Field Evaluation
Alphasense OPC-R2

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 10/16/2021 to 12/15/2021, three **Alphasense OPC-R2** 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

- Alphasense OPC-R2 (*3 units tested*):
  - Particle sensor: optical; non-FEM (Alphasense OPC-R2)
  - Each unit reports: $PM_{1.0}$, $PM_{2.5}$ and PM_{10} (µg/m^3), Temperature (°C), RH (%)
  - Unit cost: ~$435, including data acquisition interface with software
  - Time resolution: 30-sec
  - Units IDs: 0304, 0305, 0307

- GRIMM EDM 180 (*reference instrument*):
  - Optical particle counter (FEM $PM_{2.5}$)
  - Measures $PM_{1.0}$, $PM_{2.5}$, and PM_{10} (µg/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} (µg/m^3)
  - Cost: ~$21,000
  - Time resolution: 1-min

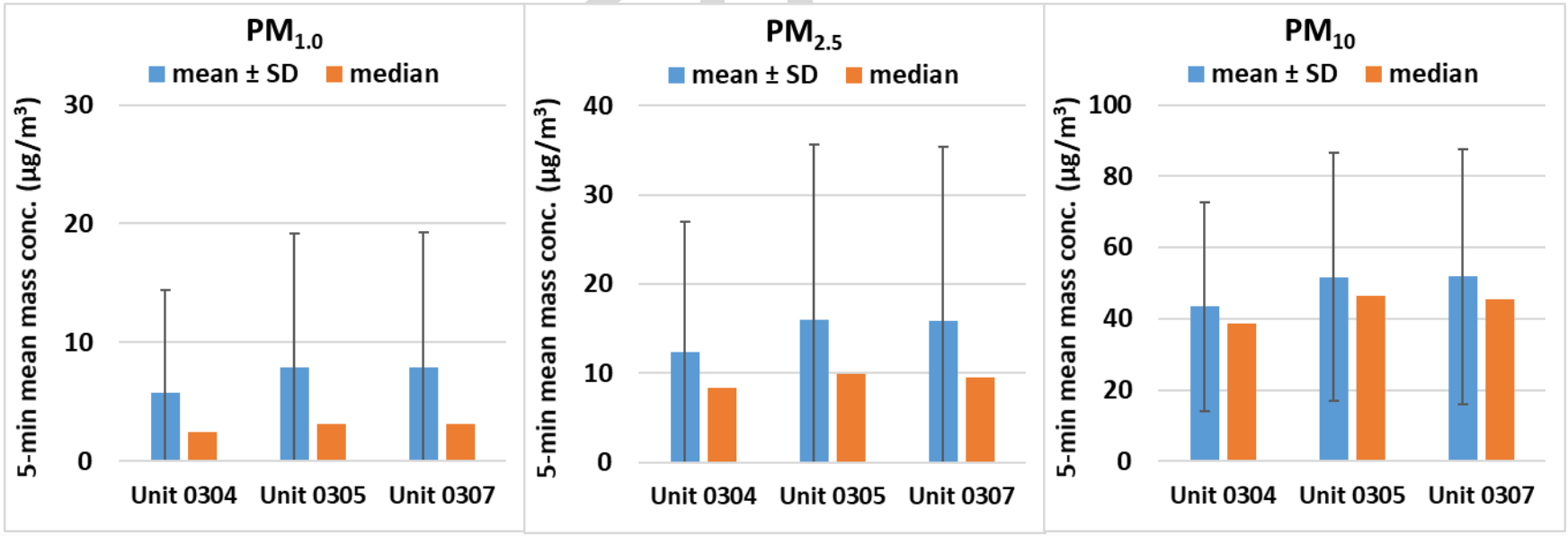
- Met Station (T, RH, P, WS, WD):
  - Cost: ~$5,000
  - Time resolution: 1-min

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

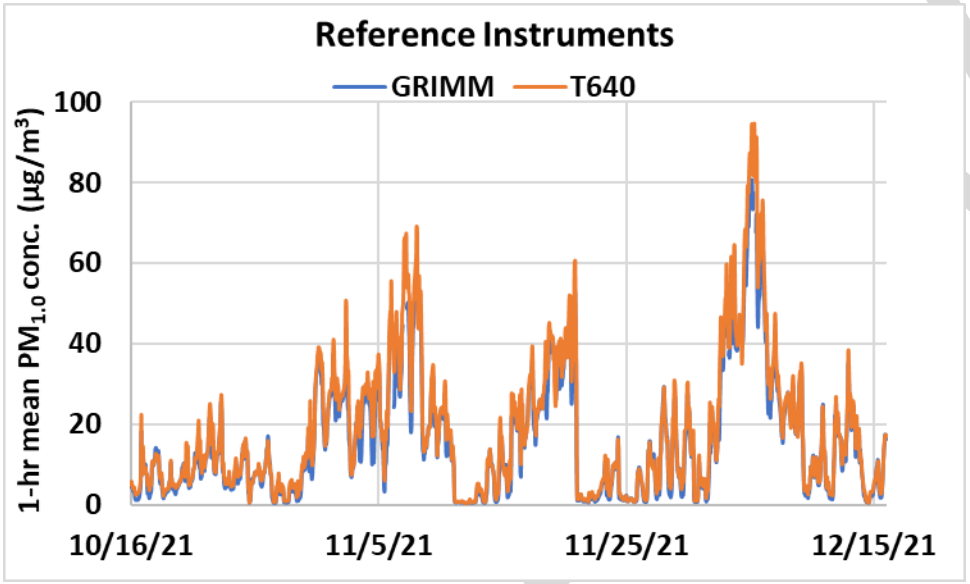
Alphasense OPC-R2; intra-model variability

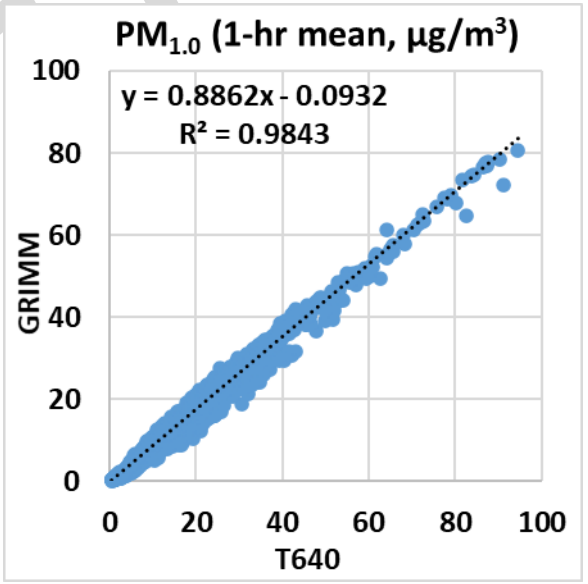
- Absolute intra-model variability was ~ 0.98, 1.69 and 3.98 µg/m^3 for $PM_{1.0}$, $PM_{2.5}$ and $PM_{10,}$ respectively (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 13.6%, 11.5% and 8.1% for $PM_{1.0}$, $PM_{2.5}$ and $PM_{10,}$ respectively (calculated as the absolute intra-model variability relative to the mean of the three sensor means)



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

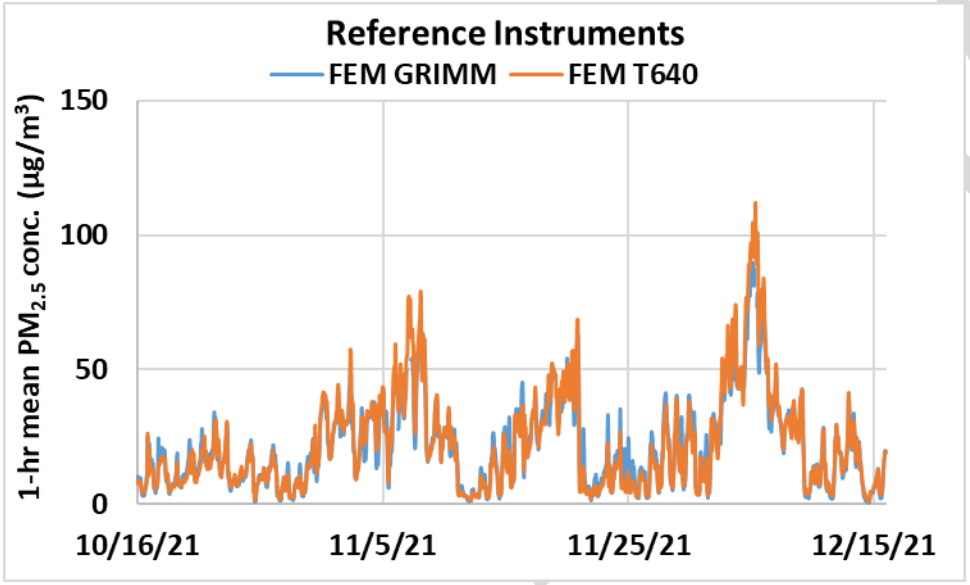
- Data recovery for $PM_{1.0}$ from GRIMM and T640 was ~ 88% and 99%, respectively.
- Very strong correlations between the reference instruments for $PM_{1.0}$ measurements (R^2 ~ 0.98) were observed.

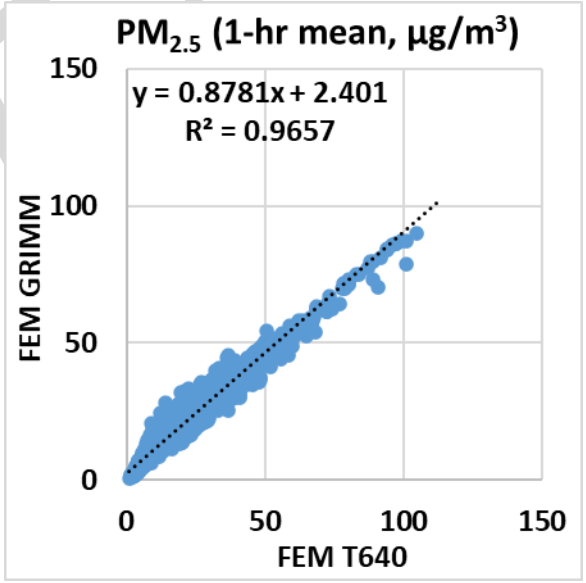




Reference Instruments: $PM_{2.5}$ FEM GRIMM and FEM T640

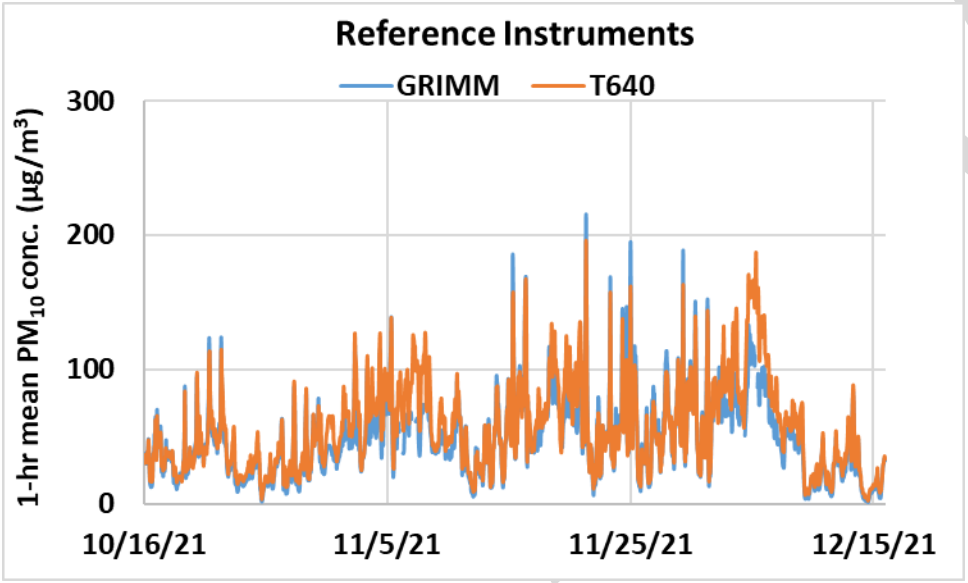
- Data recovery for $PM_{2.5}$ from FEM GRIMM and FEM T640 was ~ 88% and 99%, respectively.
- Very strong correlations between the reference instruments for $PM_{2.5}$ measurements (R^2 ~ 0.97) were observed.

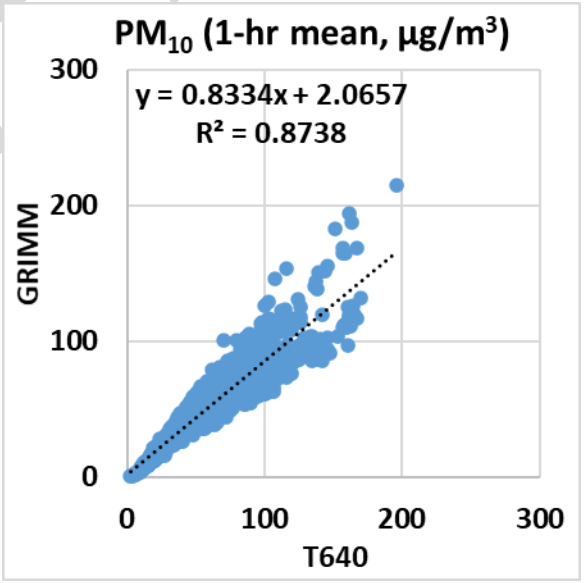




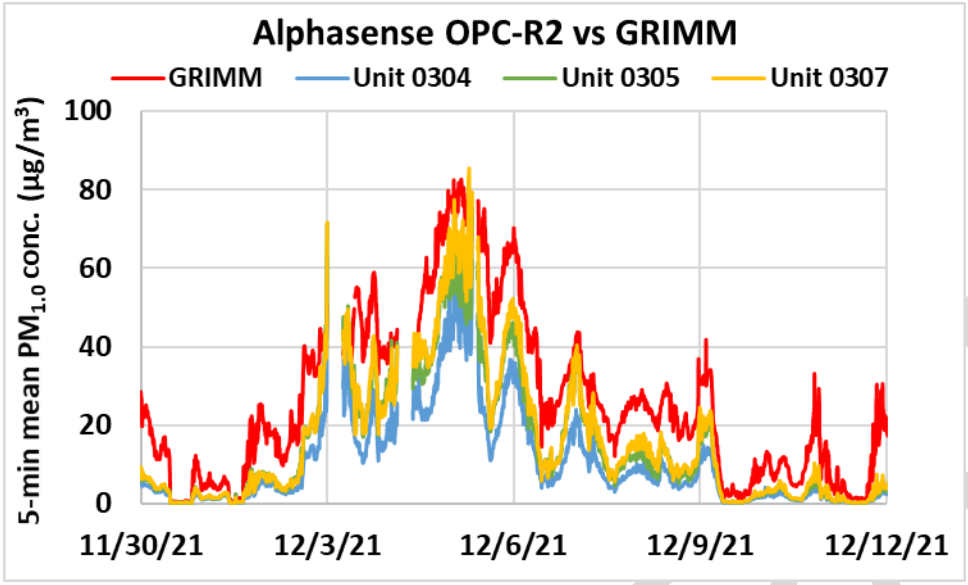
Reference Instruments: PM_{10} GRIMM and T640

- Data recovery for PM_{10} from GRIMM and T640 was ~ 88% and 99%, respectively.
- Strong correlations between the reference instruments for PM_{10} measurements (R^2 ~ 0.87) were observed.

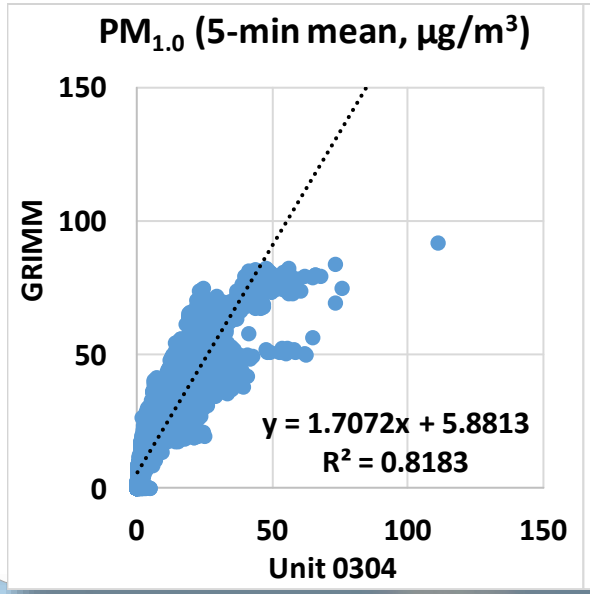


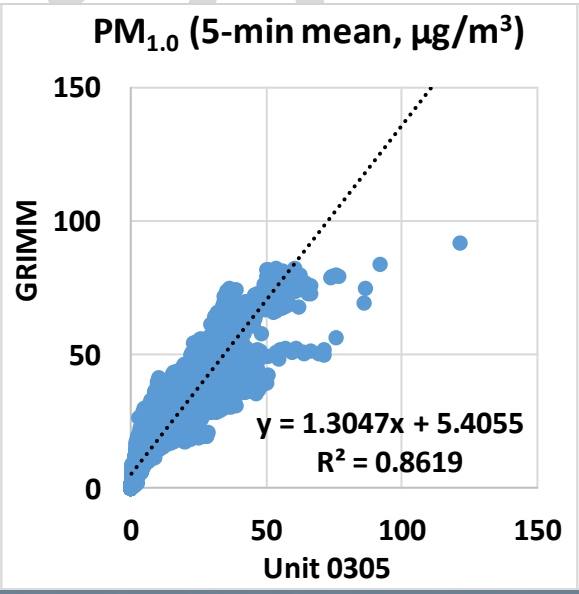


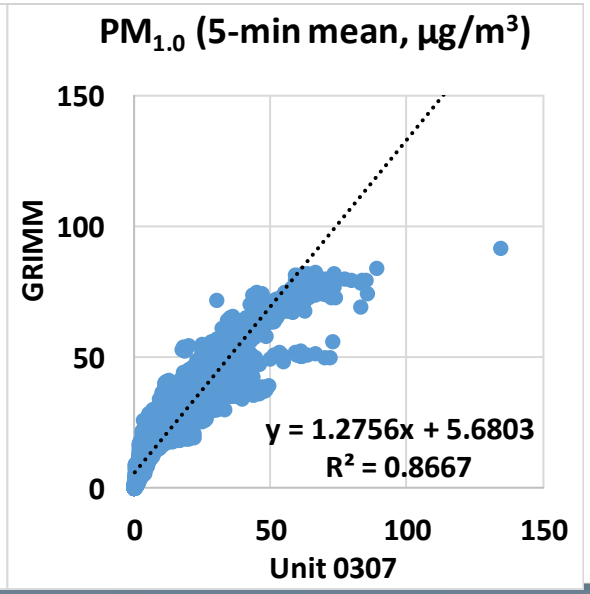
Alphasense OPC-R2 vs GRIMM ($PM_{1.0}$; 5-min mean)



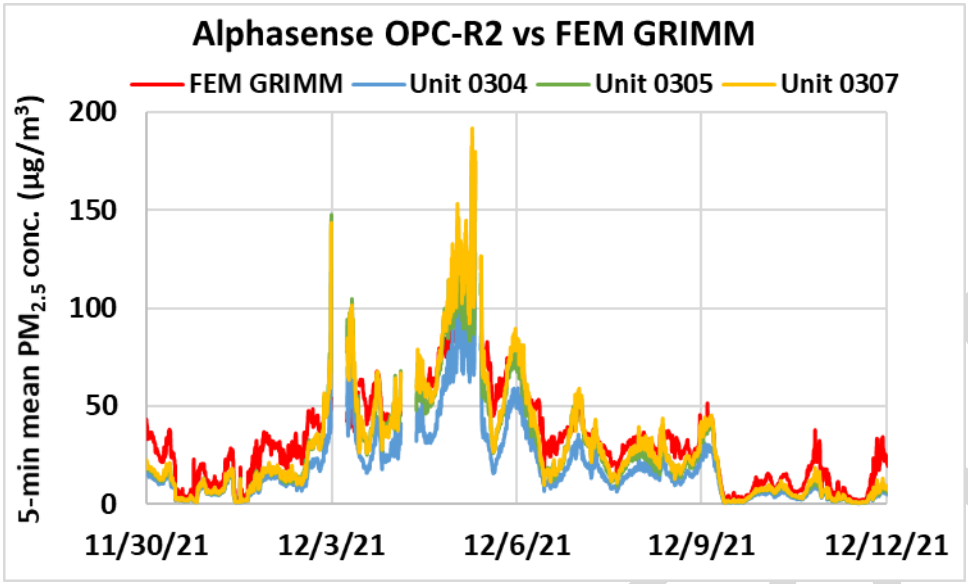
- The Alphasense OPC-R2 sensors showed strong correlations with the corresponding GRIMM data ($0.81 < R^2 < 0.87$)
- Overall, the Alphasense OPC-R2 sensors underestimated the $PM_{1.0}$ mass concentrations as measured by GRIMM
- The Alphasense OPC-R2 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by GRIMM



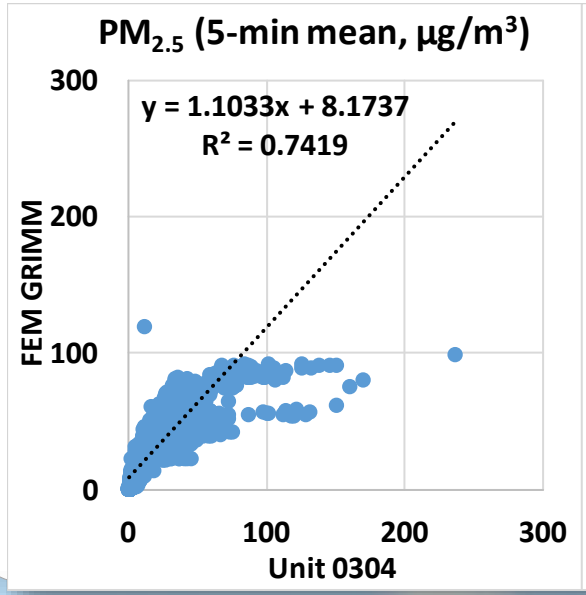


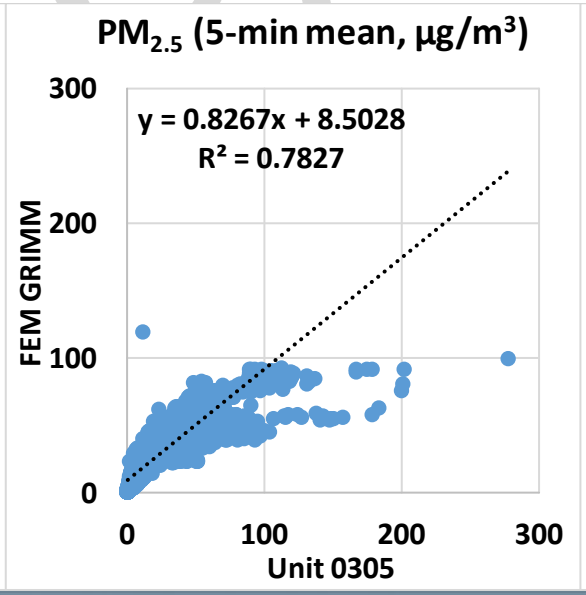


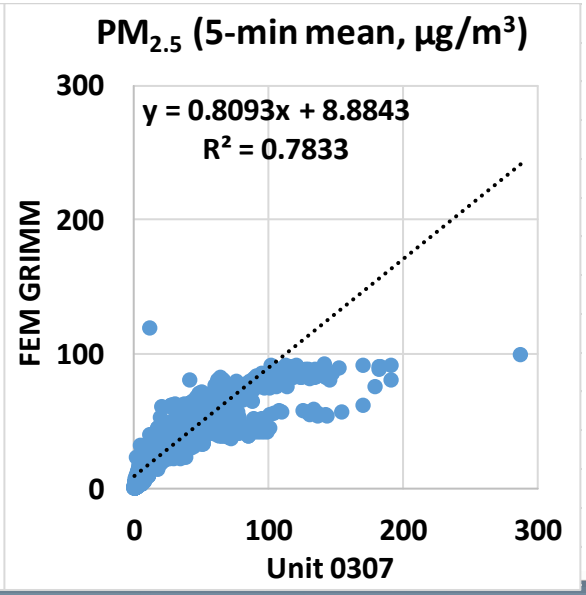
Alphasense OPC-R2 vs FEM GRIMM ($PM_{2.5}$; 5-min mean)



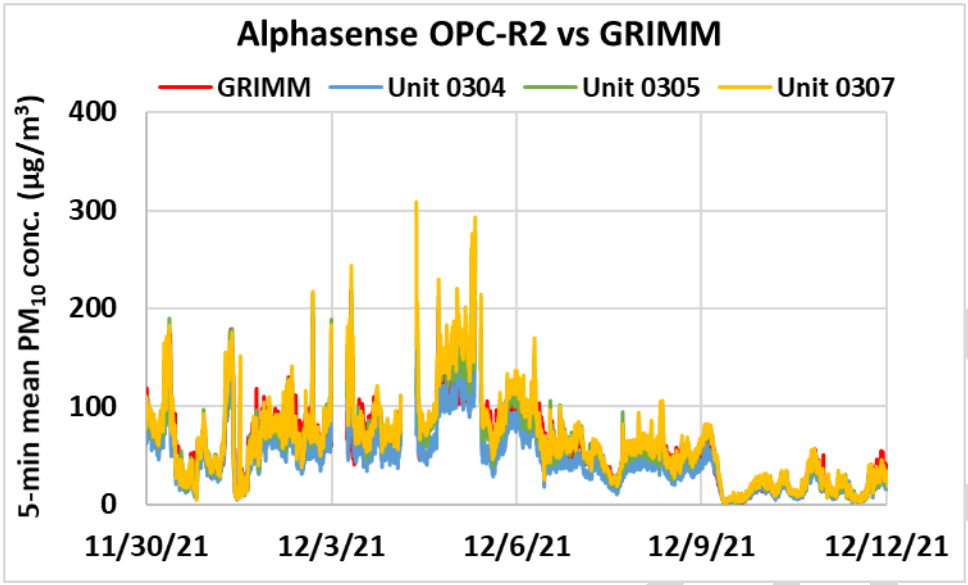
- The Alphasense OPC-R2 sensors showed strong correlations with the corresponding FEM GRIMM data ($0.74 < R^2 < 0.79$)
- Overall, the Alphasense OPC-R2 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM GRIMM
- The Alphasense OPC-R2 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM



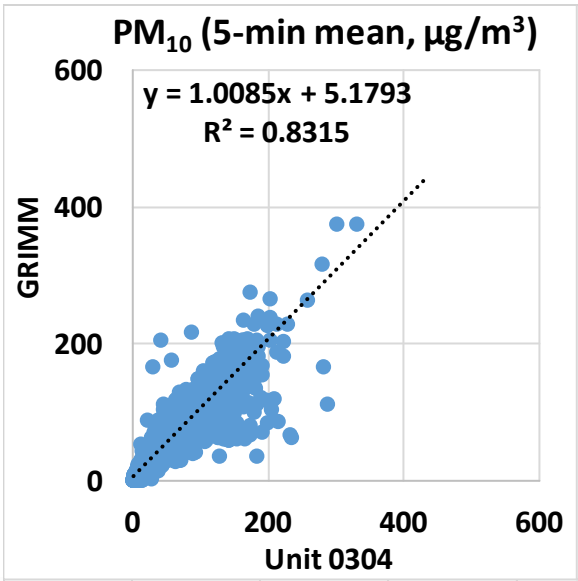


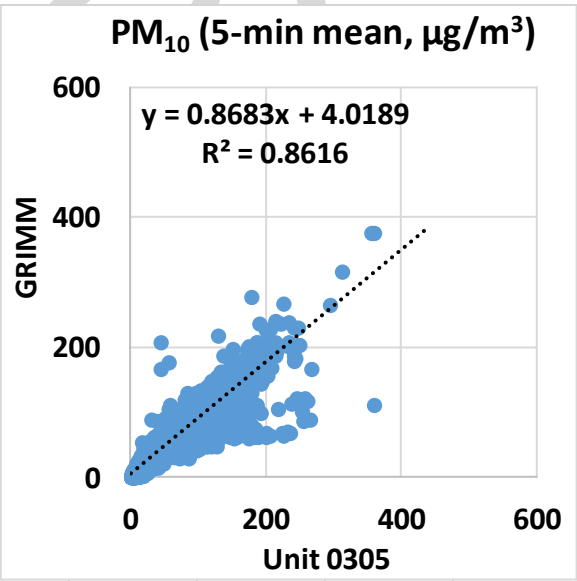


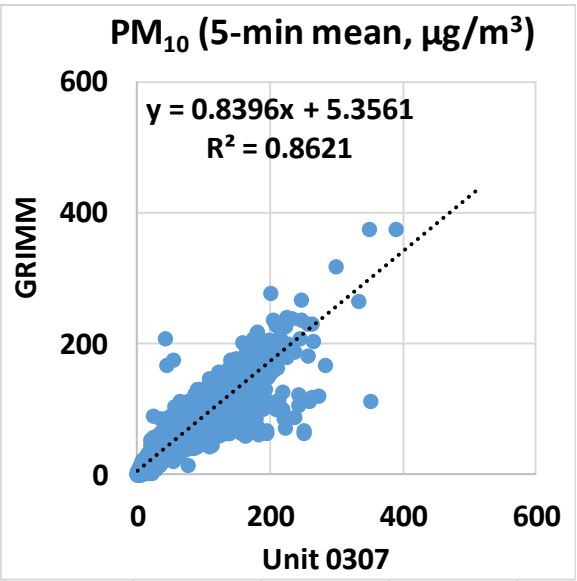
Alphasense OPC-R2 vs GRIMM (PM_{10}; 5-min mean)



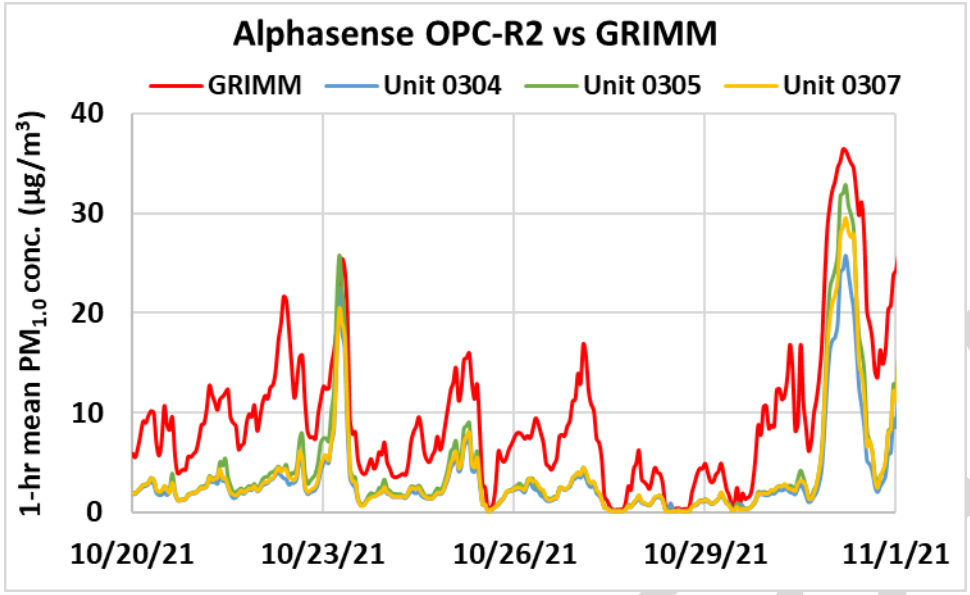
- The Alphasense OPC-R2 sensors showed strong correlations with the corresponding GRIMM data ($0.83 < R^2 < 0.87$)
- Overall, the Alphasense OPC-R2 sensors underestimated the PM_{10} mass concentrations as measured by GRIMM
- The Alphasense OPC-R2 sensors seemed to track the PM_{10} diurnal variations as recorded by GRIMM



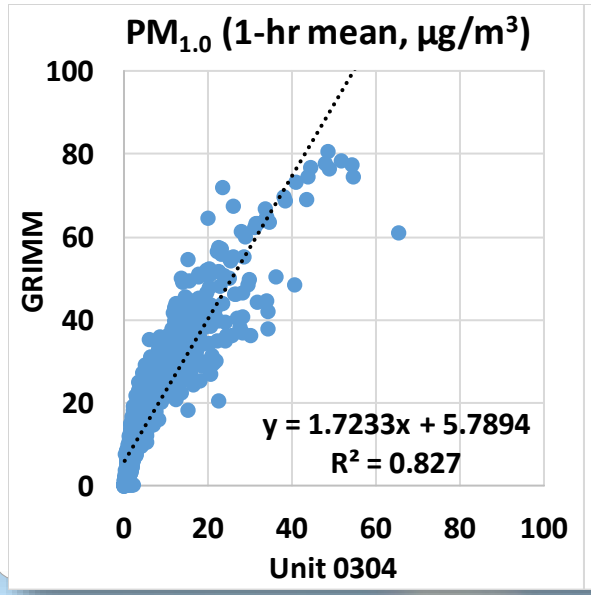


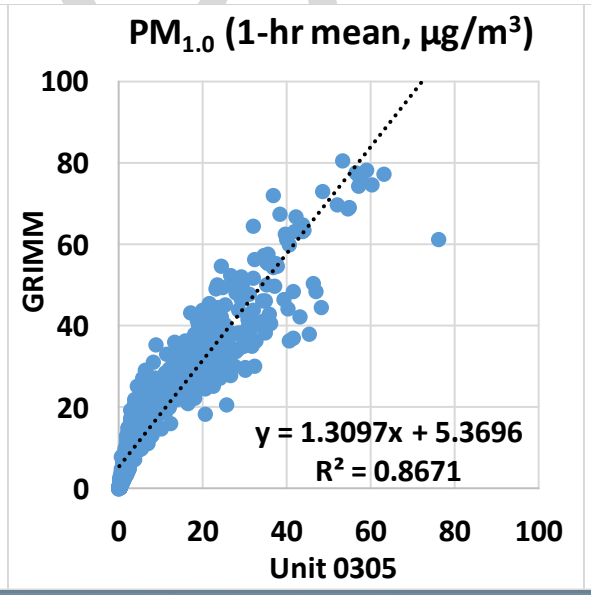


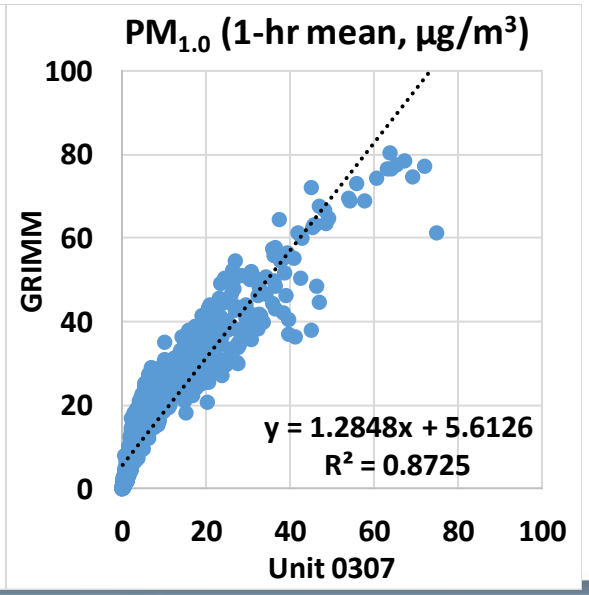
Alphasense OPC-R2 vs GRIMM ($PM_{1.0}$; 1-hr mean)



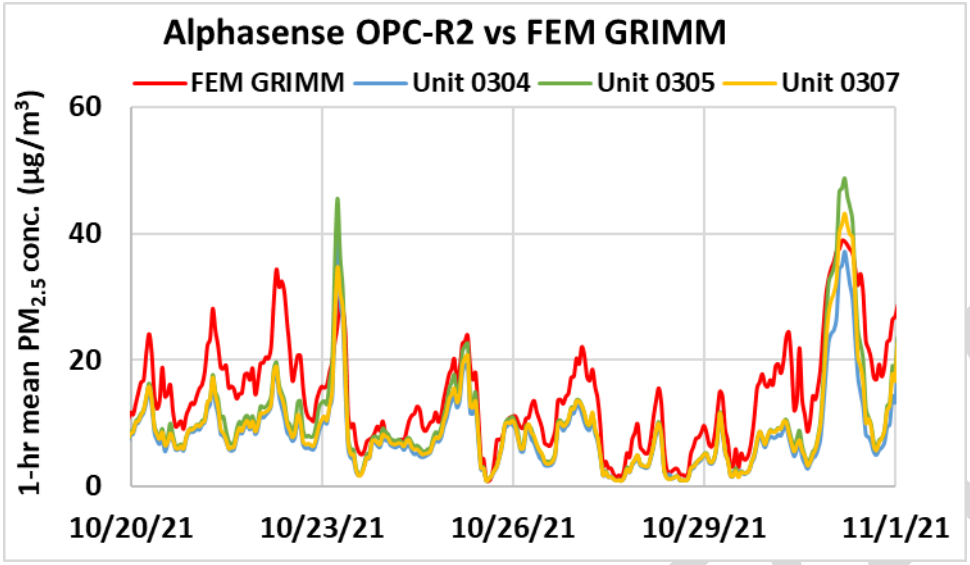
- The Alphasense OPC-R2 sensors showed strong correlations with the corresponding GRIMM data ($0.82 < R^2 < 0.88$)
- Overall, the Alphasense OPC-R2 sensors underestimated the $PM_{1.0}$ mass concentrations as measured by GRIMM
- The Alphasense OPC-R2 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by GRIMM



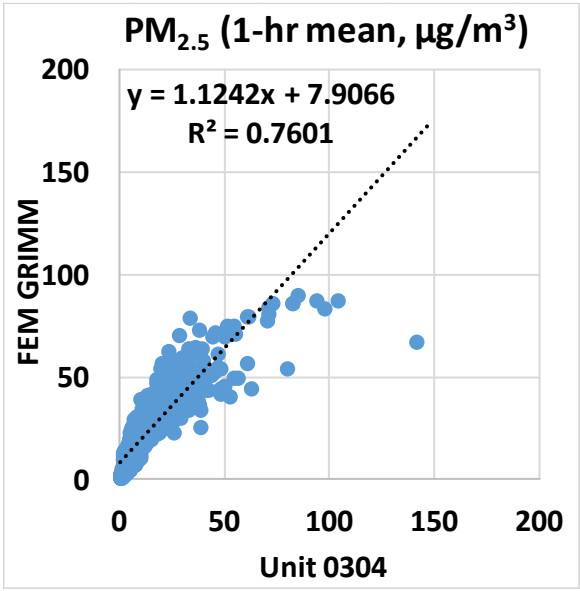


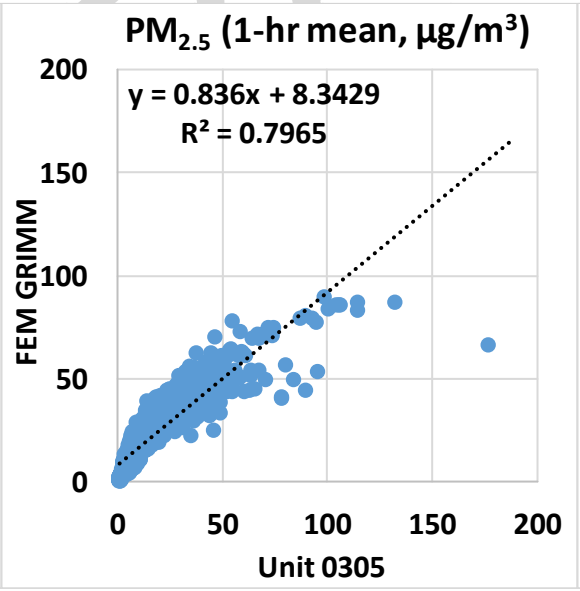


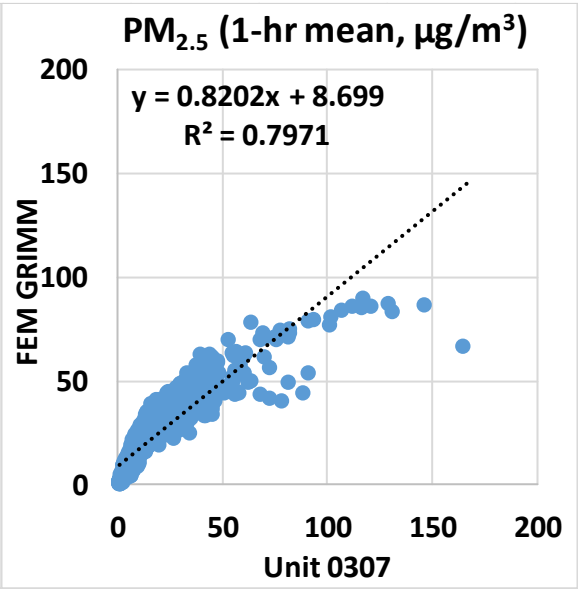
Alphasense OPC-R2 vs FEM GRIMM ($PM_{2.5}$; 1-hr mean)



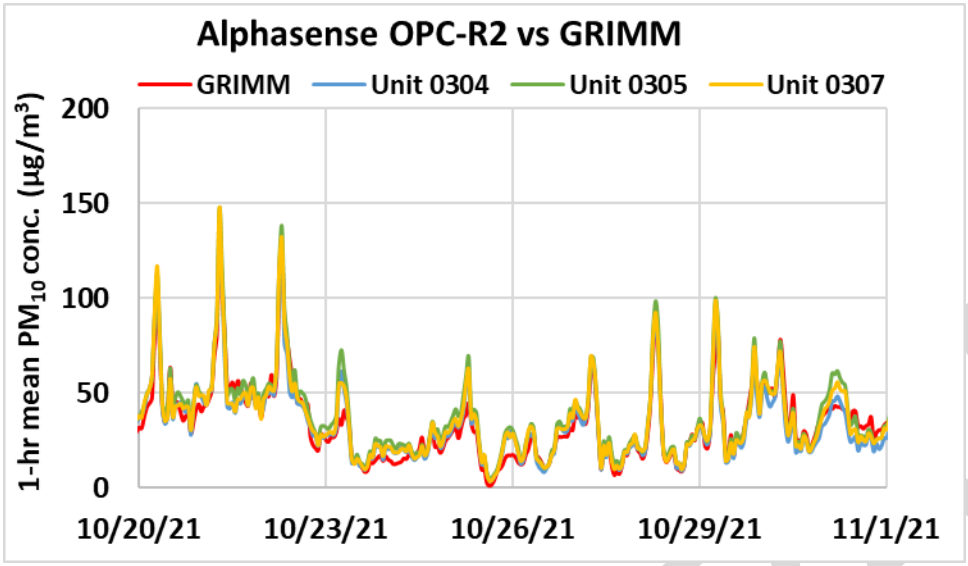
- The Alphasense OPC-R2 sensors showed strong correlations with the corresponding FEM GRIMM data ($0.76 < R^2 < 0.80$)
- Overall, the Alphasense OPC-R2 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM GRIMM
- The Alphasense OPC-R2 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM



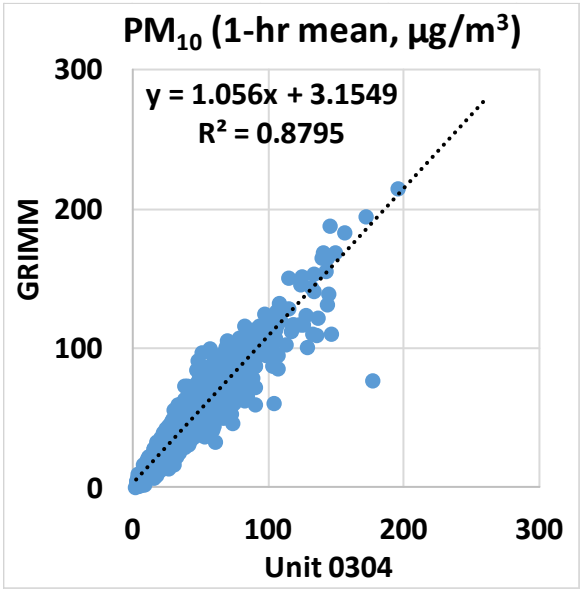


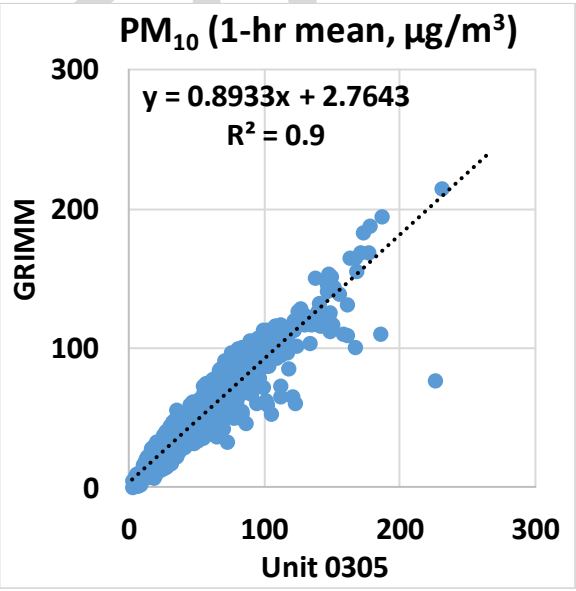


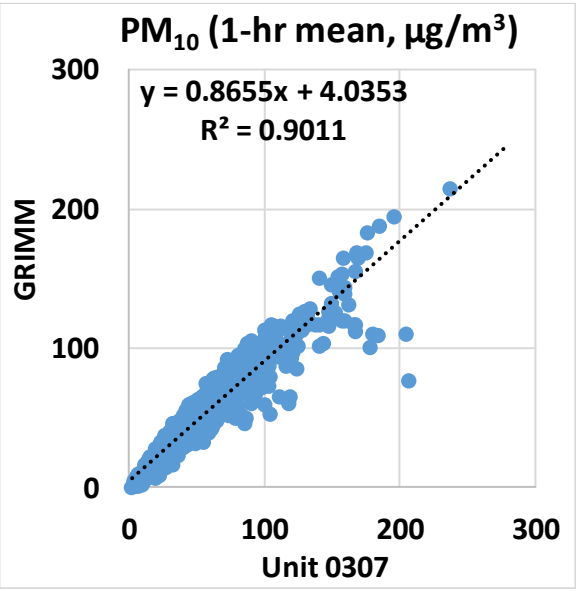
Alphasense OPC-R2 vs GRIMM (PM_{10}; 1-hr mean)



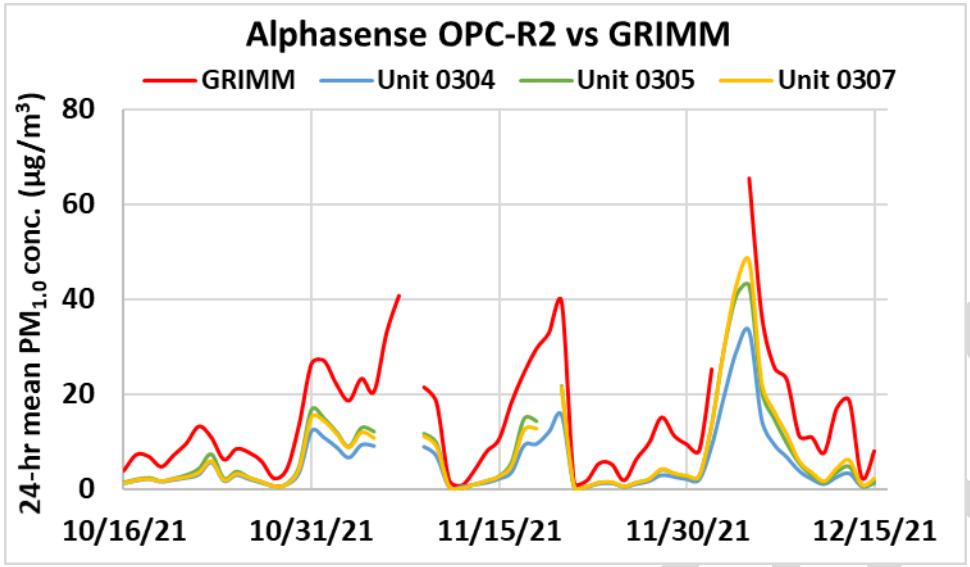
- The Alphasense OPC-R2 sensors showed strong to very strong correlations with the corresponding GRIMM data ($0.87 < R^2 < 0.91$)
- Overall, the Alphasense OPC-R2 sensors underestimated the PM_{10} mass concentrations as measured by GRIMM
- The Alphasense OPC-R2 sensors seemed to track the PM_{10} diurnal variations as recorded by GRIMM



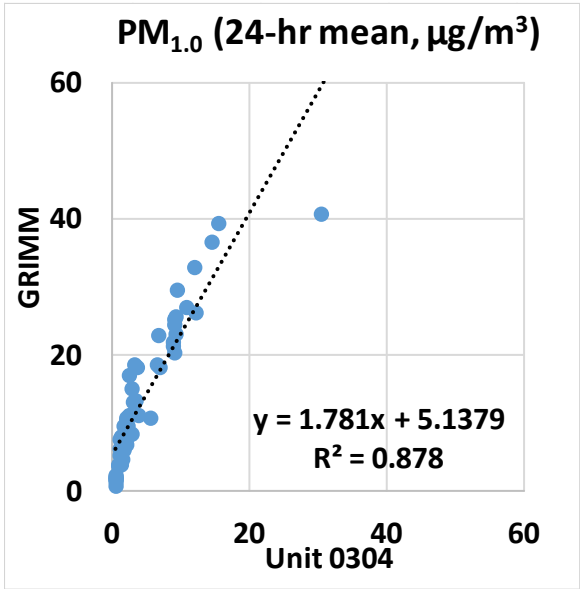


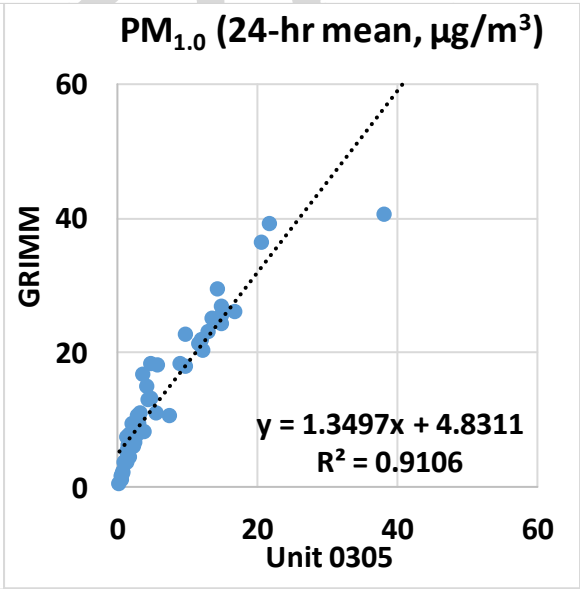


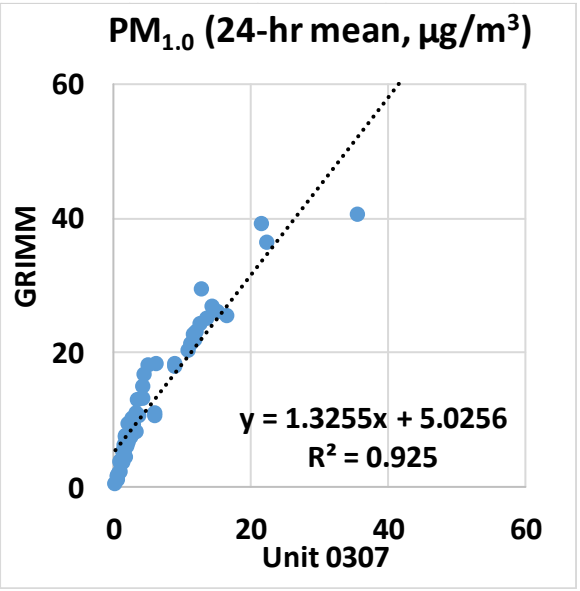
Alphasense OPC-R2 vs GRIMM ($PM_{1.0}$; 24-hr mean)



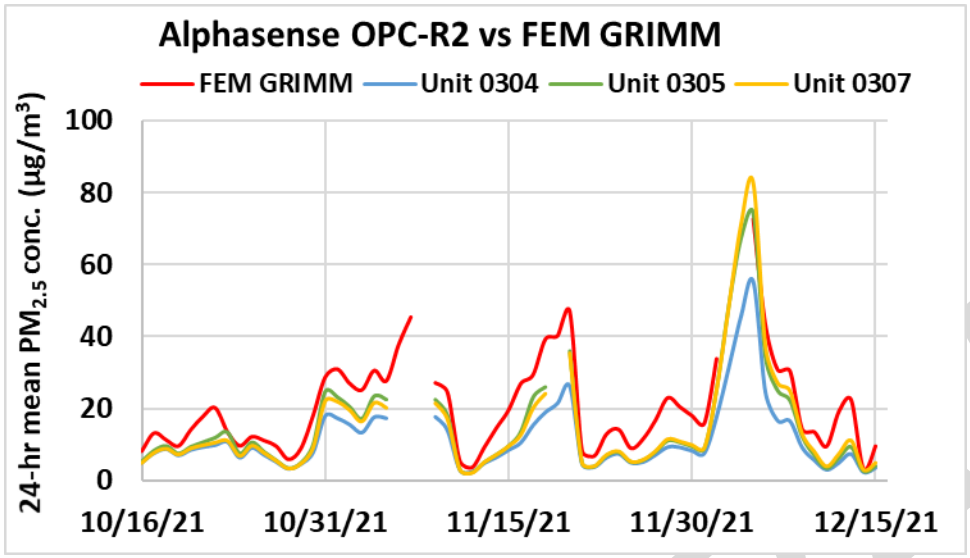
- The Alphasense OPC-R2 sensors showed strong to very strong correlations with the corresponding GRIMM data ($0.87 < R^2 < 0.93$)
- Overall, the Alphasense OPC-R2 sensors underestimated the $PM_{1.0}$ mass concentrations as measured by GRIMM
- The Alphasense OPC-R2 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by GRIMM



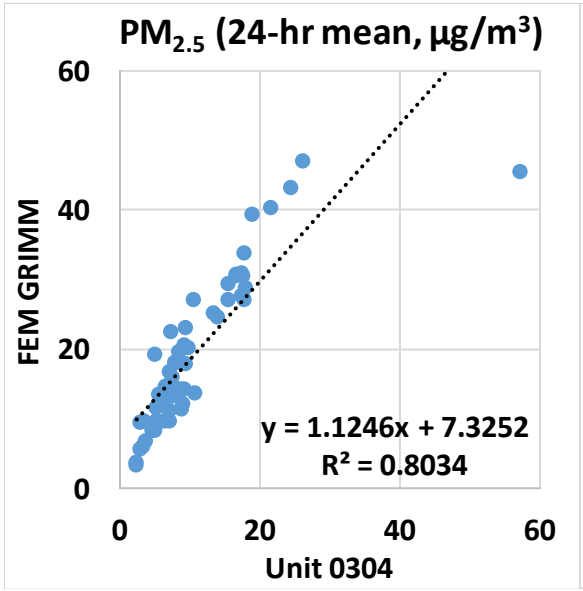


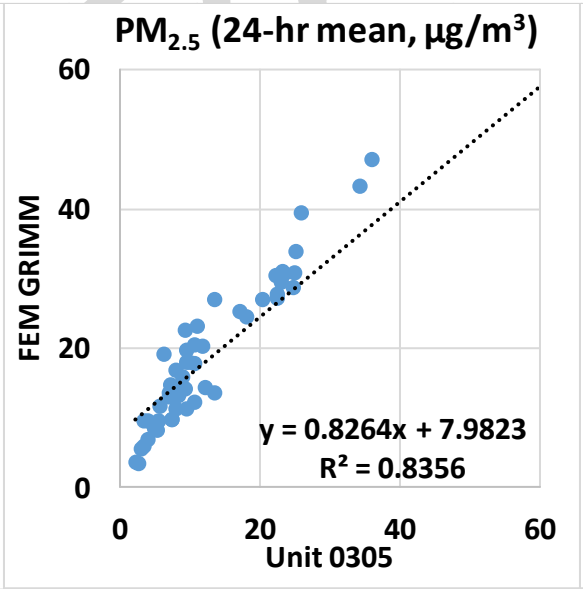


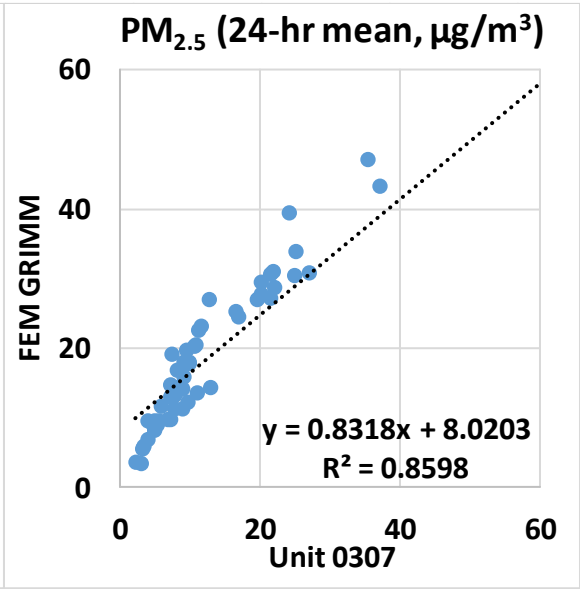
Alphasense OPC-R2 vs FEM GRIMM ($PM_{2.5}$; 24-hr mean)



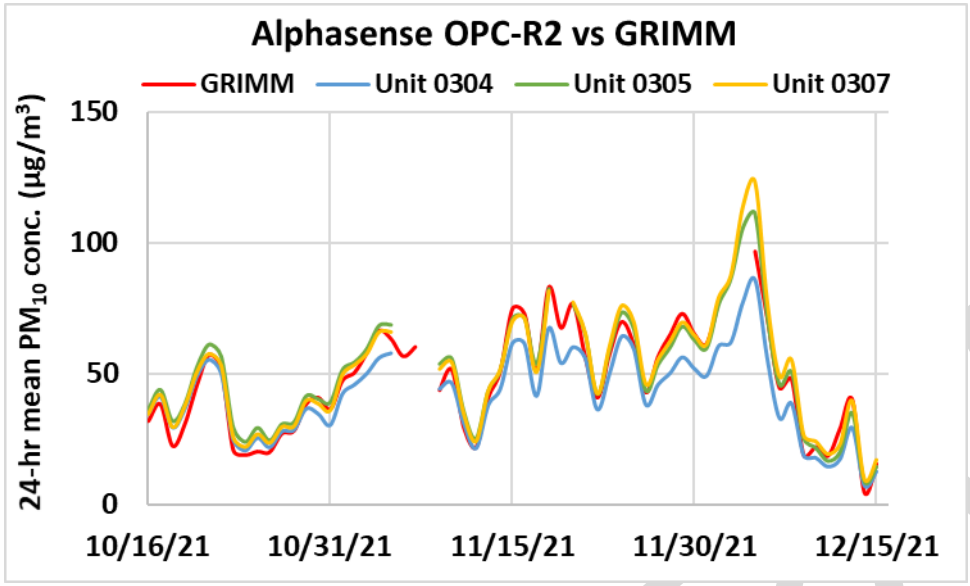
- The Alphasense OPC-R2 sensors showed strong correlations with the corresponding FEM GRIMM data ($0.80 < R^2 < 0.86$)
- Overall, the Alphasense OPC-R2 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM GRIMM
- The Alphasense OPC-R2 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM



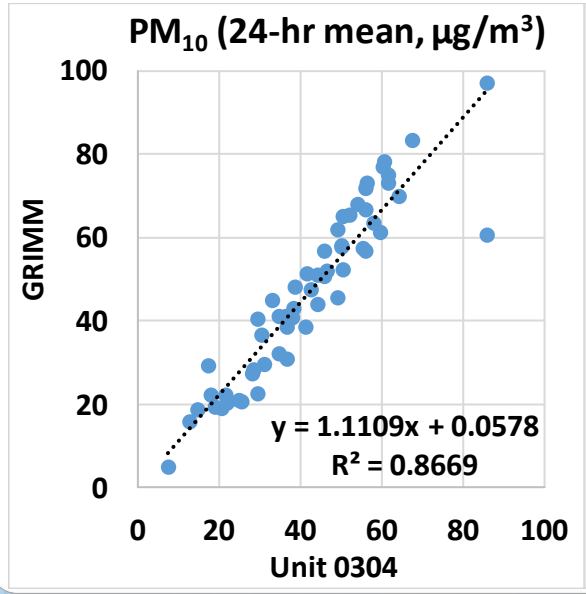


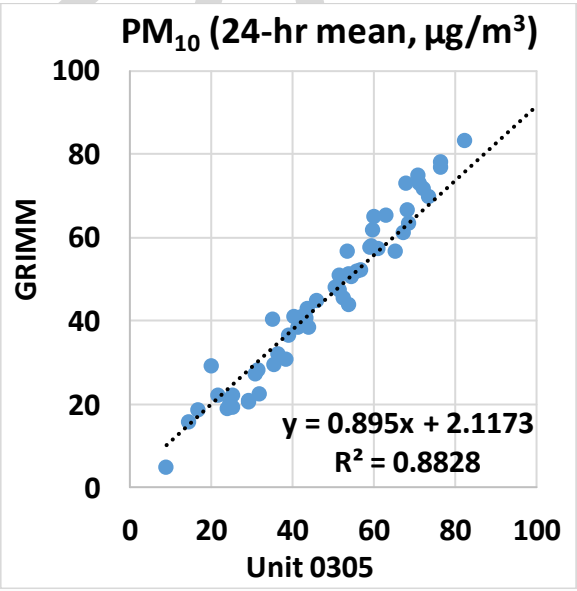


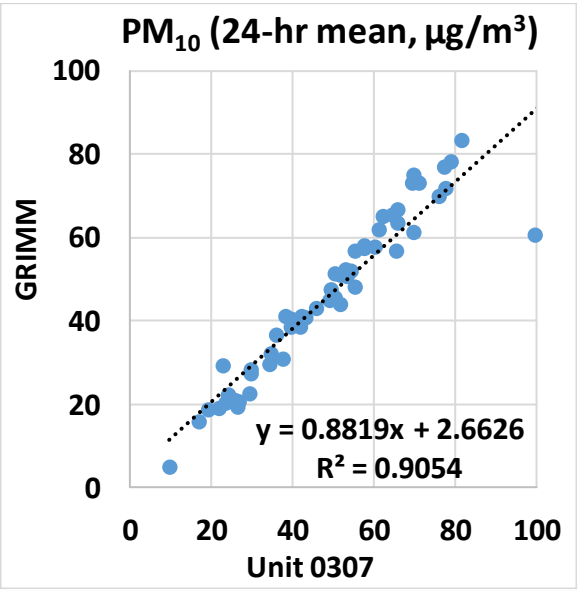
Alphasense OPC-R2 vs GRIMM (PM_{10}; 24-hr mean)



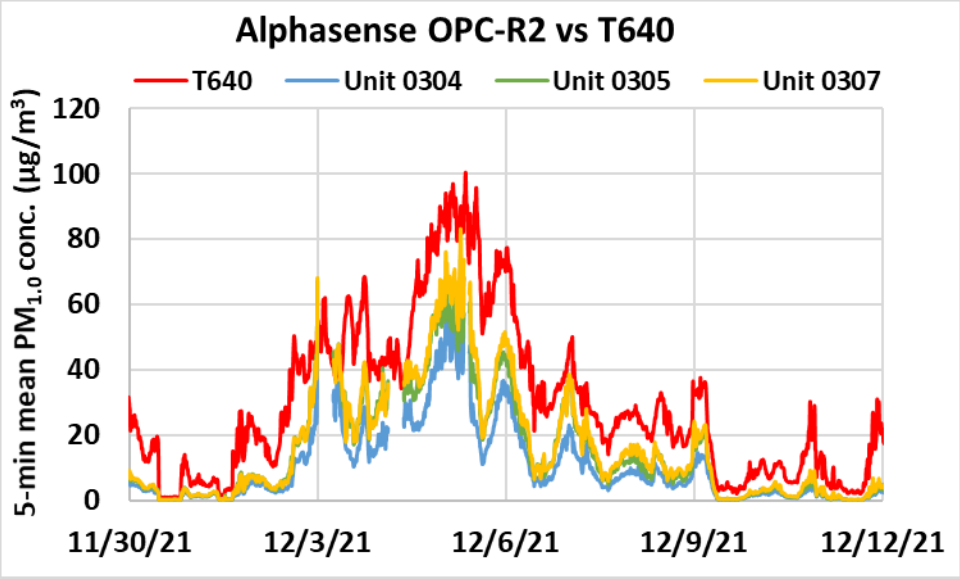
- The Alphasense OPC-R2 sensors showed strong to very strong correlations with the corresponding GRIMM data ($0.86 < R^2 < 0.91$)
- Overall, the Alphasense OPC-R2 sensors underestimated the PM_{10} mass concentrations as measured by GRIMM
- The Alphasense OPC-R2 sensors seemed to track the PM_{10} diurnal variations as recorded by GRIMM



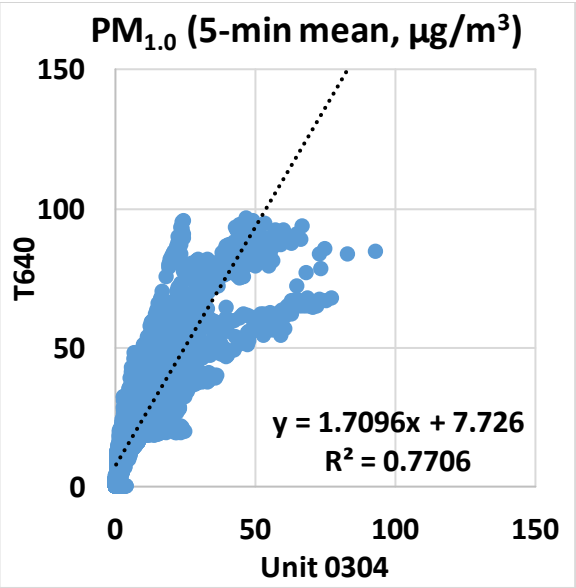


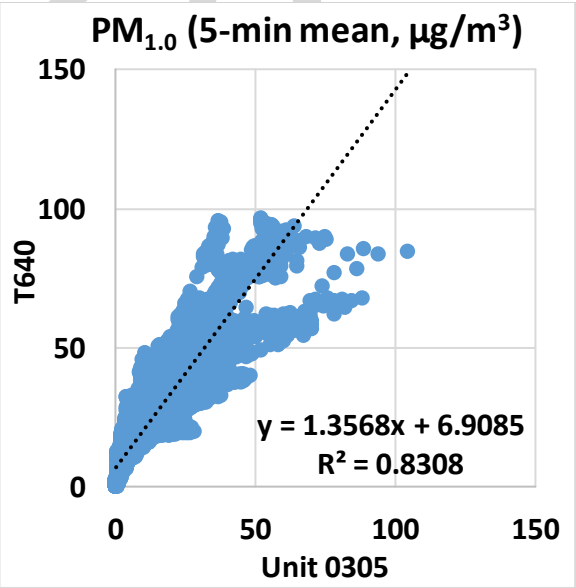


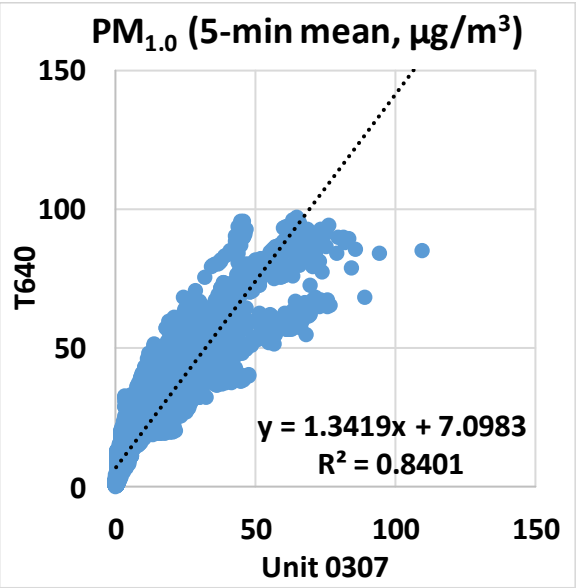
Alphasense OPC-R2 vs T640 ($PM_{1.0}$; 5-min mean)



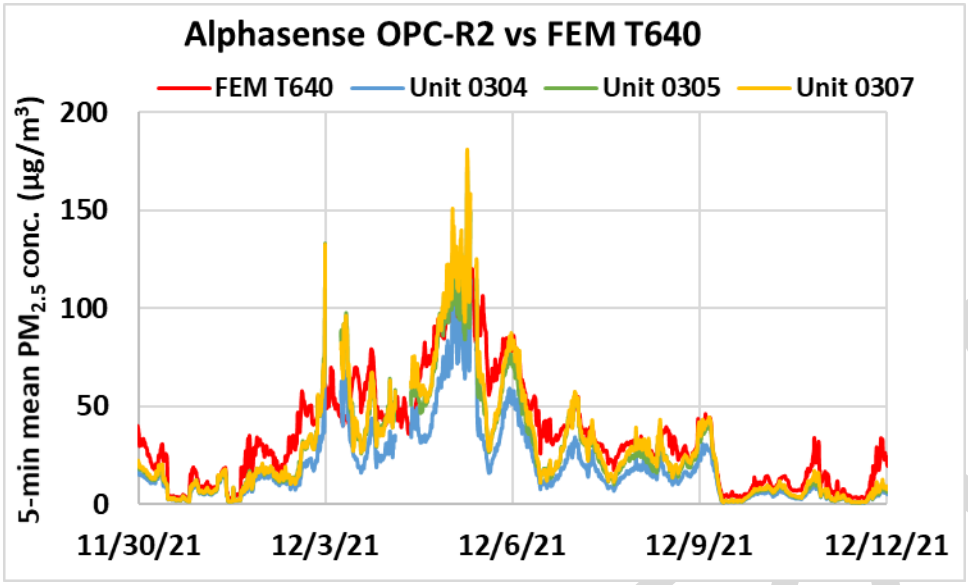
- The Alphasense OPC-R2 sensors showed strong correlations with the corresponding T640 data ($0.77 < R^2 < 0.85$)
- Overall, the Alphasense OPC-R2 sensors underestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The Alphasense OPC-R2 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640



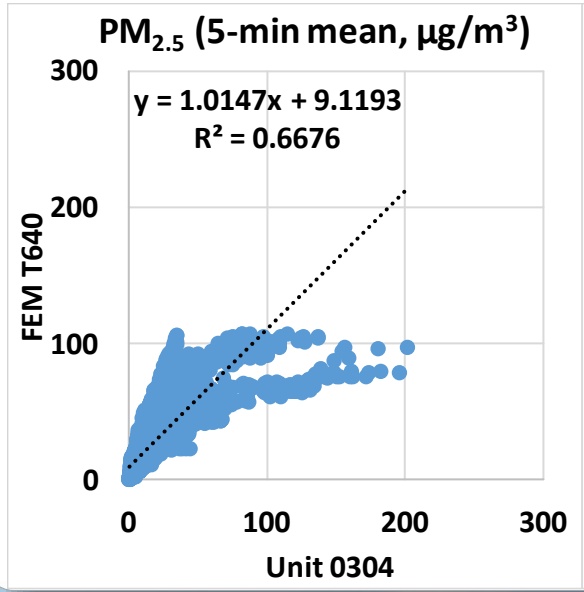


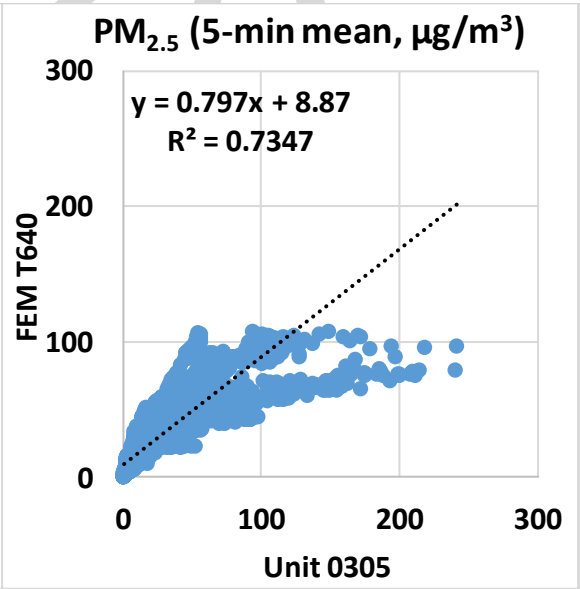


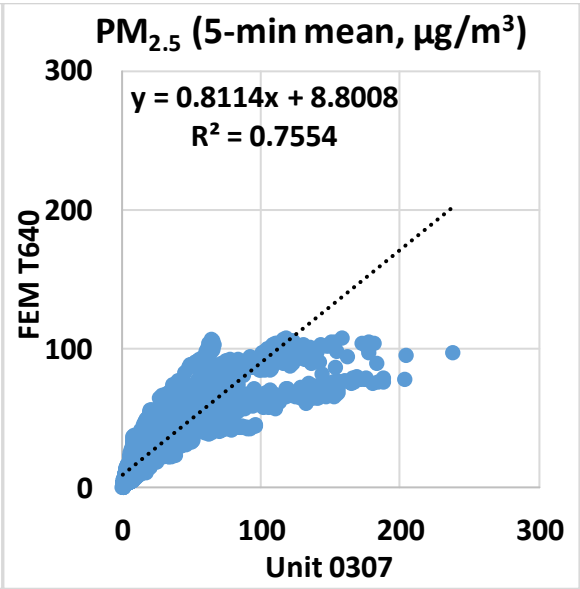
Alphasense OPC-R2 vs FEM T640 ($PM_{2.5}$; 5-min mean)



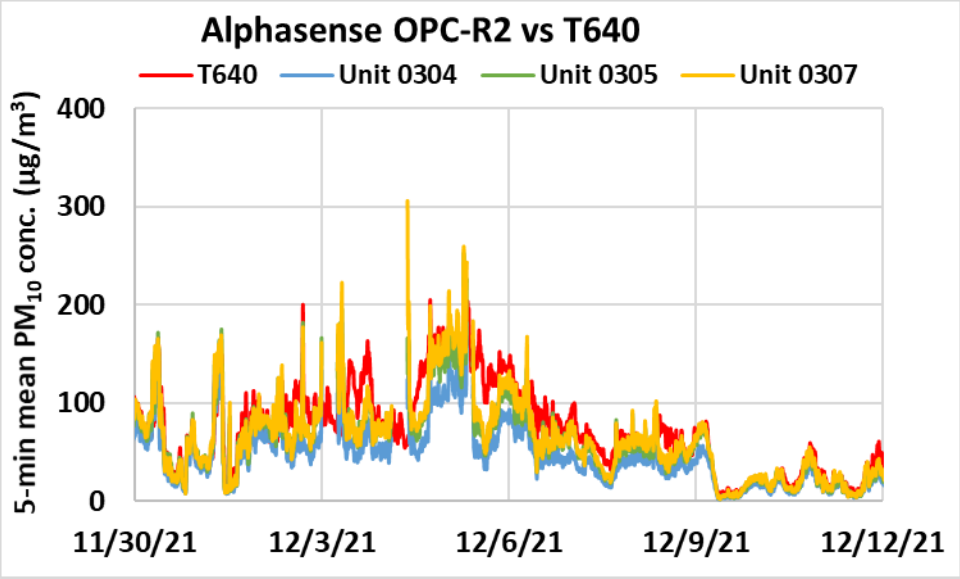
- The Alphasense OPC-R2 sensors showed moderate to strong correlations with the corresponding FEM T640 data ($0.66 < R^2 < 0.76$)
- Overall, the Alphasense OPC-R2 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The Alphasense OPC-R2 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



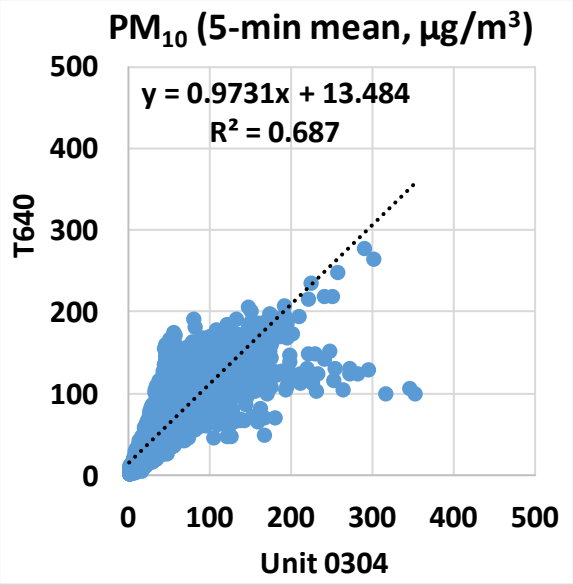


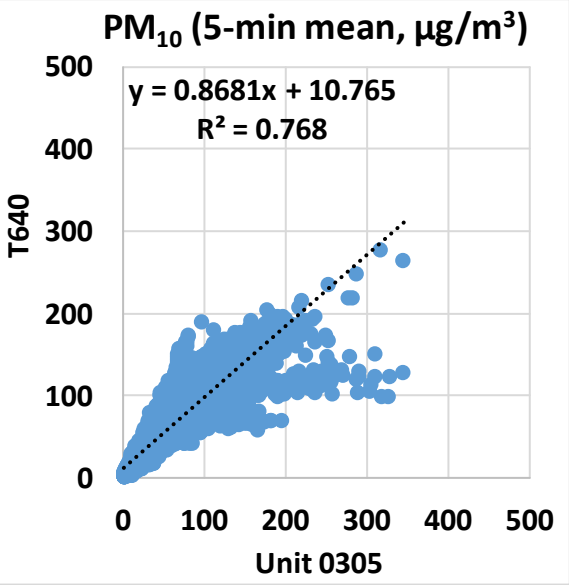


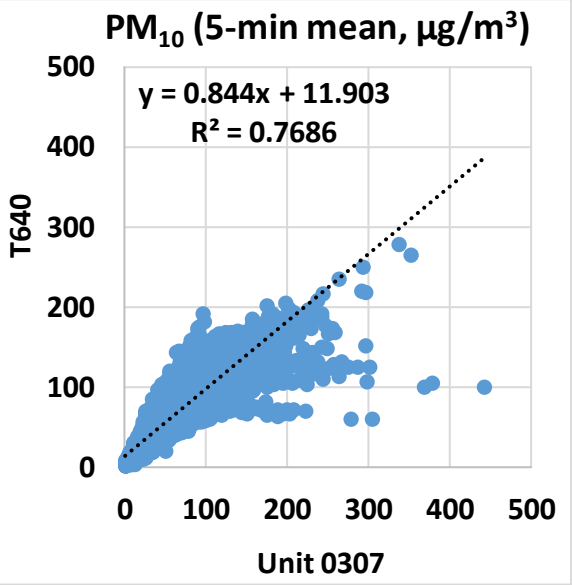
Alphasense OPC-R2 vs T640 (PM_{10}; 5-min mean)



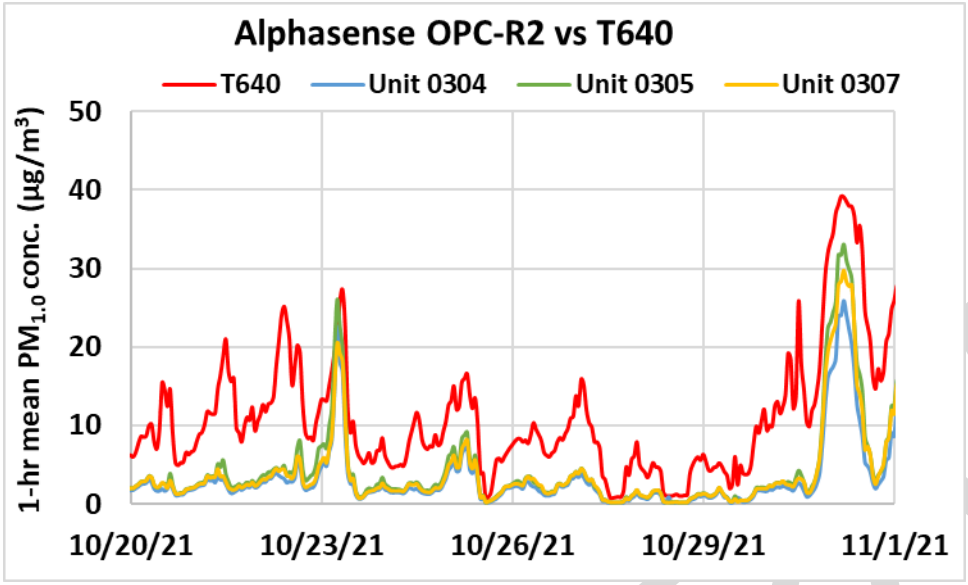
- Alphasense OPC-R2 sensors showed moderate to strong correlations with the corresponding T640 data ($0.68 < R^2 < 0.77$)
- Overall, the Alphasense OPC-R2 sensors underestimated the PM_{10} mass concentrations as measured by T640
- The Alphasense OPC-R2 sensors seemed to track the PM_{10} diurnal variations as recorded by T640



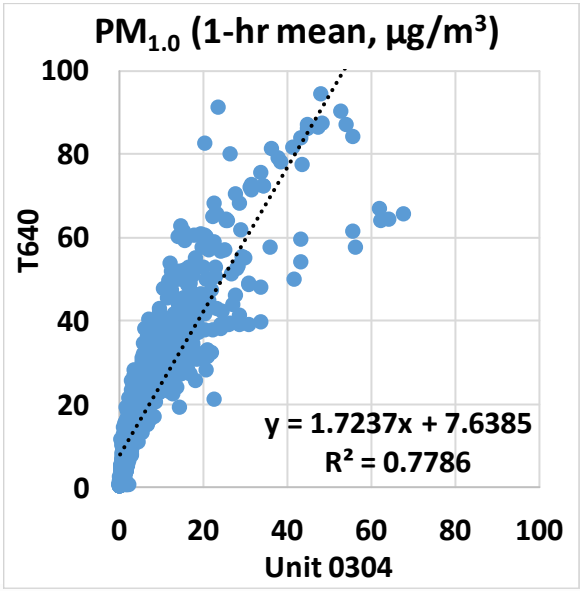


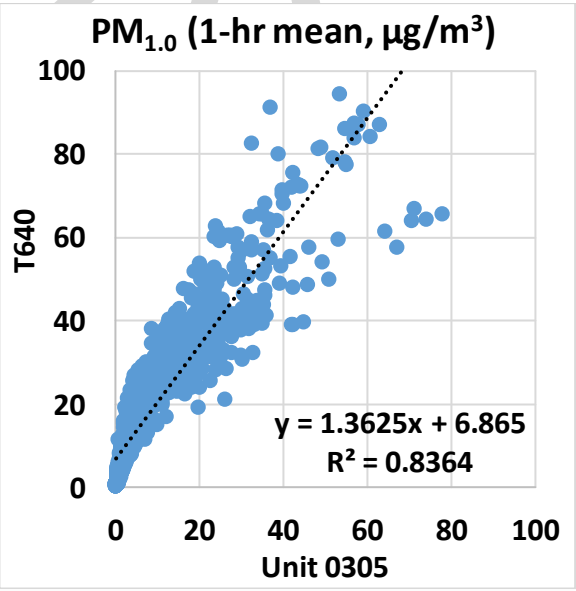


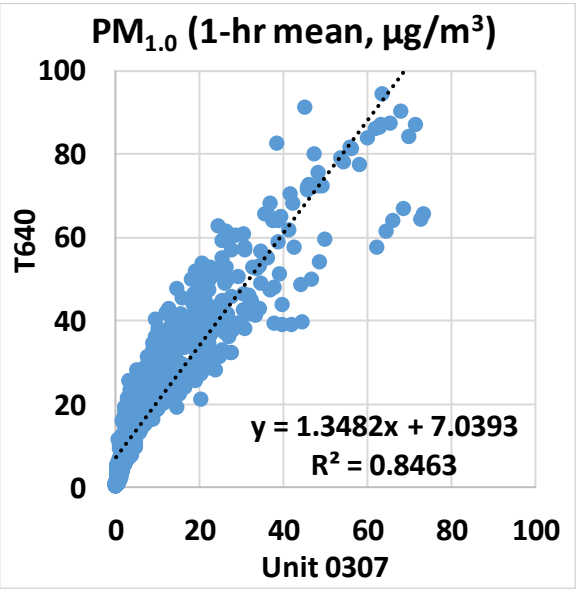
Alphasense OPC-R2 vs T640 ($PM_{1.0}$; 1-hr mean)



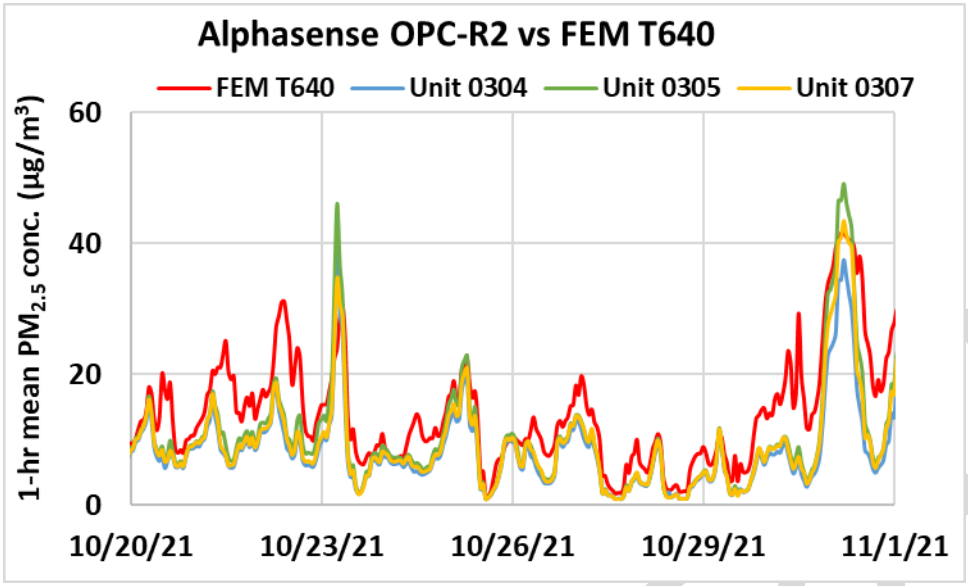
- The Alphasense OPC-R2 sensors showed strong correlations with the corresponding T640 data ($0.77 < R^2 < 0.85$)
- Overall, the Alphasense OPC-R2 sensors underestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The Alphasense OPC-R2 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640



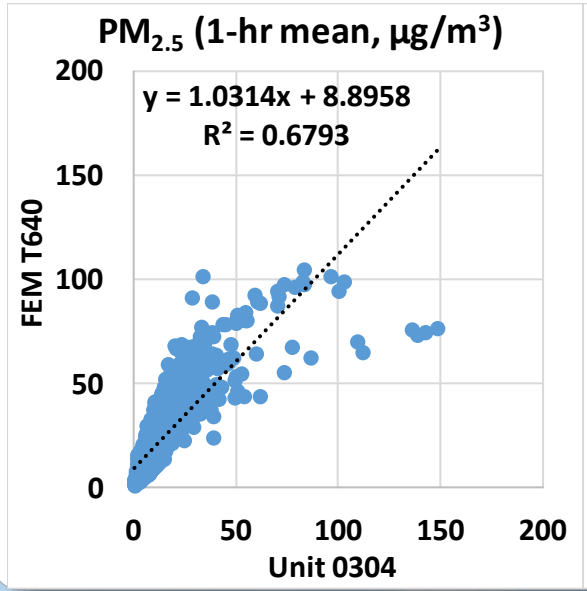


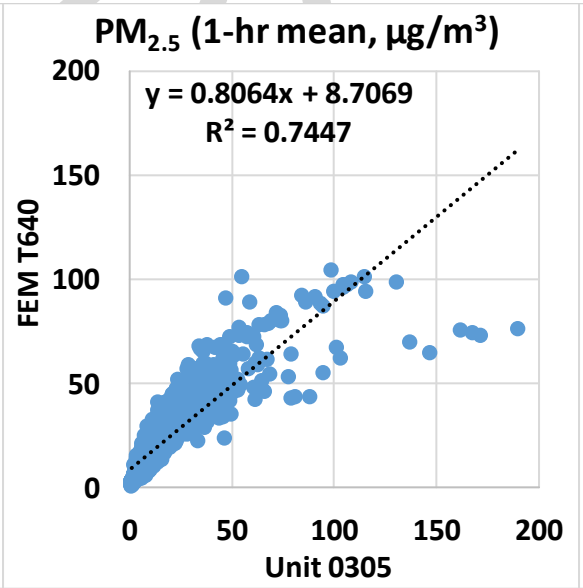


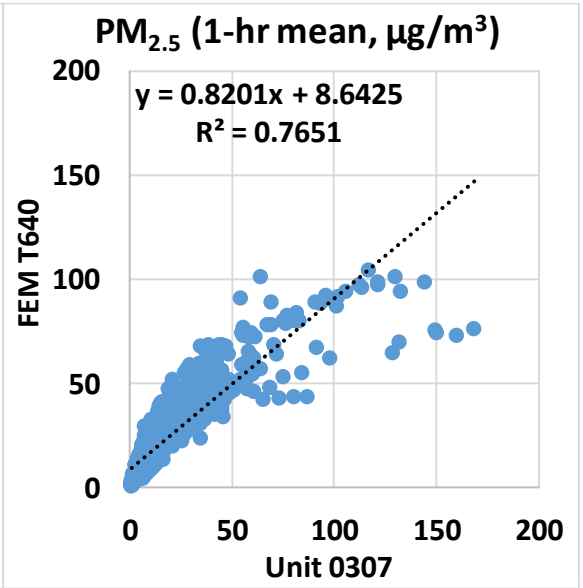
Alphasense OPC-R2 vs FEM T640 ($PM_{2.5}$; 1-hr mean)



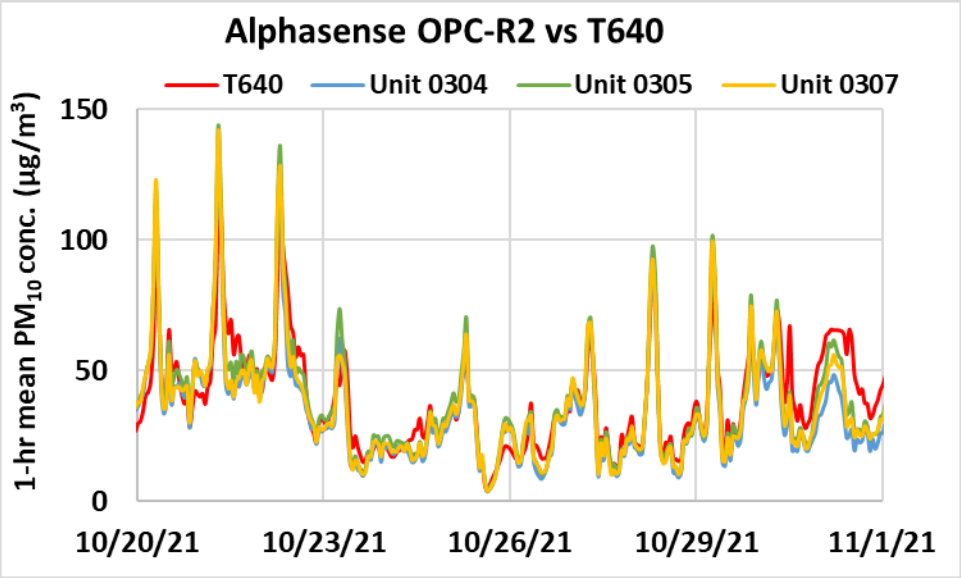
- The Alphasense OPC-R2 sensors showed moderate to strong correlations with the corresponding FEM T640 data ($0.67 < R^2 < 0.77$)
- Overall, the Alphasense OPC-R2 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The Alphasense OPC-R2 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



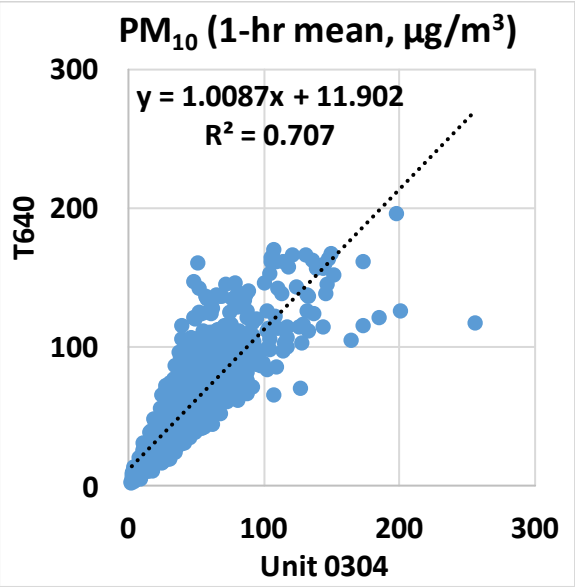


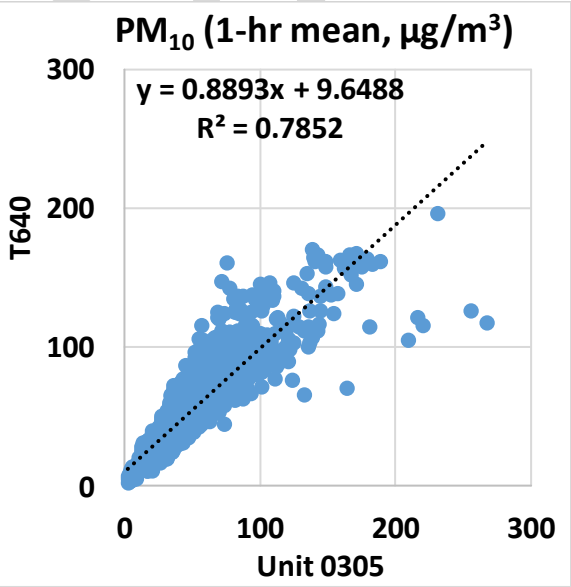


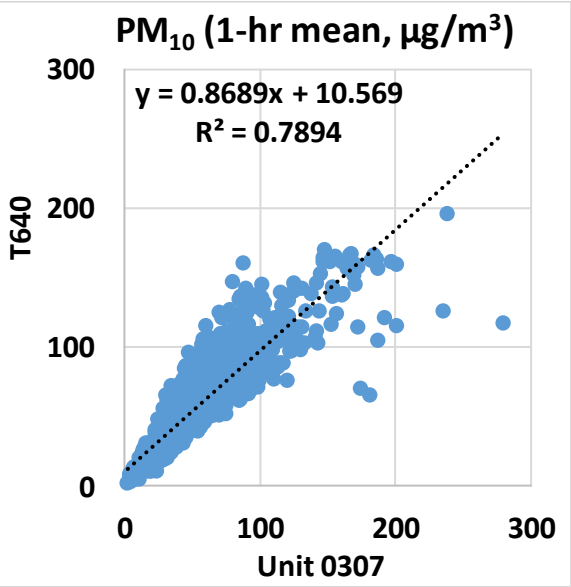
Alphasense OPC-R2 vs T640 (PM_{10}; 1-hr mean)



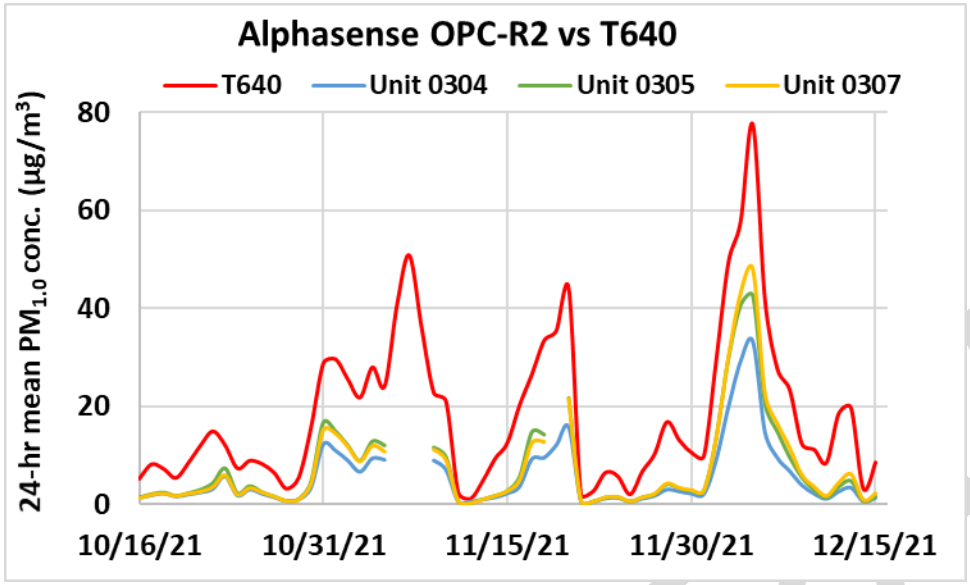
- The Alphasense OPC-R2 sensors showed strong correlations with the corresponding T640 data ($0.70 < R^2 < 0.79$)
- Overall, the Alphasense OPC-R2 sensors underestimated the PM_{10} mass concentrations as measured by T640
- The Alphasense OPC-R2 sensors seemed to track the PM_{10} diurnal variations as recorded by T640



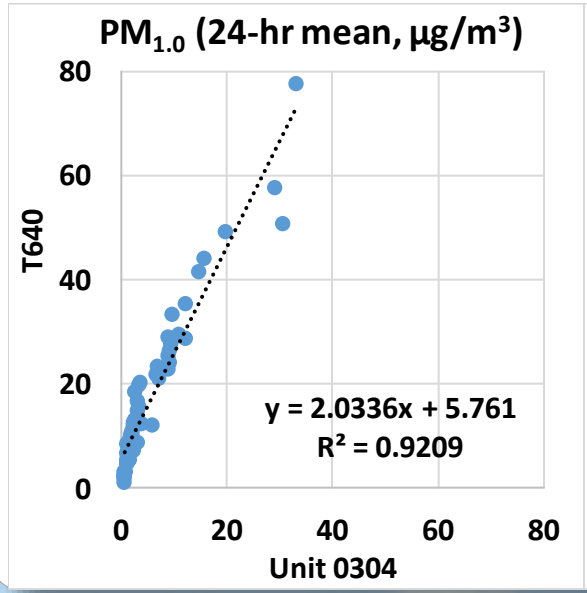


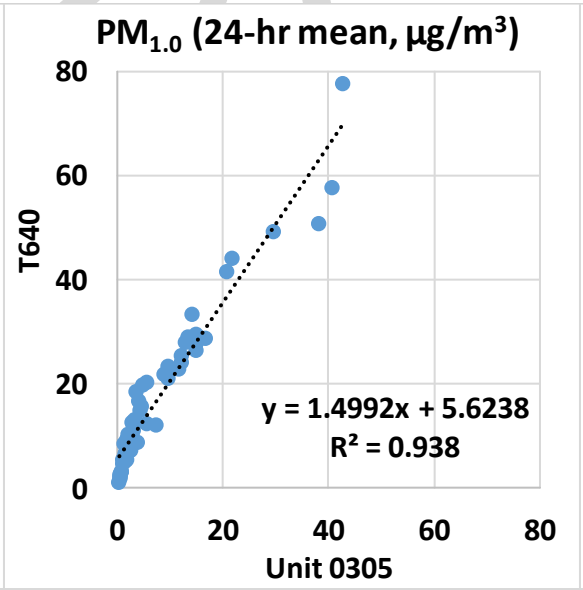


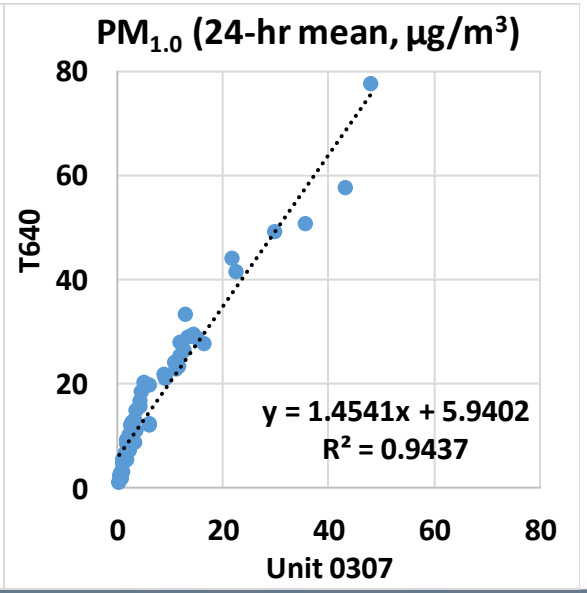
Alphasense OPC-R2 vs T640 ($PM_{1.0}$; 24-hr mean)



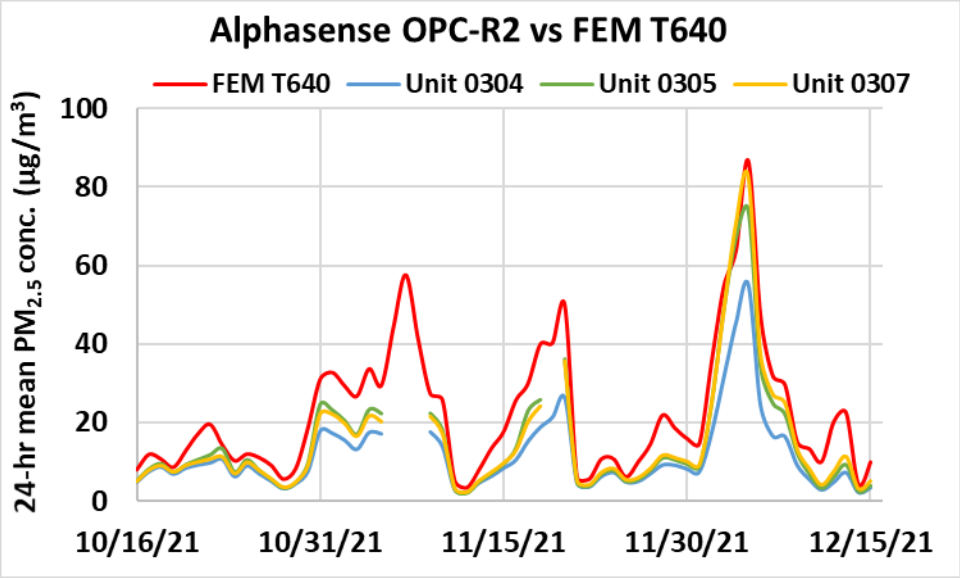
- The Alphasense OPC-R2 sensors showed very strong correlations with the corresponding T640 data ($0.92 < R^2 < 0.95$)
- Overall, the Alphasense OPC-R2 sensors underestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The Alphasense OPC-R2 sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640



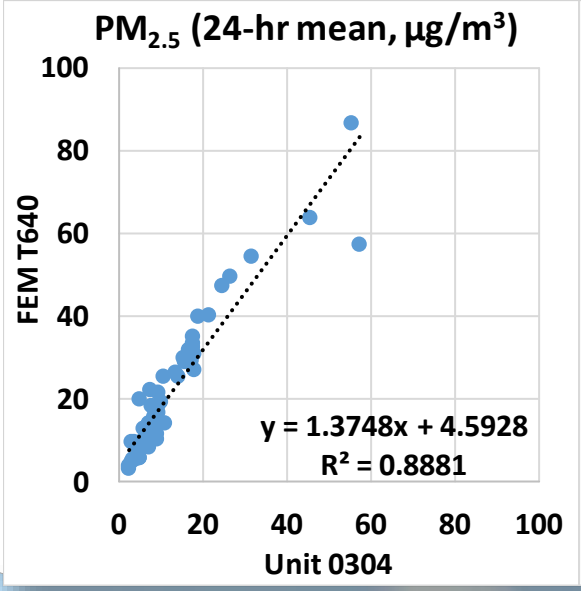


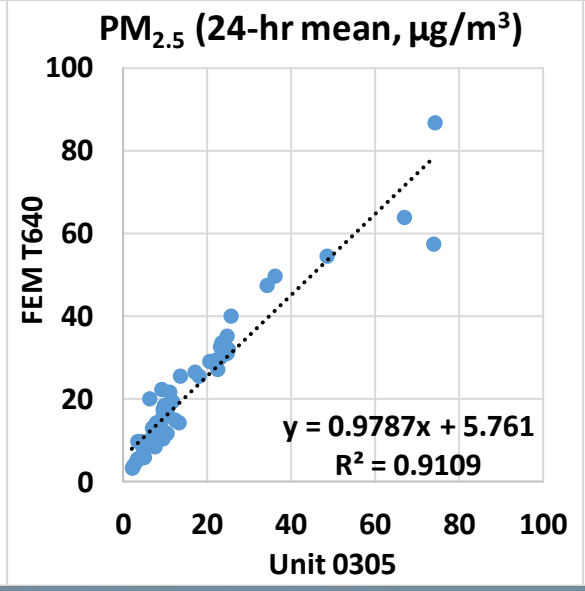


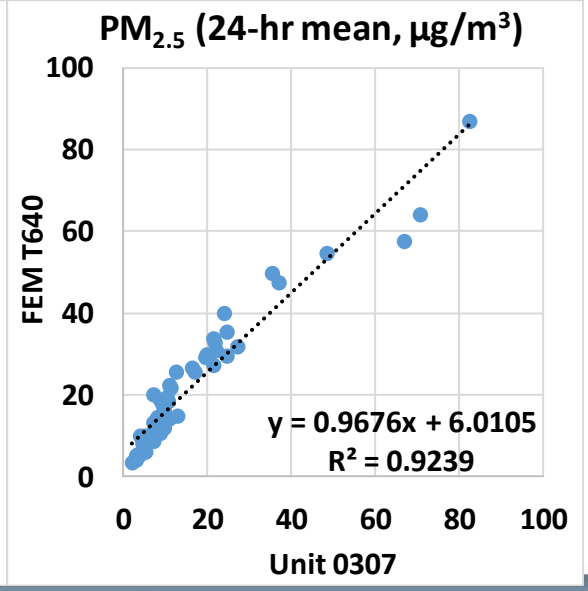
Alphasense OPC-R2 vs FEM T640 ($PM_{2.5}$; 24-hr mean)



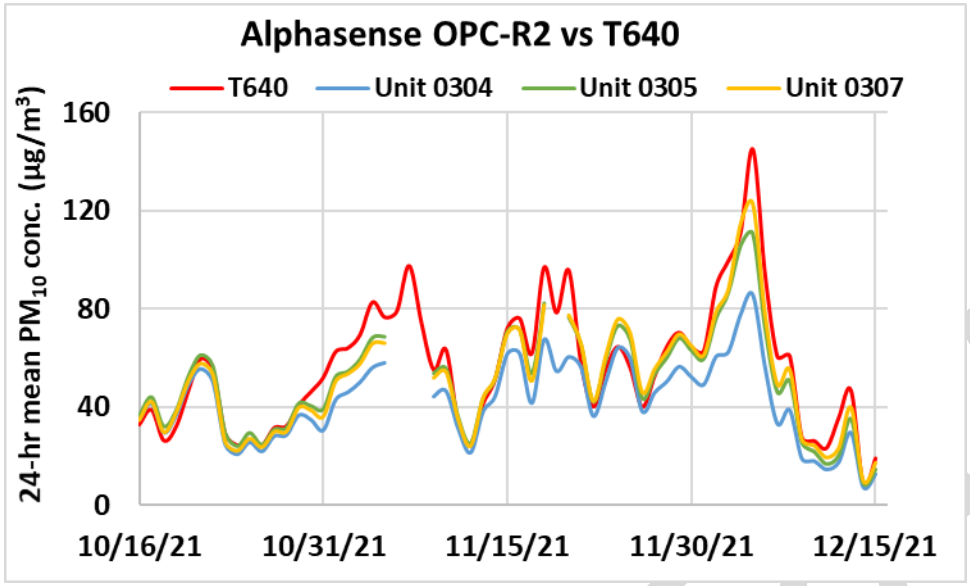
- The Alphasense OPC-R2 sensors showed strong to very strong correlations with the corresponding FEM T640 data ($0.88 < R^2 < 0.93$)
- Overall, the Alphasense OPC-R2 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The Alphasense OPC-R2 sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



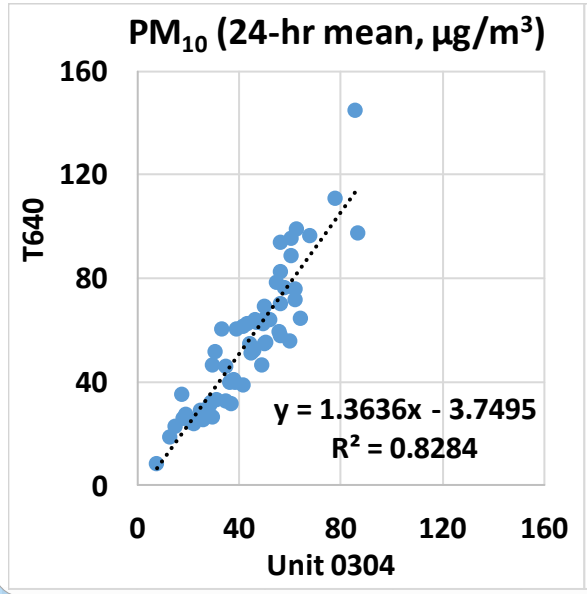


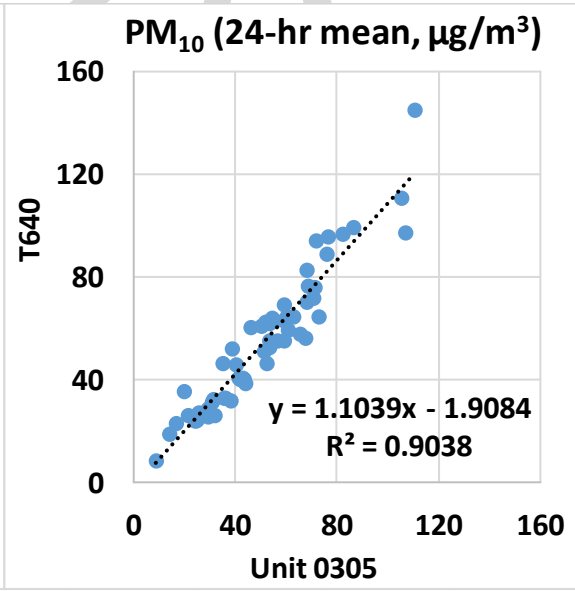


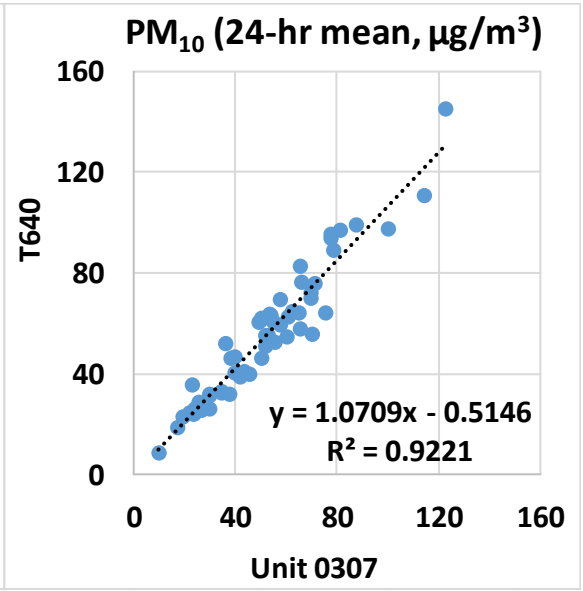
Alphasense OPC-R2 vs T640 (PM_{10}; 24-hr mean)



- The Alphasense OPC-R2 sensors showed strong to very strong correlations with the corresponding T640 data ($0.82 < R^2 < 0.93$)
- Overall, the Alphasense OPC-R2 sensors underestimated the PM_{10} mass concentrations as measured by T640
- The Alphasense OPC-R2 sensors seemed to track the PM_{10} diurnal variations as recorded by T640







Summary

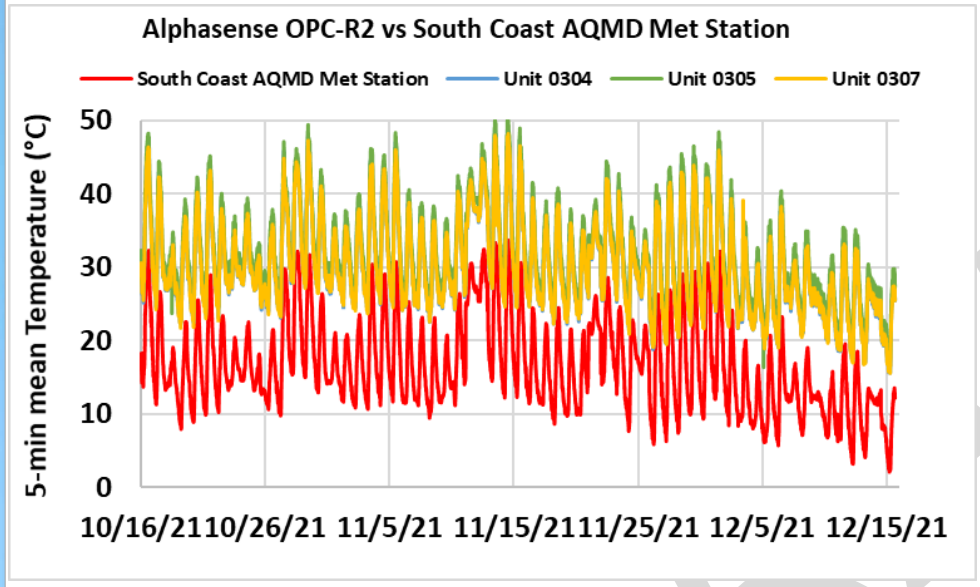
	Average of 3 Sensors, $PM_{1.0}$		Alphasense OPC-R2 vs GRIMM & T640, $PM_{1.0}$						GRIMM & T640 ($PM_{1.0}$, $\mu g/m^3$)		
	Average ($\mu g/m^3$)	SD ($\mu g/m^3$)	R^2	Slope	Intercept	MBE[1] ($\mu g/m^3$)	MAE[2] ($\mu g/m^3$)	RMSE[3] ($\mu g/m^3$)	Ref. Average	Ref. SD	Range during the field evaluation
5-min	7.1	10.4	0.77 to 0.87	1.28 to 1.71	5.4 to 7.7	-11.8 to -7.7	7.8 to 11.8	9.8 to 15.5	15.3 to 18.4	14.6 to 17.2	0.2 to 100.4
1-hr	7.2	10.3	0.78 to 0.87	1.28 to 1.72	5.4 to 7.6	-11.8 to -7.7	7.7 to 11.8	9.8 to 15.4	15.2 to 18.4	14.4 to 17.2	0.2 to 94.6
24-hr	7.2	9.1	0.88 to 0.94	1.33 to 2.03	4.8 to 5.9	-11.8 to -7.2	7.2 to 11.8	8.5 to 14.7	14.8 to 18.4	12.3 to 15.6	0.7 to 77.5
	Average of 3 Sensors, $PM_{2.5}$		Alphasense OPC-R2 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	14.6	17.9	0.67 to 0.78	0.80 to 1.10	8.2 to 9.1	-9.4 to -5.6	7.3 to 10.0	9.9 to 14.0	21.1 to 22.4	15.9 to 18.7	0.4 to 120.1
1-hr	14.7	17.7	0.68 to 0.80	0.81 to 1.12	7.9 to 8.9	-9.3 to -5.6	7.2 to 10.0	9.6 to 13.8	21.1 to 22.4	15.7 to 18.6	0.6 to 112.2
24-hr	15.4	13.5	0.80 to 0.92	0.82 to 1.37	4.6 to 8.0	-9.2 to -5.0	4.4 to 9.2	6.4 to 11.6	20.6 to 22.3	13.0 to 16.7	3.3 to 86.7
	Average of 3 Sensors, PM_{10}		Alphasense OPC-R2 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	48.6	33.3	0.69 to 0.86	0.84 to 1.01	4.0 to 13.5	-12.3 to 2.8	7.8 to 15.4	12.4 to 22.6	47.9 to 56.0	30.6 to 34.1	0.6 to 376.1
1-hr	48.8	31.5	0.71 to 0.90	0.87 to 1.06	2.8 to 11.9	-12.3 to 2.8	6.4 to 14.8	10.1 to 21.7	47.9 to 56.2	29.1 to 33.2	0.7 to 215.2
24-hr	48.9	21.1	0.83 to 0.92	0.88 to 1.36	-3.7 to 2.7	-12.0 to 3.2	4.3 to 12.7	7.5 to 17.4	47.3 to 56.0	20.0 to 26.0	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).

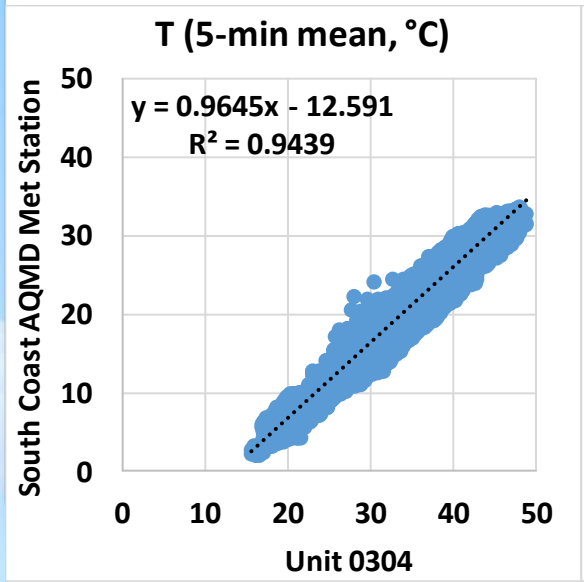
[2] Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.

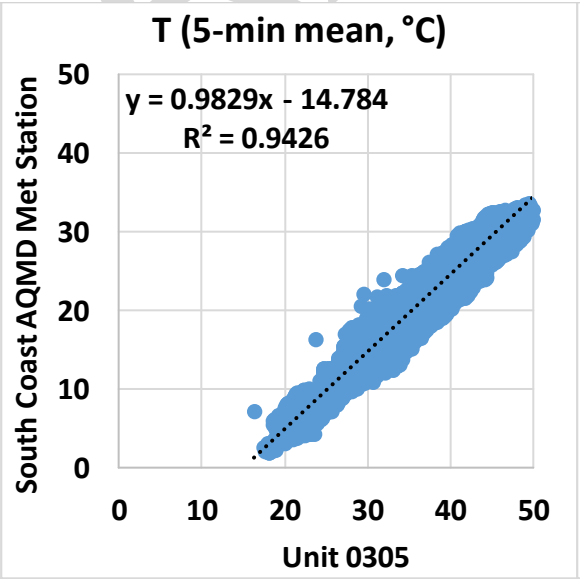
[3] Root Mean Square Error (RMSE): another metric to calculate measurement errors.

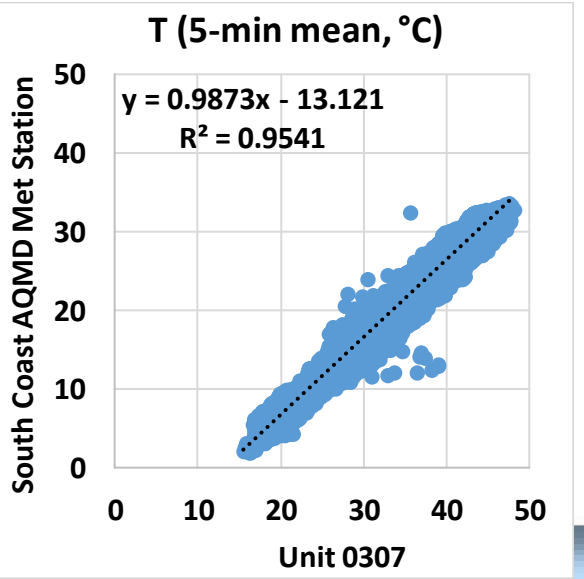
Alphasense OPC-R2 vs South Coast AQMD Met Station (Temp; 5-min mean)



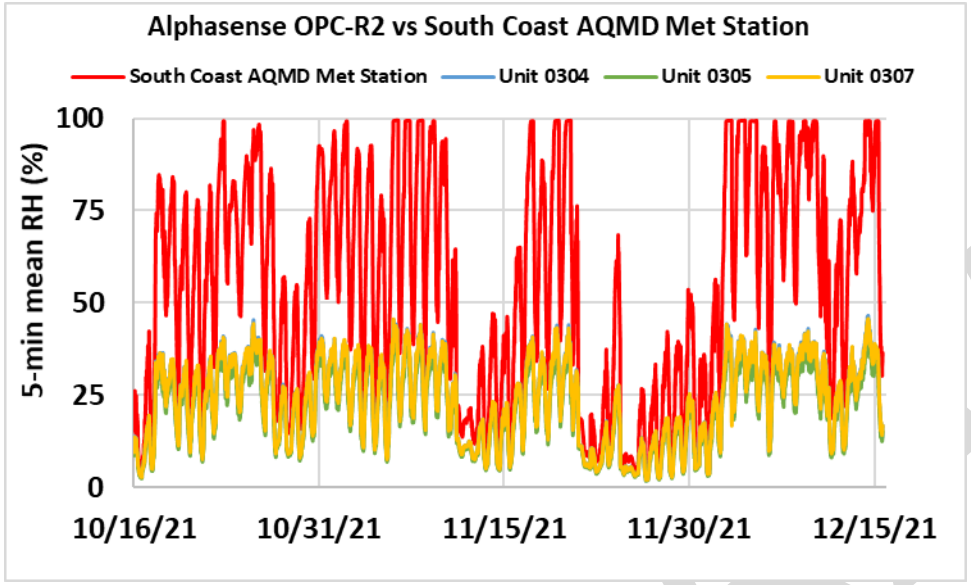
- The Alphasense OPC-R2 sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data (R^2 ~ 0.95)
- Overall, the Alphasense OPC-R2 sensors overestimated the temperature measurement as recorded by South Coast AQMD Met Station
- The Alphasense OPC-R2 sensors seemed to track the diurnal temperature variations as recorded by South Coast AQMD Met Station



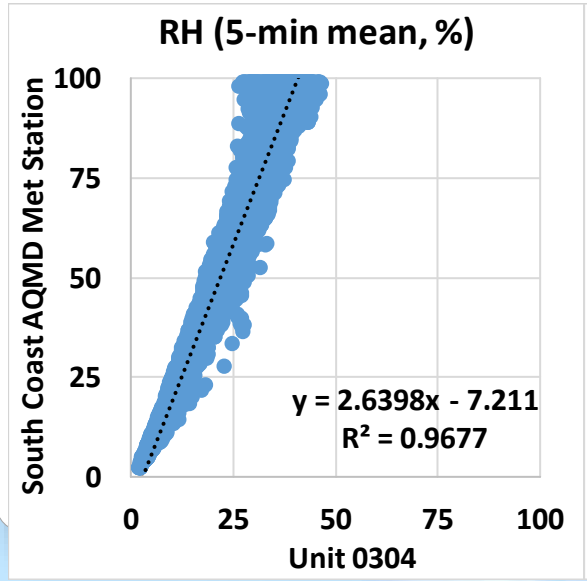


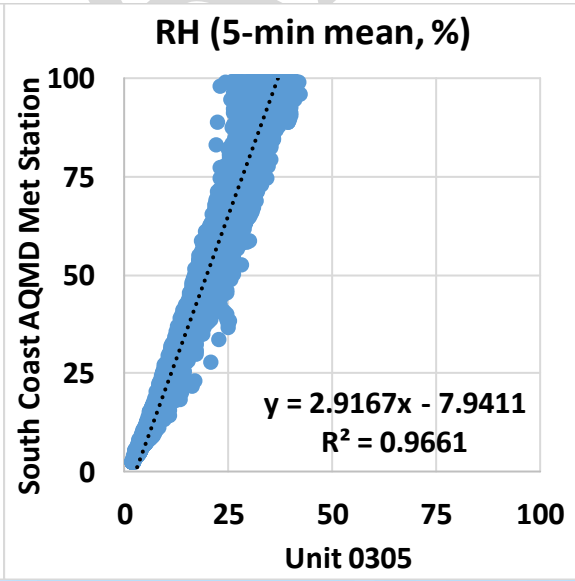


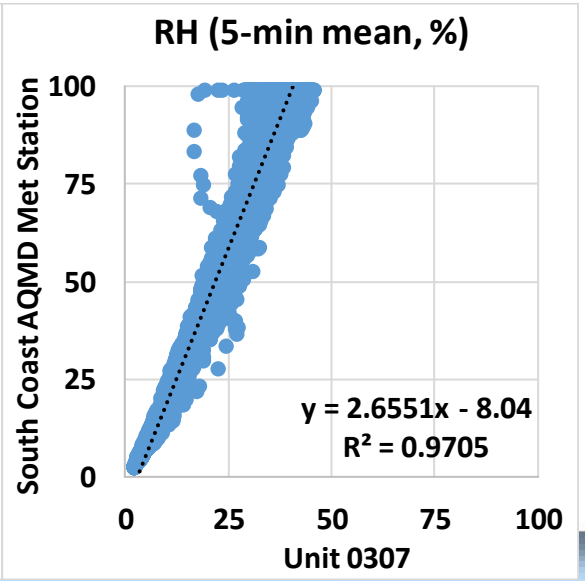
Alphasense OPC-R2 vs South Coast AQMD Met Station (RH; 5-min mean)



- The Alphasense OPC-R2 sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data (R^2 ~ 0.97)
- Overall, the Alphasense OPC-R2 sensors underestimated the RH measurement as recorded by South Coast AQMD Met Station
- The Alphasense OPC-R2 sensors seemed to track the diurnal RH variations as recorded by South Coast AQMD Met Station







Discussion

- The three **Alphasense OPC-R2** sensors' data recovery from all units was ~ 100% for all PM measurements
- The absolute intra-model variability was ~ 0.98, 1.69 and 3.98 µg/m^3 for $PM_{1.0}$, $PM_{2.5}$ and $PM_{10,}$ respectively
- Very strong correlations between GRIMM and T640 for $PM_{1.0}$ (R^2 ~ 0.98, 1-hr mean); very strong correlations between FEM GRIMM and FEM T640 for $PM_{2.5}$ (R^2 ~ 0.97, 1-hr mean) and strong correlations between GRIMM and T640 for PM_{10} (R^2 ~ 0.87, 1-hr mean) mass concentration measurements
- $PM_{1.0}$ mass concentrations measured by the Alphasense OPC-R2 sensors showed strong correlations with the corresponding GRIMM and T640 data ($0.77 < R^2 < 0.88$, 1-hr mean). The sensors underestimated $PM_{1.0}$ mass concentrations as measured by GRIMM and T640
- $PM_{2.5}$ mass concentrations measured by the Alphasense OPC-R2 sensors showed moderate to strong correlations with the corresponding FEM GRIMM and FEM T640 data ($0.67 < R^2 < 0.80$, 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 the Alphasense OPC-R2 sensors showed strong to very strong correlations with the corresponding GRIMM and T640 data ($0.70 < R^2 < 0.91$; 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