

Field Evaluation Redspira



Background

- From 10/29/2020 to 12/25/2020, three **Redspira** 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
- Redspira (3 units tested):
 - Particle sensor: **optical; non-FEM (PMS5003, Plantower)**
 - Each unit reports: $PM_{2.5}$ and PM_{10} ($\mu\text{g}/\text{m}^3$), temperature ($^{\circ}\text{C}$) and RH (%)
 - **Unit cost: \$180**
 - Time resolution: 1-min
 - Units IDs: 0083, 0084, 0085
- MetOne BAM (reference instrument):
 - Beta-attenuation monitor (**FEM $PM_{2.5}$ & PM_{10}**)
 - Measures $PM_{2.5}$ & PM_{10} ($\mu\text{g}/\text{m}^3$)
 - **Unit cost: ~\$20,000**
 - Time resolution: 1-hr
- Teledyne API T640 (reference instrument):
 - Optical particle counter (**FEM $PM_{2.5}$**)
 - Measures $PM_{2.5}$ & PM_{10} ($\mu\text{g}/\text{m}^3$)
 - **Unit cost: ~\$21,000**
 - Time resolution: 1-min
- Met station:
 - Measures T, RH, P, WS and WD
 - **Unit cost: ~\$5,000**
 - Time resolution: 1-min

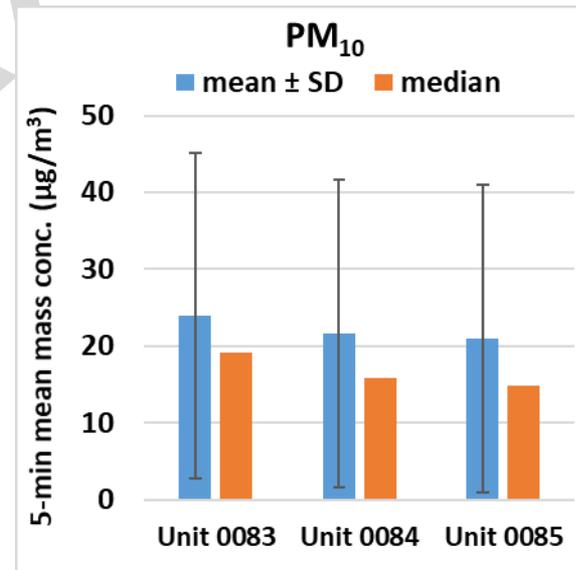
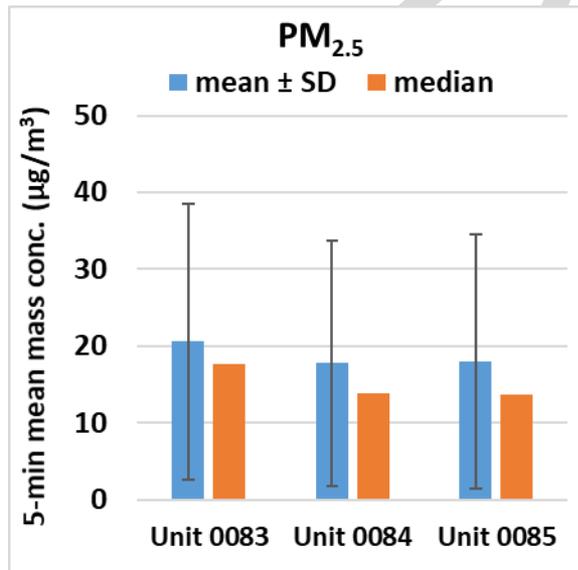


Data validation & recovery

- 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 ~ 96% for all PM measurements

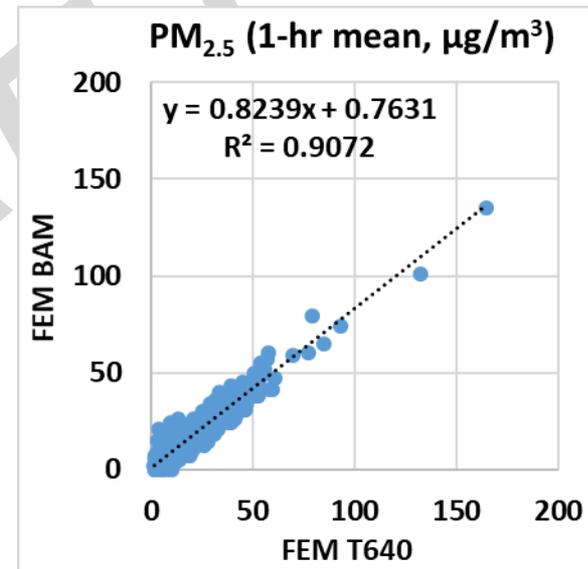
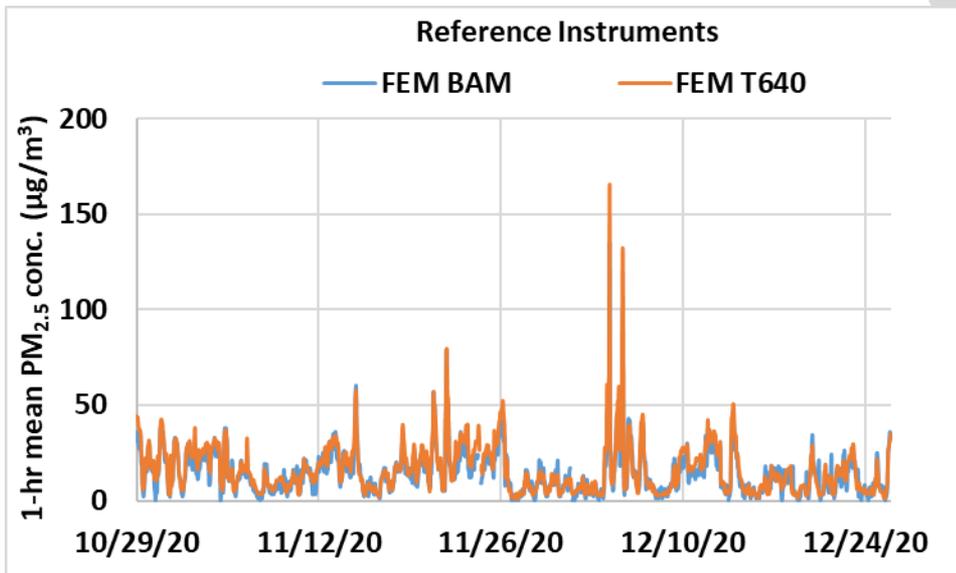
Redspira; intra-model variability

- Absolute intra-model variability was ~ 1.30 and 1.29 $\mu\text{g}/\text{m}^3$ for $\text{PM}_{2.5}$ and PM_{10} , respectively (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 6.9% and 5.8% for $\text{PM}_{2.5}$ and PM_{10} , respectively (calculated as the absolute intra-model variability relative to the mean of the three sensor means)



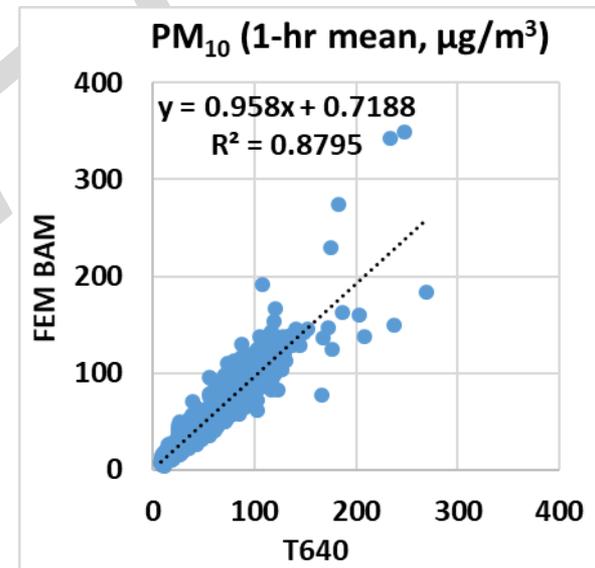
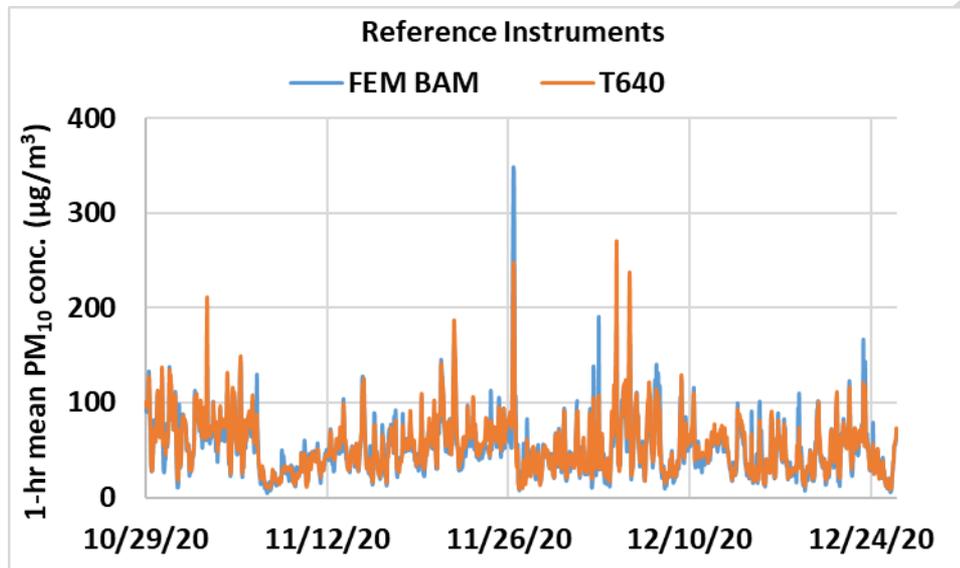
Reference Instruments: PM_{2.5} FEM BAM and FEM T640

- Data recovery for PM_{2.5} from FEM BAM and FEM T640 was ~ 98% and ~ 100%, respectively.
- Very strong correlations between the reference instruments for PM_{2.5} measurements ($R^2 \sim 0.91$) were observed.

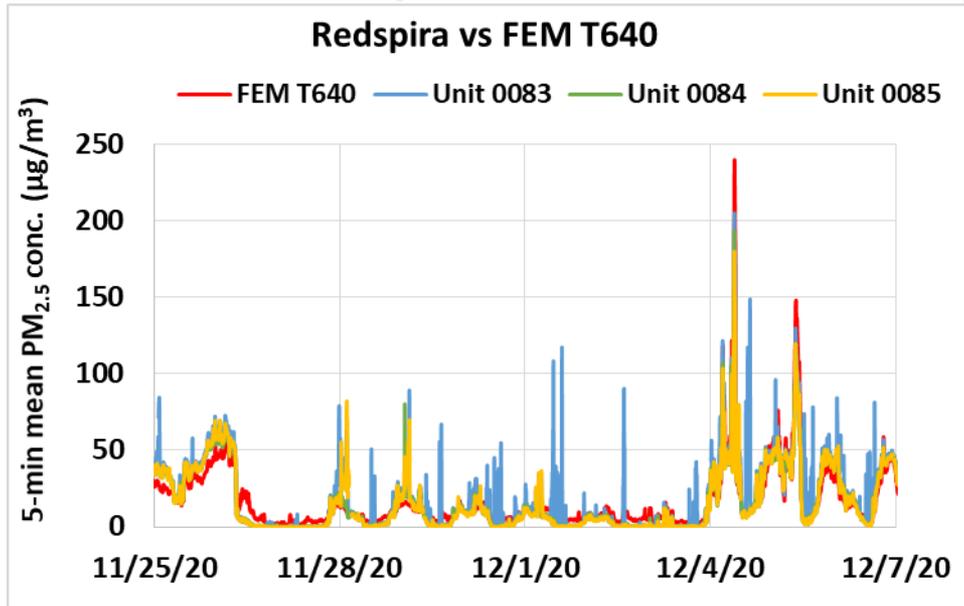


Reference Instruments: PM₁₀ FEM BAM and T640

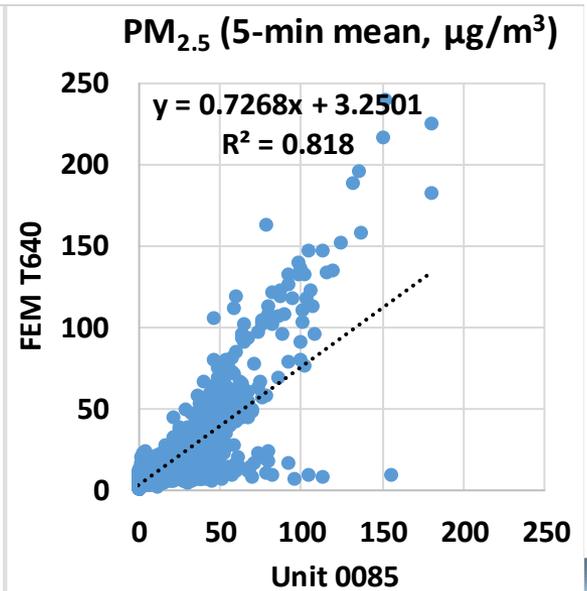
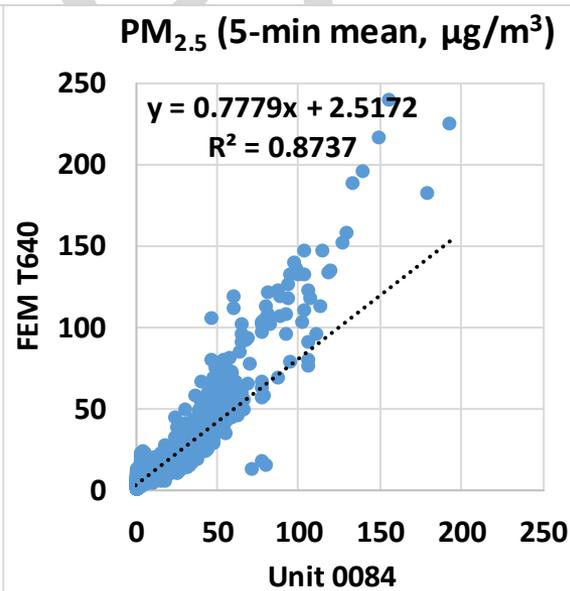
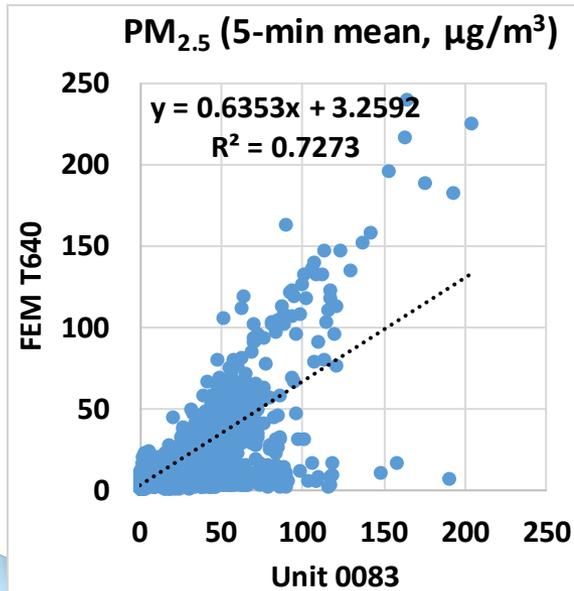
- Data recovery for PM₁₀ from FEM BAM and T640 was 99% and 100%, respectively.
- Strong correlations between the reference instruments for PM₁₀ measurements ($R^2 \sim 0.88$) were observed.



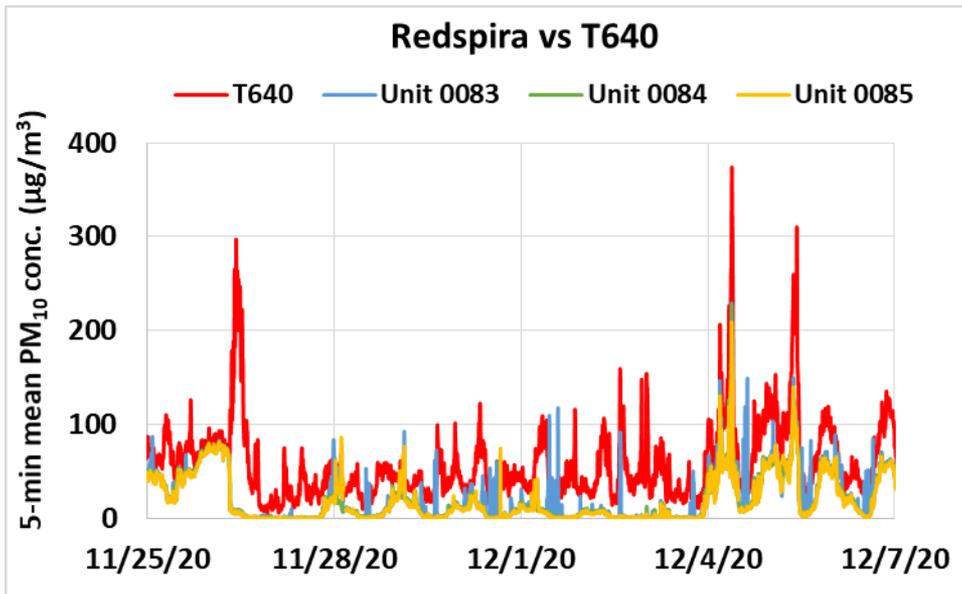
Redspira vs FEM T640 (PM_{2.5}; 5-min mean)



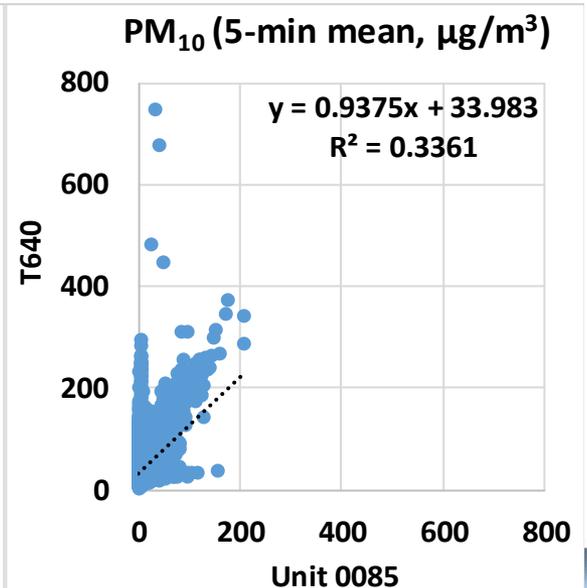
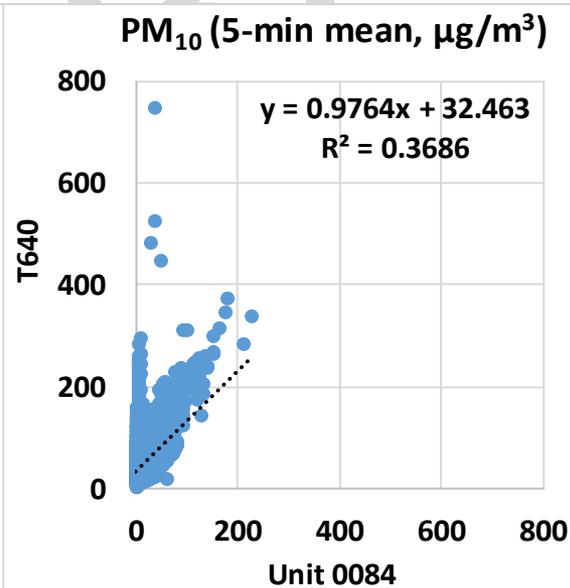
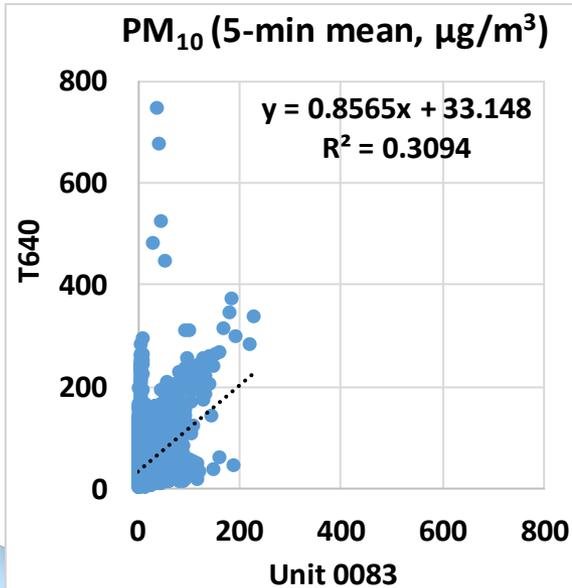
- The Redspira sensors showed strong correlations with the corresponding FEM T640 data ($0.72 < R^2 < 0.88$)
- Overall, the Redspira sensors overestimated the PM_{2.5} mass concentrations as measured by FEM T640
- The Redspira sensors seemed to track the PM_{2.5} diurnal variations as recorded by FEM T640



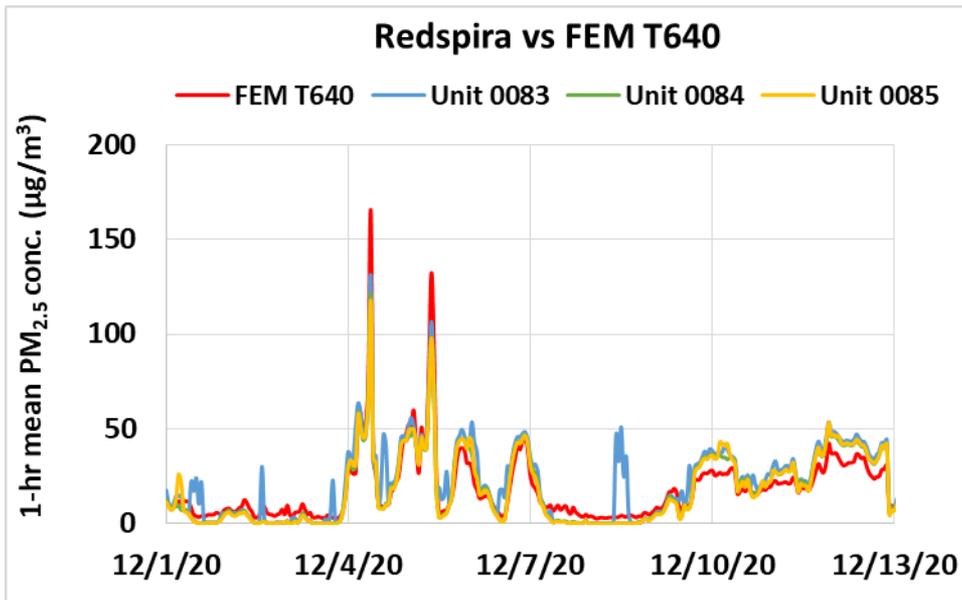
Redspira vs T640 (PM₁₀; 5-min mean)



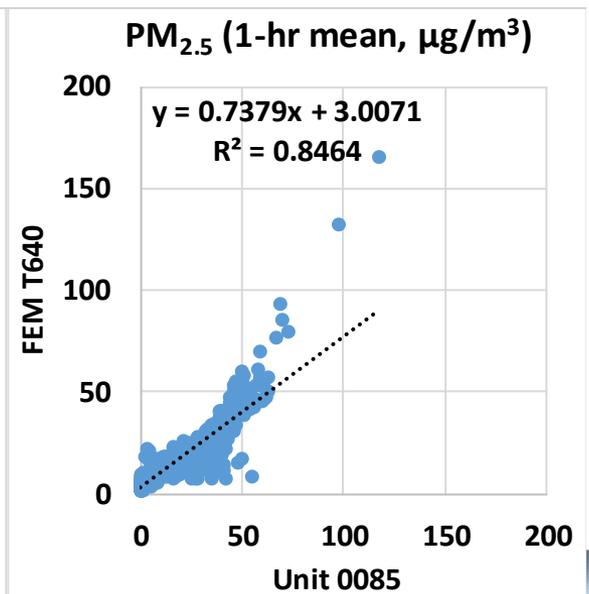
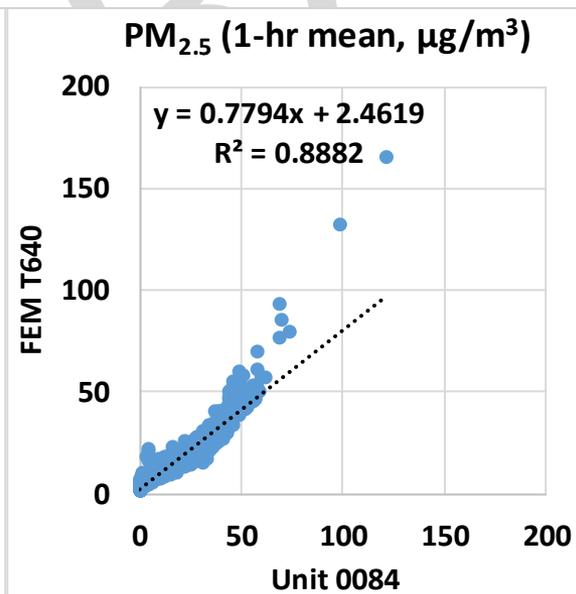
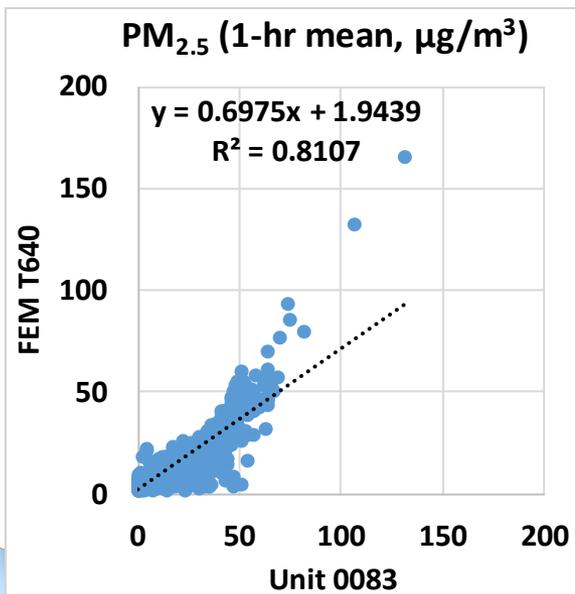
- The Redspira sensors showed weak correlations with the corresponding T640 data ($0.30 < R^2 < 0.37$)
- Overall, the Redspira sensors underestimated the PM₁₀ mass concentrations as measured by T640
- The Redspira sensors did not seem to track the PM₁₀ diurnal variations as recorded by T640



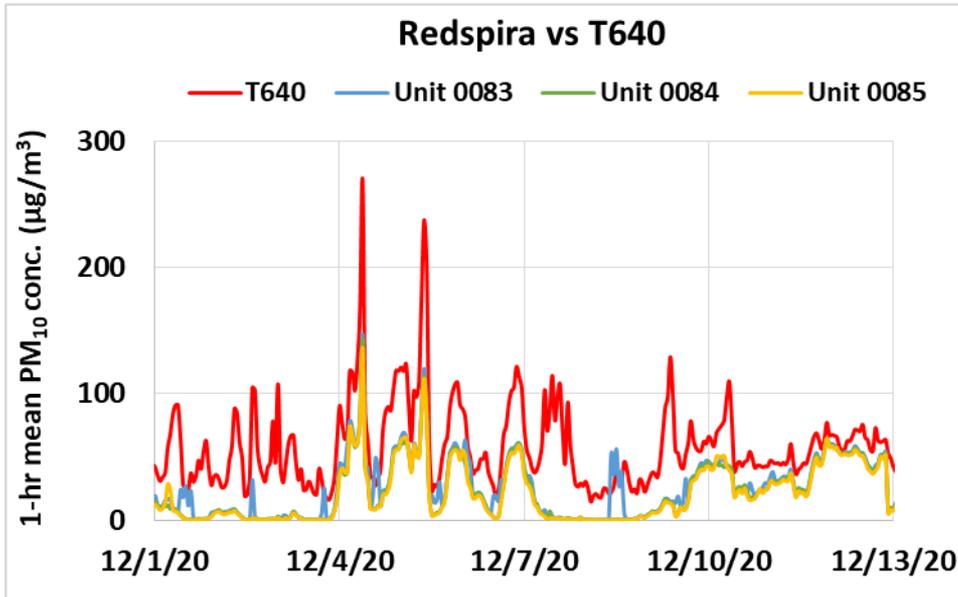
Redspira vs FEM T640 (PM_{2.5}; 1-hr mean)



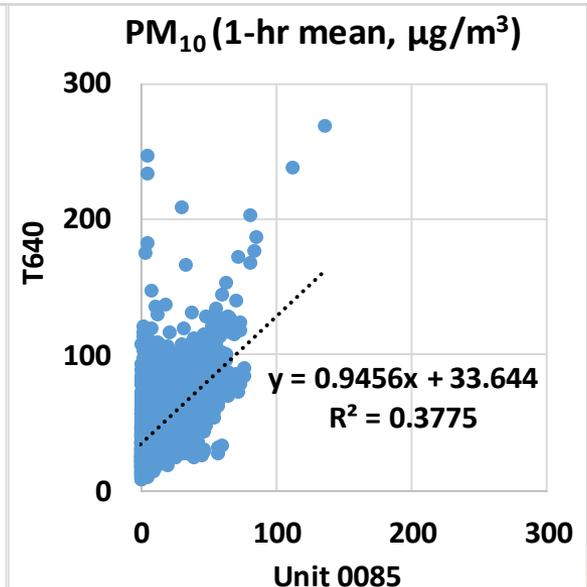
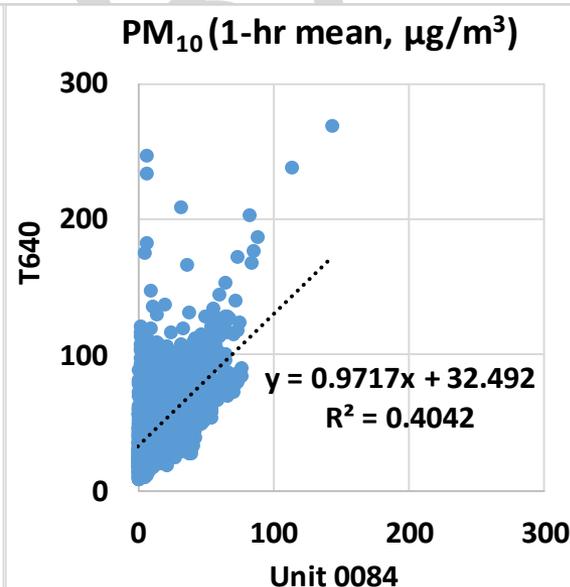
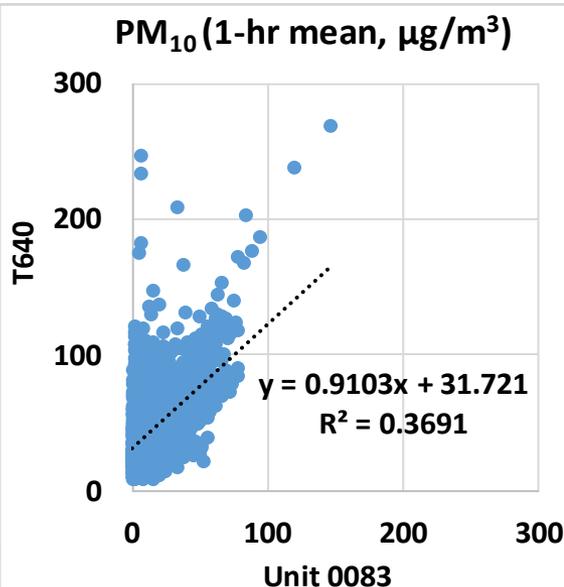
- The Redspira sensors showed strong correlations with the corresponding FEM T640 data ($0.81 < R^2 < 0.89$)
- Overall, the Redspira sensors overestimated the PM_{2.5} mass concentrations as measured by FEM T640
- The Redspira sensors seemed to track the PM_{2.5} diurnal variations as recorded by FEM T640



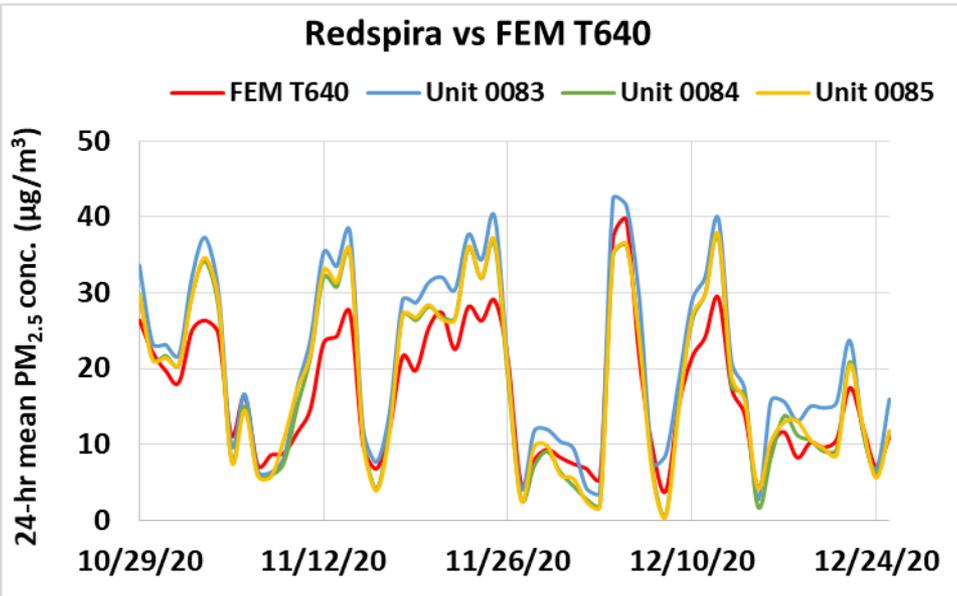
Redspira vs T640 (PM₁₀; 1-hr mean)



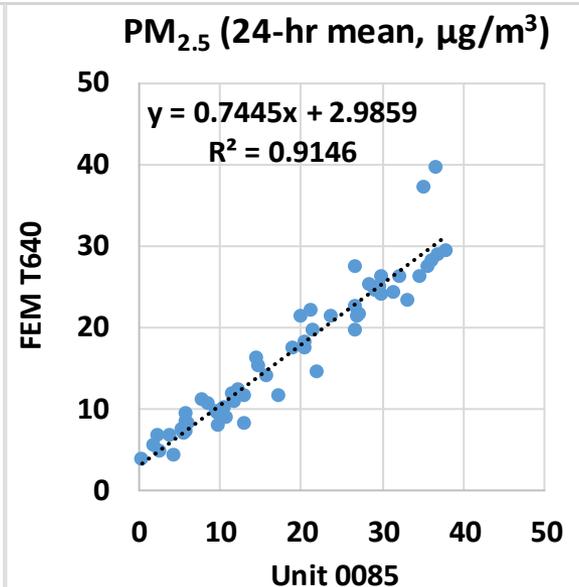
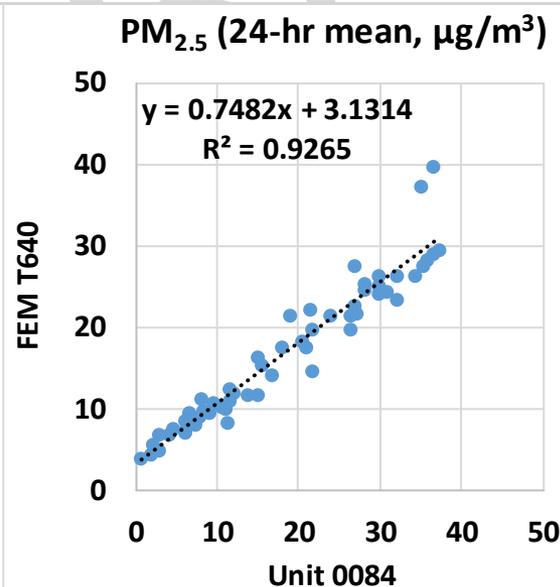
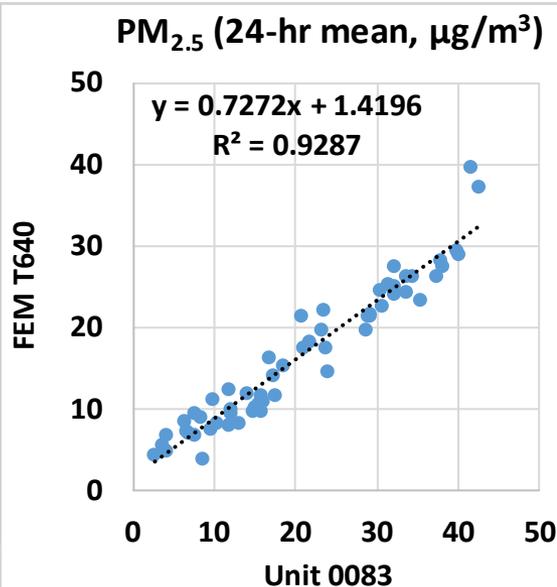
- The Redspira sensors showed weak correlations with the corresponding T640 data ($0.36 < R^2 < 0.41$)
- Overall, the Redspira sensors underestimated the PM₁₀ mass concentrations as measured by T640
- The Redspira sensors did not seem to track the PM₁₀ diurnal variations as recorded by T640



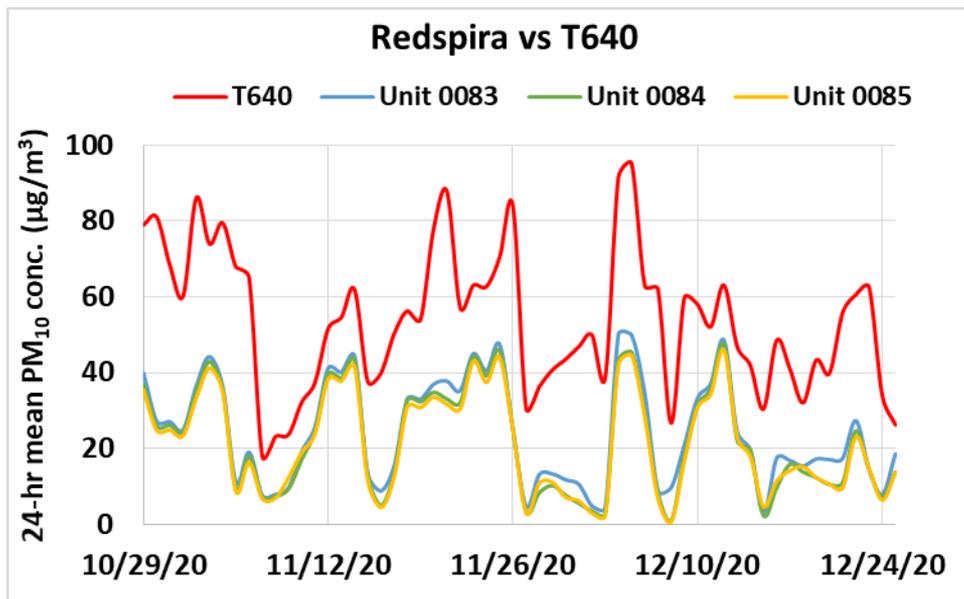
Redspira vs FEM T640 (PM_{2.5}; 24-hr mean)



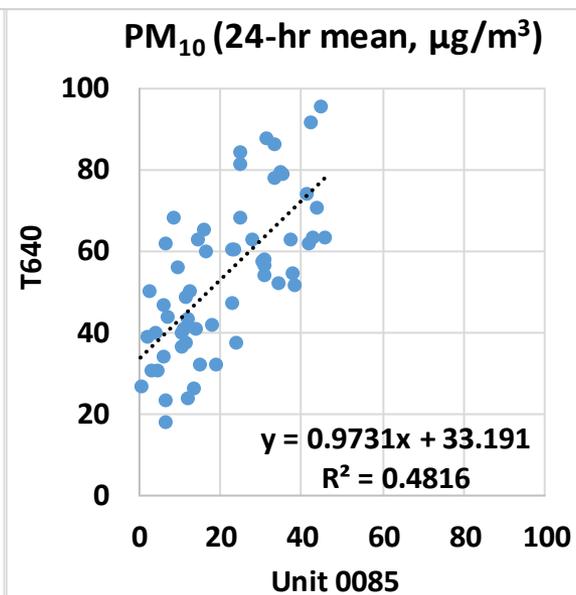
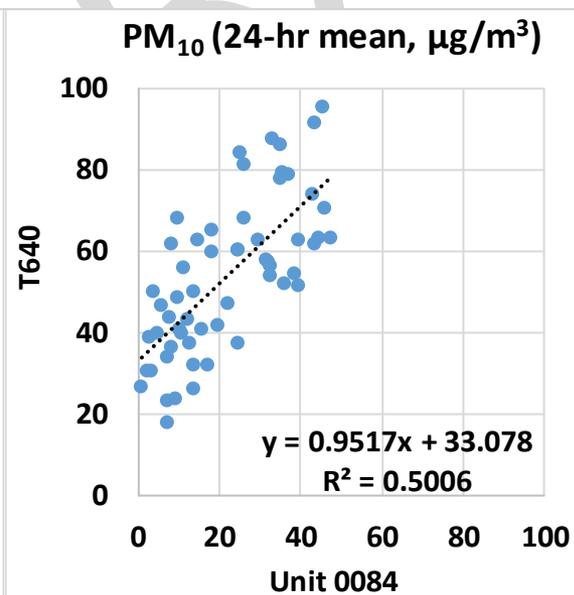
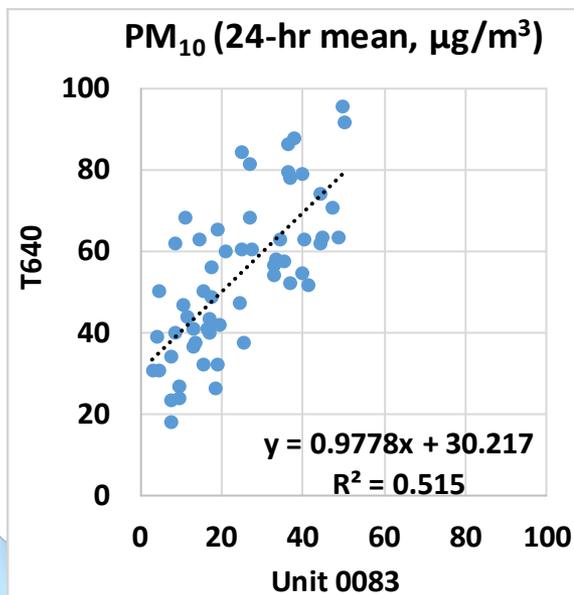
- The Redspira sensors showed very strong correlations with the corresponding FEM T640 data ($0.91 < R^2 < 0.93$)
- Overall, the Redspira sensors overestimated the PM_{2.5} mass concentrations as measured by FEM T640
- The Redspira sensors seemed to track the PM_{2.5} diurnal variations as recorded by FEM T640



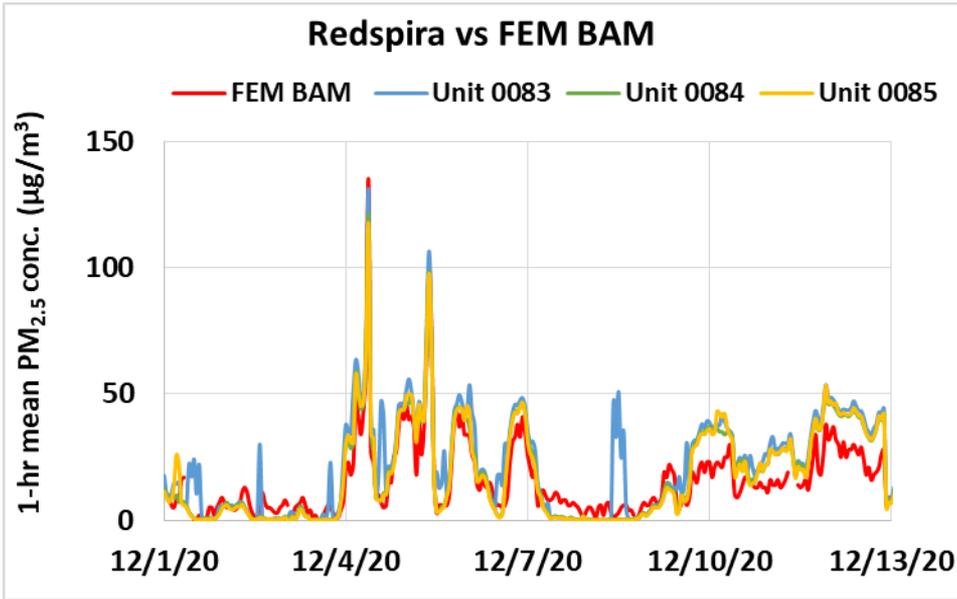
Redspira vs T640 (PM₁₀; 24-hr mean)



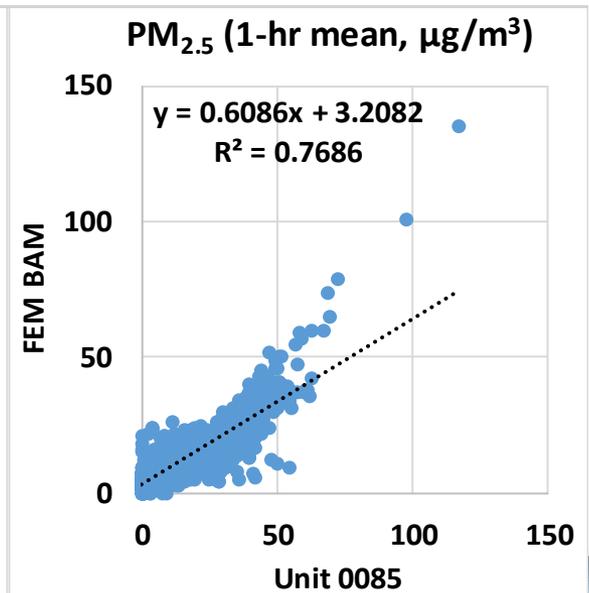
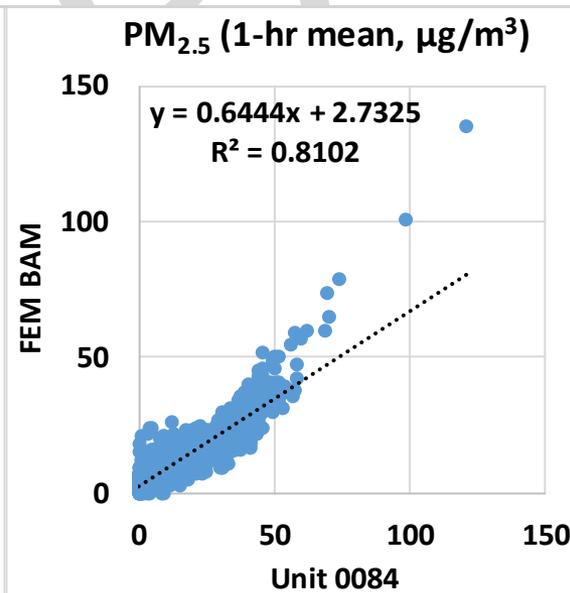
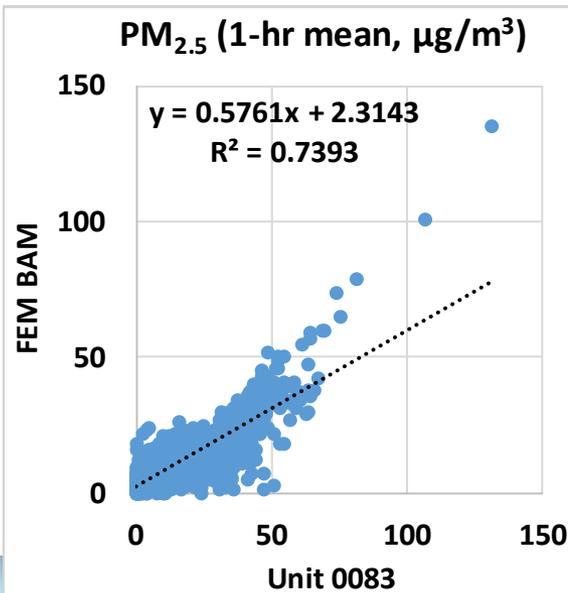
- The Redspira sensors showed weak to moderate correlations with the corresponding T640 data ($0.48 < R^2 < 0.52$)
- Overall, the Redspira sensors underestimated the PM₁₀ mass concentrations as measured by T640
- The Redspira sensors seemed to track the PM₁₀ diurnal variations as recorded by T640



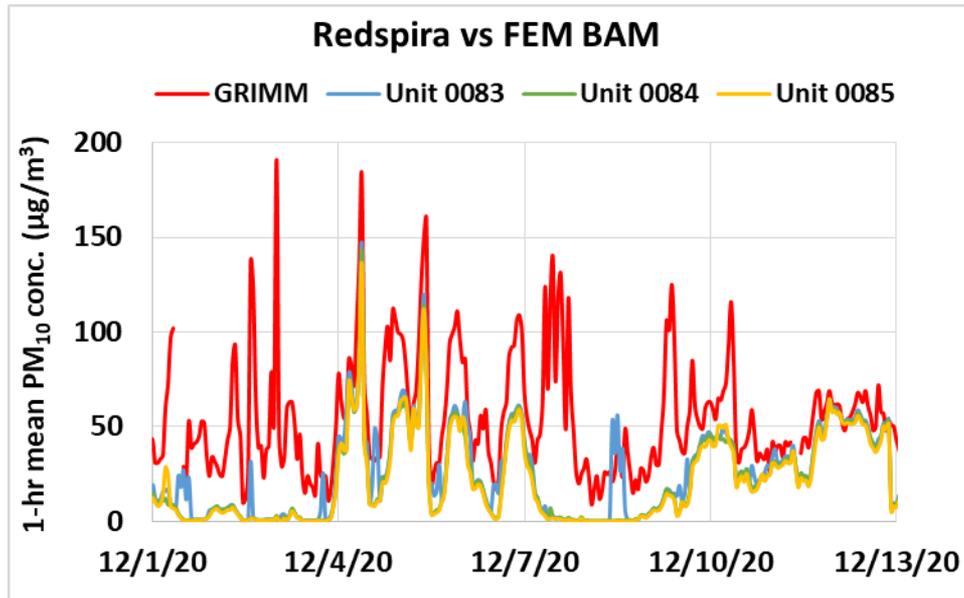
Redspira vs FEM BAM (PM_{2.5}; 1-hr mean)



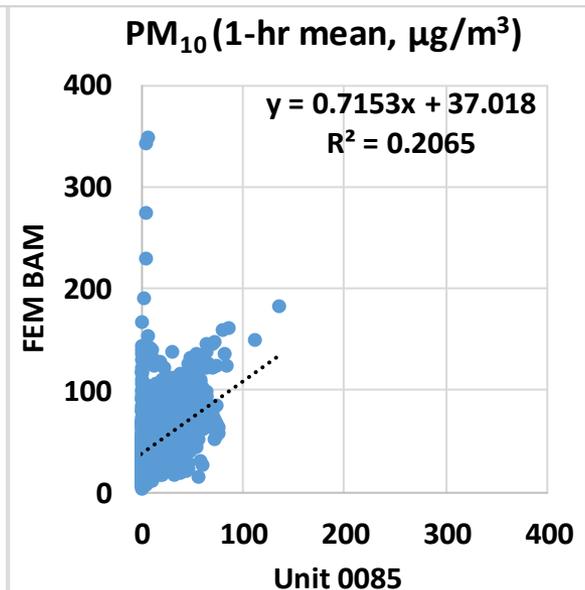
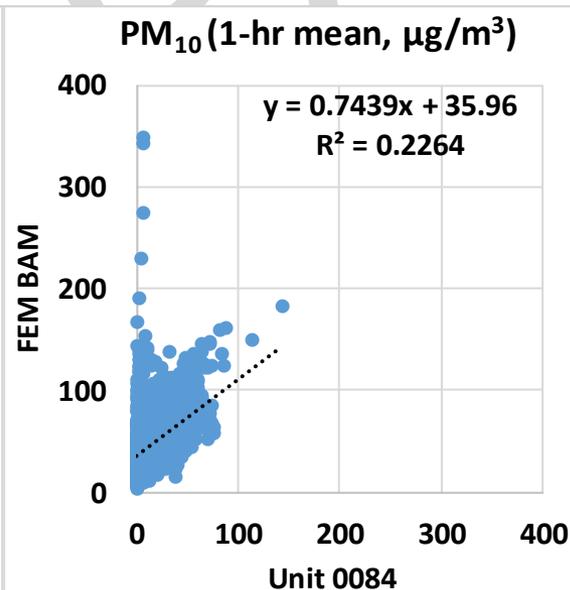
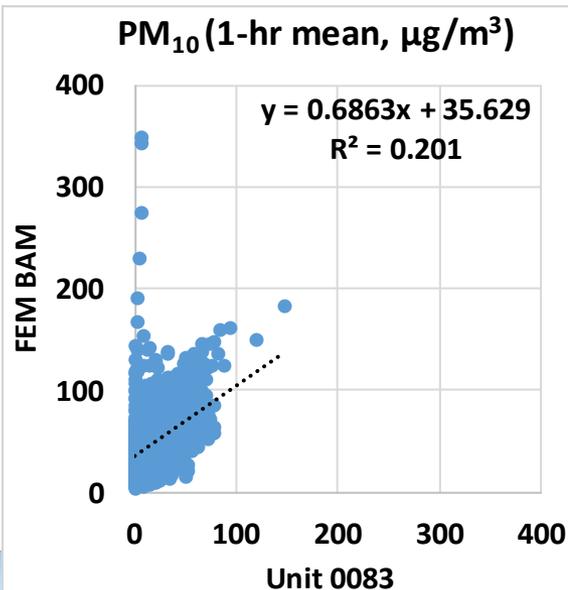
- The Redspira sensors showed strong correlations with the corresponding FEM BAM data ($0.73 < R^2 < 0.82$)
- Overall, the Redspira sensors overestimated the PM_{2.5} mass concentrations as measured by FEM BAM
- The Redspira sensors seemed to track the PM_{2.5} diurnal variations as recorded by FEM BAM



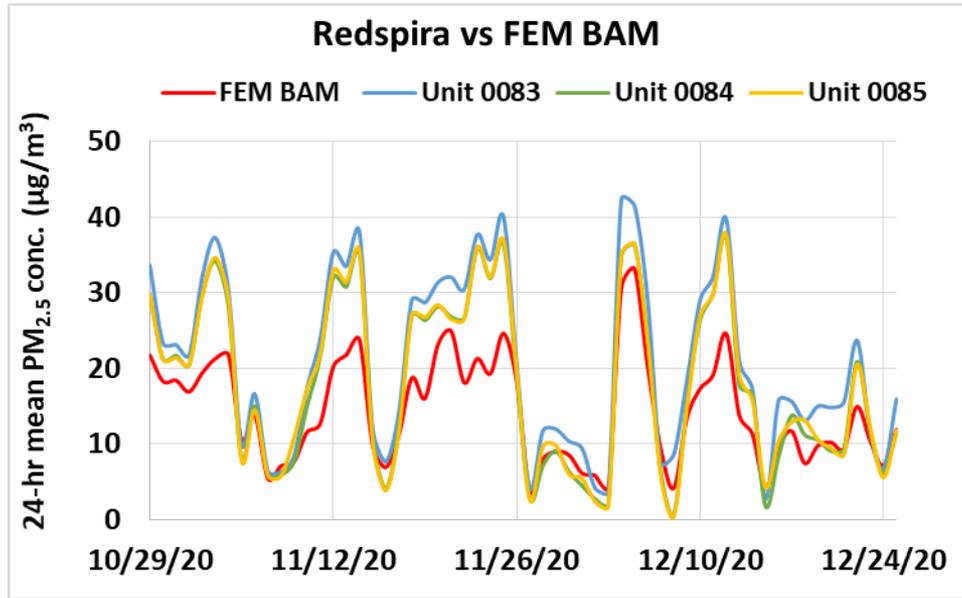
Redspira vs FEM BAM (PM₁₀; 1-hr mean)



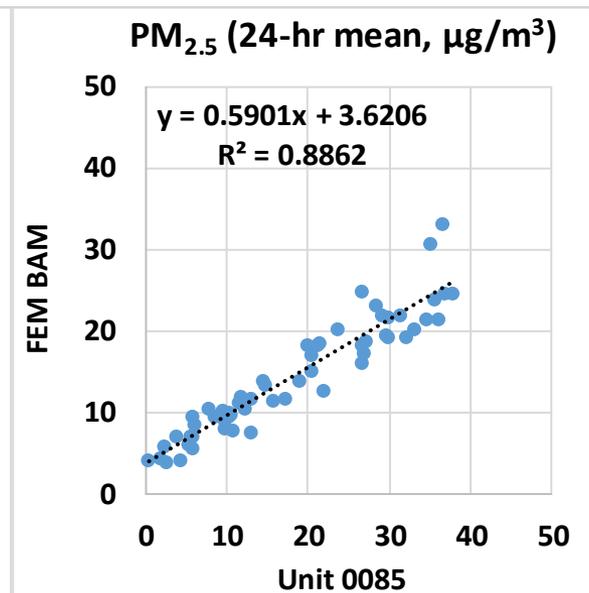
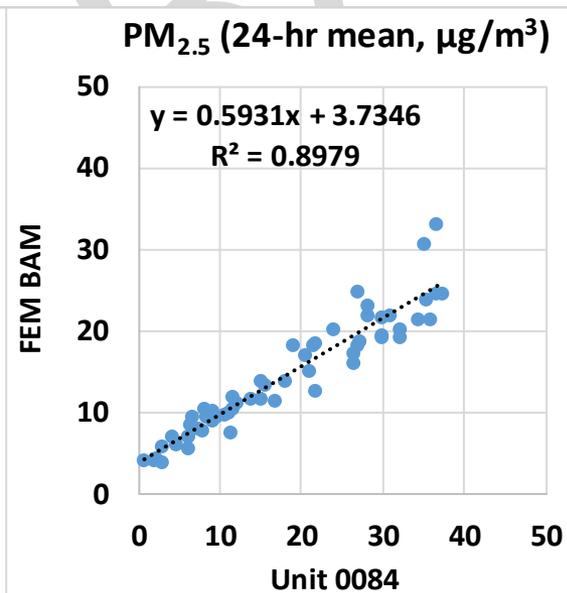
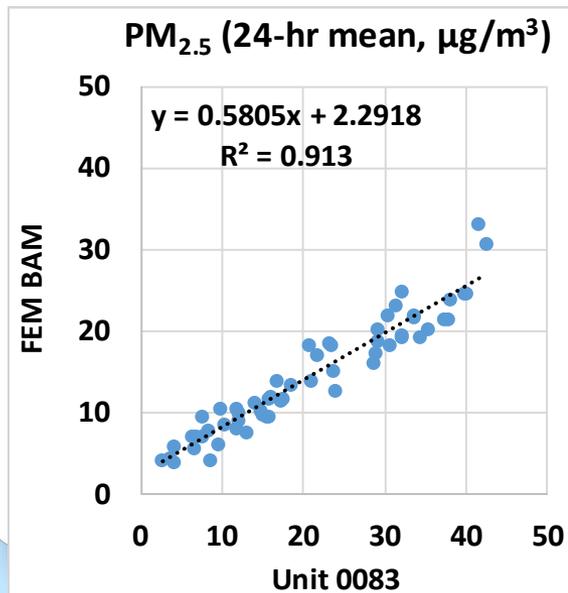
- The Redspira sensors showed very weak correlations with the corresponding FEM BAM data ($0.20 < R^2 < 0.23$)
- Overall, the Redspira sensors underestimated the PM₁₀ mass concentrations measured by FEM BAM
- The Redspira sensors did not seem to track the PM₁₀ diurnal variations as recorded by FEM BAM



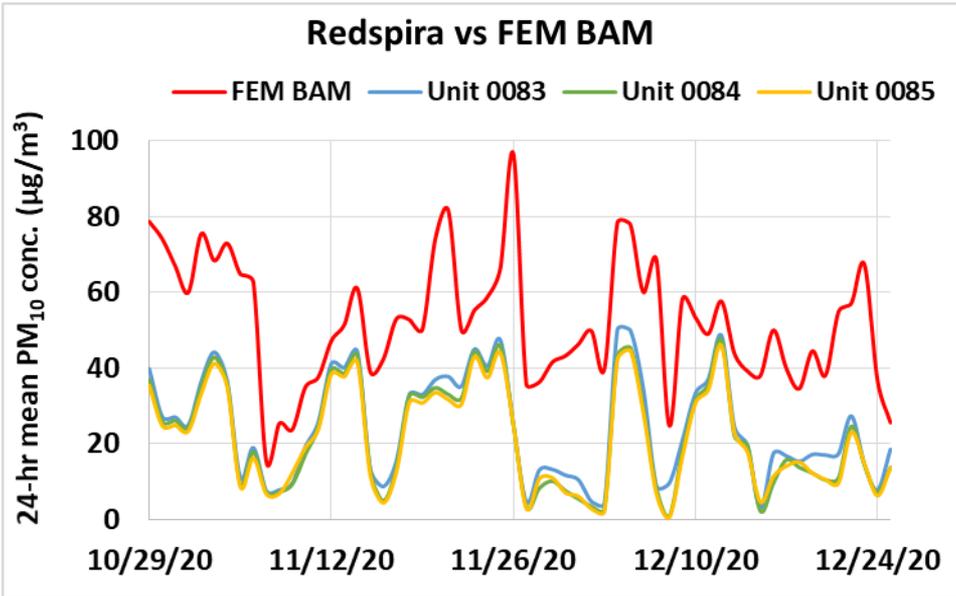
Redspira vs FEM BAM (PM_{2.5}; 24-hr mean)



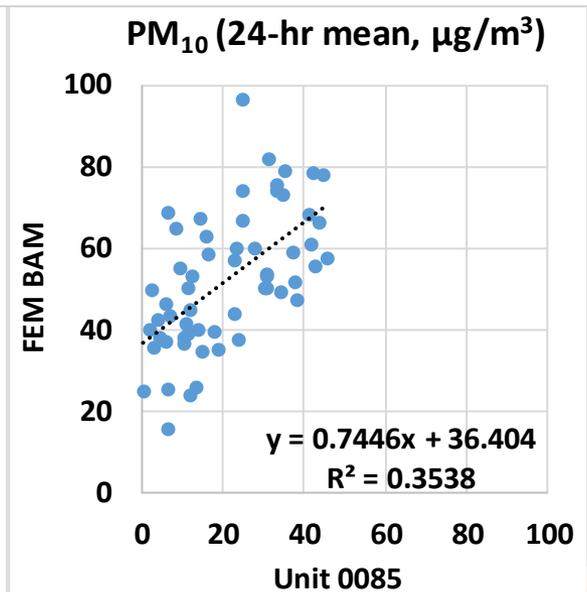
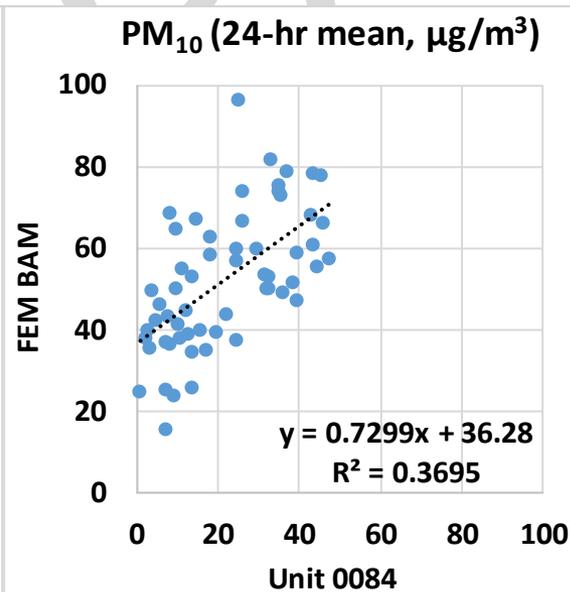
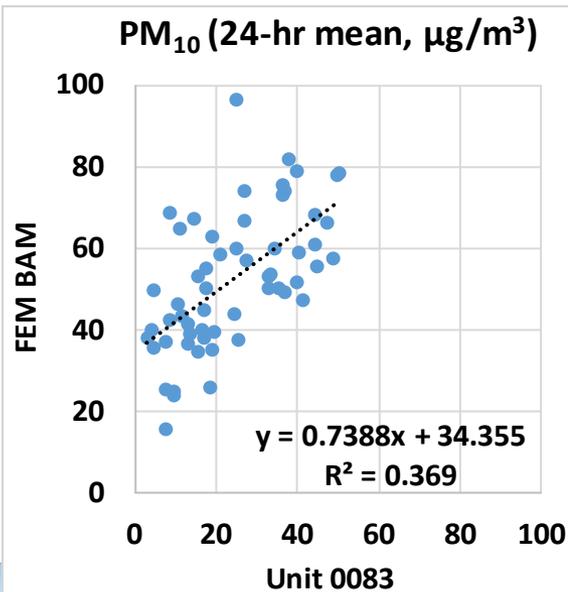
- The Redspira sensors showed strong to very strong correlations with the corresponding FEM BAM data ($0.88 < R^2 < 0.92$)
- Overall, the Redspira sensors overestimated the PM_{2.5} mass concentrations as measured by FEM BAM
- The Redspira sensors seemed to track the PM_{2.5} diurnal variations as recorded by FEM BAM



Redspira vs FEM BAM (PM₁₀; 24-hr mean)



- The Redspira sensors showed weak correlations with the corresponding FEM BAM data ($0.35 < R^2 < 0.37$)
- Overall, the Redspira sensors underestimated the PM₁₀ mass concentrations measured by FEM BAM
- The Redspira sensors did not seem to track the PM₁₀ diurnal variations as recorded by FEM BAM



Summary: PM

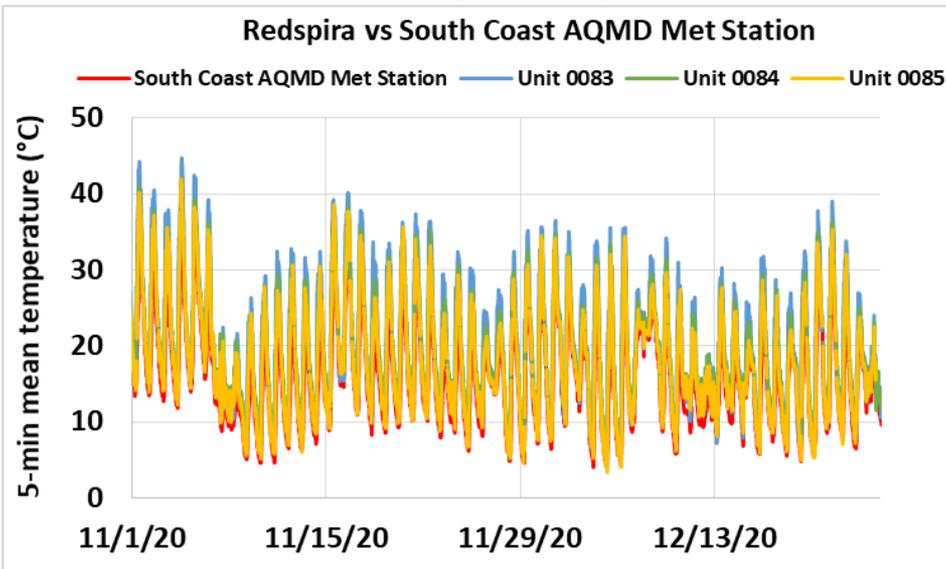
	Average of 3 Sensors, PM _{2.5}		Redspira vs FEM BAM & FEM T640, PM _{2.5}						FEM BAM & FEM T640 (PM _{2.5} , µg/m ³)		
	Average (µg/m ³)	SD (µg/m ³)	R ²	Slope	Intercept	MBE ¹ (µg/m ³)	MAE ² (µg/m ³)	RMSE ³ (µg/m ³)	Ref. Average	Ref. SD	Range during the field evaluation
5-min	19.0	16.8	0.73 to 0.87	0.64 to 0.78	2.5 to 3.3	1.5 to 4.3	4.7 to 7.1	6.1 to 10.5	16.6	13.3	1.1 to 239
1-hr	19.1	16.2	0.74 to 0.89	0.58 to 0.78	1.9 to 3.2	1.5 to 6.6	4.5 to 8.7	5.8 to 11.3	14.5 to 16.6	11.2 to 13.0	0 to 165.1
24-hr	19.0	11.2	0.89 to 0.93	0.58 to 0.75	1.4 to 3.7	1.4 to 6.4	3.1 to 6.6	3.9 to 8.3	14.5 to 16.6	6.9 to 8.6	3.4 to 39.7
	Average of 3 Sensors, PM ₁₀		Redspira vs vs FEM BAM & T640, PM ₁₀						FEM BAM and T640 (PM ₁₀ , µg/m ³)		
	Average (µg/m ³)	SD (µg/m ³)	R ²	Slope	Intercept	MBE ¹ (µg/m ³)	MAE ² (µg/m ³)	RMSE ³ (µg/m ³)	Ref. Average	Ref. SD	Range during the field evaluation
5-min	22.4	20.4	0.31 to 0.37	0.86 to 0.98	32.5 to 34.0	-32.7 to -29.7	30.8 to 33.1	40.9 to 42.0	53.9	32.3	4.1 to 749
1-hr	22.6	19.8	0.20 to 0.40	0.69 to 0.97	31.7 to 37.0	-32.5 to -28.0	29.1 to 32.8	38.1 to 41.7	52.3 to 53.9	30.1 to 30.8	4.0 to 349
24-hr	22.5	13.6	0.35 to 0.52	0.73 to 0.98	30.2 to 36.4	-32.6 to -28.0	28.0 to 32.6	31.2 to 35.3	52.2 to 53.9	16.6 to 18.6	15.3 to 96.5

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).

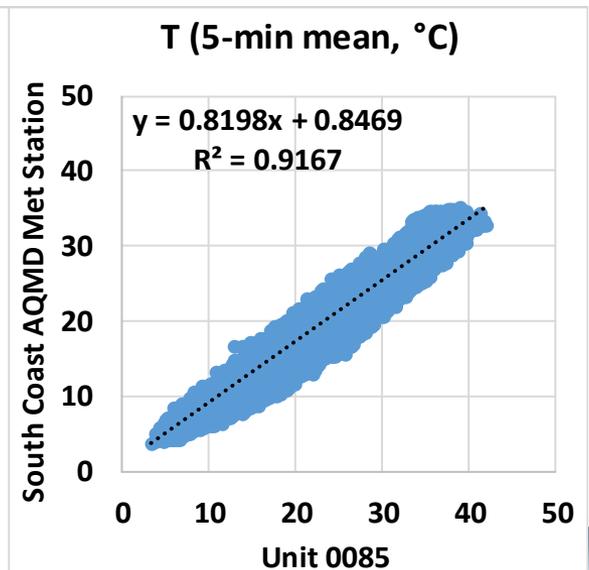
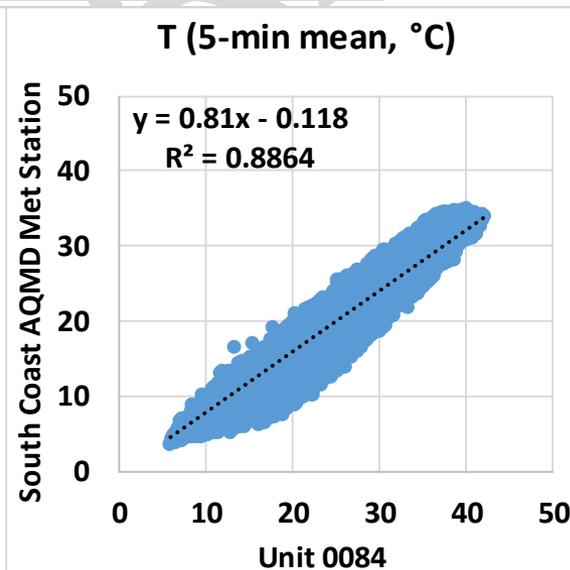
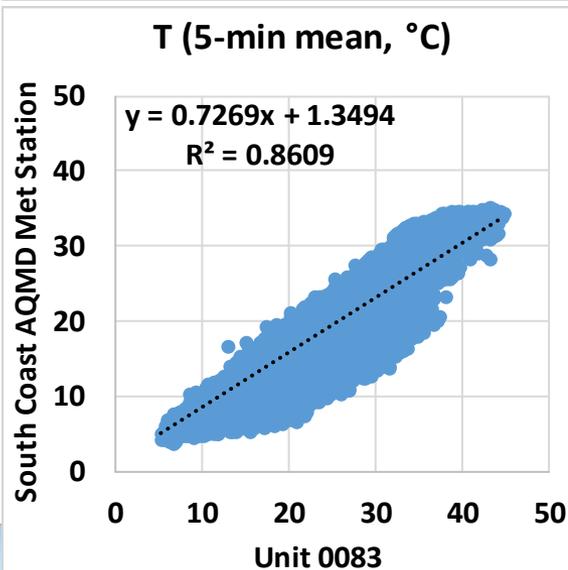
² Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.

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

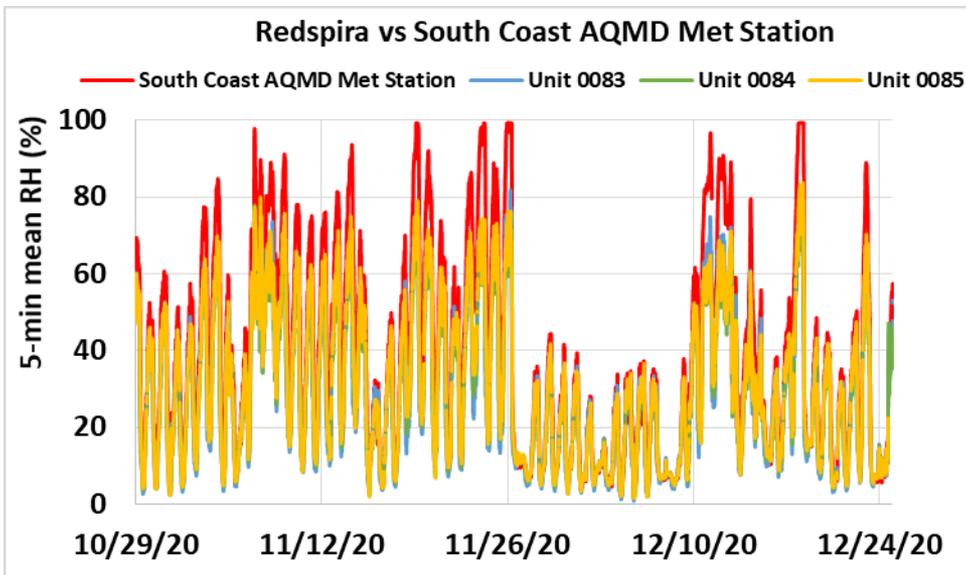
Redspira vs South Coast AQMD Met Station (Temperature; 5-min mean)



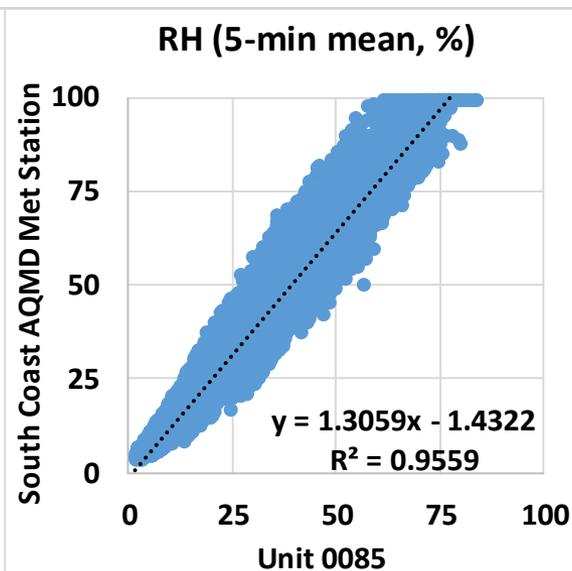
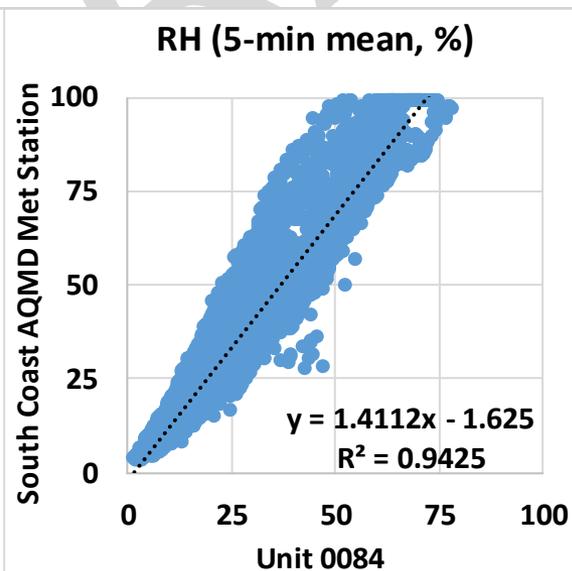
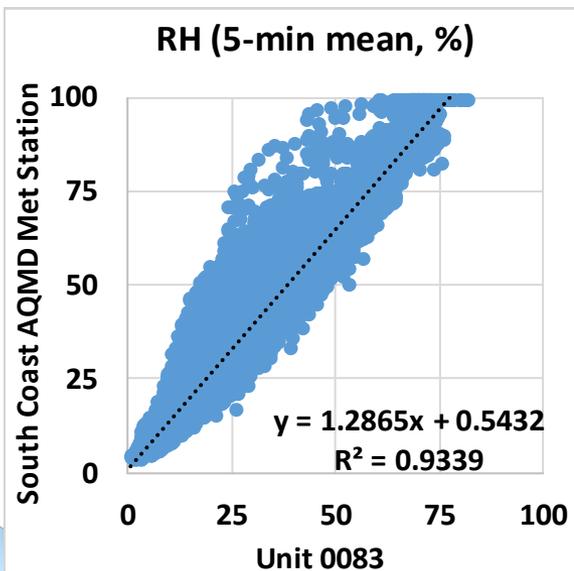
- The Redspira sensors showed strong to very strong correlations with the corresponding South Coast Met Station data ($0.86 < R^2 < 0.92$)
- Overall, the Redspira sensors overestimated the temperature measurements as recorded by South Coast Met Station
- The Redspira sensors seemed to track the diurnal temperature variations as recorded by South Coast Met Station



Redspira vs South Coast AQMD Met Station (RH; 5-min mean)



- Redspira sensors showed very strong correlations with the corresponding South Coast Met Station data ($0.93 < R^2 < 0.96$)
- Overall, the Redspira sensors underestimated the RH measurements as recorded by South Coast Met Station
- The Redspira sensors seemed to track the diurnal RH variations as recorded by South Coast Met Station



Discussion

- The three **Redspira** sensors' data recovery from all units was ~ 96% for all PM measurements
- The absolute intra-model variability was ~ 1.30 and 1.29 $\mu\text{g}/\text{m}^3$ for $\text{PM}_{2.5}$ and PM_{10} , respectively
- Very strong correlations between FEM BAM and FEM T640 for $\text{PM}_{2.5}$ ($R^2 \sim 0.91$, 1-hr mean) and strong correlations between FEM BAM and T640 for PM_{10} ($R^2 \sim 0.88$, 1-hr mean) mass concentration measurements
- $\text{PM}_{2.5}$ mass concentrations measured by Redspira sensors showed strong correlations with the corresponding FEM T640 and FEM BAM data ($0.73 < R^2 < 0.89$, 1-hr mean). The sensors overestimated $\text{PM}_{2.5}$ mass concentrations as measured by FEM T640 and FEM BAM
- PM_{10} mass concentrations measured by Redspira sensors showed very weak to weak correlations with the corresponding T640 and FEM BAM data ($0.20 < R^2 < 0.41$; 1-hr mean). The sensors underestimated PM_{10} mass concentrations measured by T640 and FEM BAM
- No sensor calibration was performed by South Coast AQMD Staff prior to the beginning of this test
- Laboratory chamber testing is necessary to fully evaluate the performance of these sensors under known aerosol concentrations and controlled temperature and relative humidity conditions
- All results are still preliminary