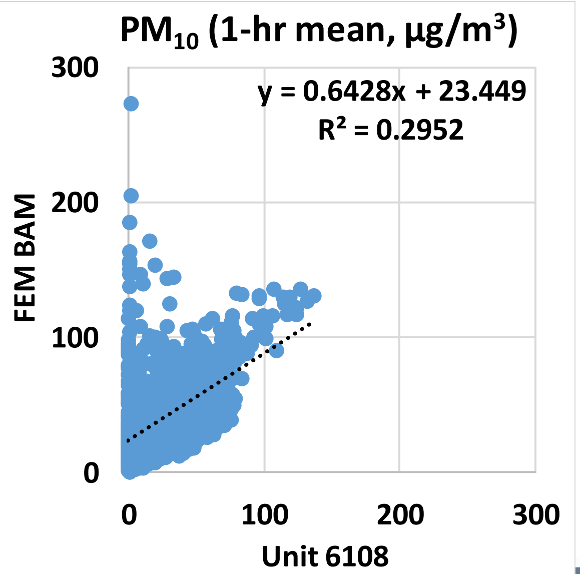
Air Quality Egg 2022 Model vs FEM BAM (PM_{10}; 1-hr mean)



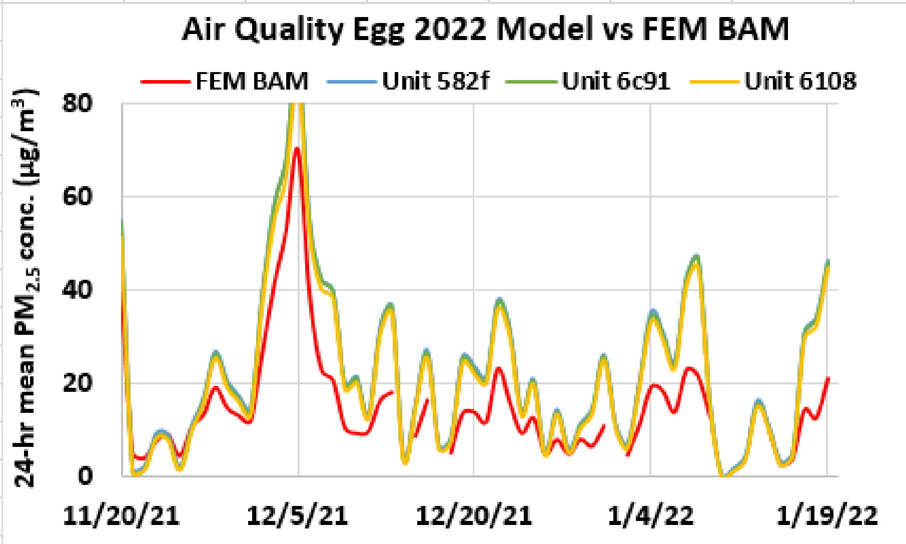
- The Air Quality Egg 2022 Model sensors showed very weak to weak correlations with the corresponding FEM BAM data ($0.29 < R^2 < 0.31$)
- Overall, the Air Quality Egg 2022 Model sensors underestimated the PM_{10} mass concentrations as measured by FEM BAM
- The Air Quality Egg 2022 Model sensors did not seem to track the PM_{10} diurnal variations as recorded by FEM BAM



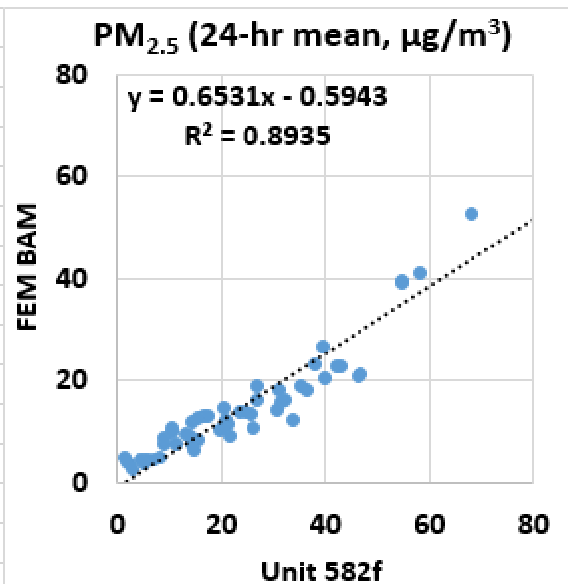


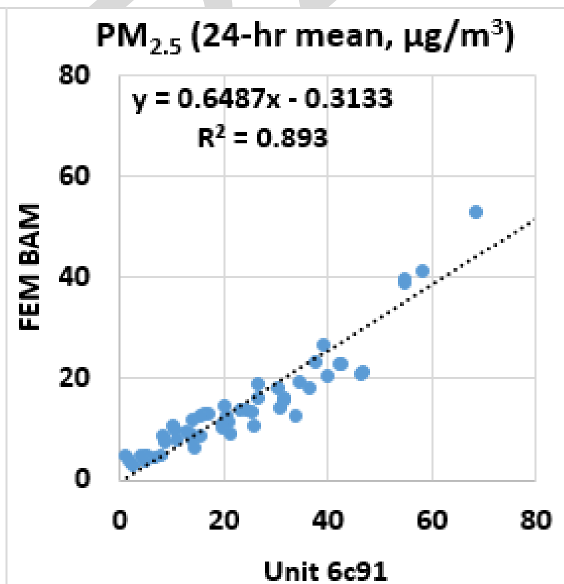


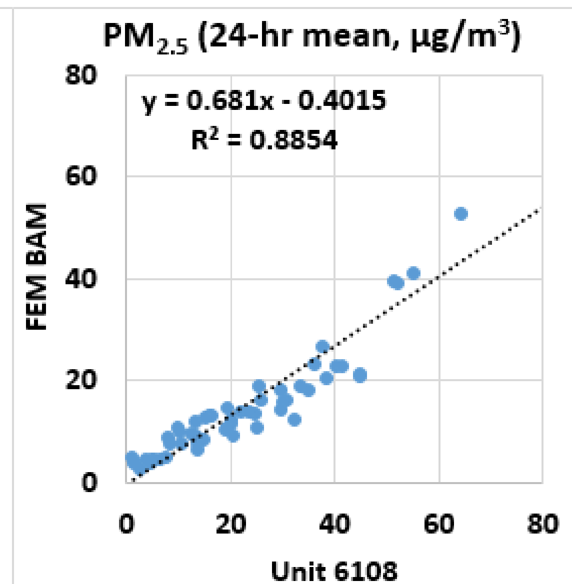
Air Quality Egg 2022 Model vs FEM BAM ($PM_{2.5}$; 24-hr mean)



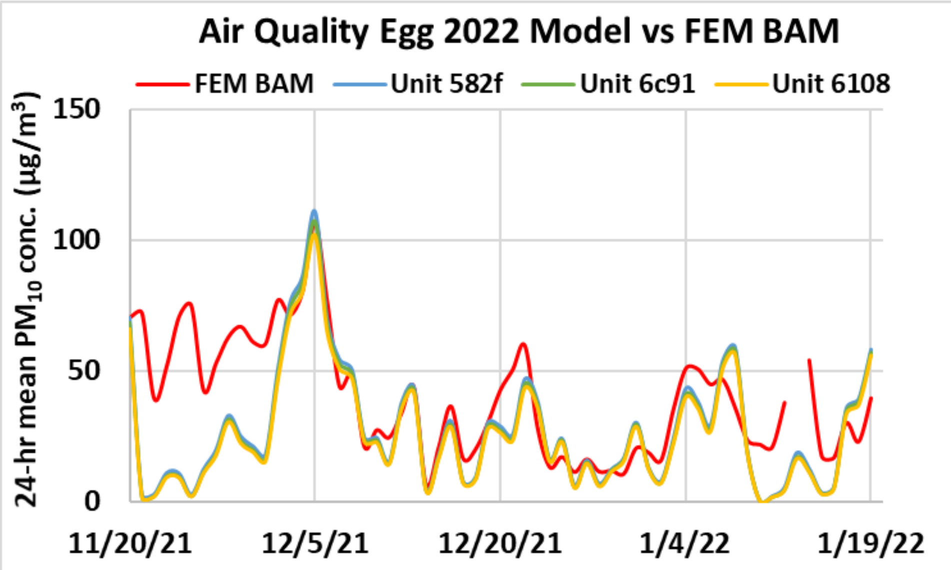
- The Air Quality Egg 2022 Model sensors showed strong correlations with the corresponding FEM BAM data ($0.88 < R^2 < 0.90$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM BAM
- The Air Quality Egg 2022 Model sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM BAM



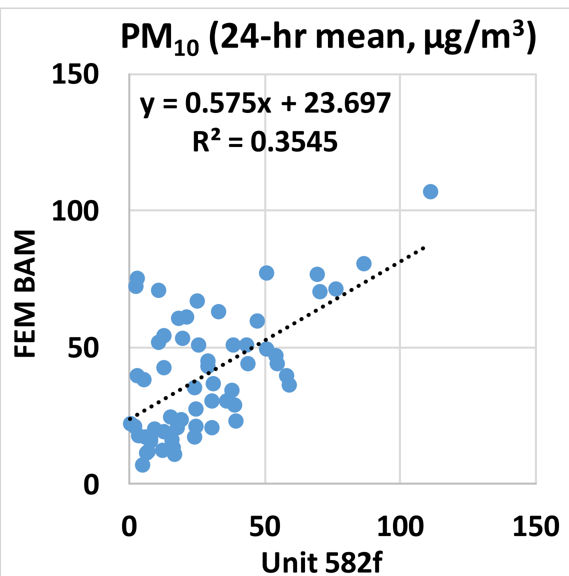


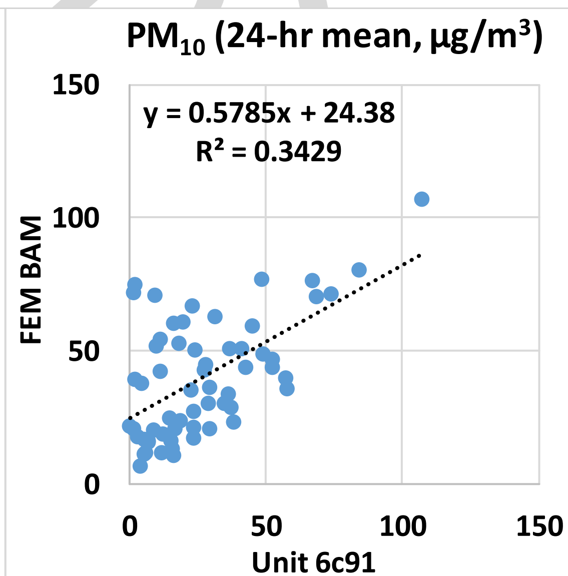


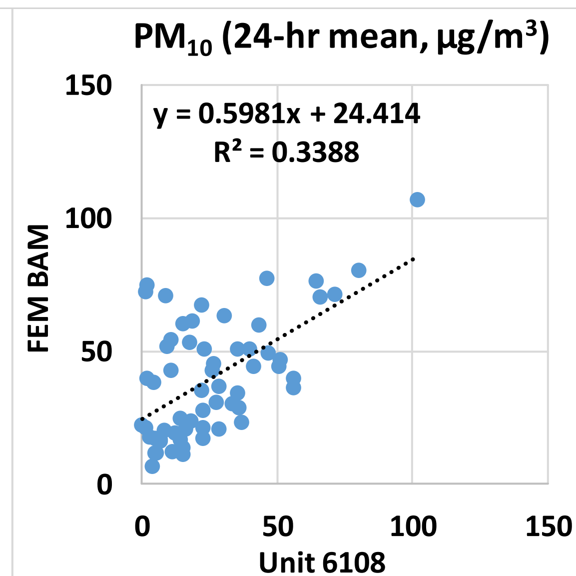
Air Quality Egg 2022 Model vs FEM BAM (PM_{10}; 24-hr mean)



- The Air Quality Egg 2022 Model sensors showed weak correlations with the corresponding FEM BAM data ($0.33 < R^2 < 0.36$)
- Overall, the Air Quality Egg 2022 Model sensors underestimated the PM_{10} mass concentrations as measured by FEM BAM
- The Air Quality Egg 2022 Model sensors did not seem to track the PM_{10} diurnal variations as recorded by FEM BAM







Summary: PM

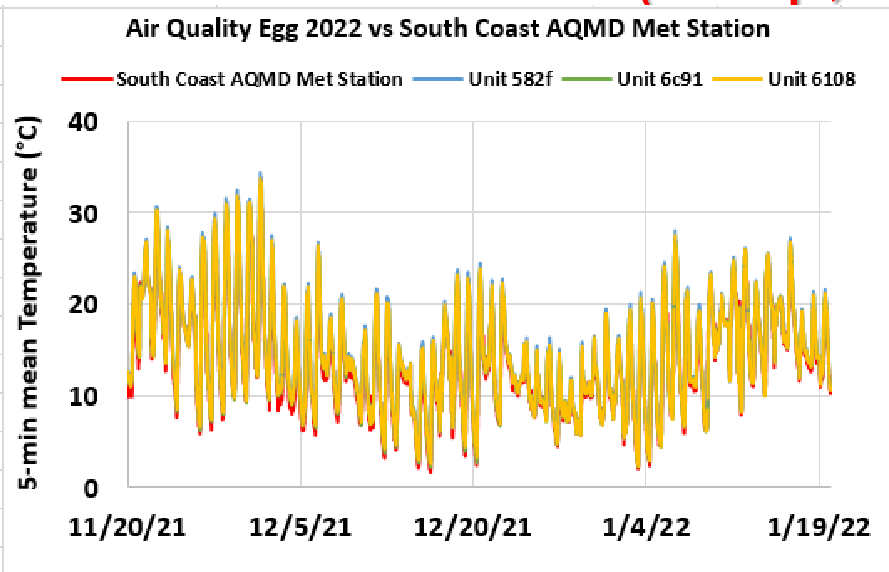
	Average of 3 Sensors, $PM_{1.0}$		Air Quality Egg 2022 Model vs GRIMM & T640, $PM_{1.0}$						GRIMM & T640 ($PM_{1.0}$, $\mu g/m^3$)		
	Average ($\mu g/m^3$)	SD ($\mu g/m^3$)	R^2	Slope	Intercept	MBE[1] ($\mu g/m^3$)	MAE[2] ($\mu g/m^3$)	RMSE[3] ($\mu g/m^3$)	Ref. Average	Ref. SD	Range during the field evaluation
5-min	13.9	12.4	0.84 to 0.89	1.07 to 1.23	-1.66 to -1.41	-1.78 to 0.70	2.93 to 3.87	4.81 to 7.24	13.2 to 15.5	14.1 to 16.3	0.2 to 155.7
1-hr	13.9	12.3	0.85 to 0.90	1.08 to 1.24	-1.75 to -1.48	-1.79 to 0.70	2.83 to 3.75	4.61 to 7.07	13.2 to 15.5	14.0 to 16.1	0.4 to 94.6
24-hr	13.9	10.1	0.89 to 0.93	1.10 to 1.38	-3.59 to -2.30	-1.79 to 1.10	2.08 to 2.93	3.30 to 6.28	12.4 to 15.6	11.2 to 14.5	0.5 to 77.5
	Average of 3 Sensors, $PM_{2.5}$		Air Quality Egg 2022 Model vs FEM BAM, FEM GRIMM & FEM T640, $PM_{2.5}$						FEM BAM, 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	22.4	21.1	0.88 to 0.90	0.71 to 0.82	0.18 to 1.89	3.46 to 4.87	6.02 to 7.12	7.83 to 9.40	17.4 to 18.5	15.7 to 17.8	0.4 to 165.7
1-hr	22.4	20.9	0.81 to 0.91	0.63 to 0.82	-0.56 to 1.83	3.46 to 9.60	5.90 to 11.0	7.59 to 13.9	15.5 to 18.5	15.0 to 17.7	0.0 to 112.2
24-hr	22.4	18.0	0.89 to 0.93	0.65 to 0.87	-0.92 to 1.90	3.57 to 9.16	4.64 to 9.47	6.01 to 11.8	15.5 to 18.6	12.3 to 15.8	2.4 to 86.7
	Average of 3 Sensors, PM_{10}		Air Quality Egg 2022 Model vs FEM BAM, GRIMM & T640, PM_{10}						FEM BAM, 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	27.0	26.2	0.29 to 0.52	0.66 to 0.95	18.4 to 20.6	-18.3 to -10.3	18.5 to 20.8	28.7 to 30.3	37.7 to 44.4	31.3 to 34.2	0.6 to 376.1
1-hr	27.0	26.1	0.30 to 0.54	0.62 to 0.95	18.5 to 23.5	-18.3 to -10.3	18.3 to 20.6	27.9 to 30.2	37.7 to 44.4	30.0 to 33.5	0.0 to 273.0
24-hr	27.0	22.5	0.27 to 0.62	0.58 to 0.99	16.9 to 24.4	-17.6 to -10.3	16.3 to 18.6	23.1 to 24.9	36.7 to 44.1	22.5 to 28.0	4.9 to 144.8

[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).

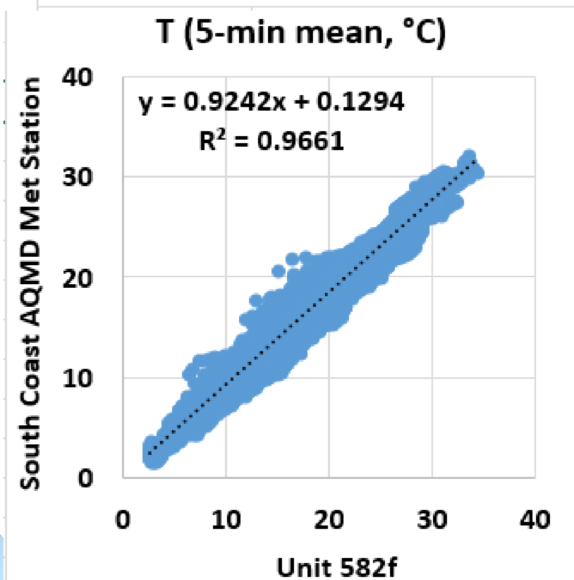
[2] Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.

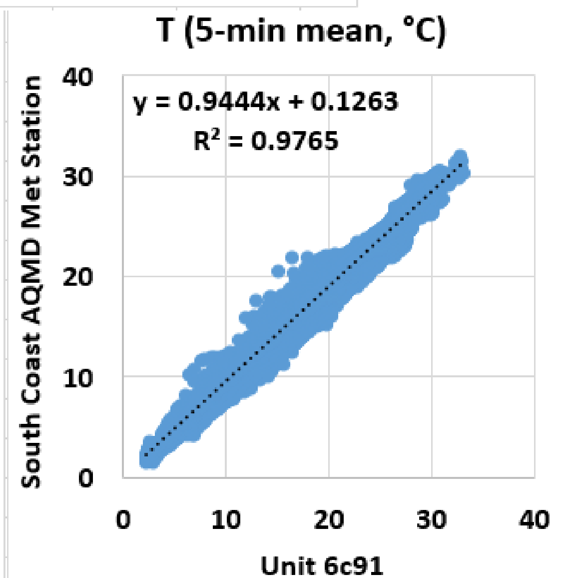
[3] Root Mean Square Error (RMSE): another metric to calculate measurement errors.

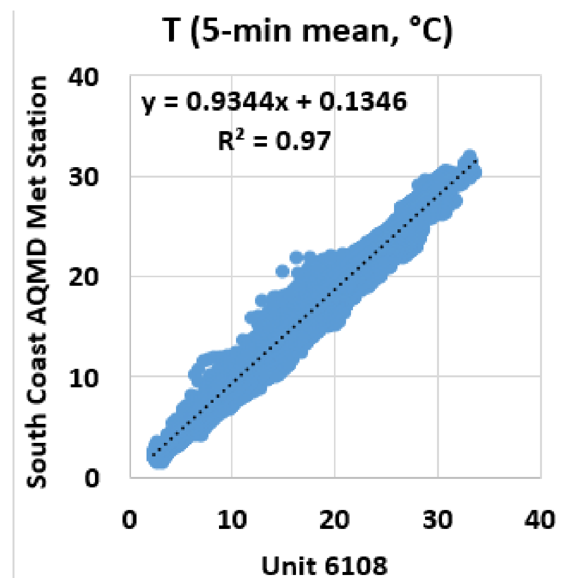
Air Quality Egg 2022 vs South Coast AQMD Met Station (Temp; 5-min mean)



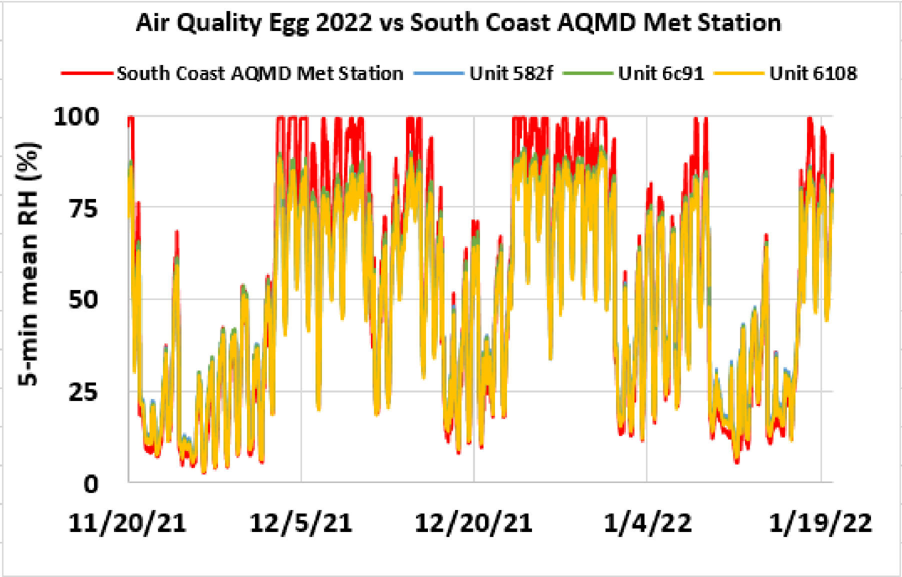
- The Air Quality Egg 2022 Model sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.97$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the temperature measurement as recorded by South Coast AQMD Met Station
- The Air Quality Egg 2022 Model sensors seemed to track the diurnal temperature variations as recorded by South Coast AQMD Met Station



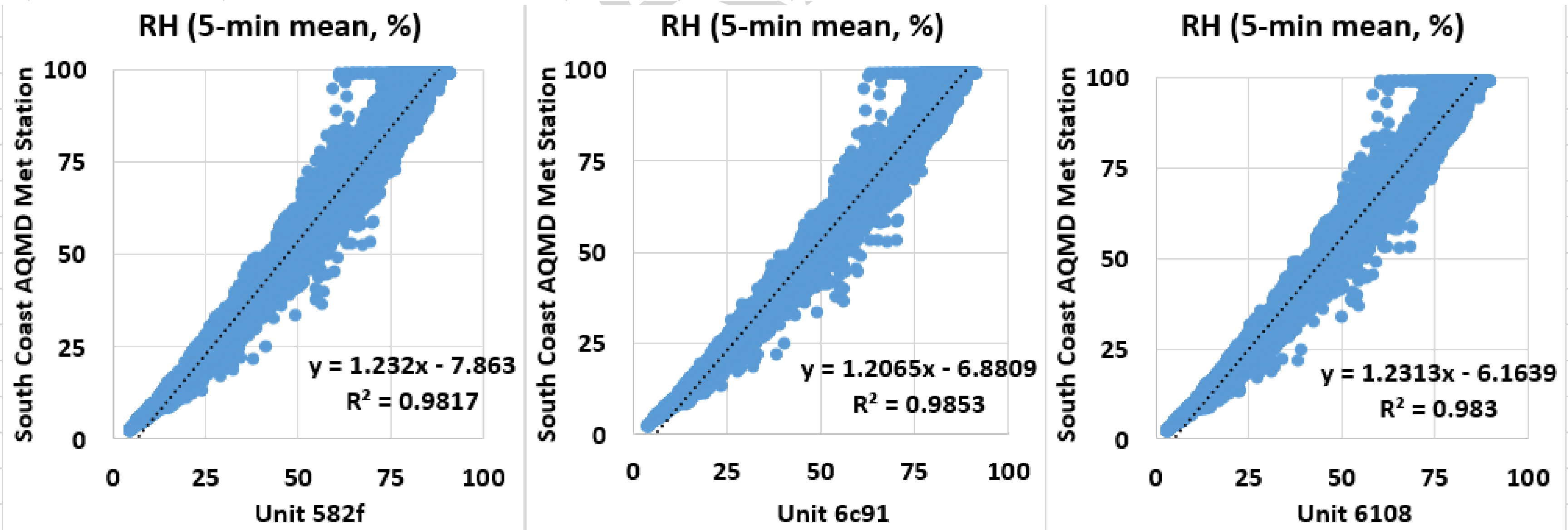




Air Quality Egg 2022 vs South Coast AQMD Met Station (RH; 5-min mean)



- The Air Quality Egg 2022 Model sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data (R^2 ~ 0.98)
- Overall, the Air Quality Egg 2022 Model sensors underestimated the RH measurement as recorded by South Coast AQMD Met Station
- The Air Quality Egg 2022 Model sensors seemed to track the diurnal RH variations as recorded by South Coast AQMD Met Station



Discussion

- The three **Air Quality Egg 2022 Model** sensors' data recovery from all units was ~ 99% for all CO and PM measurements
- The absolute intra-model variability was ~ 0.10 ppm for CO and ~ 0.29, 0.63 and 1.14 $\mu g/m^3$ for $PM_{1.0}$, $PM_{2.5}$ and PM_{10}, respectively
- CO concentrations measured by the Air Quality Egg 2022 Model sensors showed moderate to strong correlations with the corresponding FRM Horiba CO data ($0.60 < R^2 < 0.79$, 5-min mean). The sensors overestimated CO concentrations as measured by FRM Horiba.
- Very strong correlations between GRIMM and T640 for $PM_{1.0}$ ($R^2 \sim 0.99$, 1-hr mean); very strong correlations between FEM BAM, FEM GRIMM and FEM T640 for $PM_{2.5}$ ($0.91 < R^2 < 0.98$, 1-hr mean); and strong to very strong correlations between FEM BAM, GRIMM and T640 for PM_{10} ($0.88 < R^2 < 0.96$, 1-hr mean) mass concentration measurements
- $PM_{1.0}$ mass concentrations measured by the Air Quality Egg 2022 Model sensors showed strong correlations with the corresponding GRIMM and T640 data ($0.85 < R^2 < 0.90$, 1-hr mean). The sensors overestimated $PM_{1.0}$ mass concentrations as measured by GRIMM and underestimated $PM_{1.0}$ mass concentrations as measured by T640
- $PM_{2.5}$ mass concentrations measured by the Air Quality Egg 2022 Model sensors showed strong to very strong correlations with the corresponding FEM GRIMM, FEM T640 and FEM BAM data ($0.80 < R^2 < 0.91$, 1-hr mean). The sensors overestimated $PM_{2.5}$ mass concentrations as measured by FEM GRIMM, FEM T640 and FEM BAM
- PM_{10} mass concentrations measured by the Air Quality Egg 2022 Model sensors showed very weak to moderate correlations with the corresponding GRIMM, T640 and FEM BAM data ($0.29 < R^2 < 0.54$; 1-hr mean). The sensors underestimated PM_{10} mass concentrations as measured by GRIMM, T640 and FEM BAM
- 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