

Field Evaluation IQAir - AirVisual Outdoor



Background

- From 10/27/2022 to 12/27/2022, three **IQAir – AirVisual Outdoor** 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
- IQAir AirVisual Outdoor (3 units tested):
 - Particle sensor: **optical; non-FEM**
 - Each unit reports: PM_{1.0}, PM_{2.5} and PM₁₀ (µg/m³), T (°F), RH (%)
 - Also measures: CO₂ (ppm)
 - **Unit cost: \$289**
 - Time resolution: 1-min
 - Units IDs: ZFW8, JM83, Y5EF
- GRIMM EDM180 (reference instrument):
 - Optical particle counter (**FEM PM_{2.5}**)
 - Measures PM_{1.0}, PM_{2.5}, and PM₁₀ (µg/m³)
 - **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 PM₁₀ (µg/m³)
 - **Cost: ~\$21,000**
 - Time resolution: 1-min
- Met Station (T, RH, P, WS, WD):
 - **Cost: ~\$5,000**
 - Time resolution: 1-min



FEM GRIMM



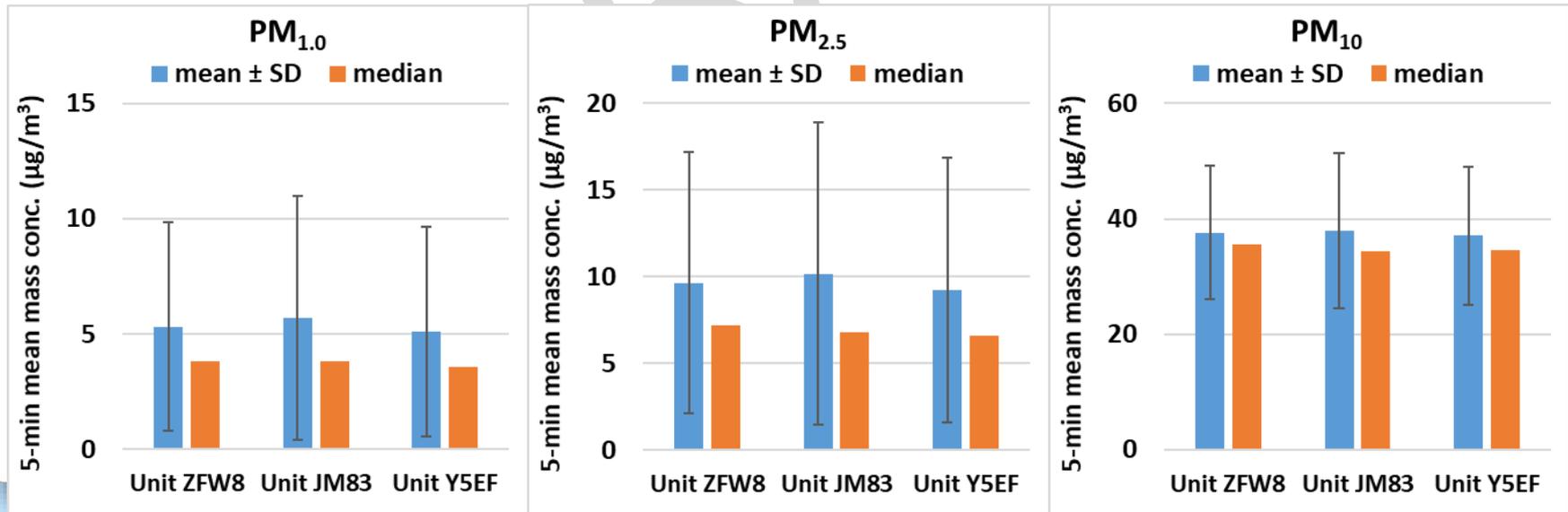
FEM T640

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%, ~98% and ~100% respectively for PM_{1.0}, PM_{2.5} and PM₁₀, respectively

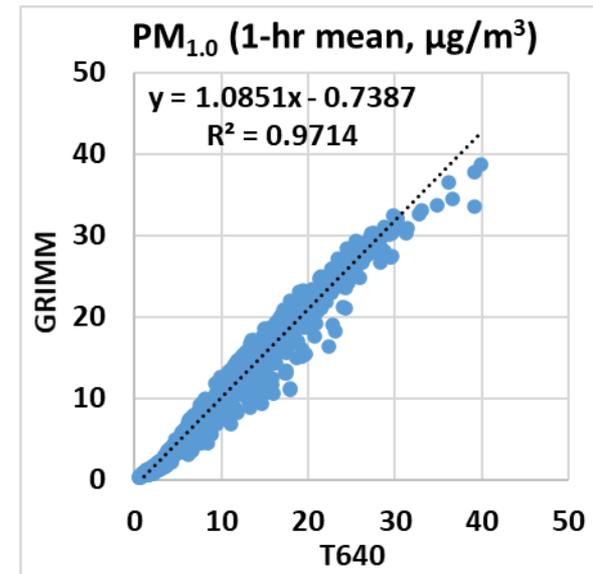
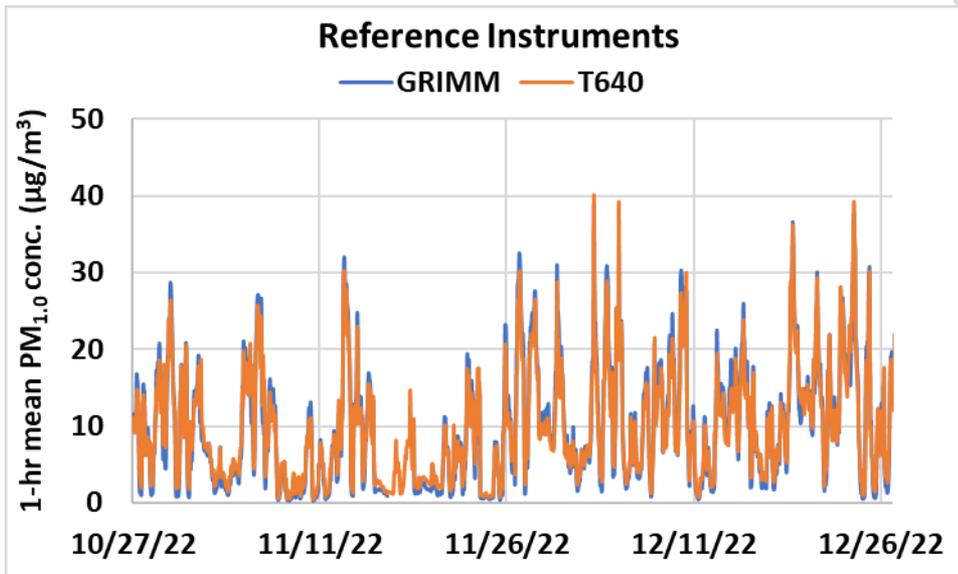
IQAir AirVisual Outdoor; intra-model variability

- Absolute intra-model variability was ~0.24, ~0.39 and ~0.34 $\mu\text{g}/\text{m}^3$ for PM_{1.0}, PM_{2.5} and PM₁₀, respectively (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~4.4%, ~4.0% and ~0.9% for PM_{1.0}, PM_{2.5} and PM₁₀, respectively (calculated as the absolute intra-model variability relative to the mean of the three sensor means)



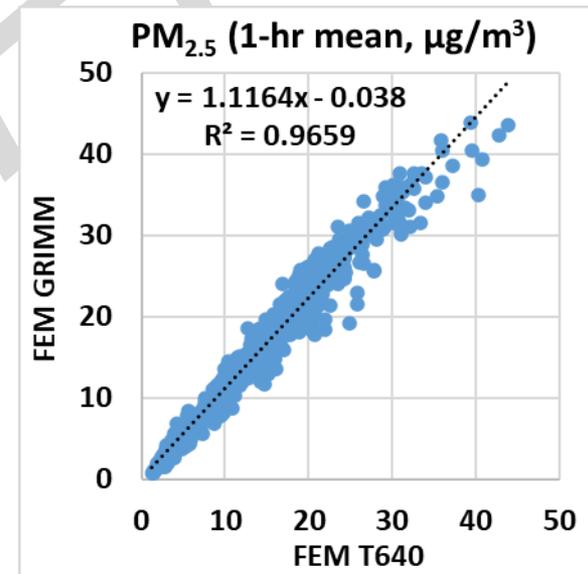
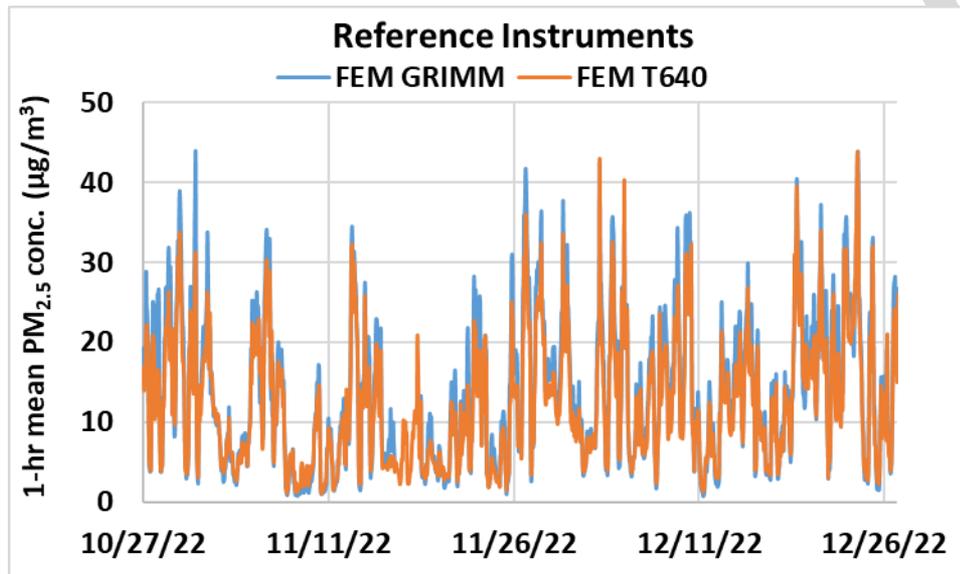
Reference Instruments: PM_{1.0} GRIMM and T640

- Data recovery for PM_{1.0} from GRIMM and T640 was ~96.7% and ~100%, respectively.
- Very strong correlations between the reference instruments for PM_{1.0} measurements ($R^2 \sim 0.97$) were observed.



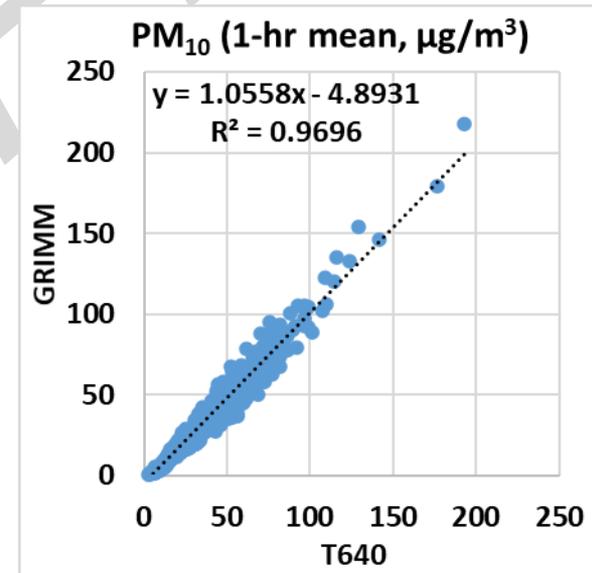
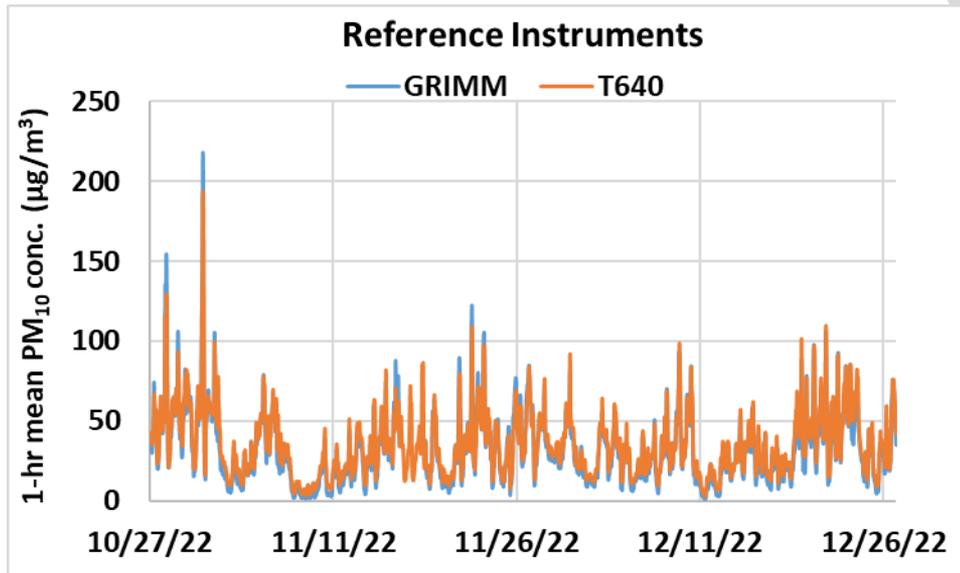
Reference Instruments: PM_{2.5} FEM GRIMM and FEM T640

- Data recovery for PM_{2.5} from FEM GRIMM and FEM T640 was ~96.7% and ~100%, respectively.
- Very strong correlations between the reference instruments for PM_{2.5} measurements ($R^2 \sim 0.97$) were observed.

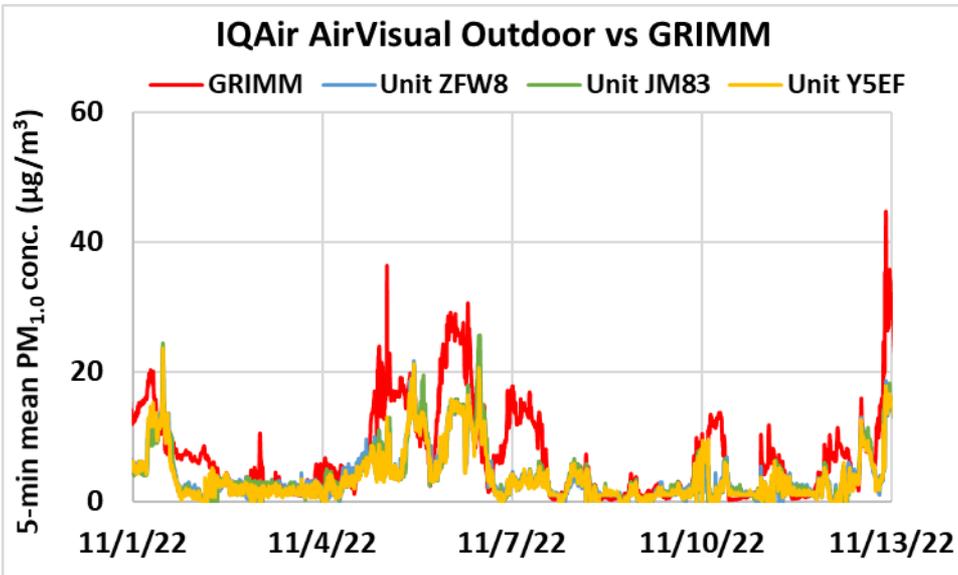


Reference Instruments: PM₁₀ GRIMM and T640

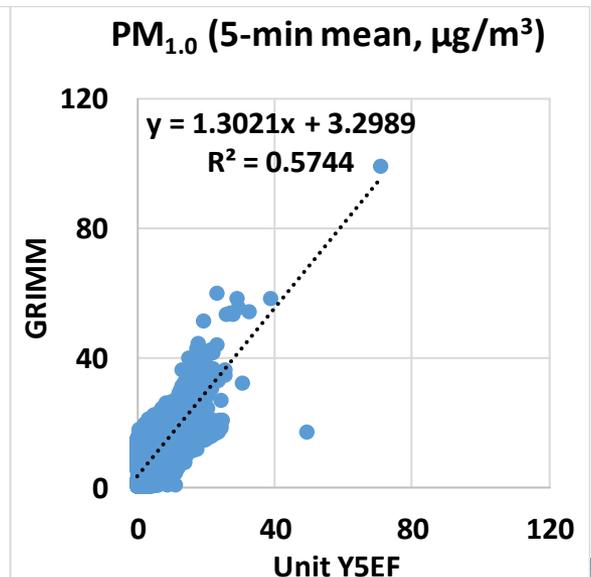
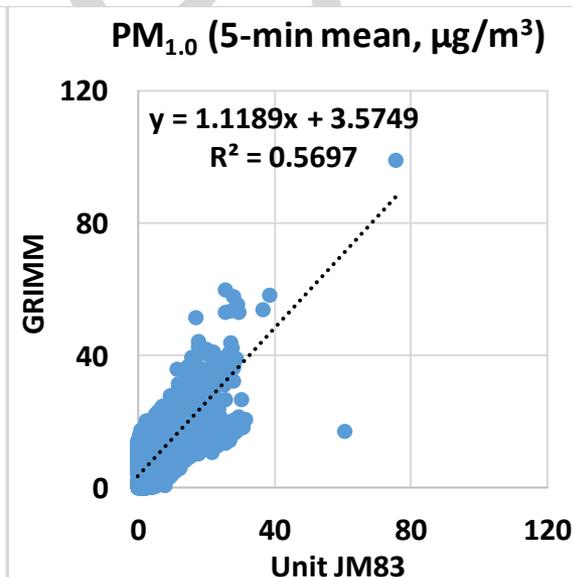
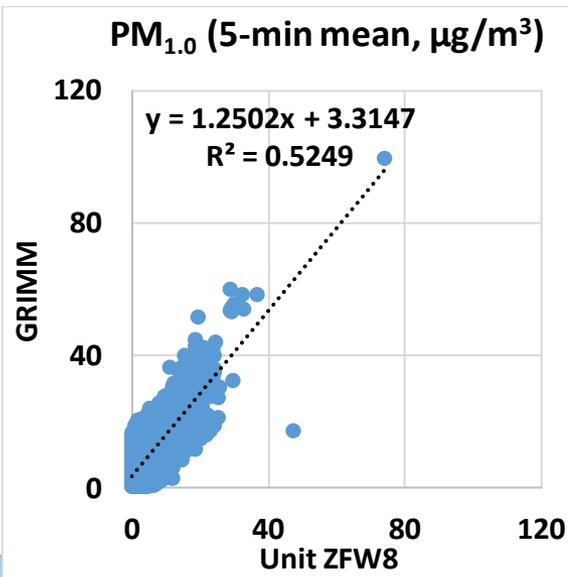
- Data recovery for PM₁₀ from GRIMM and T640 was ~96.7% and ~100%, respectively.
- Very strong correlations between the reference instruments for PM₁₀ measurements ($R^2 \sim 0.97$) were observed.



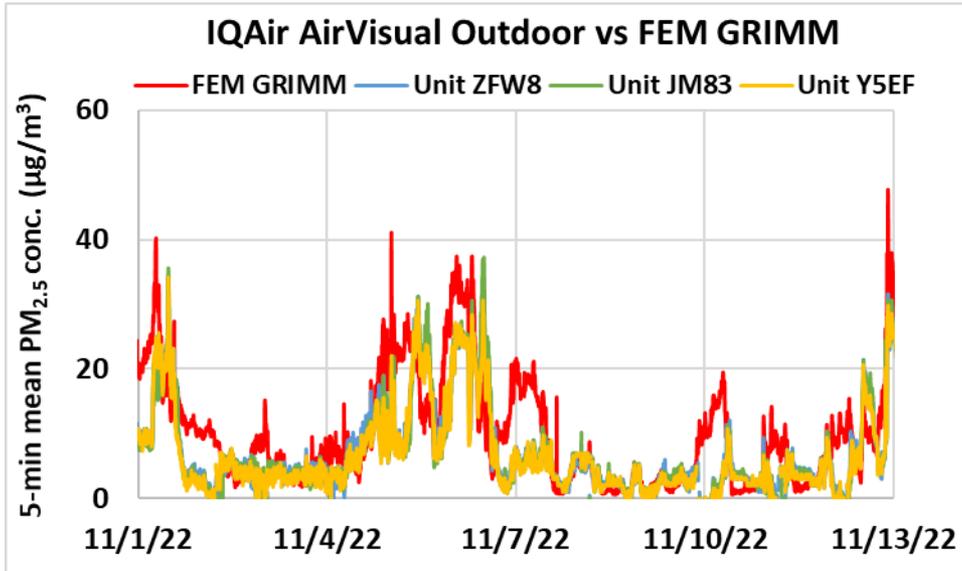
IQAir AirVisual Outdoor vs GRIMM (PM_{1.0}; 5-min mean)



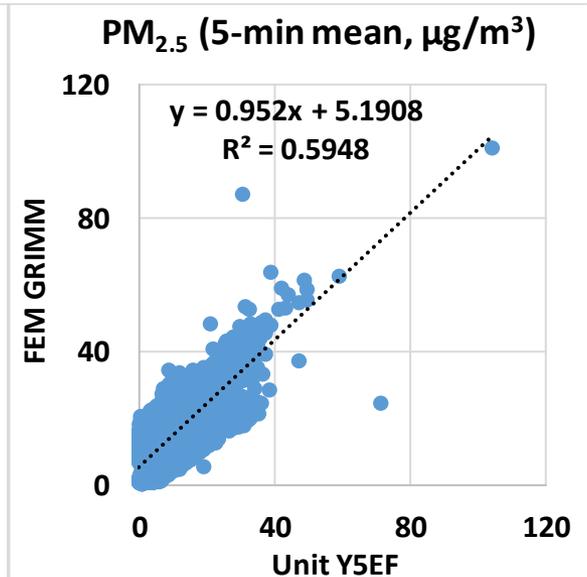
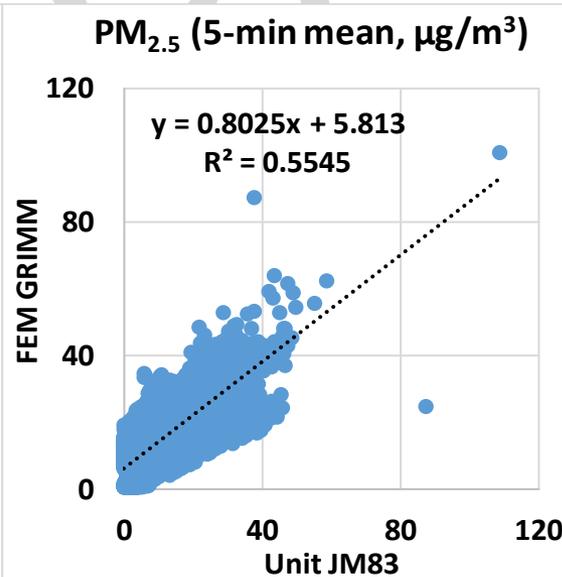
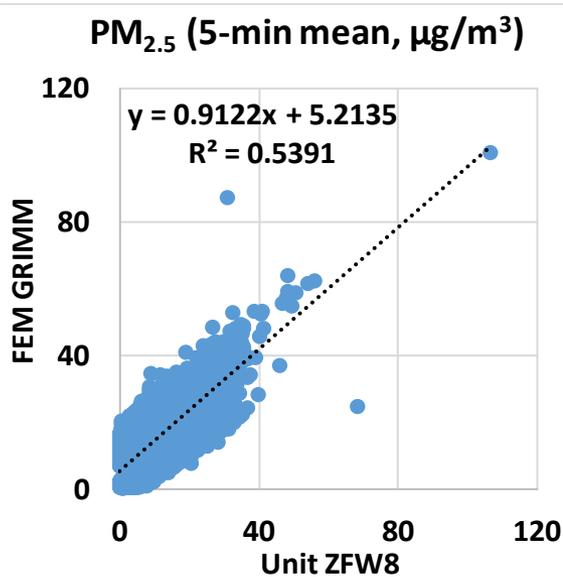
- The IQAir AirVisual Outdoor sensors showed moderate correlations with the corresponding GRIMM data ($0.52 < R^2 < 0.58$)
- Overall, the IQAir AirVisual Outdoor sensors underestimated the PM_{1.0} mass concentrations as measured by GRIMM
- The IQAir AirVisual Outdoor sensors seemed to track the PM_{1.0} diurnal variations as recorded by GRIMM



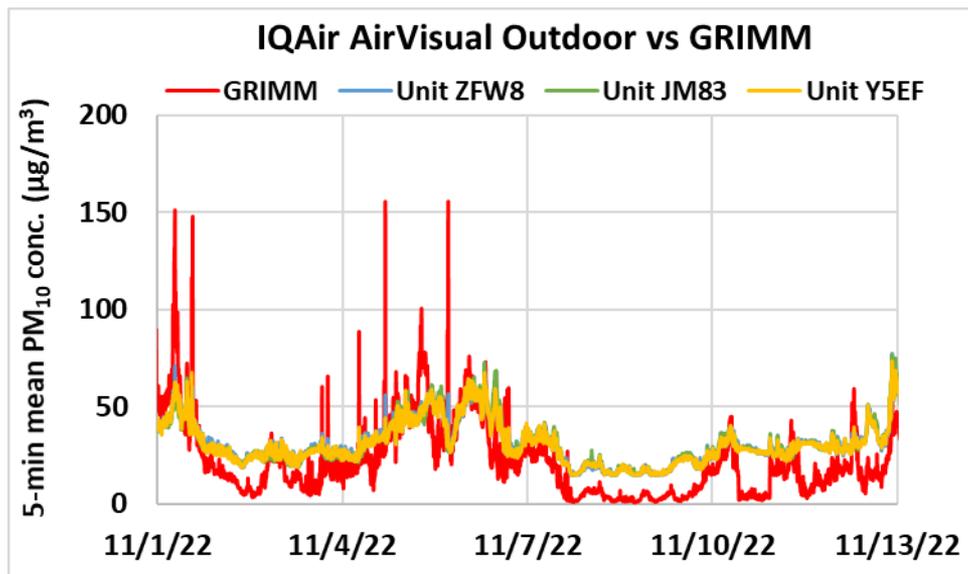
IQAir AirVisual Outdoor vs FEM GRIMM (PM_{2.5}; 5-min mean)



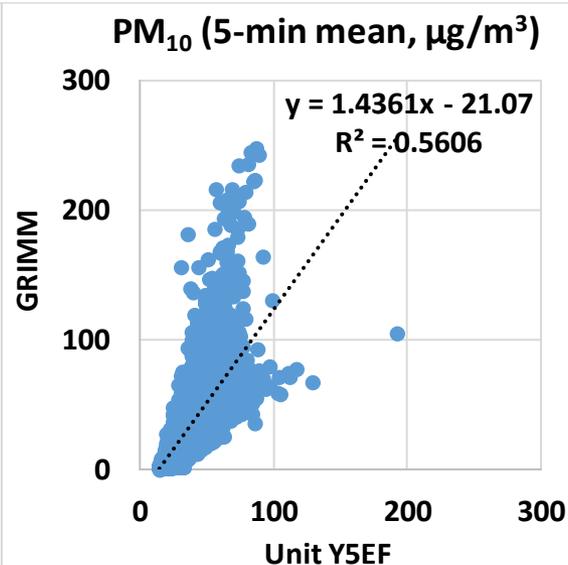
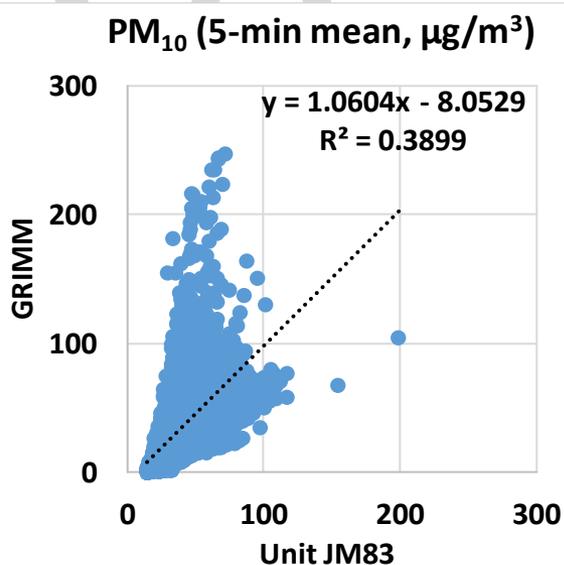
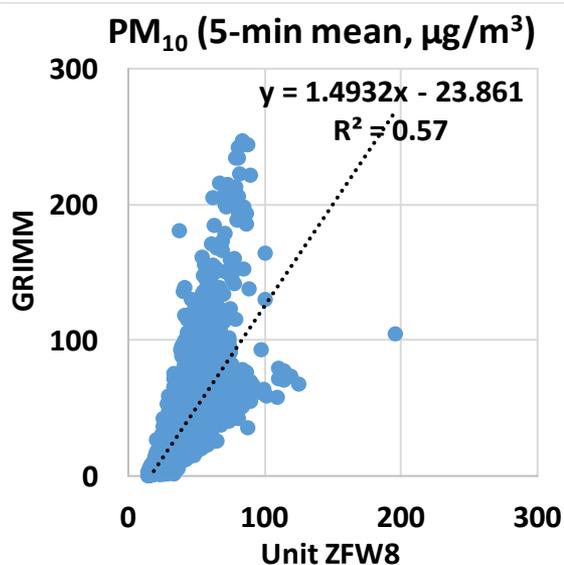
- The IQAir AirVisual Outdoor sensors showed moderate correlations with the corresponding FEM GRIMM data ($0.53 < R^2 < 0.60$)
- Overall, the IQAir AirVisual Outdoor sensors underestimated the PM_{2.5} mass concentrations as measured by FEM GRIMM
- The IQAir AirVisual Outdoor sensors seemed to track the PM_{2.5} diurnal variations as recorded by FEM GRIMM



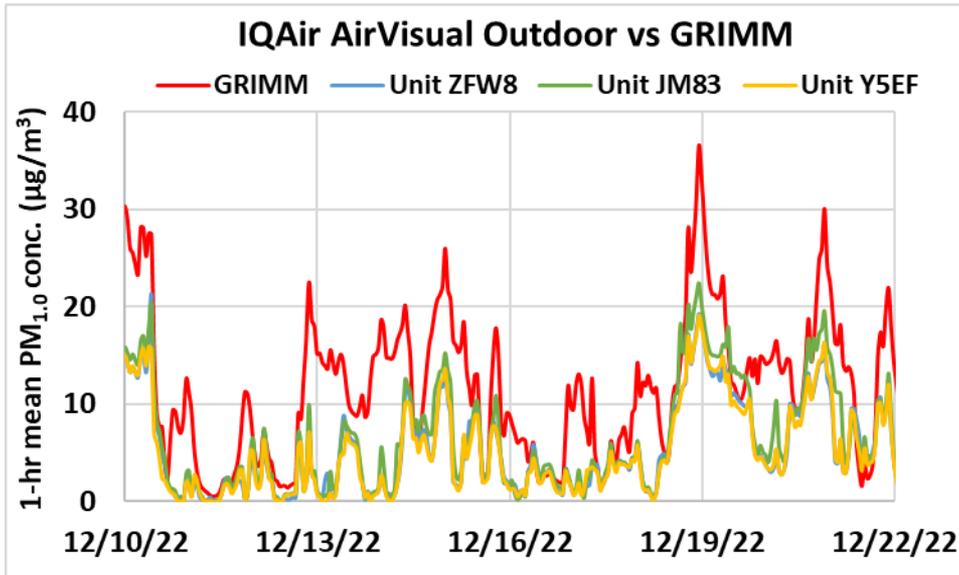
IQAir AirVisual Outdoor vs GRIMM (PM₁₀; 5-min mean)



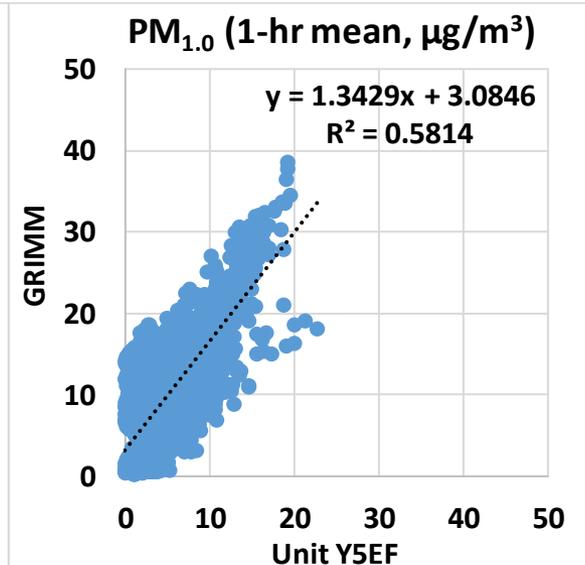
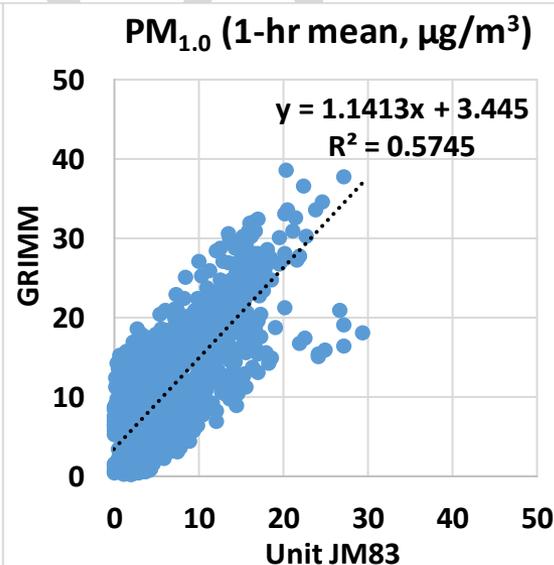
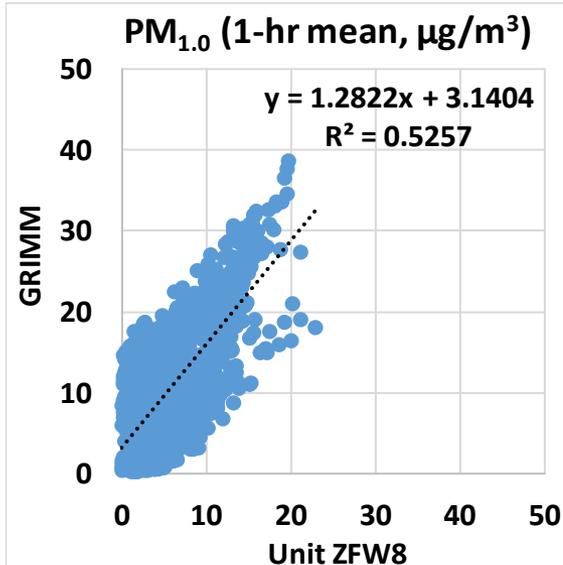
- The IQAir AirVisual Outdoor sensors showed weak to moderate correlations with the corresponding GRIMM data ($0.38 < R^2 < 0.58$)
- Overall, the IQAir AirVisual Outdoor sensors overestimated the PM₁₀ mass concentrations as measured by GRIMM
- The IQAir AirVisual Outdoor sensors sometimes seemed to track the PM₁₀ diurnal variations as recorded by GRIMM



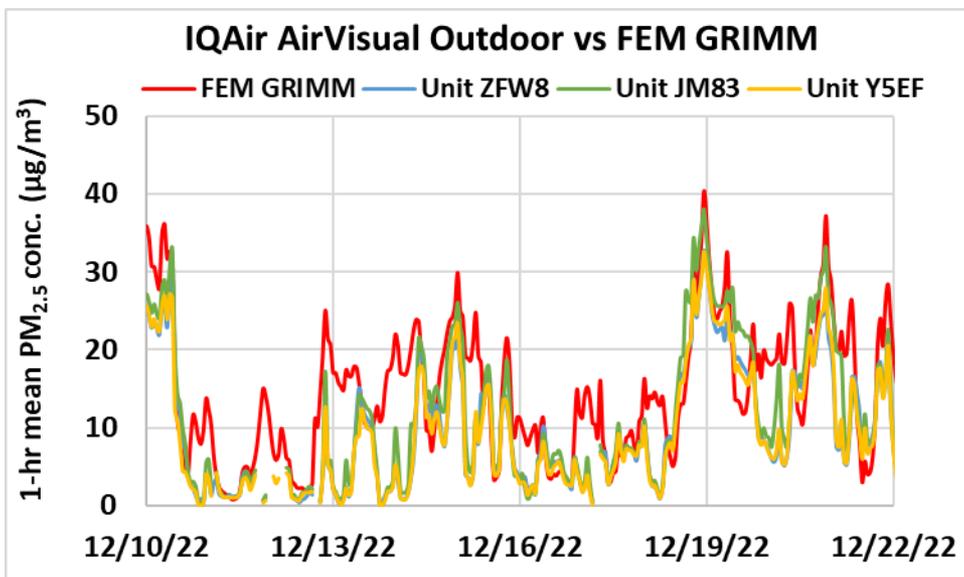
IQAir AirVisual Outdoor vs GRIMM (PM_{1.0}; 1-hr mean)



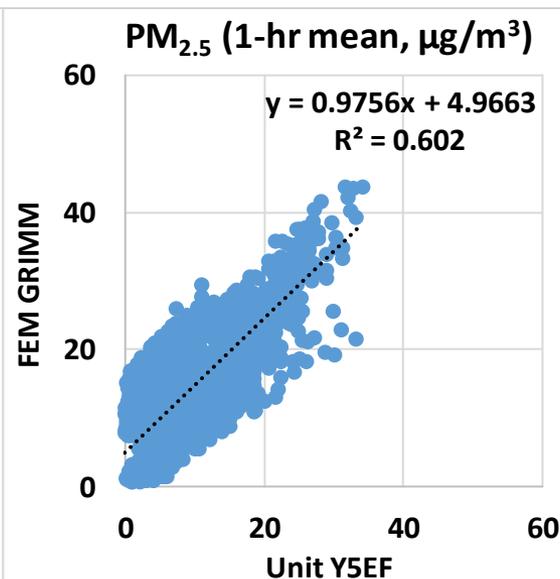
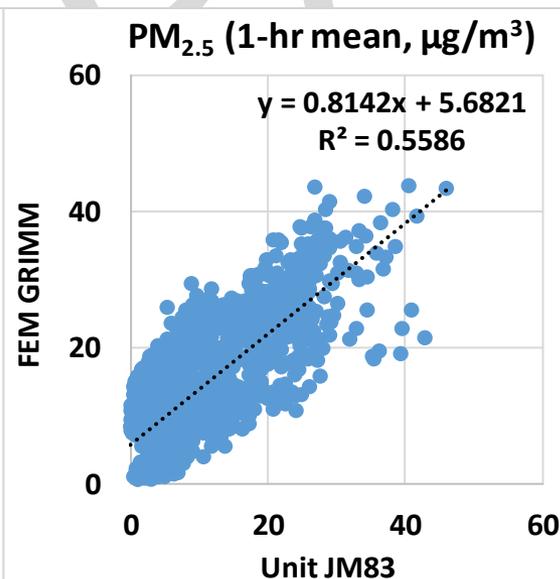
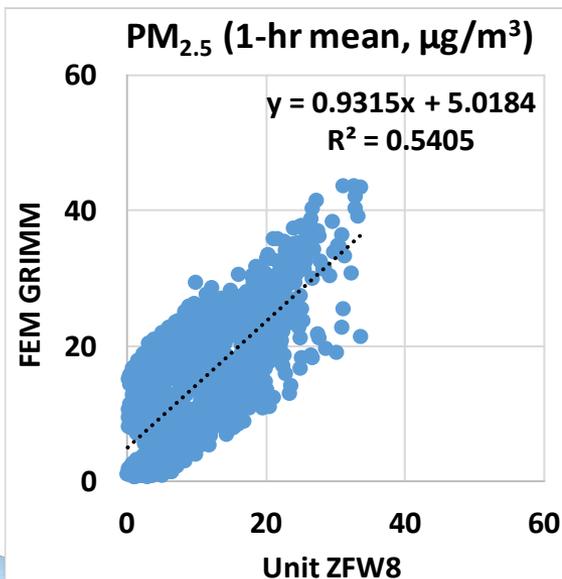
- The IQAir AirVisual Outdoor sensors showed moderate correlations with the corresponding GRIMM data ($0.52 < R^2 < 0.59$)
- Overall, the IQAir AirVisual Outdoor sensors underestimated the PM_{1.0} mass concentrations as measured by GRIMM
- The IQAir AirVisual Outdoor sensors seemed to track the PM_{1.0} diurnal variations as recorded by GRIMM



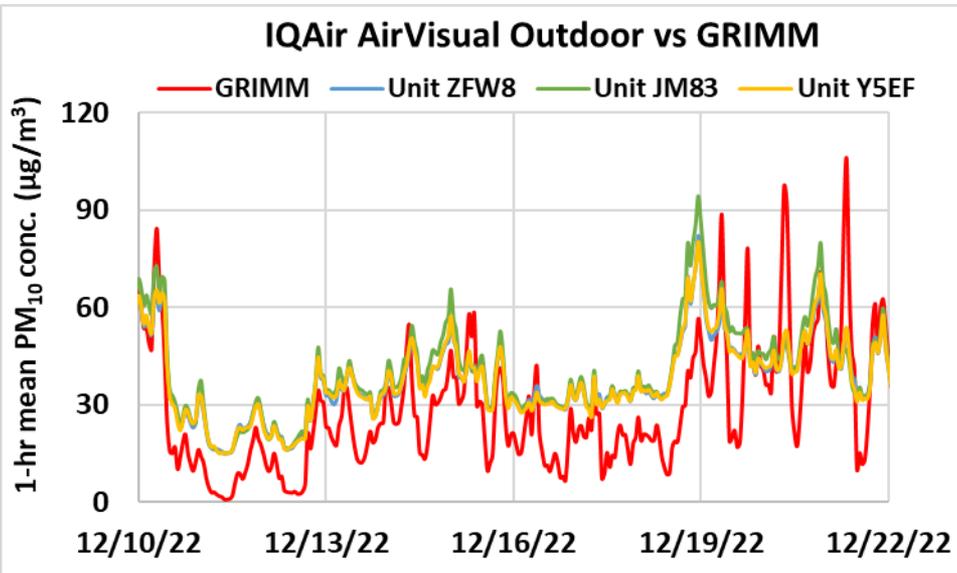
IQAir AirVisual Outdoor vs FEM GRIMM (PM_{2.5}; 1-hr mean)



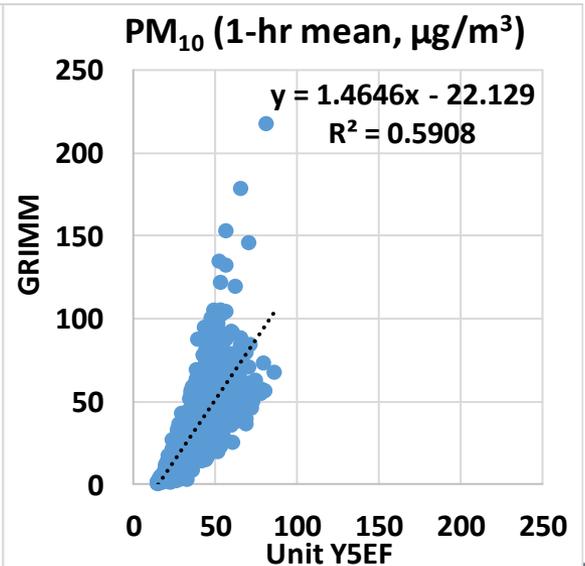
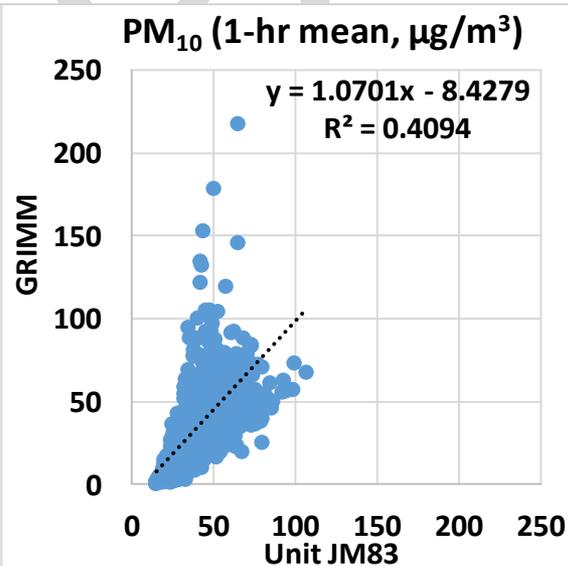
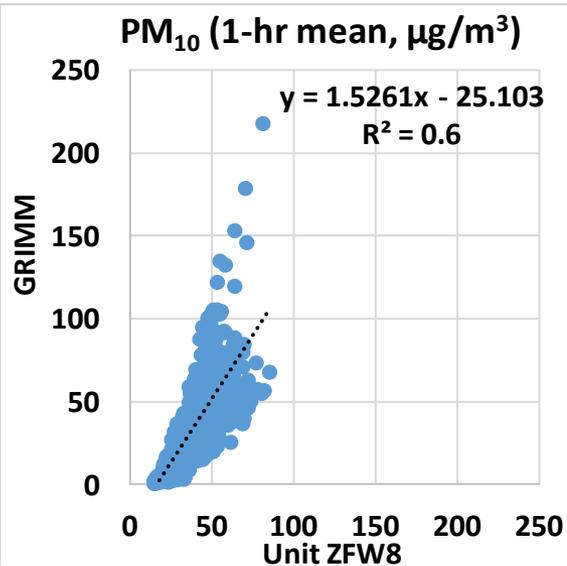
- The IQAir AirVisual Outdoor sensors showed moderate correlations with the corresponding FEM GRIMM data ($0.54 < R^2 < 0.61$)
- Overall, the IQAir AirVisual Outdoor sensors underestimated the PM_{2.5} mass concentrations as measured by FEM GRIMM
- The IQAir AirVisual Outdoor sensors seemed to track the PM_{2.5} diurnal variations as recorded by FEM GRIMM



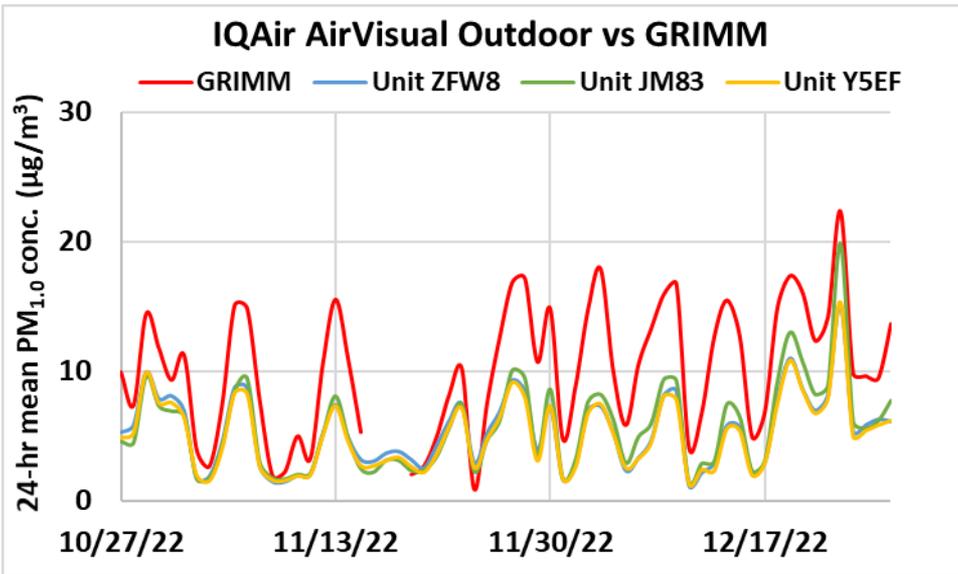
IQAir AirVisual Outdoor vs GRIMM (PM₁₀; 1-hr mean)



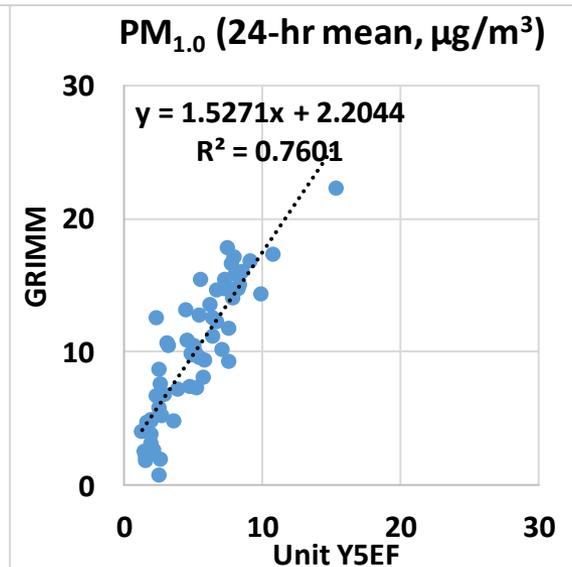
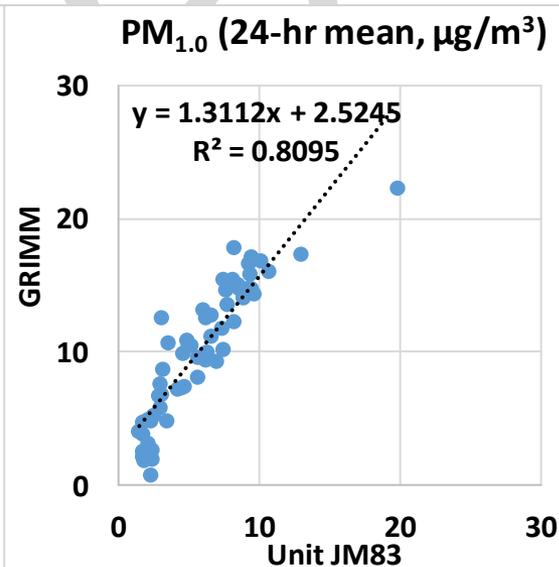
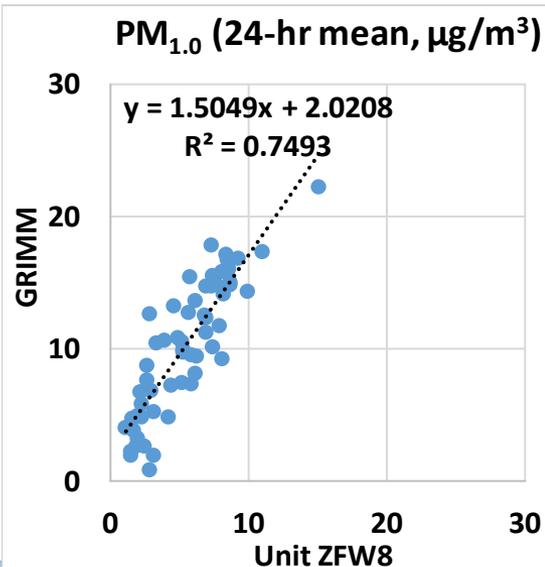
- The IQAir AirVisual Outdoor sensors showed weak to moderate correlations with the corresponding GRIMM data ($0.40 < R^2 < 0.61$)
- Overall, the IQAir AirVisual Outdoor sensors overestimated the PM₁₀ mass concentrations as measured by GRIMM
- The IQAir AirVisual Outdoor sensors sometimes seemed to track the PM₁₀ diurnal variations as recorded by GRIMM



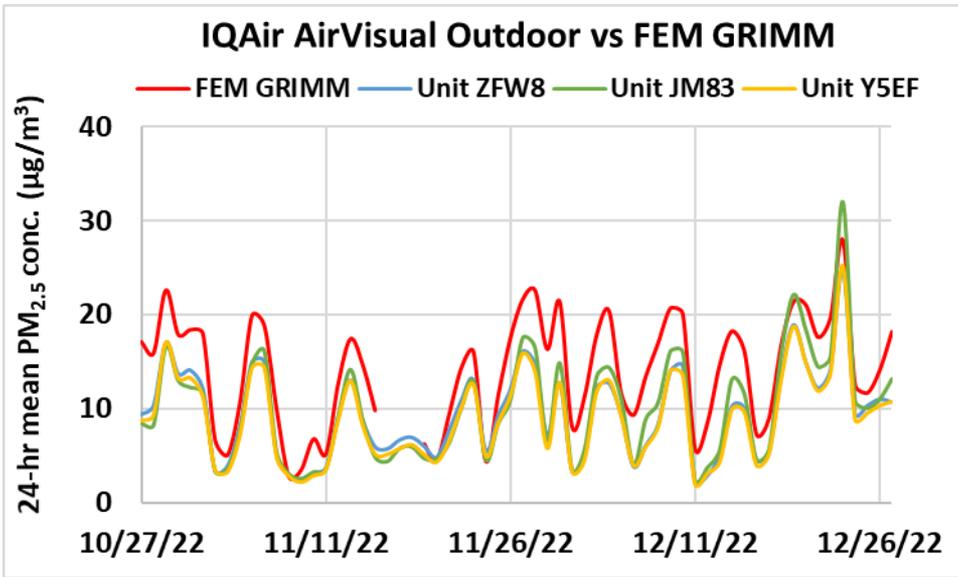
IQAir AirVisual Outdoor vs GRIMM (PM_{1.0}; 24-hr mean)



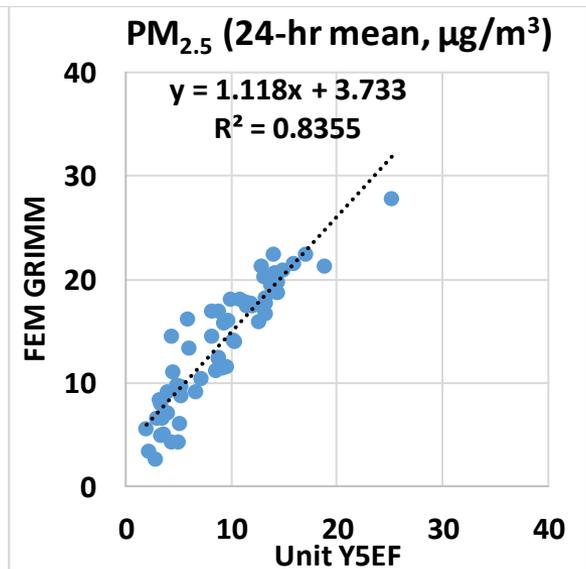
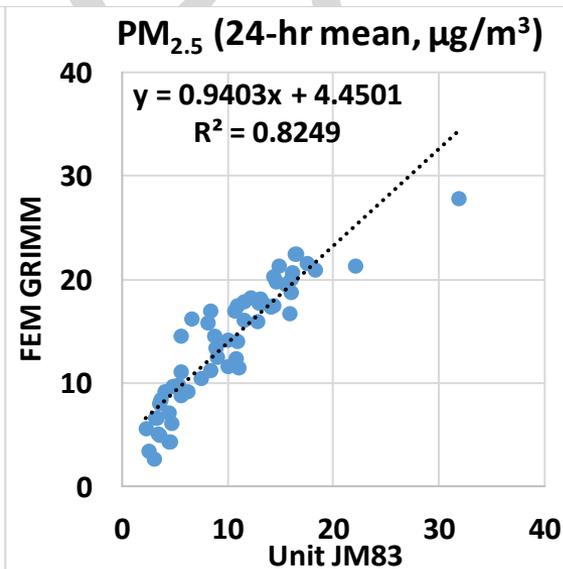
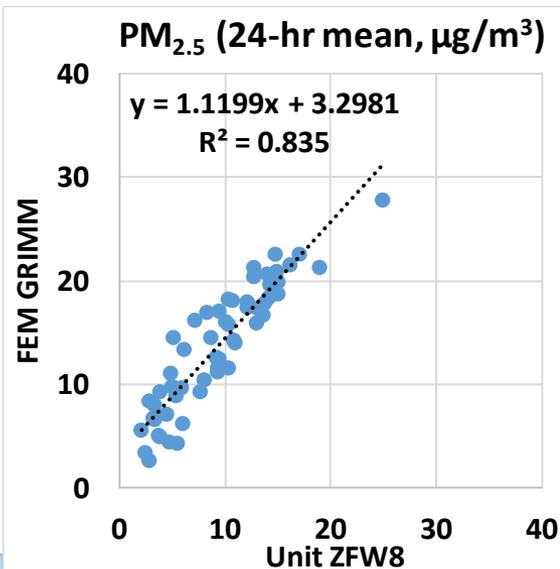
- The IQAir AirVisual Outdoor sensors showed strong correlations with the corresponding GRIMM data ($0.74 < R^2 < 0.81$)
- Overall, the IQAir AirVisual Outdoor sensors underestimated the PM_{1.0} mass concentrations as measured by GRIMM
- The IQAir AirVisual Outdoor sensors seemed to track the PM_{1.0} daily variations as recorded by GRIMM



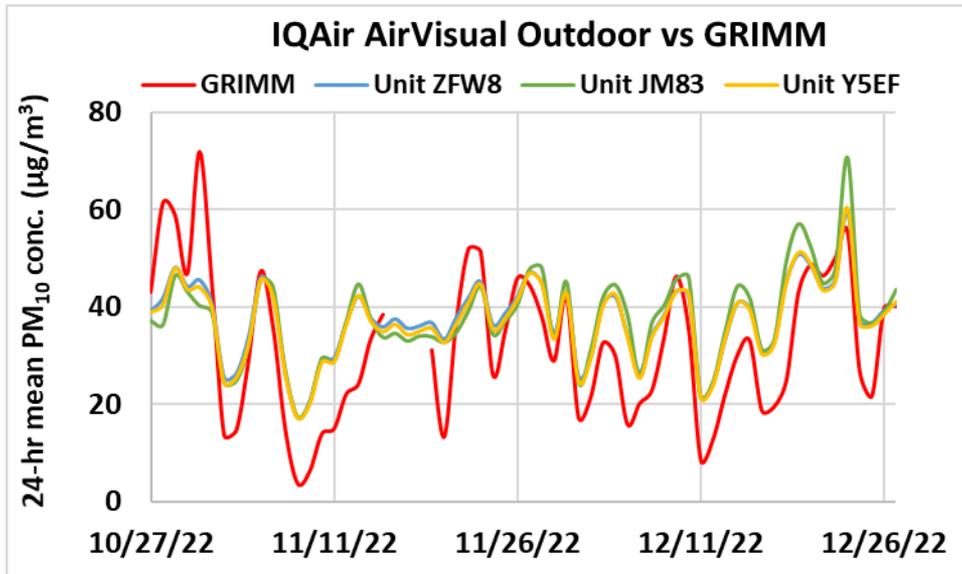
IQAir AirVisual Outdoor vs FEM GRIMM (PM_{2.5}; 24-hr mean)



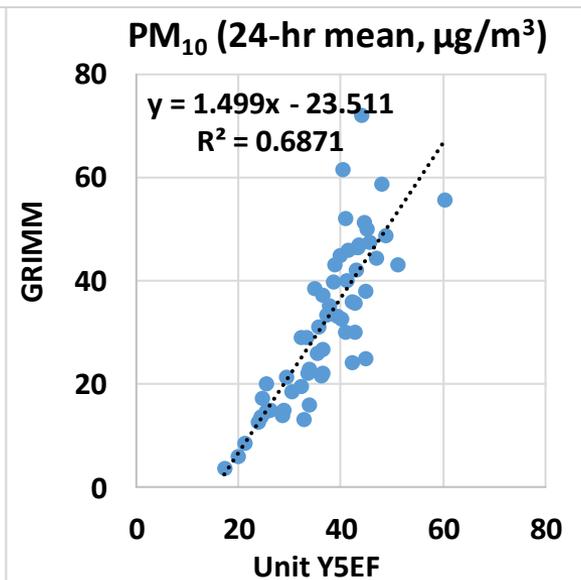
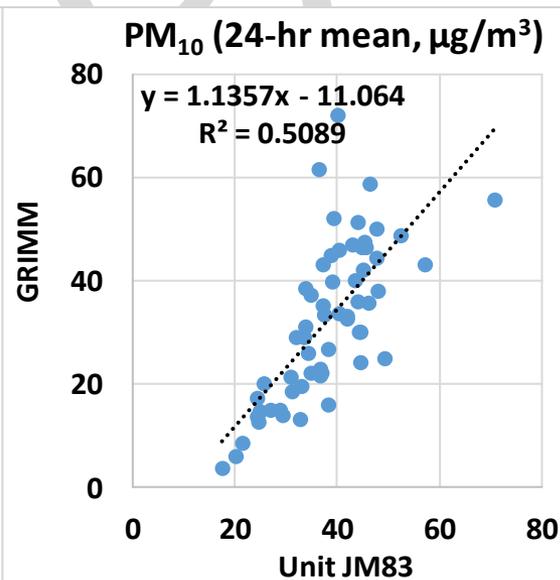
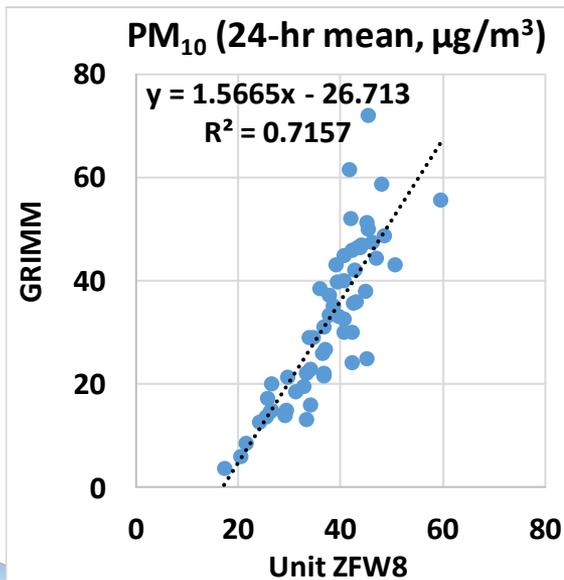
- The IQAir AirVisual Outdoor sensors showed strong correlations with the corresponding FEM GRIMM data ($0.82 < R^2 < 0.84$)
- Overall, the IQAir AirVisual Outdoor sensors underestimated the PM_{2.5} mass concentrations as measured by FEM GRIMM
- The IQAir AirVisual Outdoor sensors seemed to track the PM_{2.5} daily variations as recorded by FEM GRIMM



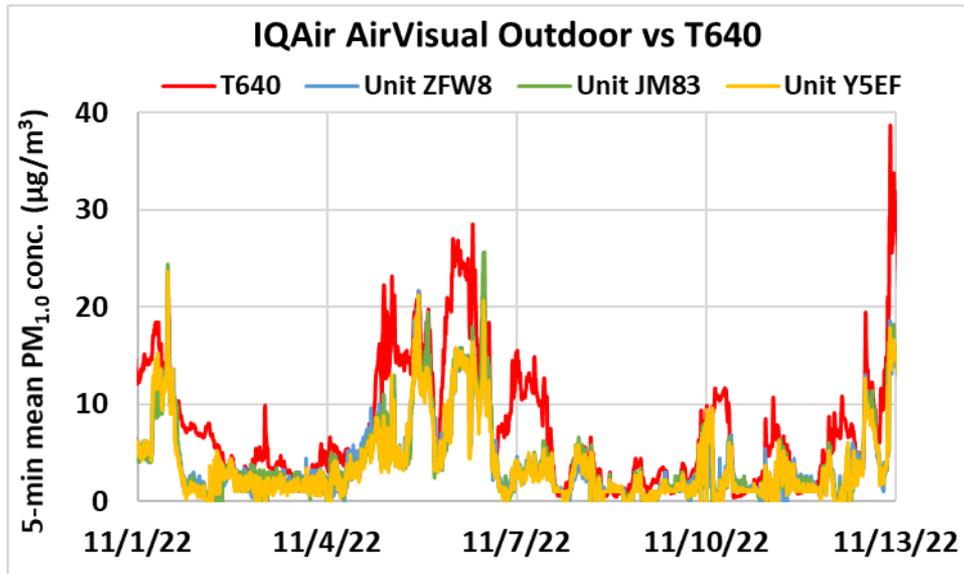
IQAir AirVisual Outdoor vs GRIMM (PM₁₀; 24-hr mean)



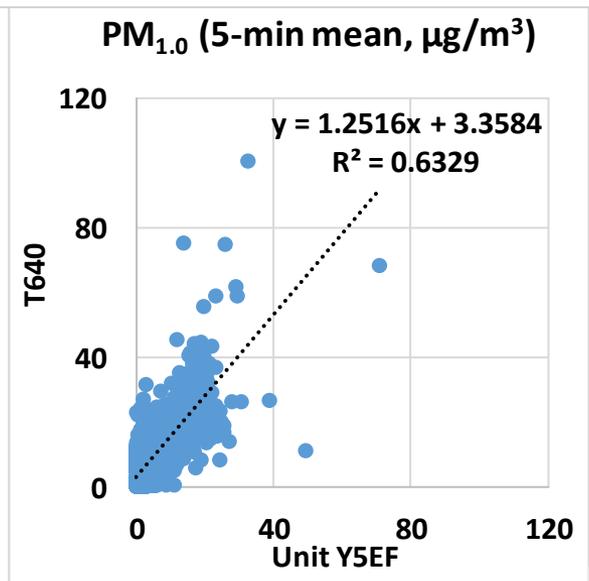
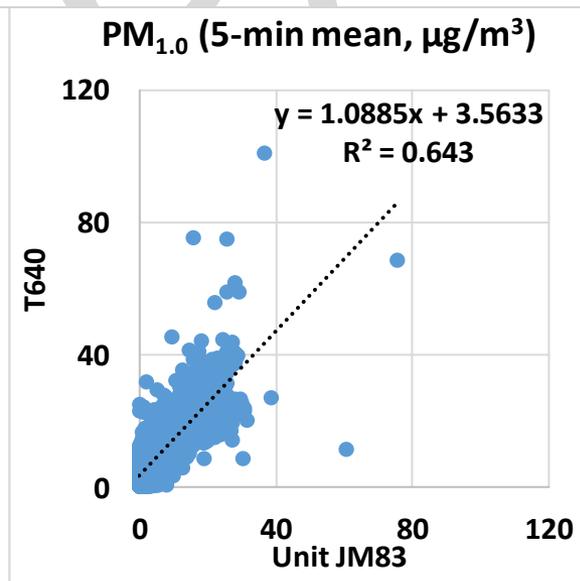
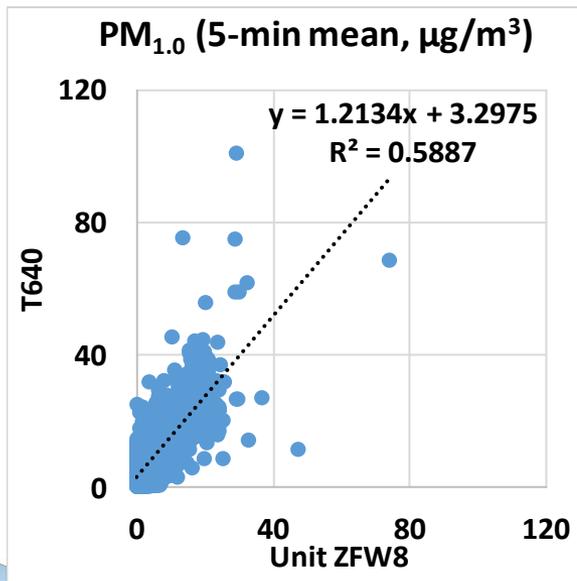
- The IQAir AirVisual Outdoor sensors showed moderate to strong correlations with the corresponding GRIMM data ($0.50 < R^2 < 0.72$)
- Overall, the IQAir AirVisual Outdoor sensors overestimated the PM₁₀ mass concentrations as measured by GRIMM
- The IQAir AirVisual Outdoor sensors sometimes seemed to track the PM₁₀ daily variations as recorded by GRIMM



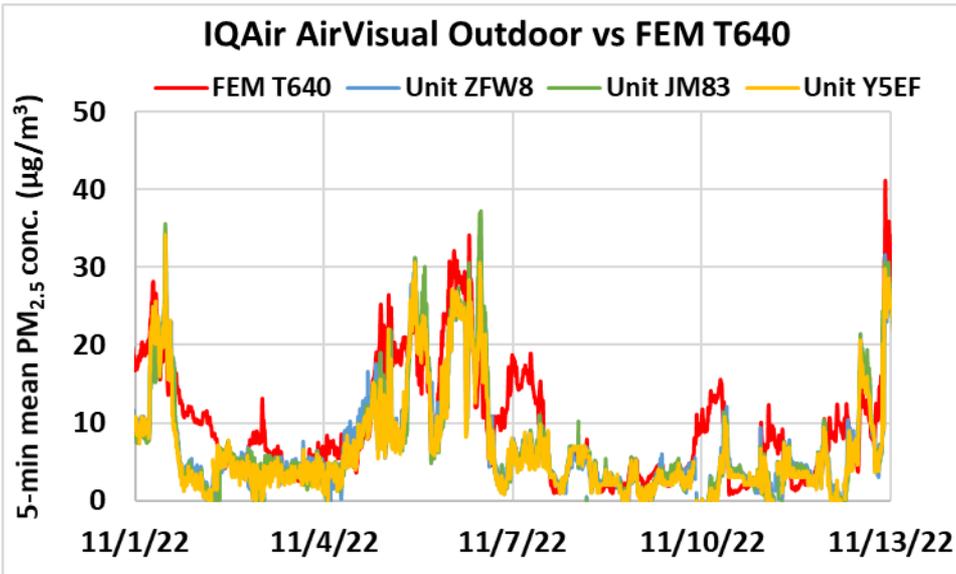
IQAir AirVisual Outdoor vs T640 (PM_{1.0}; 5-min mean)



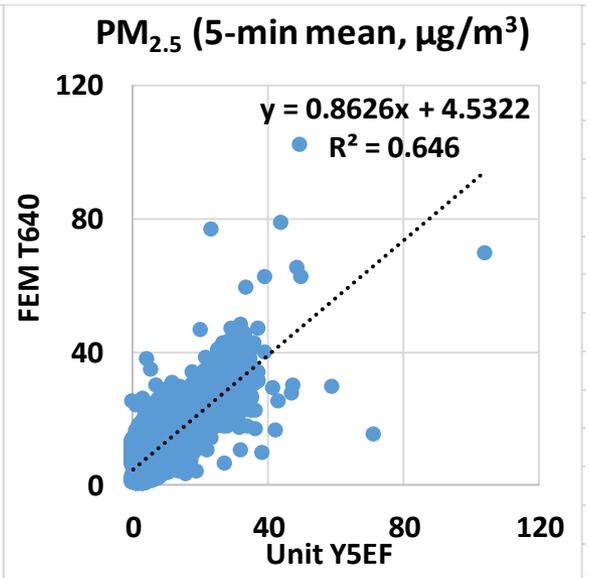
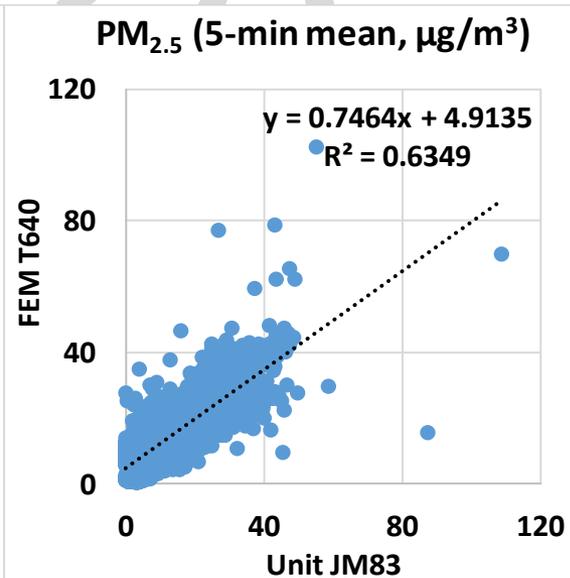
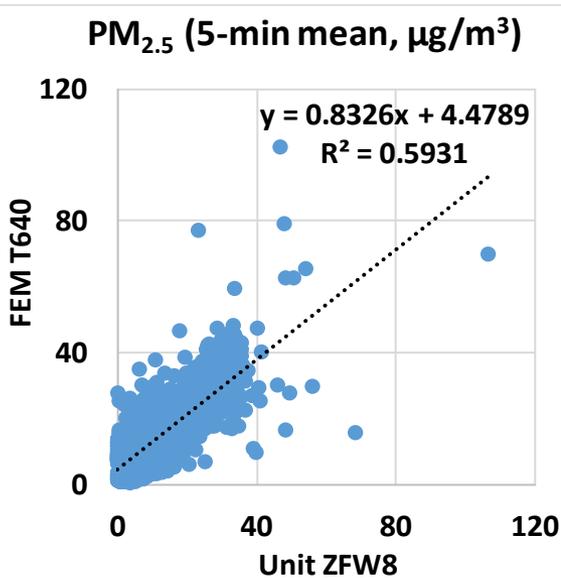
- The IQAir AirVisual Outdoor sensors showed moderate correlations with the corresponding T640 data ($0.58 < R^2 < 0.65$)
- Overall, the IQAir AirVisual Outdoor sensors underestimated the PM_{1.0} mass concentrations as measured by T640
- The IQAir AirVisual Outdoor sensors seemed to track the PM_{1.0} diurnal variations as recorded by T640



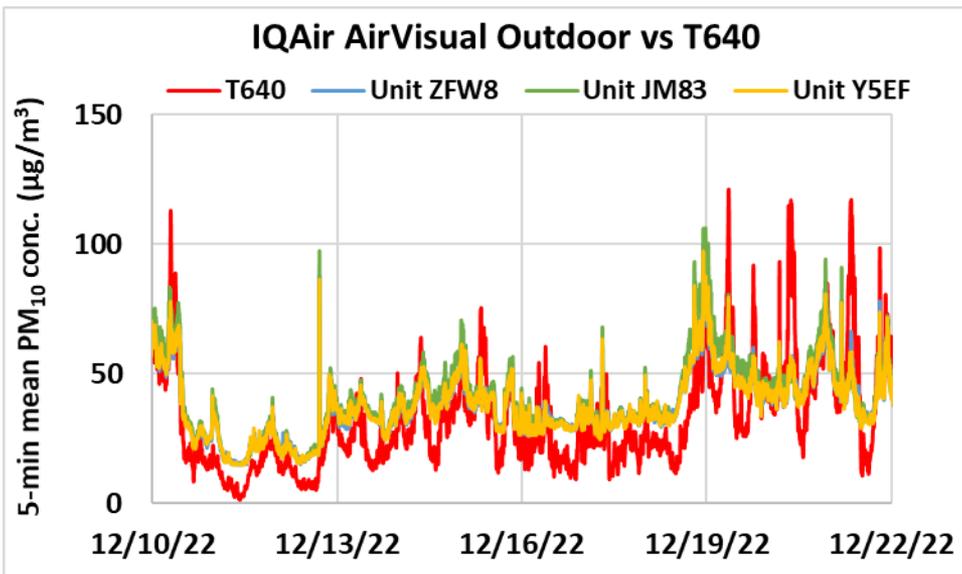
IQAir AirVisual Outdoor vs FEM T640 (PM_{2.5}; 5-min mean)



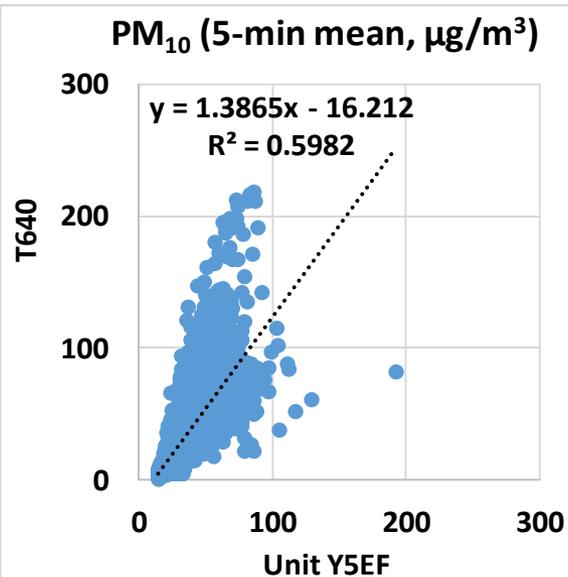
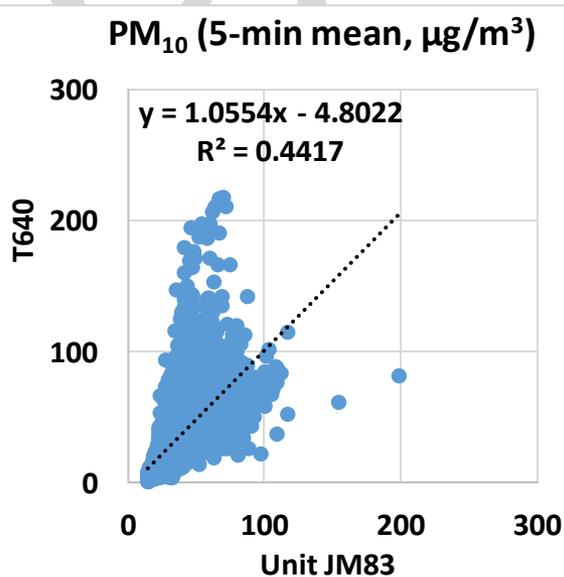
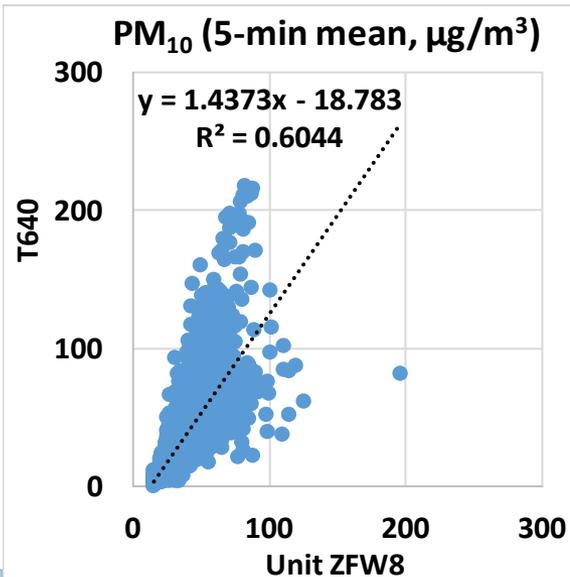
- The IQAir AirVisual Outdoor sensors showed moderate correlations with the corresponding FEM T640 data ($0.59 < R^2 < 0.65$)
- Overall, the IQAir AirVisual Outdoor sensors underestimated the PM_{2.5} mass concentrations as measured by FEM T640
- The IQAir AirVisual Outdoor sensors seemed to track the PM_{2.5} diurnal variations as recorded by FEM T640



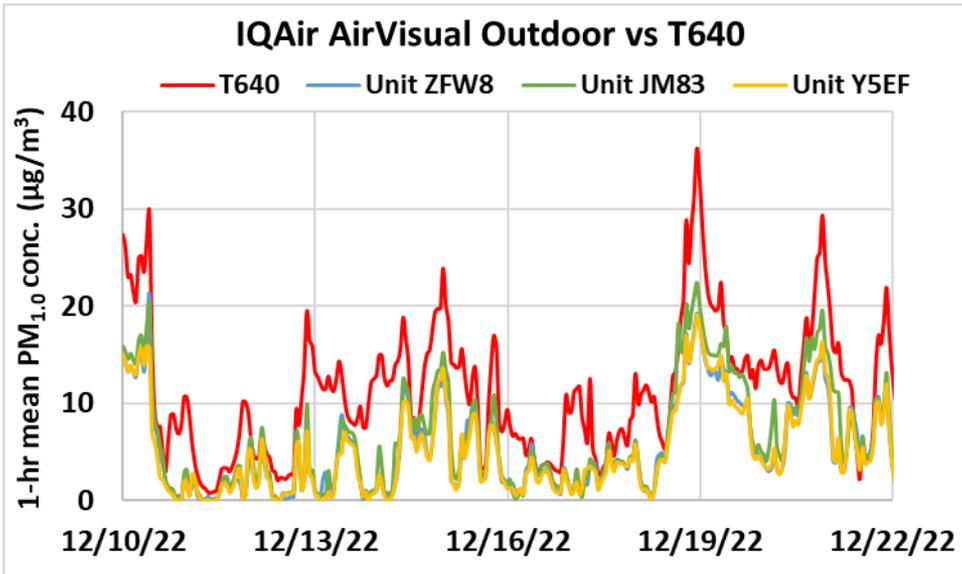
IQAir AirVisual Outdoor vs T640 (PM₁₀; 5-min mean)



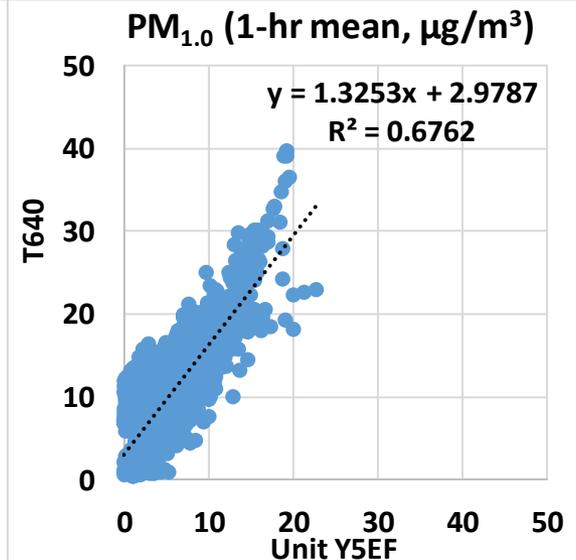
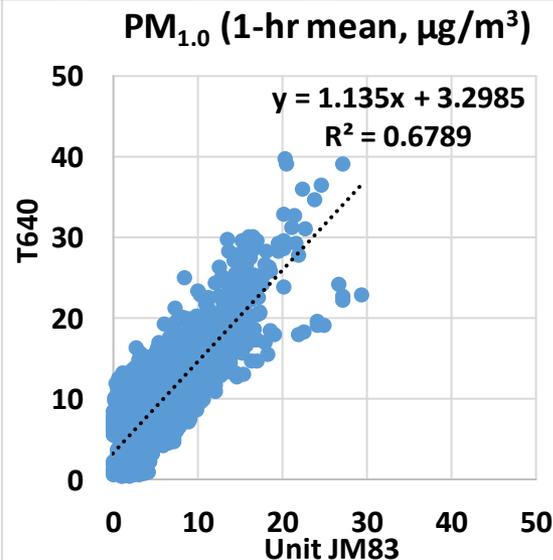
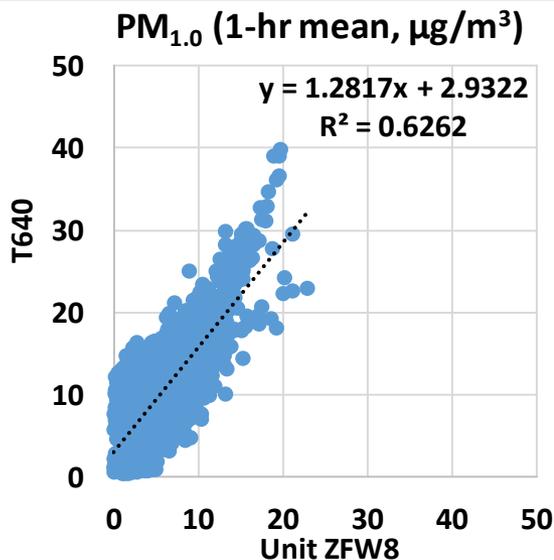
- The IQAir AirVisual Outdoor sensors showed weak to moderate correlations with the corresponding T640 data ($0.44 < R^2 < 0.61$)
- Overall, the IQAir AirVisual Outdoor sensors overestimated the PM₁₀ mass concentrations as measured by T640
- The IQAir AirVisual Outdoor sensors seemed to track the PM₁₀ diurnal variations as recorded by T640



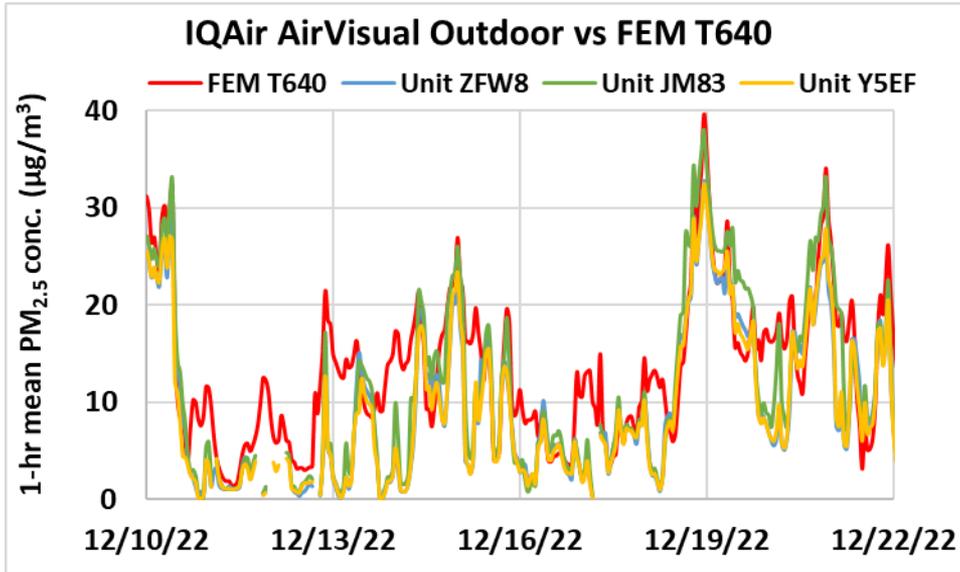
IQAir AirVisual Outdoor vs T640 (PM_{1.0}; 1-hr mean)



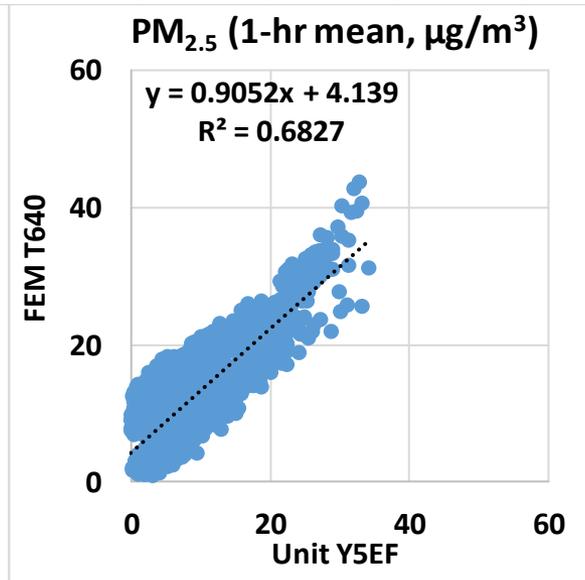
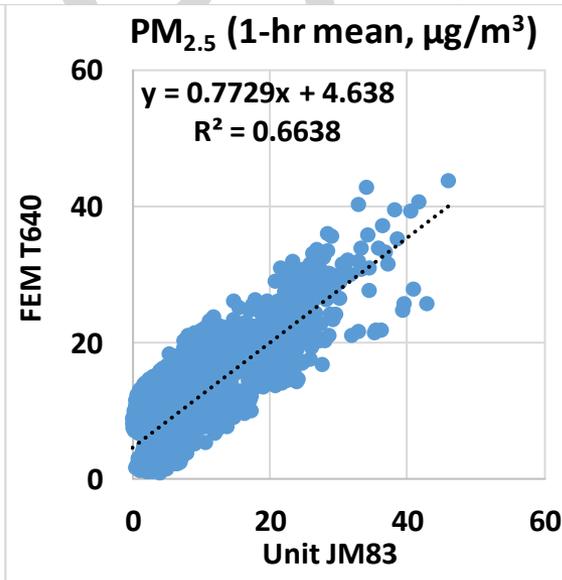
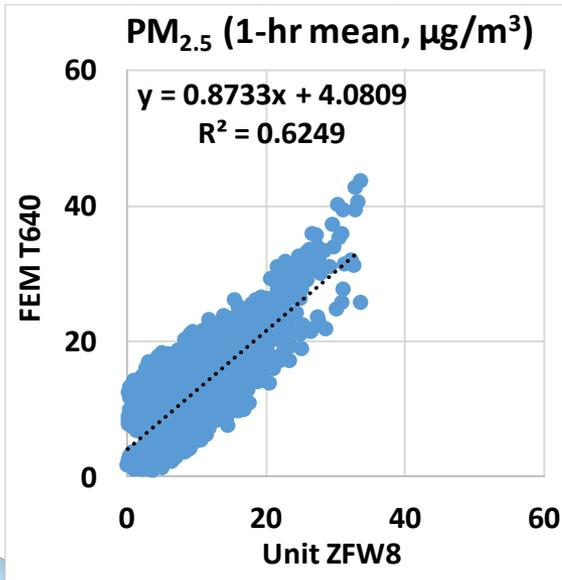
- The IQAir AirVisual Outdoor sensors showed moderate correlations with the corresponding T640 data ($0.62 < R^2 < 0.68$)
- Overall, the IQAir AirVisual Outdoor sensors underestimated the PM_{1.0} mass concentrations as measured by T640
- The IQAir AirVisual Outdoor sensors seemed to track the PM_{1.0} diurnal variations as recorded by T640



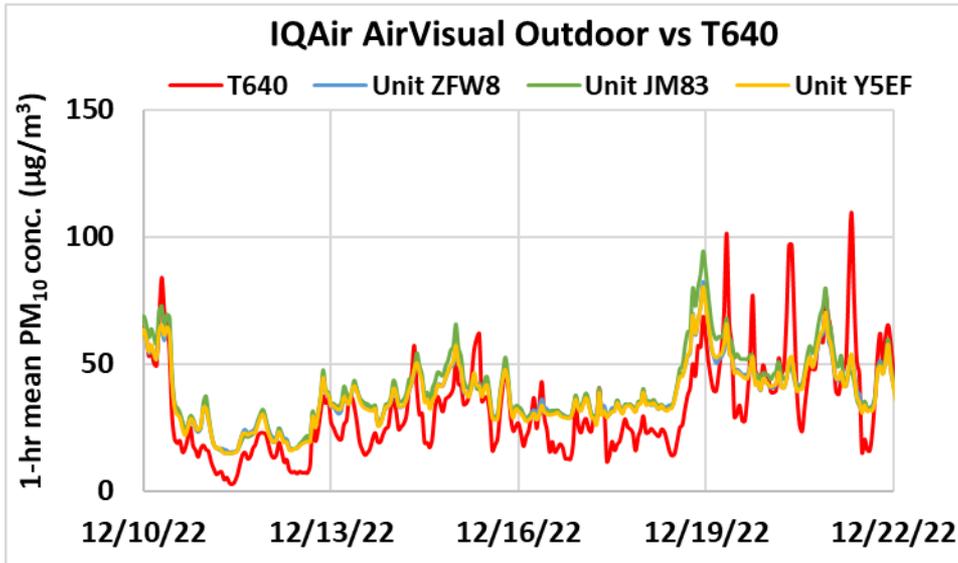
IQAir AirVisual Outdoor vs FEM T640 (PM_{2.5}; 1-hr mean)



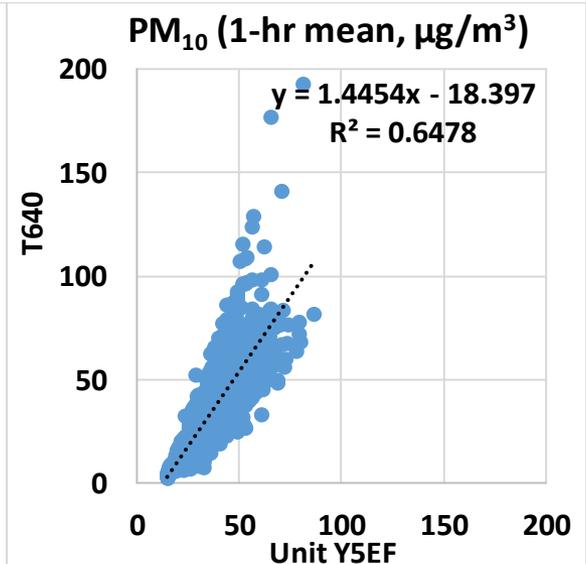
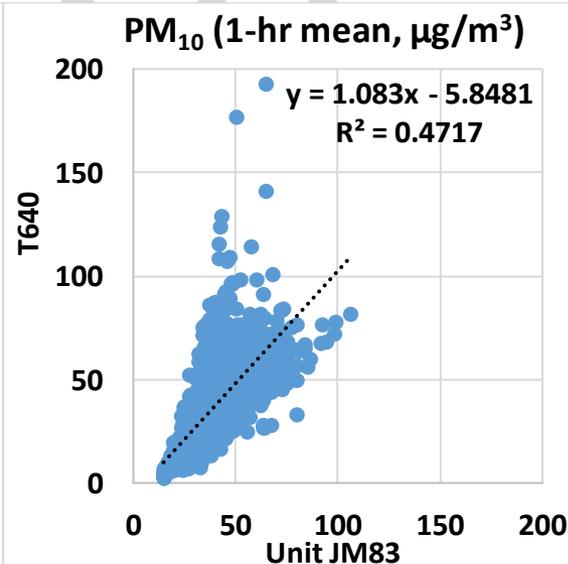
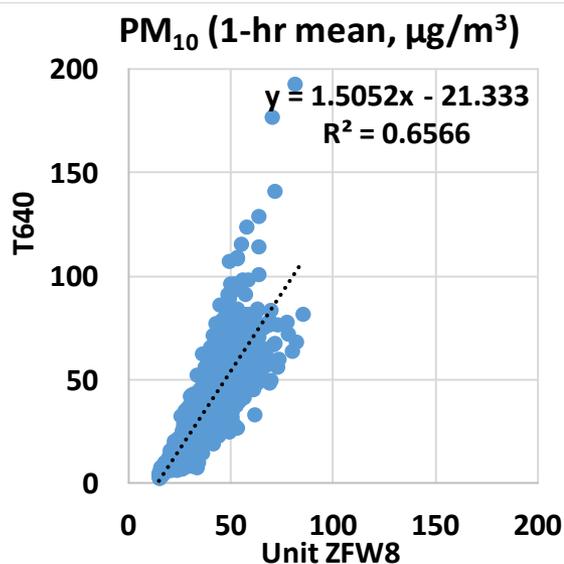
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- Overall, the IQAir AirVisual Outdoor sensors underestimated the PM_{2.5} mass concentrations as measured by FEM T640
- The IQAir AirVisual Outdoor sensors seemed to track the PM_{2.5} diurnal variations as recorded by FEM T640



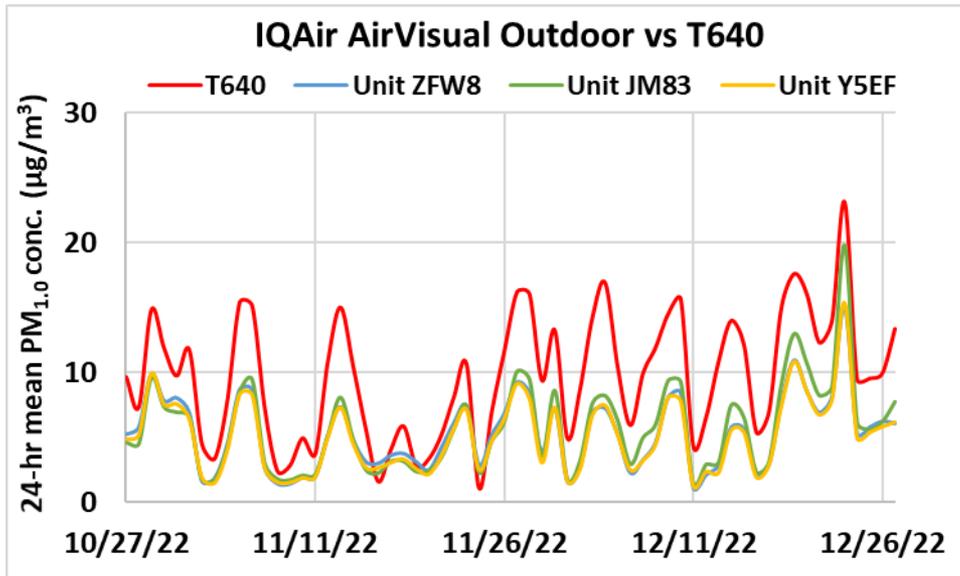
IQAir AirVisual Outdoor vs T640 (PM₁₀; 1-hr mean)



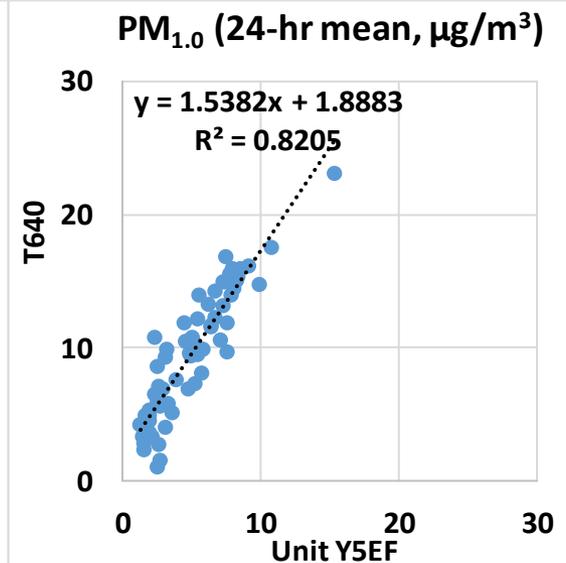
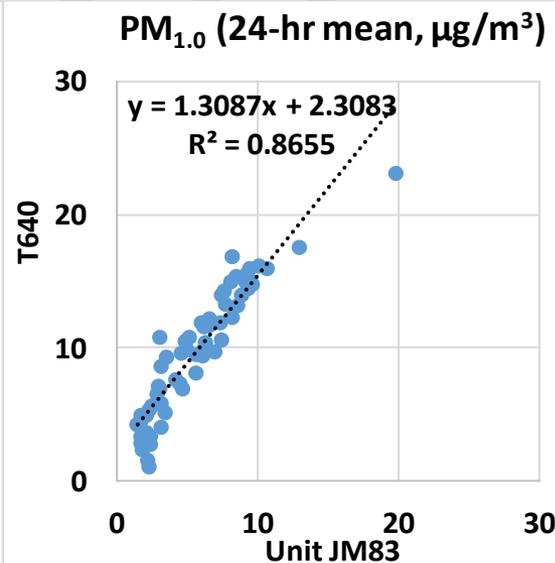
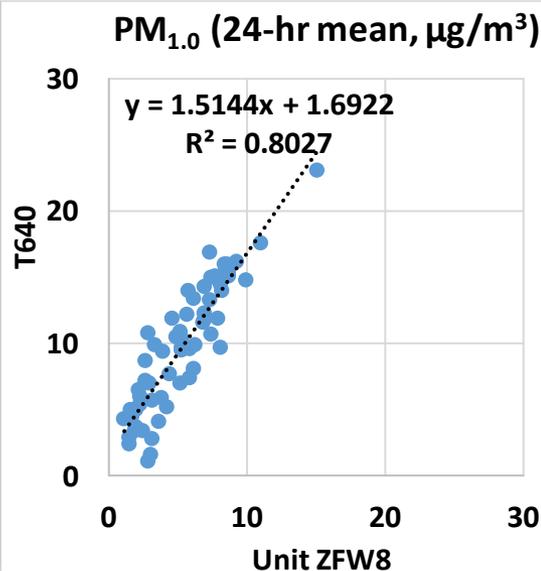
- The IQAir AirVisual Outdoor sensors showed weak to moderate correlations with the corresponding T640 data ($0.47 < R^2 < 0.66$)
- Overall, the IQAir AirVisual Outdoor sensors overestimated the PM₁₀ mass concentrations as measured by T640
- The IQAir AirVisual Outdoor sensors seemed to track the PM₁₀ diurnal variations as recorded by T640



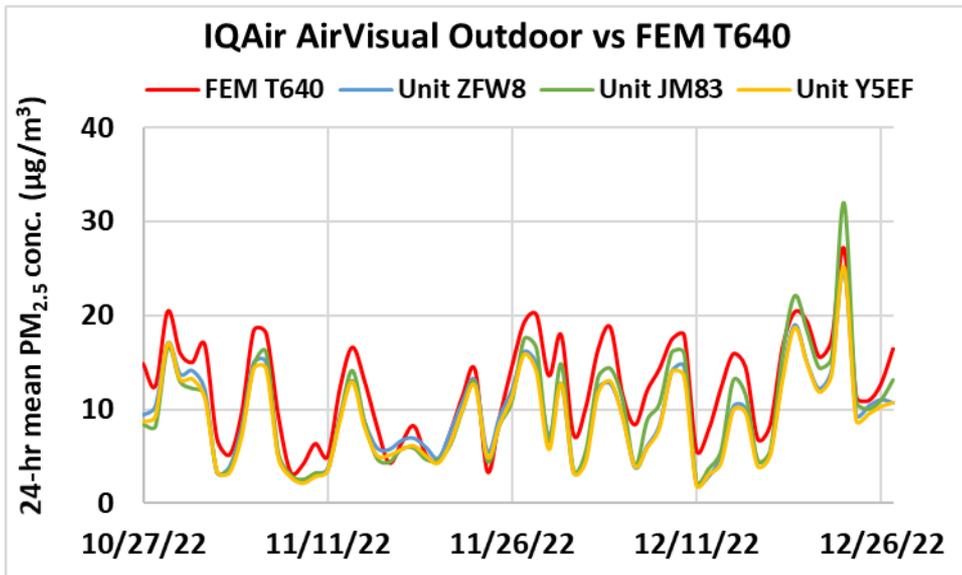
IQAir AirVisual Outdoor vs T640 (PM_{1.0}; 24-hr mean)



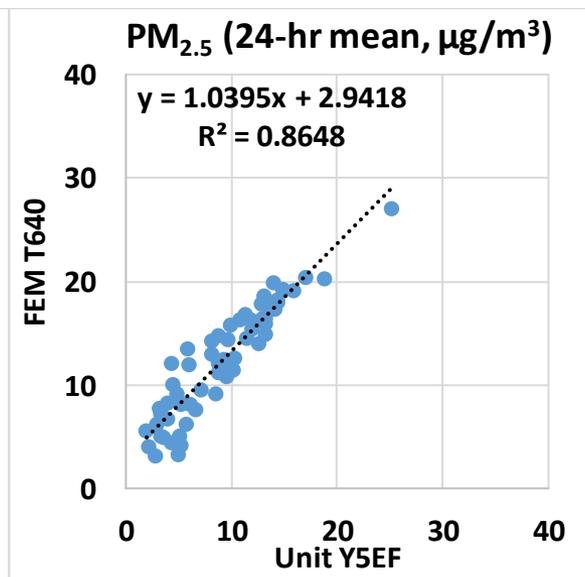
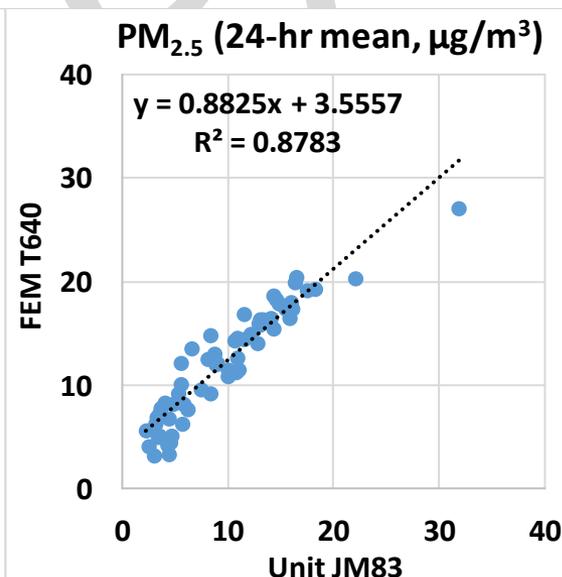
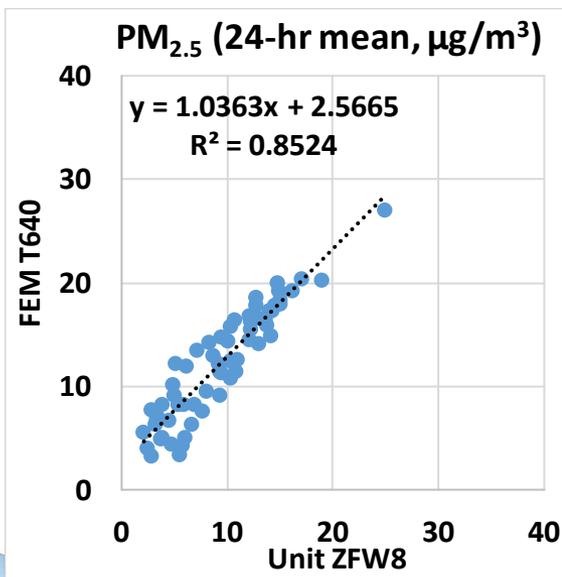
- The IQAir AirVisual Outdoor sensors showed strong correlations with the corresponding T640 data ($0.80 < R^2 < 0.87$)
- Overall, the IQAir AirVisual Outdoor sensors underestimated the PM_{1.0} mass concentrations as measured by T640
- The IQAir AirVisual Outdoor sensors seemed to track the PM_{1.0} daily variations as recorded by T640



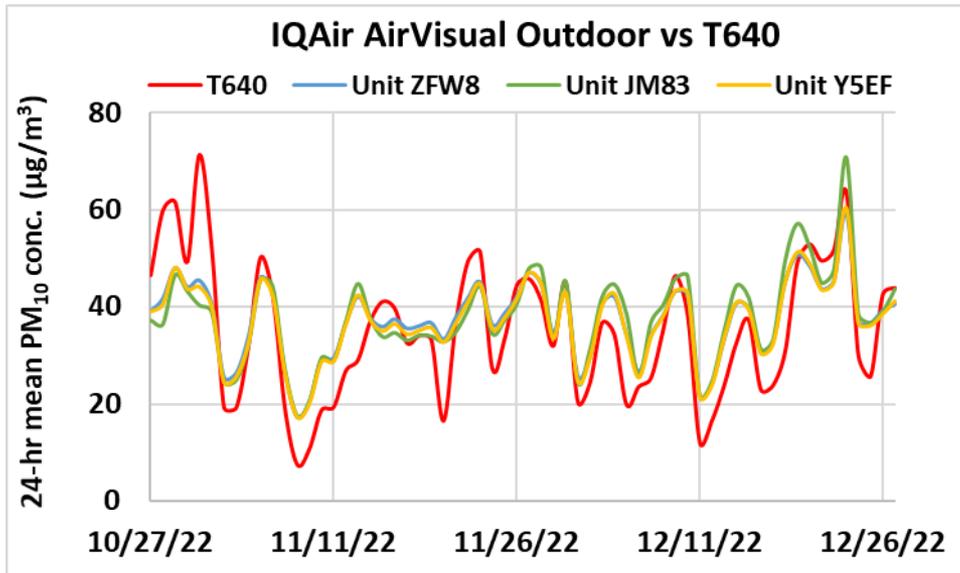
IQAir AirVisual Outdoor vs FEM T640 (PM_{2.5}; 24-hr mean)



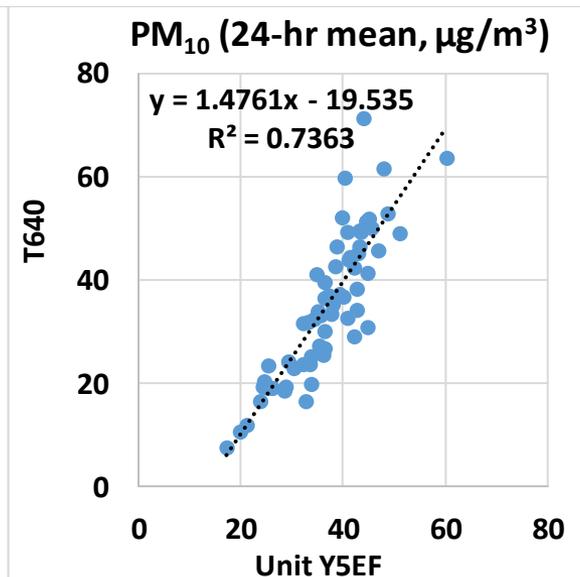
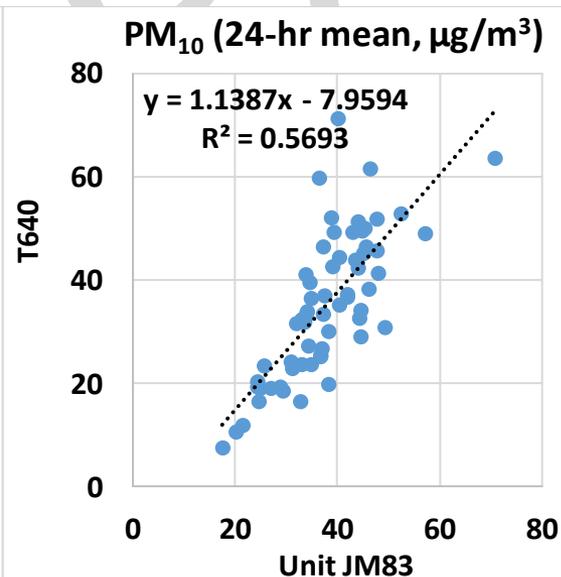
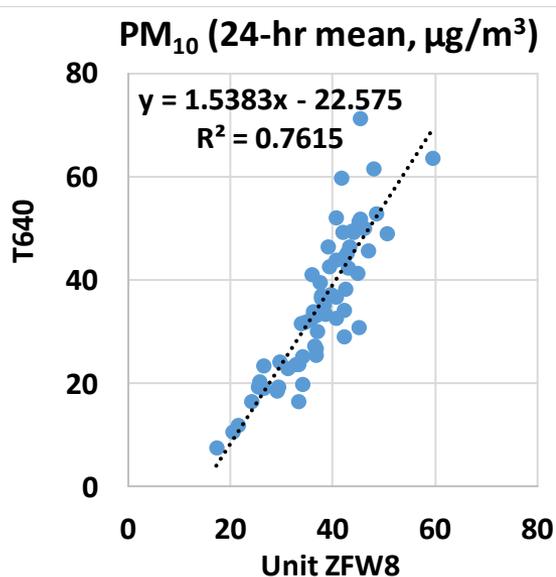
- The IQAir AirVisual Outdoor sensors showed strong correlations with the corresponding FEM T640 data ($0.85 < R^2 < 0.88$)
- Overall, the IQAir AirVisual Outdoor sensors underestimated the PM_{2.5} mass concentrations as measured by FEM T640
- The IQAir AirVisual Outdoor sensors seemed to track the PM_{2.5} daily variations as recorded by FEM T640



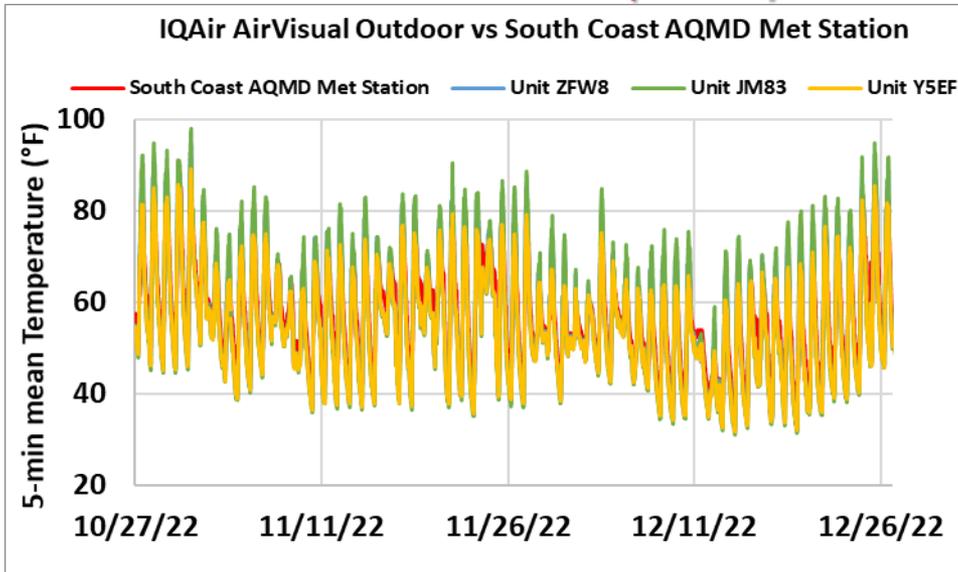
IQAir AirVisual Outdoor vs T640 (PM₁₀; 24-hr mean)



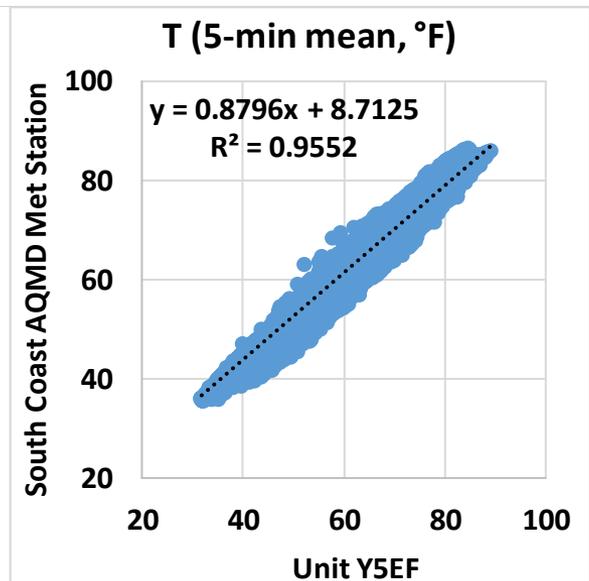
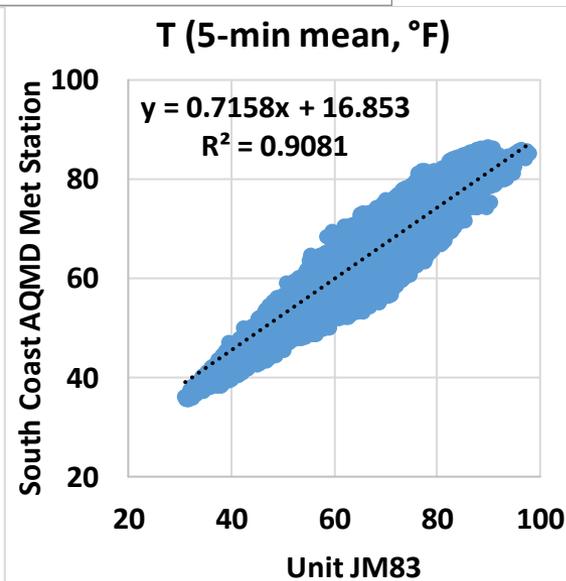
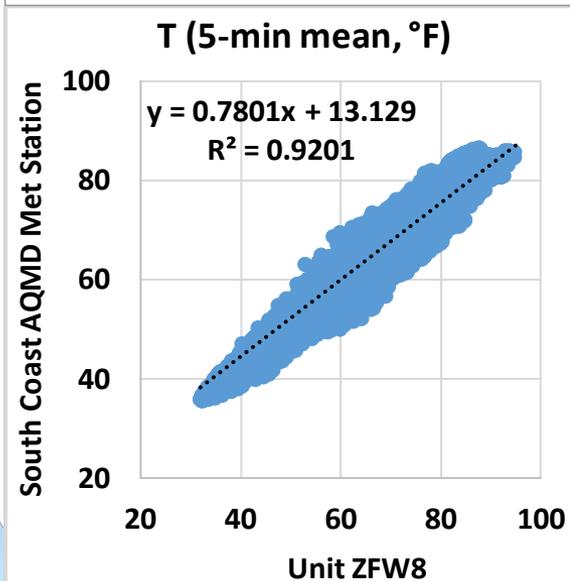
- The IQAir AirVisual Outdoor sensors showed moderate to strong correlations with the corresponding T640 data ($0.56 < R^2 < 0.77$)
- Overall, the IQAir AirVisual Outdoor sensors overestimated the PM₁₀ mass concentrations as measured by T640
- The IQAir AirVisual Outdoor sensors seemed to track the PM₁₀ daily variations as recorded by T640



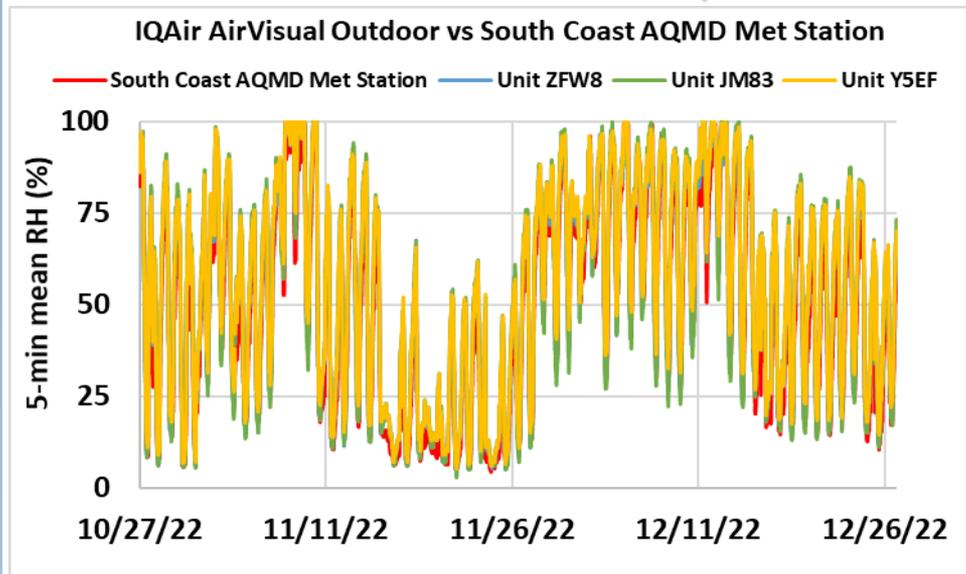
IQAir AirVisual Outdoor vs South Coast AQMD Met Station (Temp; 5-min mean)



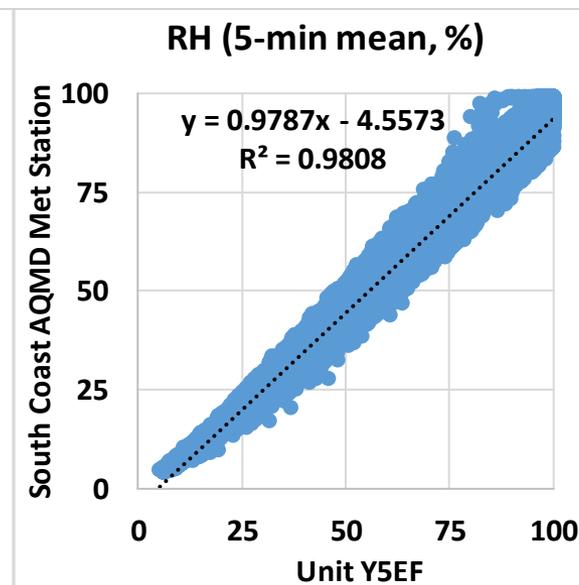
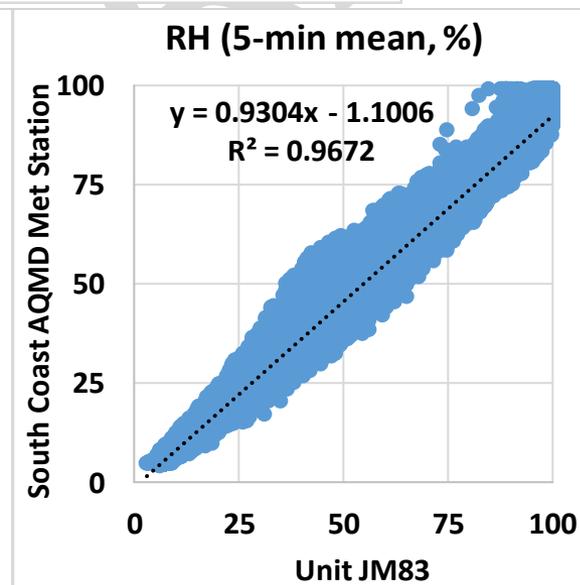
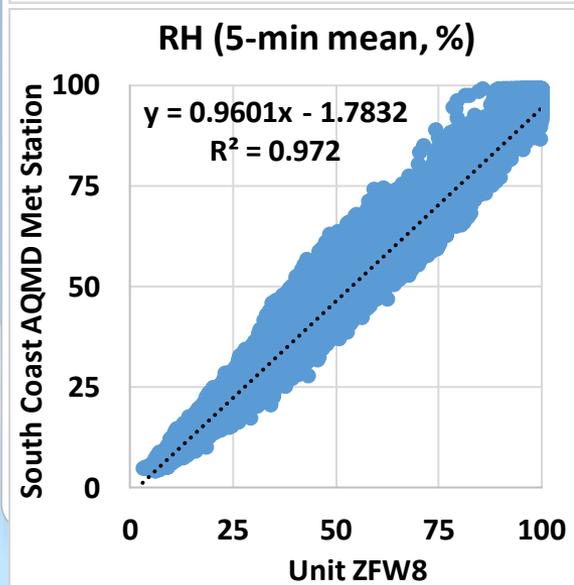
- The IQAir AirVisual Outdoor sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($0.90 < R^2 < 0.96$)
- Overall, the IQAir AirVisual Outdoor sensors underestimated the temperature measurement as recorded by South Coast AQMD Met Station
- The IQAir AirVisual Outdoor sensors seemed to track the diurnal temperature variations as recorded by South Coast AQMD Met Station



IQAir AirVisual Outdoor vs South Coast AQMD Met Station (RH; 5-min mean)



- The IQAir AirVisual Outdoor sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($0.96 < R^2 < 0.99$)
- Overall, the IQAir AirVisual Outdoor sensors overestimated the RH measurement as recorded by South Coast AQMD Met Station
- The IQAir AirVisual Outdoor sensors seemed to track the diurnal RH variations as recorded by South Coast AQMD Met Station



Summary

Average of 3 Sensors, PM _{1.0}		IQAir AirVisual Outdoor vs GRIMM & T640, PM _{1.0}							GRIMM & T640 (PM _{1.0} , 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	5.4	4.8	0.52 to 0.64	1.09 to 1.30	3.3 to 3.6	-4.9 to -4.1	4.5 to 5.6	5.9 to 7.3	9.8 to 10.1	7.2 to 7.9	0.2 to 101.2
1-hr	5.4	4.6	0.53 to 0.68	1.14 to 1.34	2.9 to 3.4	-4.9 to -4.1	4.4 to 5.5	5.7 to 7.2	9.8 to 10.1	7.0 to 7.7	0.3 to 39.9
24-hr	5.4	3.0	0.75 to 0.87	1.31 to 1.54	1.7 to 2.5	-5.0 to -4.1	4.1 to 5.0	4.5 to 5.7	9.8 to 10.2	4.8 to 5.0	0.9 to 23.1
Average of 3 Sensors, PM _{2.5}		IQAir AirVisual Outdoor vs FEM GRIMM & FEM T640, PM _{2.5}							FEM GRIMM & 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	9.6	7.9	0.54 to 0.65	0.75 to 0.95	4.5 to 5.8	-4.7 to -2.4	4.4 to 6.0	5.9 to 7.8	12.3 to 13.9	8.1 to 9.4	0.4 to 102.7
1-hr	9.6	7.6	0.54 to 0.68	0.77 to 0.98	4.1 to 5.7	-4.7 to -2.3	4.2 to 6.0	5.5 to 7.6	12.3 to 13.9	7.9 to 9.1	0.7 to 43.9
24-hr	9.5	5.0	0.82 to 0.88	0.88 to 1.12	2.6 to 4.5	-4.8 to -2.4	2.6 to 4.8	3.1 to 5.4	12.3 to 14.0	5.3 to 5.9	2.7 to 27.9
Average of 3 Sensors, PM ₁₀		IQAir AirVisual Outdoor vs GRIMM & T640, PM ₁₀							GRIMM & 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	37.5	12.3	0.39 to 0.60	1.06 to 1.49	-23.9 to -4.8	1.9 to 5.8	10.5 to 14.4	14.4 to 19.0	32.3 to 35.2	21.3 to 23.1	0.5 to 247.7
1-hr	37.5	11.8	0.41 to 0.66	1.07 to 1.53	-25.1 to -5.8	1.9 to 5.8	9.9 to 13.8	13.3 to 17.9	32.3 to 35.2	20.5 to 22.0	0.9 to 217.9
24-hr	37.5	8.4	0.51 to 0.76	1.14 to 1.57	-26.7 to -8.0	1.9 to 5.9	6.6 to 10.1	8.3 to 12.1	32.2 to 35.2	13.9 to 14.9	3.7 to 72.0

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

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

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

Discussion

- The three **IQAir AirVisual Outdoor** sensors' data recovery from all units was ~100%, ~98% and ~100% respectively for PM_{1.0}, PM_{2.5} and PM₁₀, respectively
- The absolute intra-model variability was ~0.24, ~0.39 and ~0.34 µg/m³ for PM_{1.0}, PM_{2.5} and PM₁₀, respectively
- Reference instruments: very strong correlations between GRIMM and T640 for PM_{1.0} ($R^2 \sim 0.97$, 1-hr mean); very strong correlations between FEM GRIMM and FEM T640 for PM_{2.5} ($R^2 \sim 0.97$, 1-hr mean) and very strong correlations between GRIMM and T640 for PM₁₀ ($R^2 \sim 0.97$, 1-hr mean) mass concentration measurements
- PM_{1.0} mass concentrations measured by the IQAir AirVisual Outdoor sensors showed moderate correlations with the corresponding GRIMM and T640 data ($0.52 < R^2 < 0.68$, 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 IQAir AirVisual Outdoor sensors showed moderate correlations with the corresponding FEM GRIMM and FEM T640 data ($0.54 < R^2 < 0.69$, 1-hr mean). The sensors underestimated PM_{2.5} mass concentrations as measured by FEM GRIMM and FEM T640
- PM₁₀ mass concentrations measured by the IQAir AirVisual Outdoor sensors showed weak to moderate correlations with the corresponding GRIMM and T640 data ($0.40 < R^2 < 0.66$; 1-hr mean). The sensors overestimated PM₁₀ 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