

# Field Evaluation Qingping - Air Monitor Lite



# Background

- From 11/07/2022 to 01/07/2023, three **Qingping – Air Monitor Lite** 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
- Qingping Air Monitor Lite (3 units tested):
  - Particle sensor: **optical; non-FEM (Grandway, Model 7500)**
  - Each unit reports: PM<sub>2.5</sub> and PM<sub>10</sub> (µg/m<sup>3</sup>), T (°C), RH (%)
  - **Unit cost: \$96**
  - Time resolution: 1-min
  - Units IDs: BE8A, C4F1, CAB7



- GRIMM EDM180 (reference instrument):
  - Optical particle counter (**FEM PM<sub>2.5</sub>**)
  - Measures PM<sub>1.0</sub>, PM<sub>2.5</sub>, and PM<sub>10</sub> (µg/m<sup>3</sup>)
  - **Cost: ~\$25,000 and up**
  - Time resolution: 1-min
- Teledyne API T640 (reference instrument):
  - Optical particle counter (**FEM PM<sub>2.5</sub>**)
  - Measures PM<sub>1.0</sub>, PM<sub>2.5</sub> and PM<sub>10</sub> (µg/m<sup>3</sup>)
  - **Cost: ~\$21,000**
  - Time resolution: 1-min
- Met Station (T, RH, P, WS, WD):
  - **Cost: ~\$5,000**
  - Time resolution: 1-min



FEM GRIMM



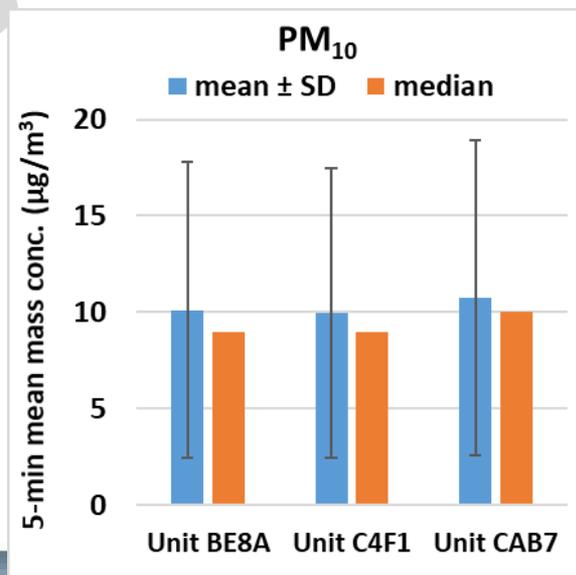
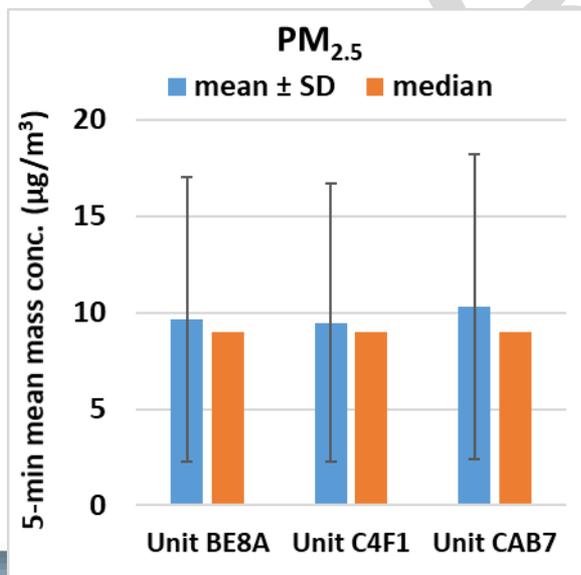
FEM T640

# 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 ~97% for PM<sub>2.5</sub> and PM<sub>10</sub> mass concentration measurements

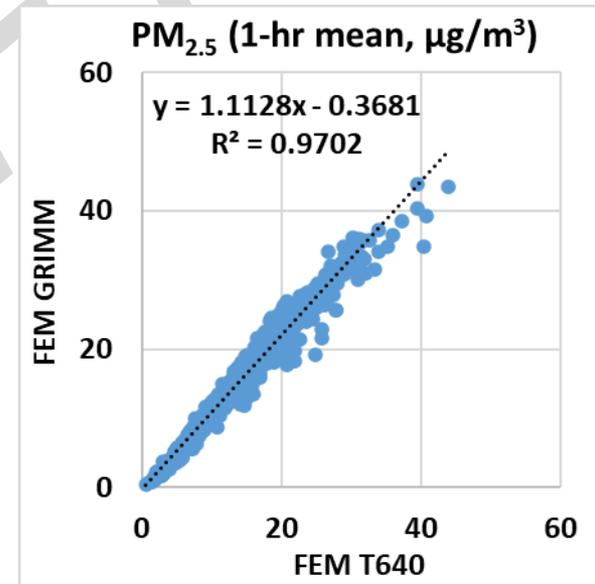
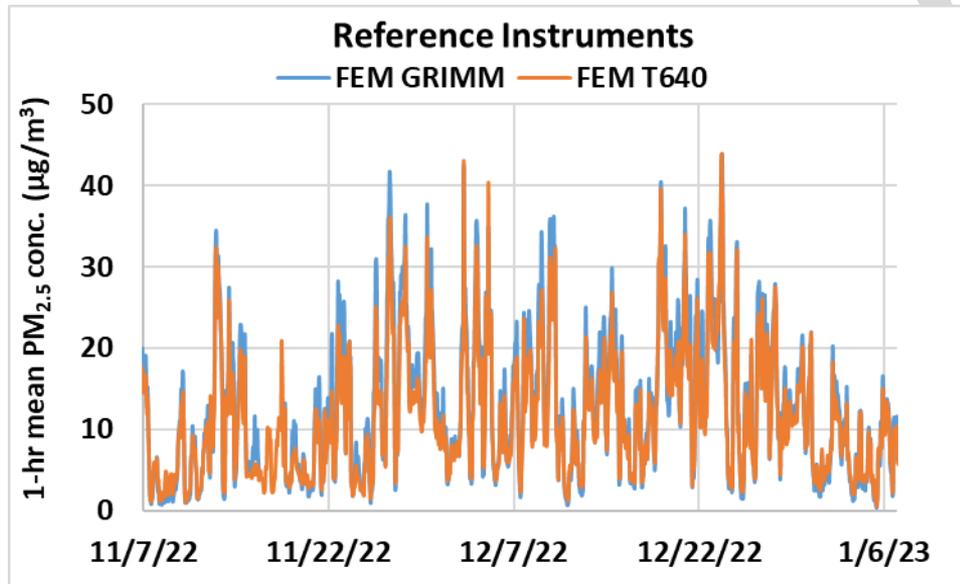
## Qingping Air Monitor Lite; intra-model variability

- Absolute intra-model variability was ~0.35 and ~0.37  $\mu\text{g}/\text{m}^3$  for PM<sub>2.5</sub> and PM<sub>10</sub>, respectively (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~3.6% and ~3.6% for PM<sub>2.5</sub> and PM<sub>10</sub>, respectively (calculated as the absolute intra-model variability relative to the mean of the three sensor means)



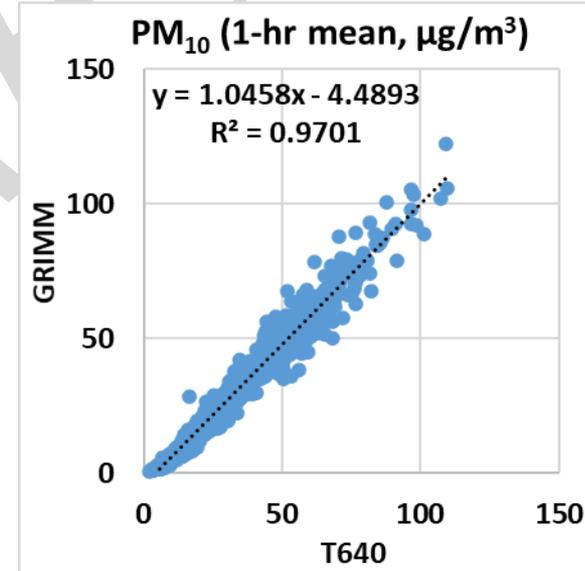
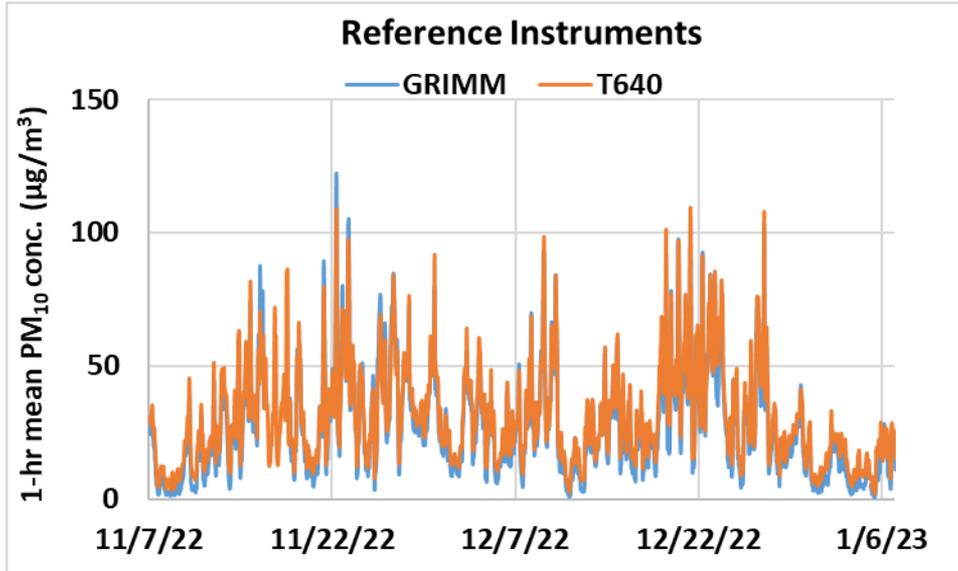
# Reference Instruments: PM<sub>2.5</sub> FEM GRIMM and FEM T640

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

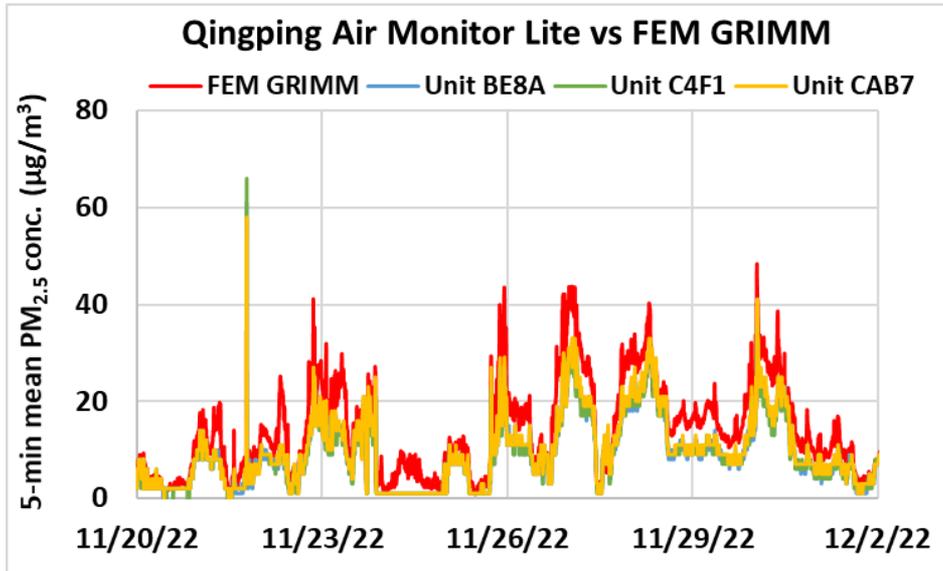


# Reference Instruments: PM<sub>10</sub> GRIMM and T640

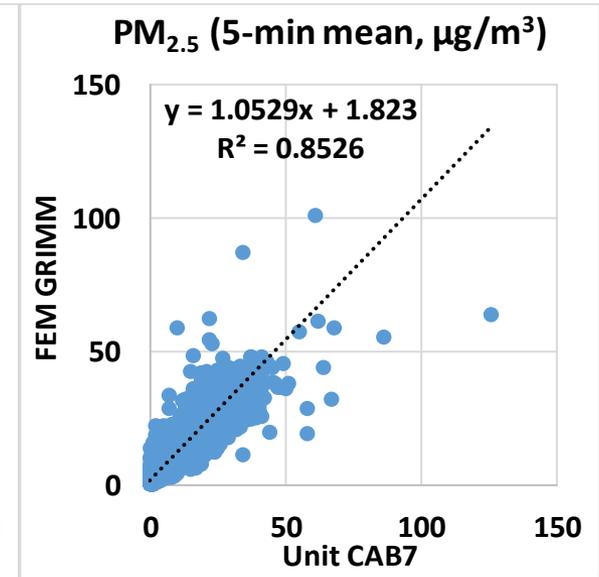
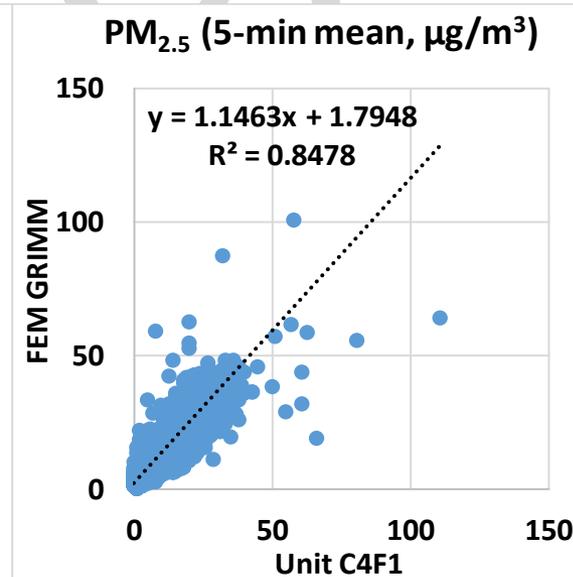
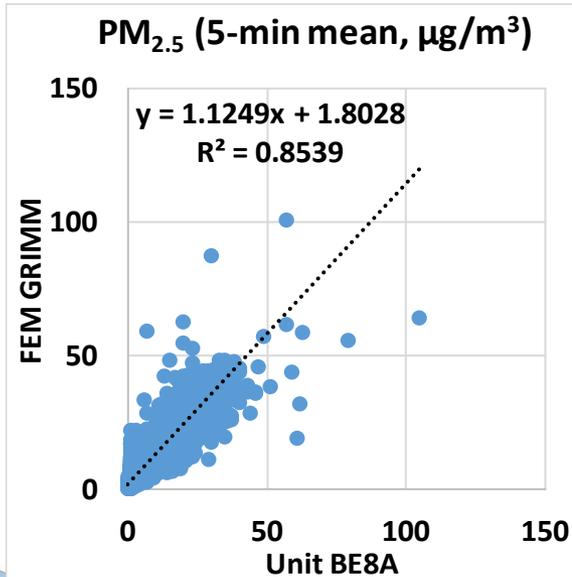
- Data recovery for PM<sub>10</sub> from GRIMM and T640 was ~96.7% and ~100%, respectively.
- Very strong correlations between the reference instruments for PM<sub>10</sub> measurements ( $R^2 \sim 0.97$ ) were observed.



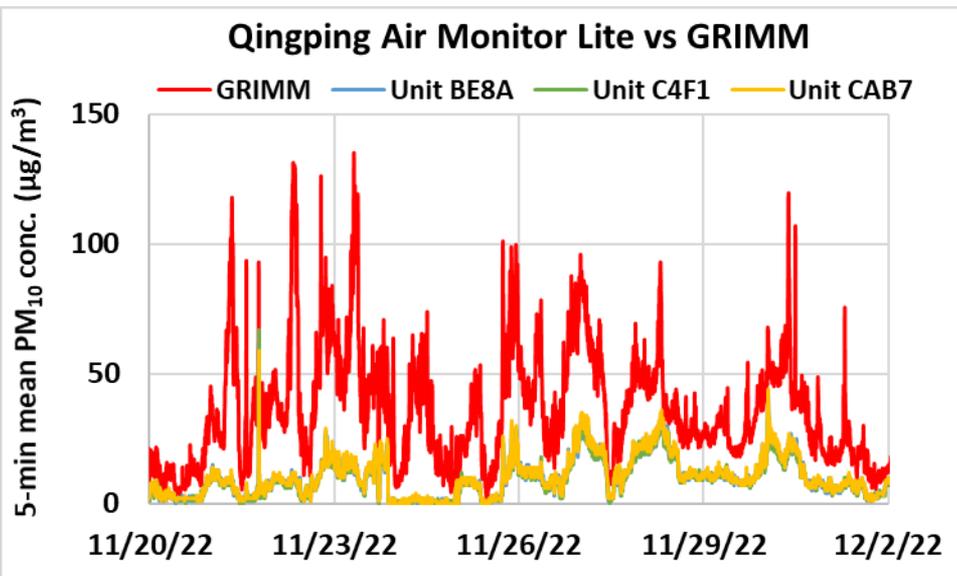
# Qingping Air Monitor Lite vs FEM GRIMM (PM<sub>2.5</sub>; 5-min mean)



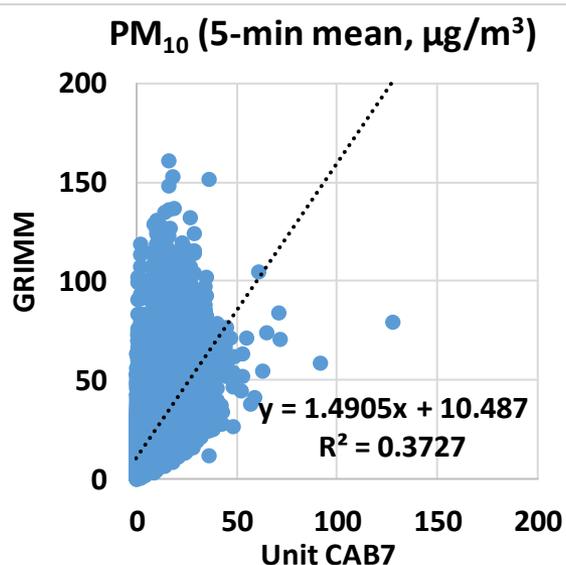
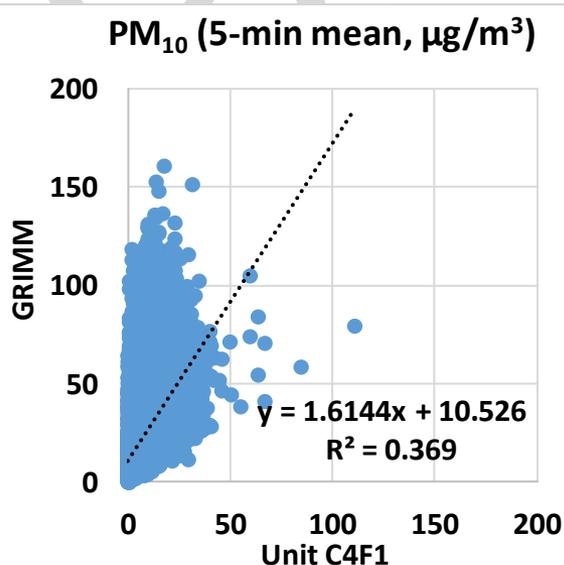
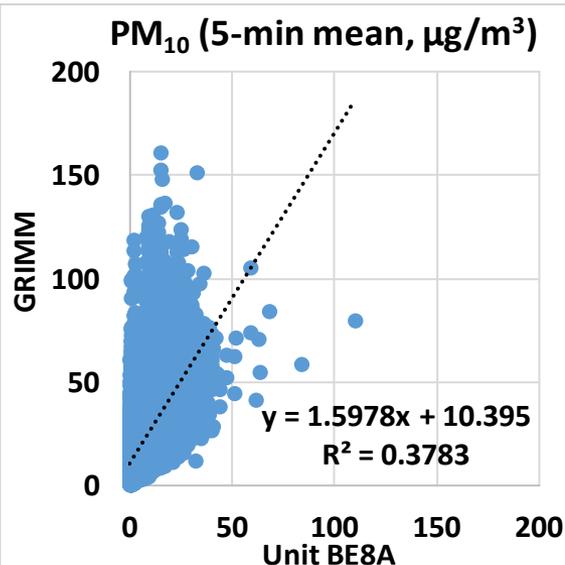
- The Qingping Air Monitor Lite sensors showed strong correlations with the corresponding FEM GRIMM data ( $0.84 < R^2 < 0.86$ )
- Overall, the Qingping Air Monitor Lite sensors underestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM GRIMM
- The Qingping Air Monitor Lite sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM GRIMM



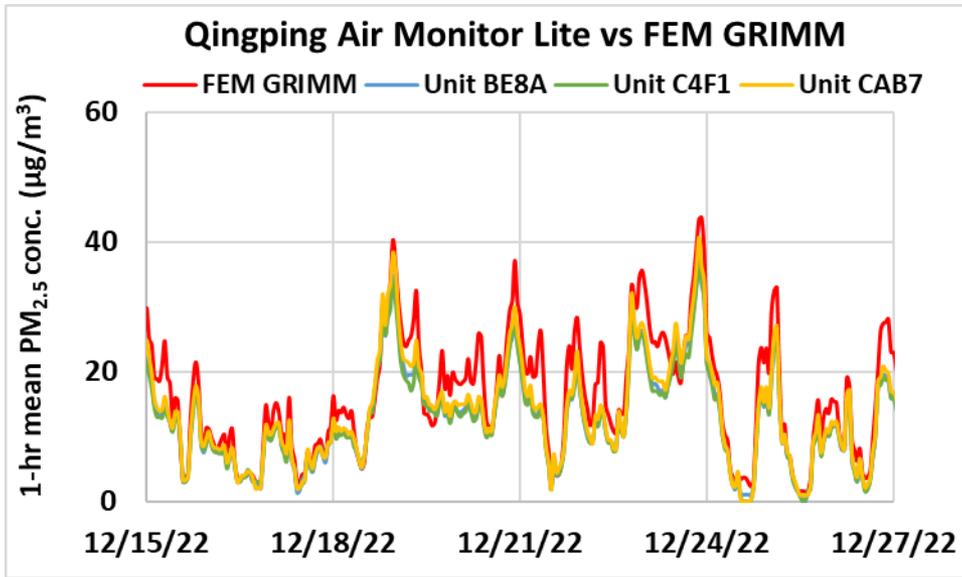
# Qingping Air Monitor Lite vs GRIMM (PM<sub>10</sub>; 5-min mean)



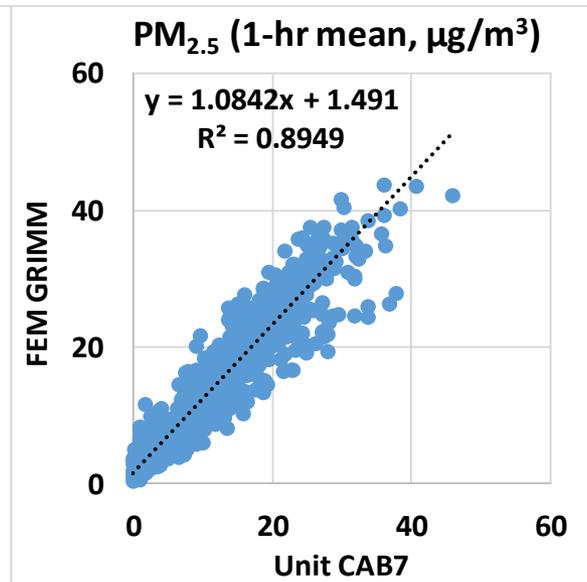
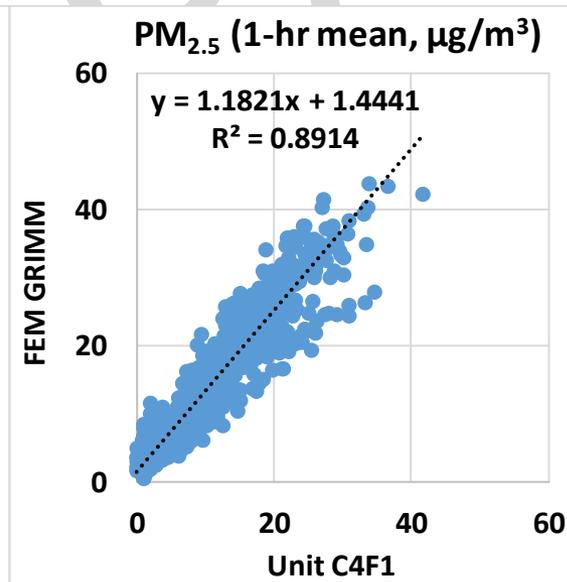
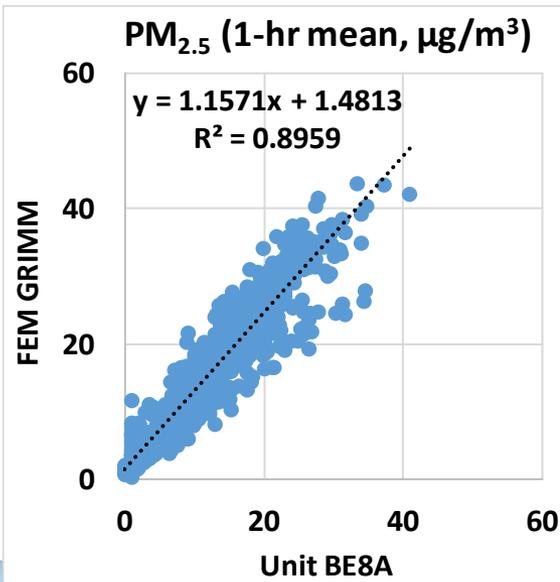
- The Qingping Air Monitor Lite sensors showed weak correlations with the corresponding GRIMM data ( $0.36 < R^2 < 0.38$ )
- Overall, the Qingping Air Monitor Lite sensors underestimated the PM<sub>10</sub> mass concentrations as measured by GRIMM
- The Qingping Air Monitor Lite sensors sometimes seemed to track the PM<sub>10</sub> diurnal variations as recorded by GRIMM



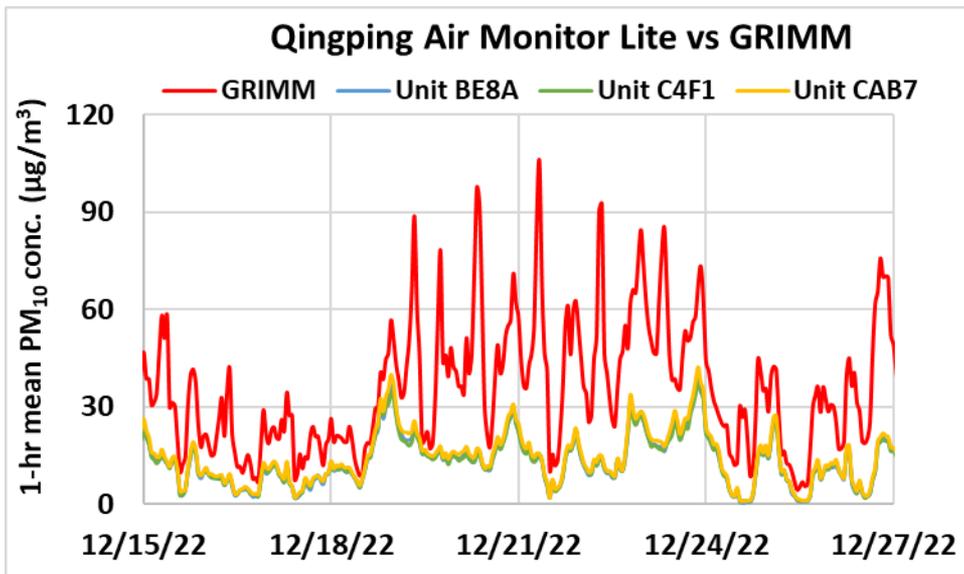
# Qingping Air Monitor Lite vs FEM GRIMM (PM<sub>2.5</sub>; 1-hr mean)



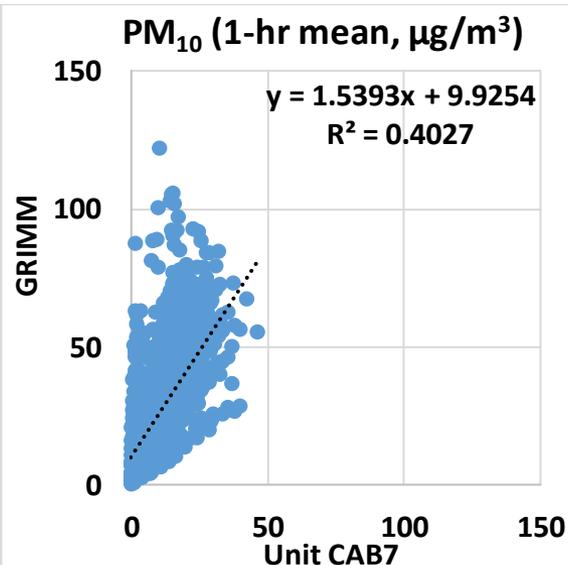
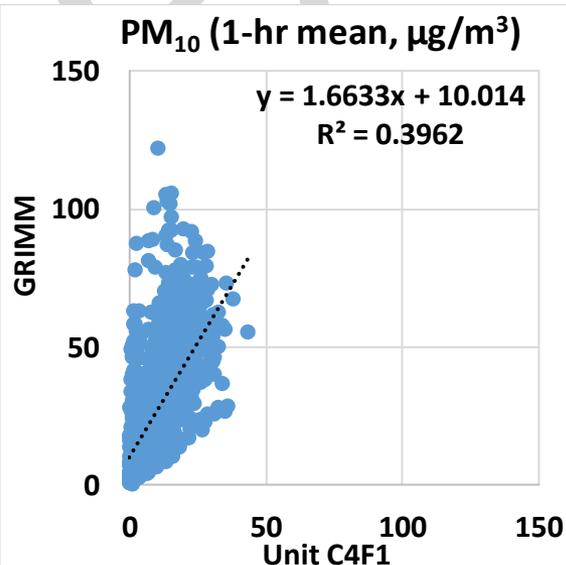
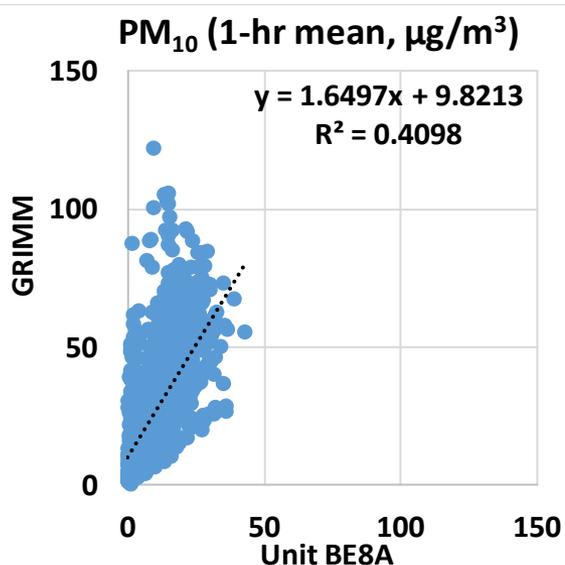
- The Qingping Air Monitor Lite sensors showed strong correlations with the corresponding FEM GRIMM data ( $0.89 < R^2 < 0.90$ )
- Overall, the Qingping Air Monitor Lite sensors underestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM GRIMM
- The Qingping Air Monitor Lite sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM GRIMM



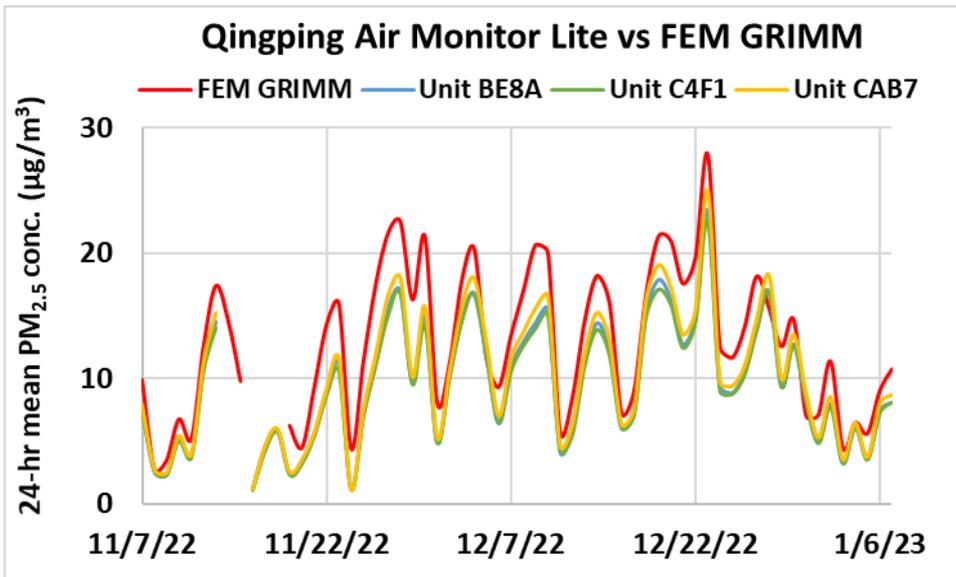
# Qingping Air Monitor Lite vs GRIMM (PM<sub>10</sub>; 1-hr mean)



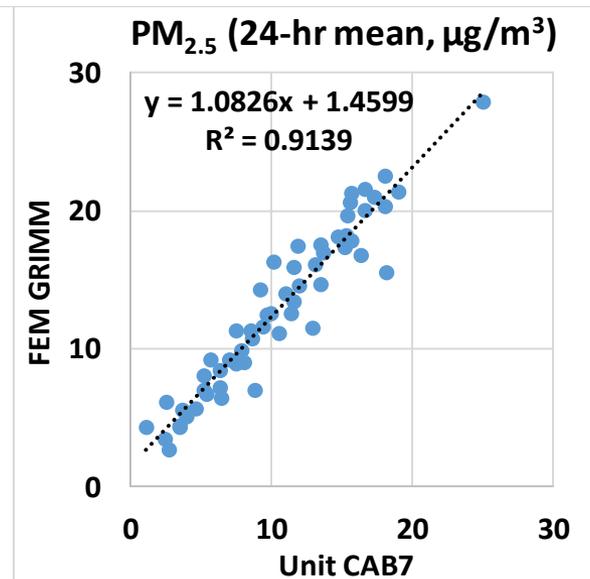
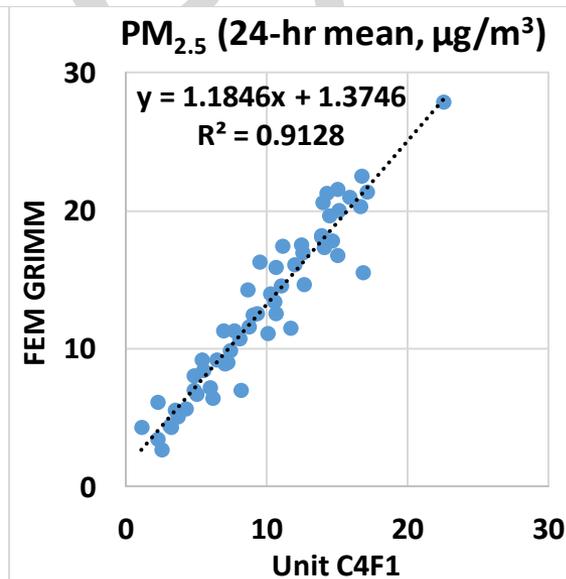
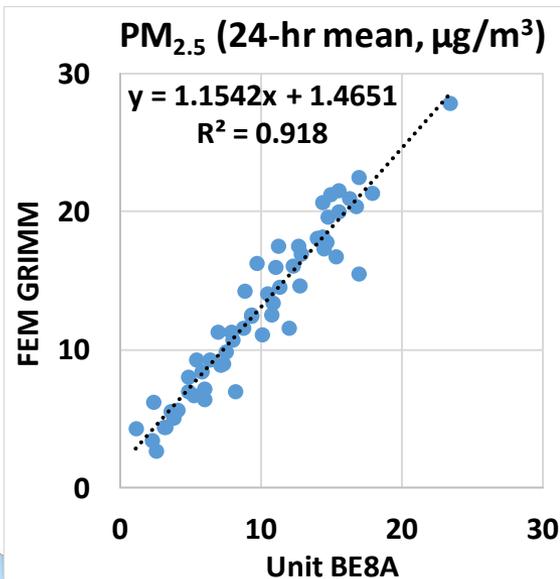
- The Qingping Air Monitor Lite sensors showed weak correlations with the corresponding GRIMM data ( $0.39 < R^2 < 0.41$ )
- Overall, the Qingping Air Monitor Lite sensors underestimated the PM<sub>10</sub> mass concentrations as measured by GRIMM
- The Qingping Air Monitor Lite sensors sometimes seemed to track the PM<sub>10</sub> diurnal variations as recorded by GRIMM



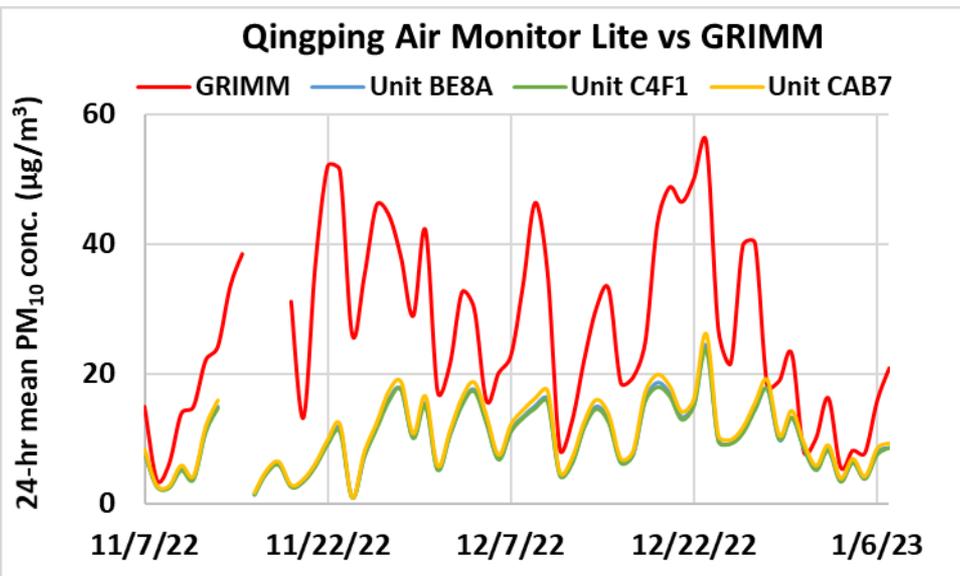
# Qingping Air Monitor Lite vs FEM GRIMM (PM<sub>2.5</sub>; 24-hr mean)



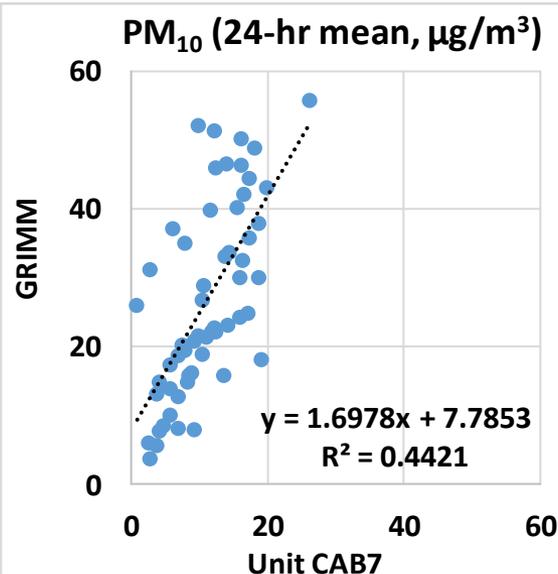
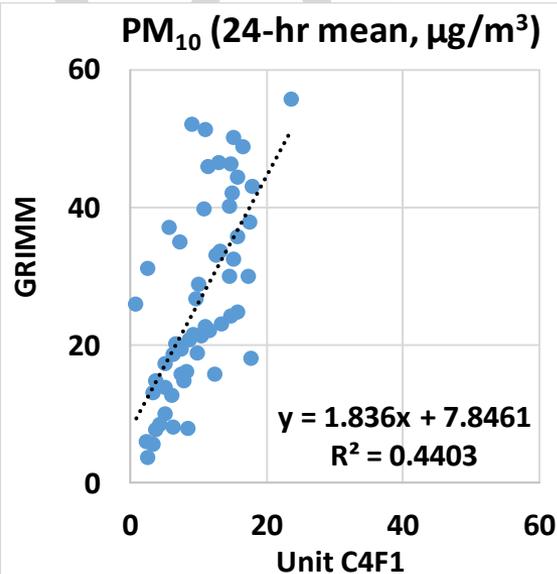
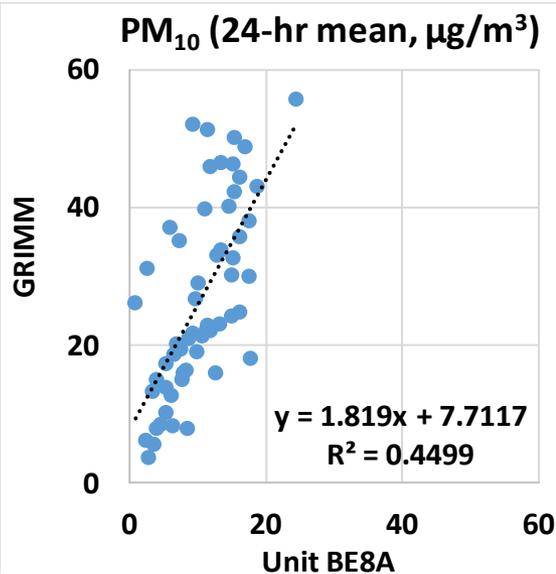
- The Qingping Air Monitor Lite sensors showed very strong correlations with the corresponding FEM GRIMM data ( $0.91 < R^2 < 0.92$ )
- Overall, the Qingping Air Monitor Lite sensors underestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM GRIMM
- The Qingping Air Monitor Lite sensors seemed to track the PM<sub>2.5</sub> daily variations as recorded by FEM GRIMM



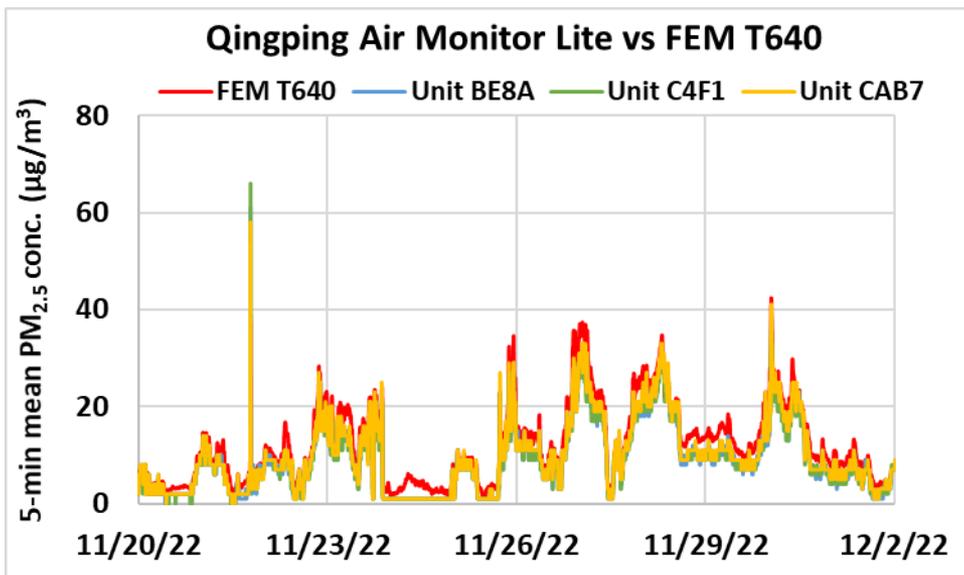
# Qingping Air Monitor Lite vs GRIMM (PM<sub>10</sub>; 24-hr mean)



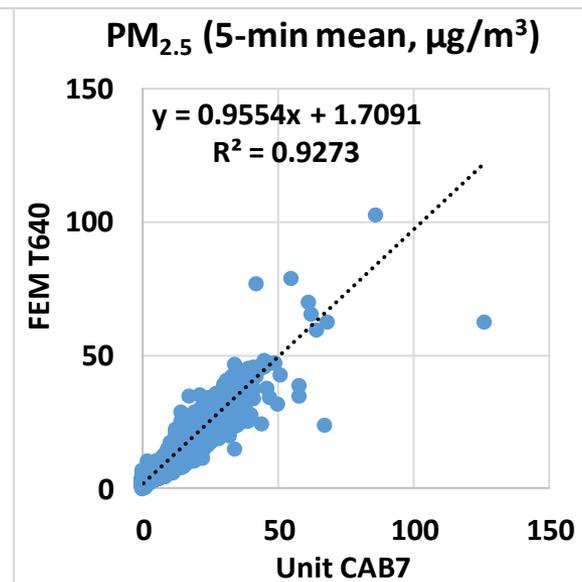
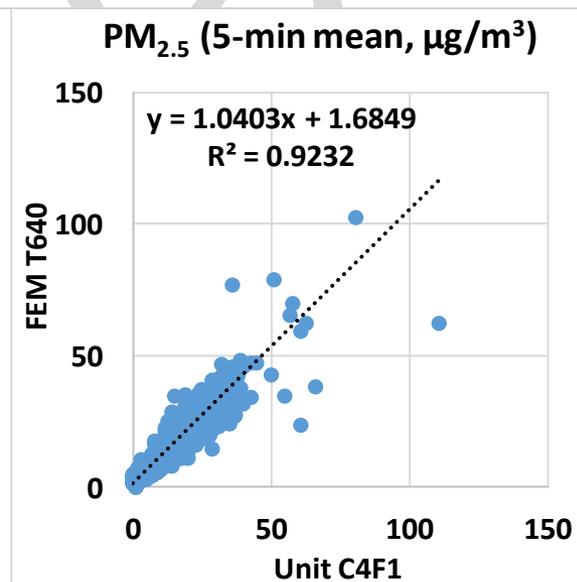
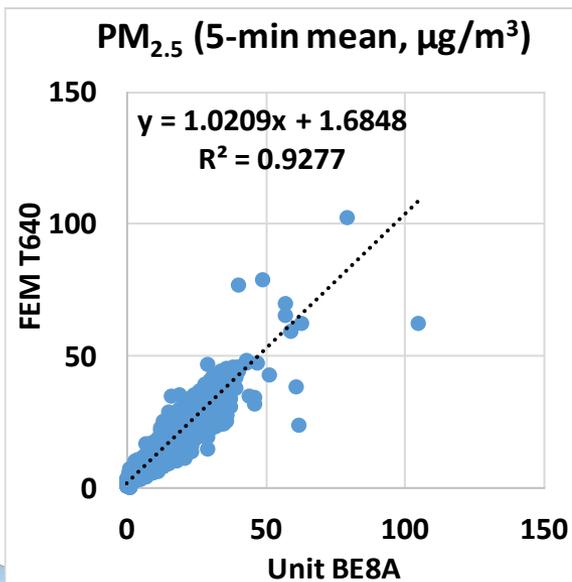
- The Qingping Air Monitor Lite sensors showed weak correlations with the corresponding GRIMM data ( $0.44 < R^2 < 0.45$ )
- Overall, the Qingping Air Monitor Lite sensors overestimated the PM<sub>10</sub> mass concentrations as measured by GRIMM
- The Qingping Air Monitor Lite sensors sometimes seemed to track the PM<sub>10</sub> daily variations as recorded by GRIMM



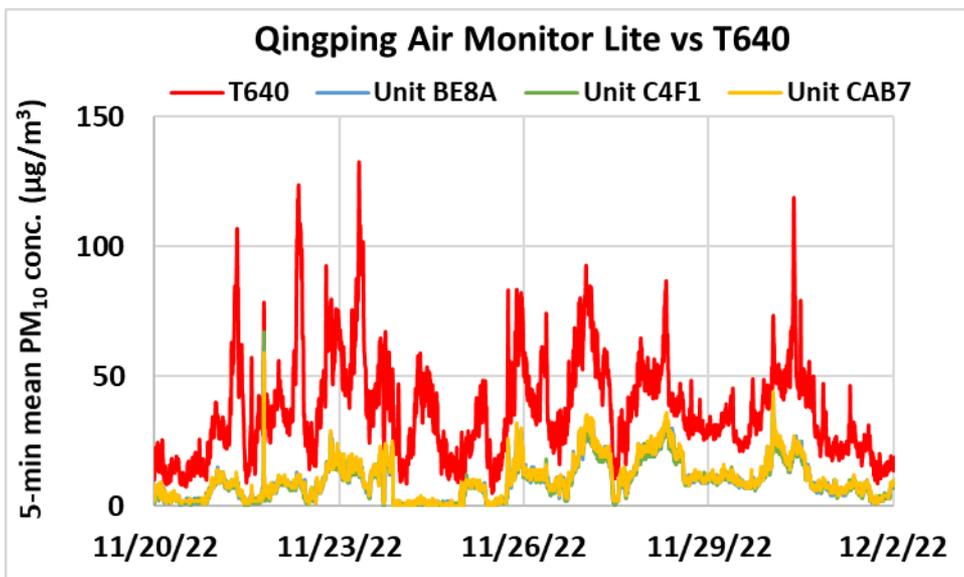
# Qingping Air Monitor Lite vs FEM T640 (PM<sub>2.5</sub>; 5-min mean)



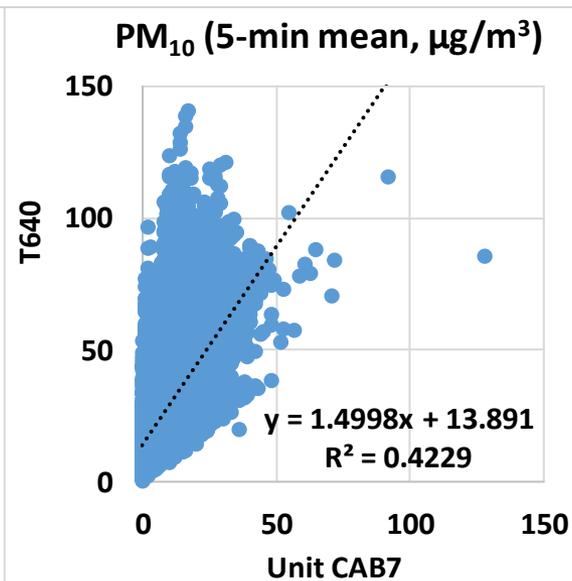
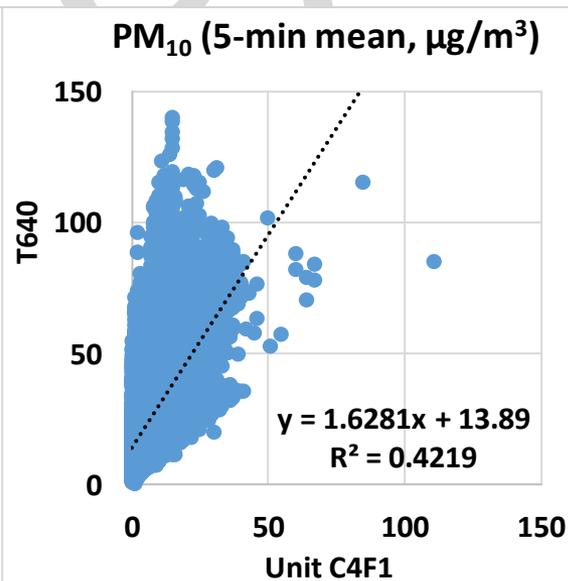
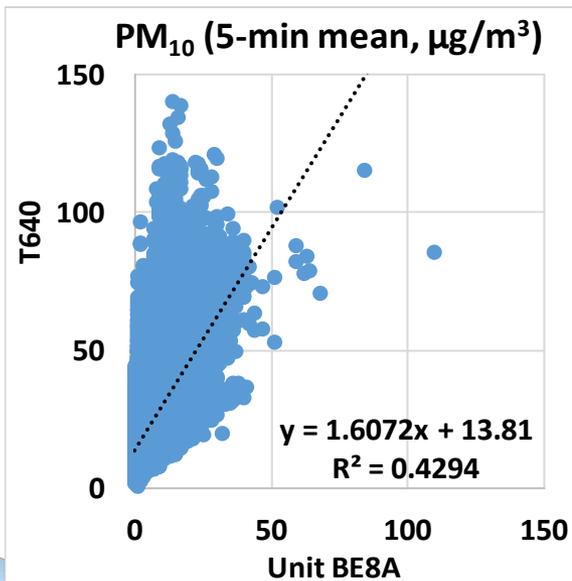
- The Qingping Air Monitor Lite sensors showed very strong correlations with the corresponding FEM T640 data ( $0.92 < R^2 < 0.93$ )
- Overall, the Qingping Air Monitor Lite sensors underestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM T640
- The Qingping Air Monitor Lite sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM T640



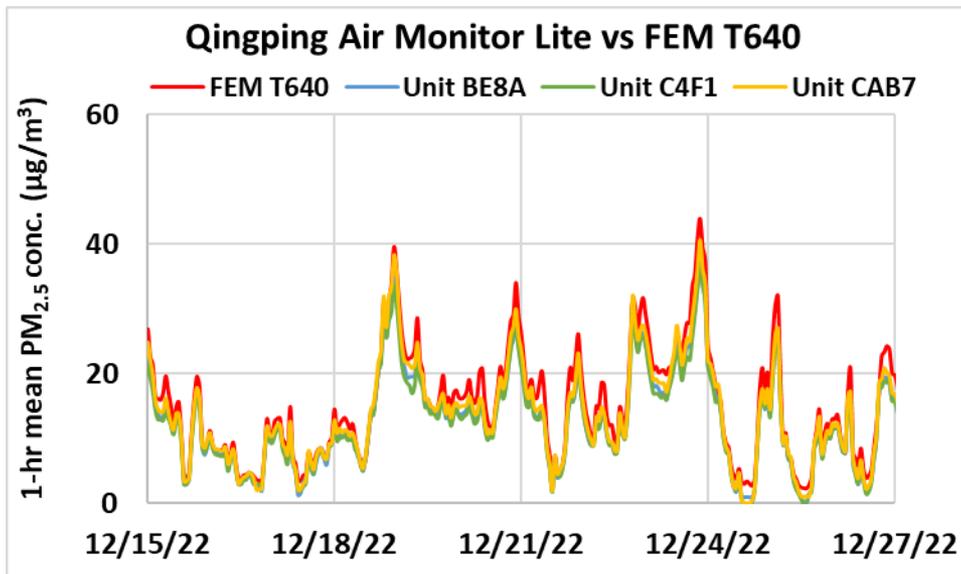
# Qingping Air Monitor Lite vs T640 (PM<sub>10</sub>; 5-min mean)



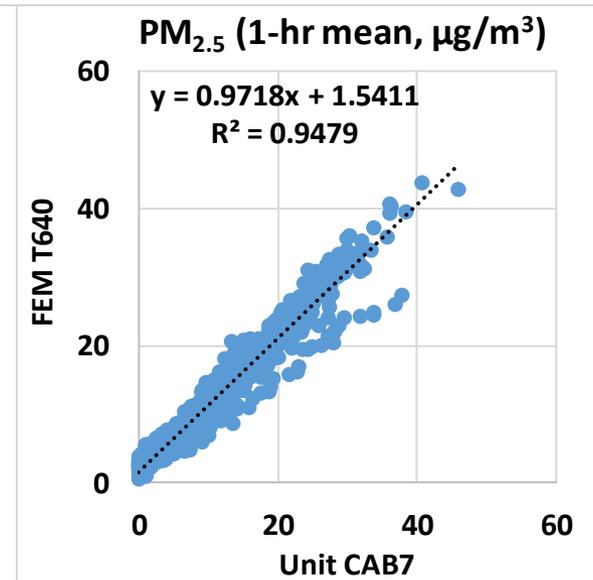
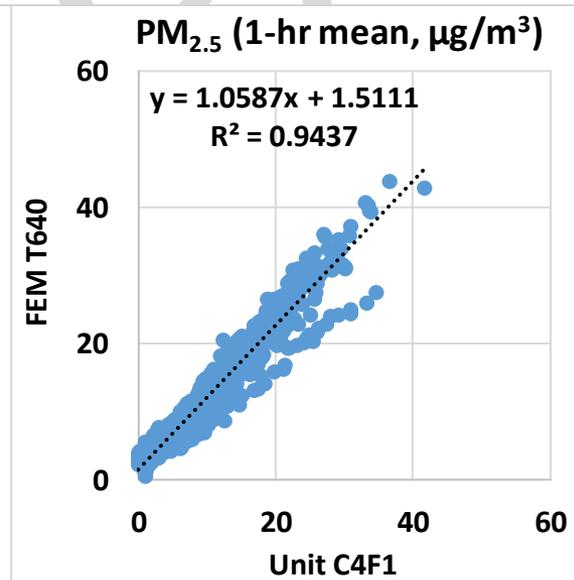
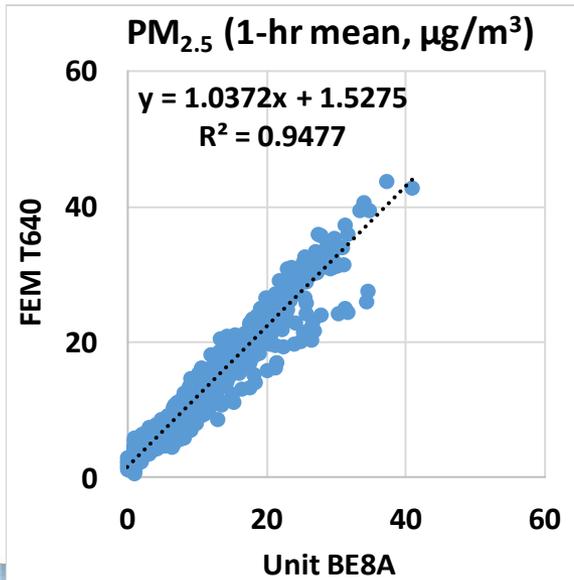
- The Qingping Air Monitor Lite sensors showed weak correlations with the corresponding T640 data ( $0.42 < R^2 < 0.43$ )
- Overall, the Qingping Air Monitor Lite sensors underestimated the PM<sub>10</sub> mass concentrations as measured by T640
- The Qingping Air Monitor Lite sensors seemed to track the PM<sub>10</sub> diurnal variations as recorded by T640



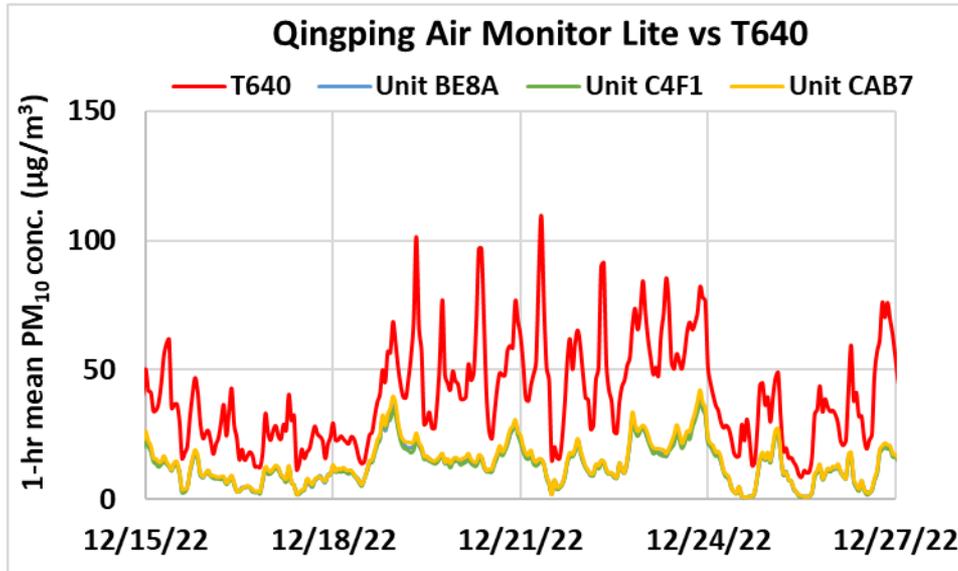
# Qingping Air Monitor Lite vs FEM T640 (PM<sub>2.5</sub>; 1-hr mean)



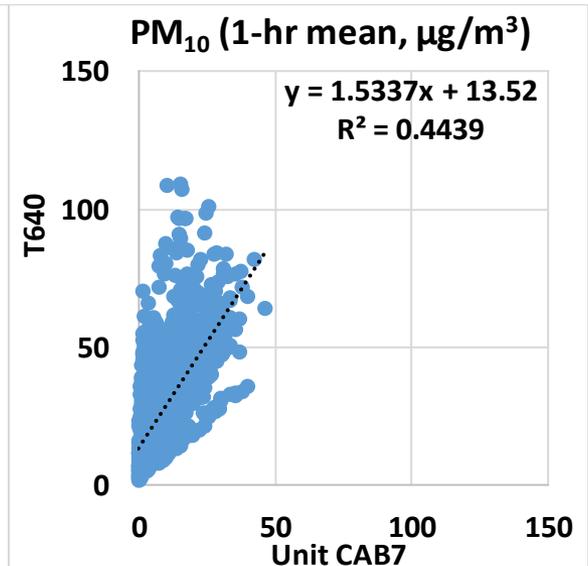
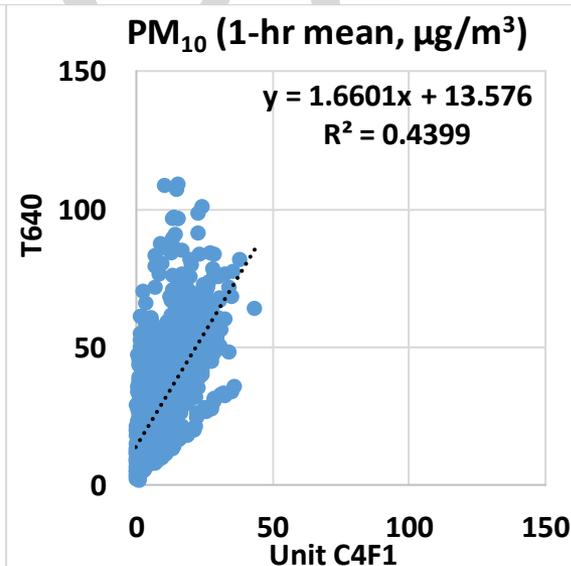
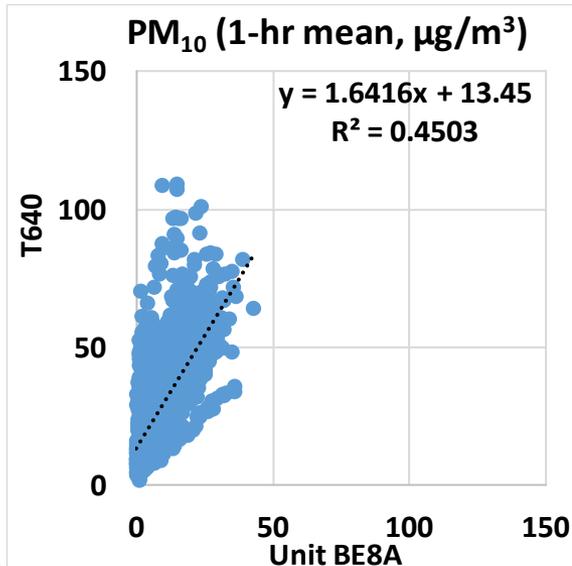
- The Qingping Air Monitor Lite sensors showed very strong correlations with the corresponding FEM T640 data ( $0.94 < R^2 < 0.95$ )
- Overall, the Qingping Air Monitor Lite sensors underestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM T640
- The Qingping Air Monitor Lite sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM T640



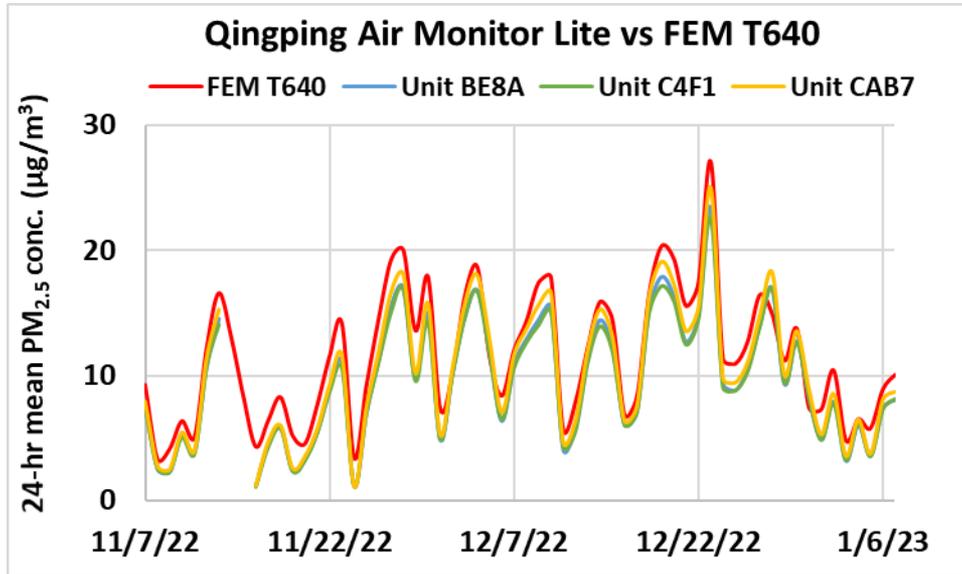
# Qingping Air Monitor Lite vs T640 (PM<sub>10</sub>; 1-hr mean)



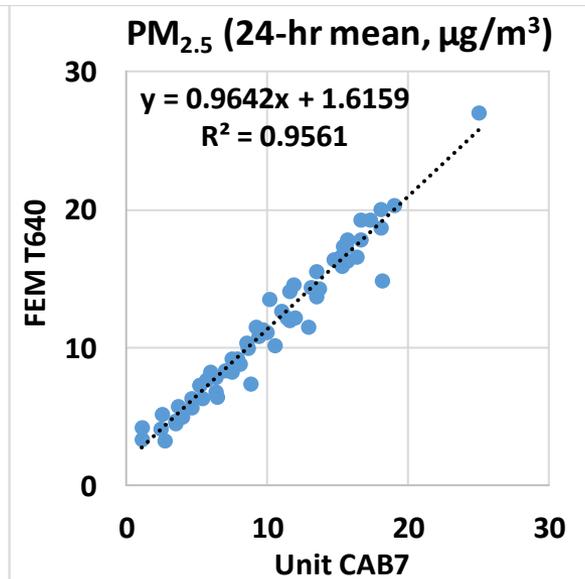
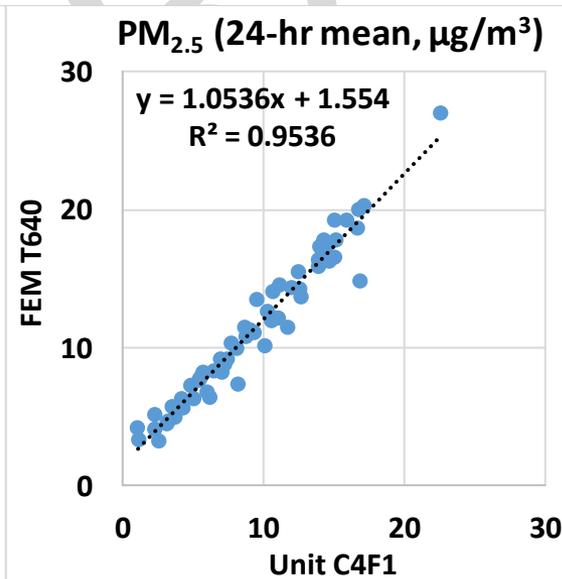
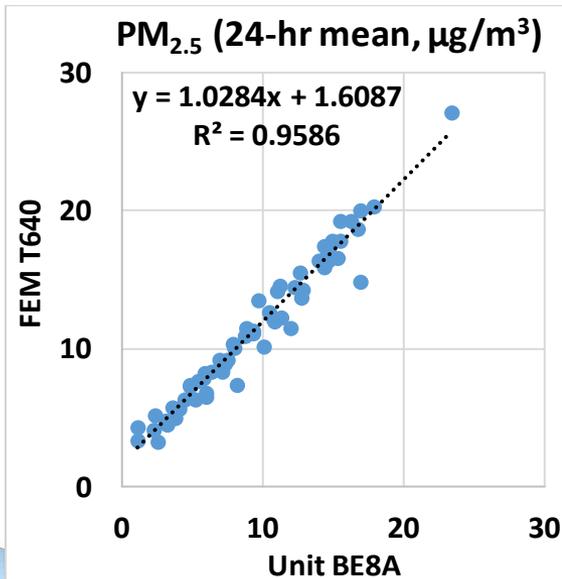
- The Qingping Air Monitor Lite sensors showed weak correlations with the corresponding T640 data ( $0.43 < R^2 < 0.46$ )
- Overall, the Qingping Air Monitor Lite sensors underestimated the PM<sub>10</sub> mass concentrations as measured by T640
- The Qingping Air Monitor Lite sensors seemed to track the PM<sub>10</sub> diurnal variations as recorded by T640



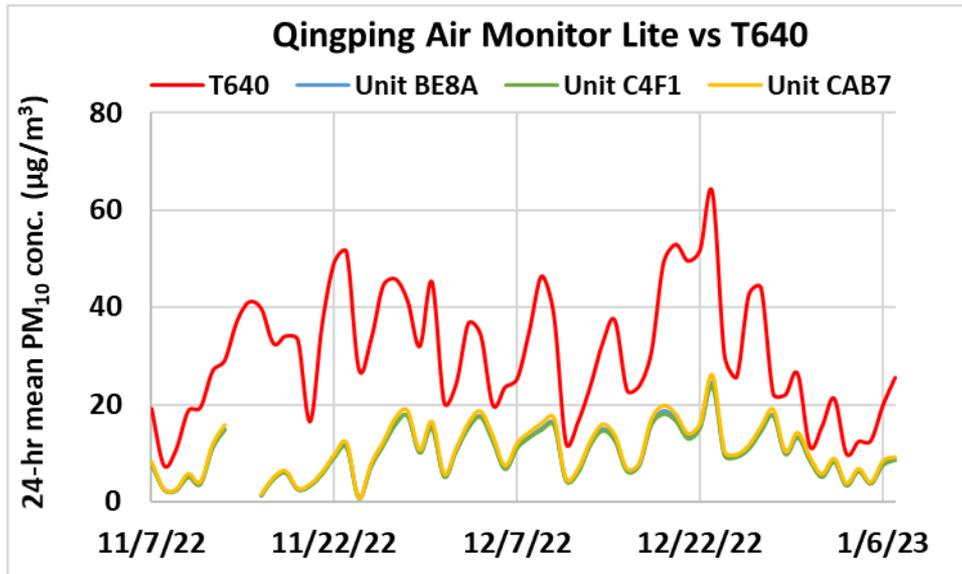
# Qingping Air Monitor Lite vs FEM T640 (PM<sub>2.5</sub>; 24-hr mean)



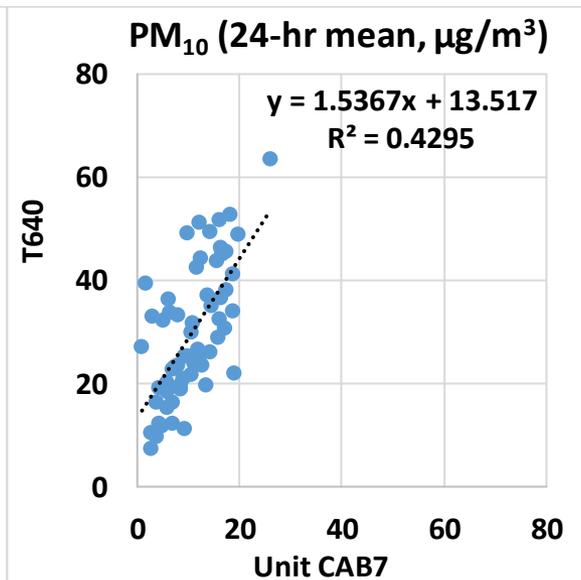
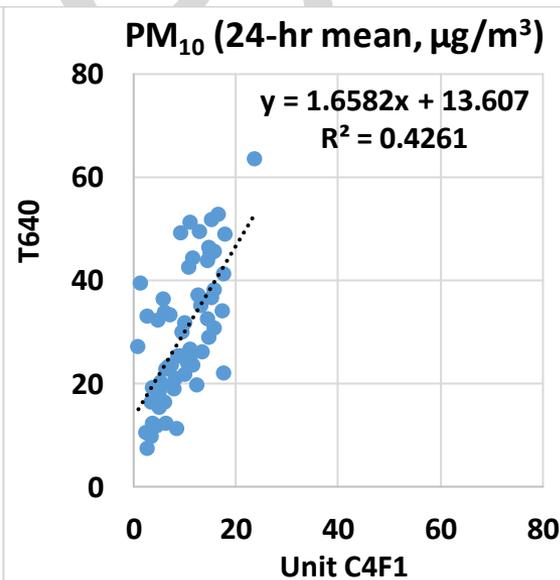
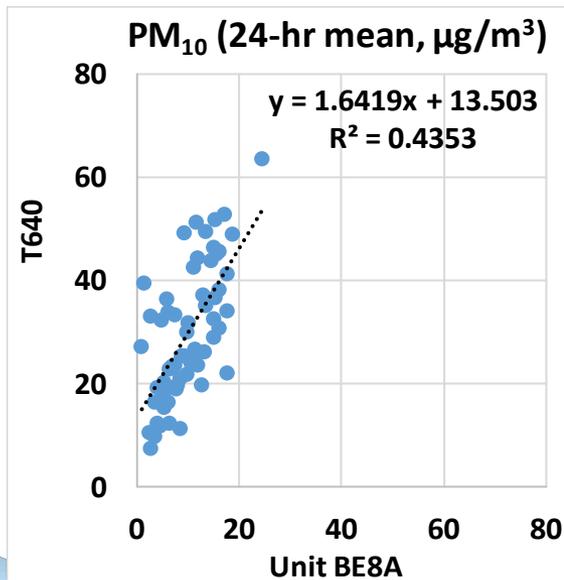
- The Qingping Air Monitor Lite sensors showed very strong correlations with the corresponding FEM T640 data ( $0.95 < R^2 < 0.96$ )
- Overall, the Qingping Air Monitor Lite sensors underestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM T640
- The Qingping Air Monitor Lite sensors seemed to track the PM<sub>2.5</sub> daily variations as recorded by FEM T640



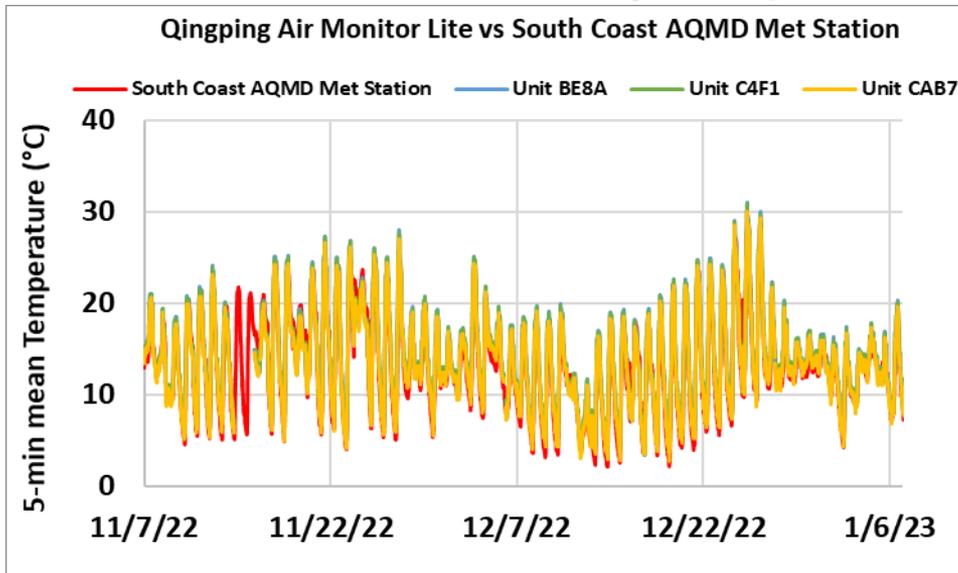
# Qingping Air Monitor Lite vs T640 (PM<sub>10</sub>; 24-hr mean)



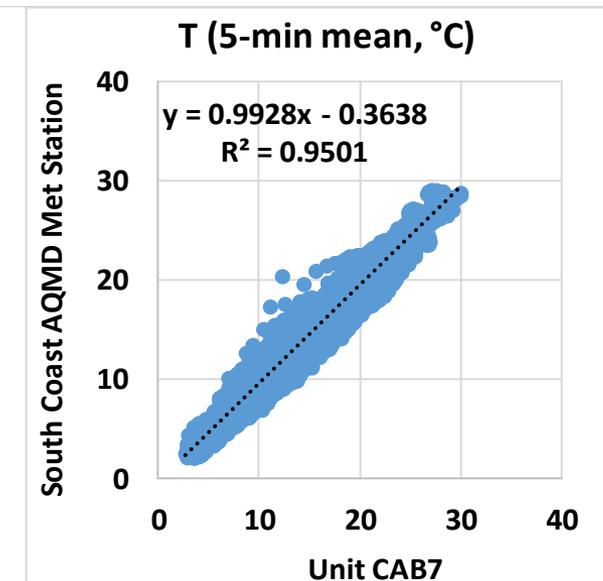
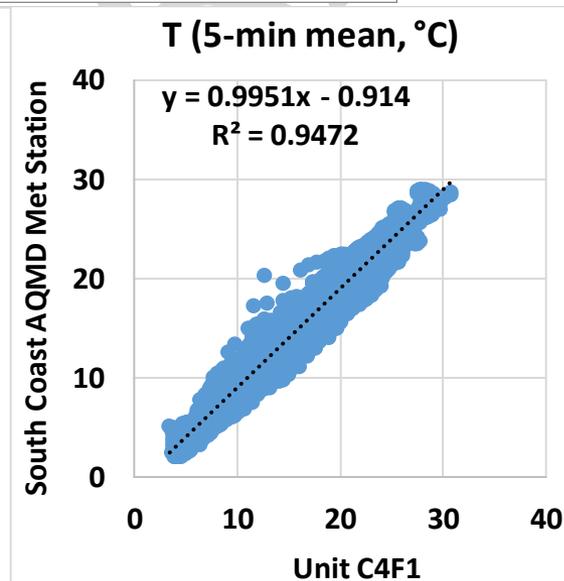
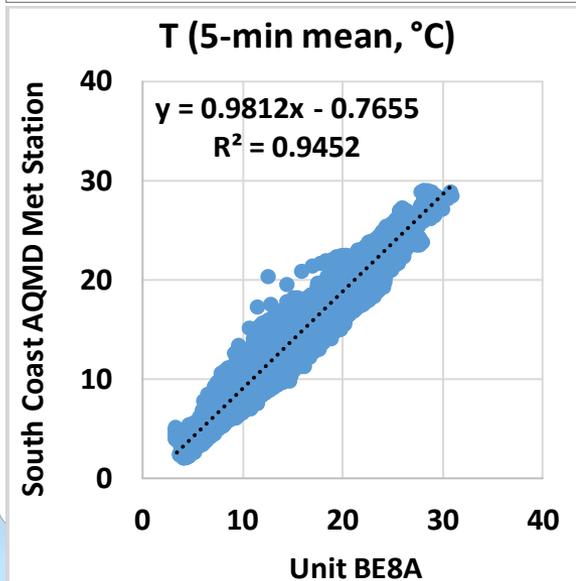
- The Qingping Air Monitor Lite sensors showed weak correlations with the corresponding T640 data ( $0.42 < R^2 < 0.44$ )
- Overall, the Qingping Air Monitor Lite sensors overestimated the PM<sub>10</sub> mass concentrations as measured by T640
- The Qingping Air Monitor Lite sensors seemed to track the PM<sub>10</sub> daily variations as recorded by T640



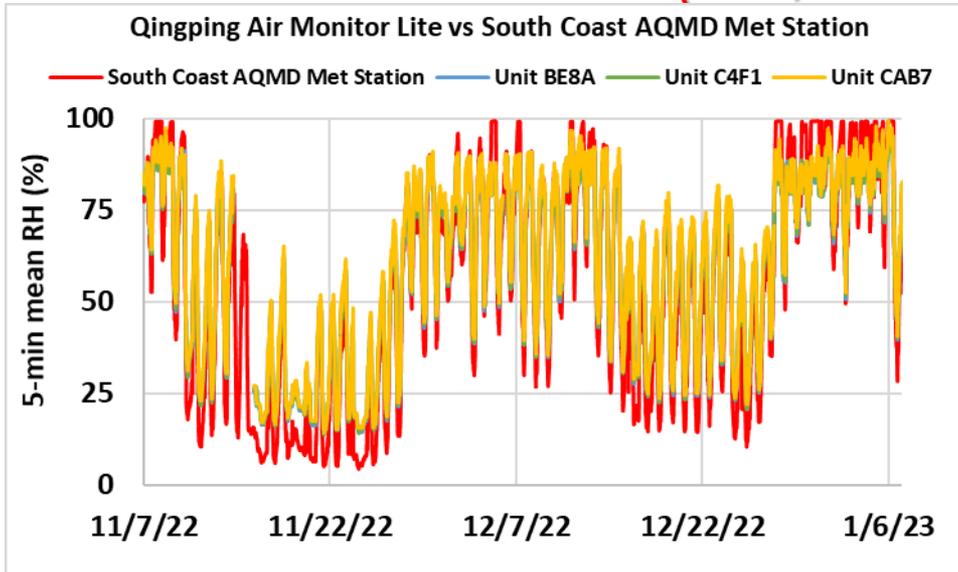
# Qingping Air Monitor Lite vs South Coast AQMD Met Station (Temp; 5-min mean)



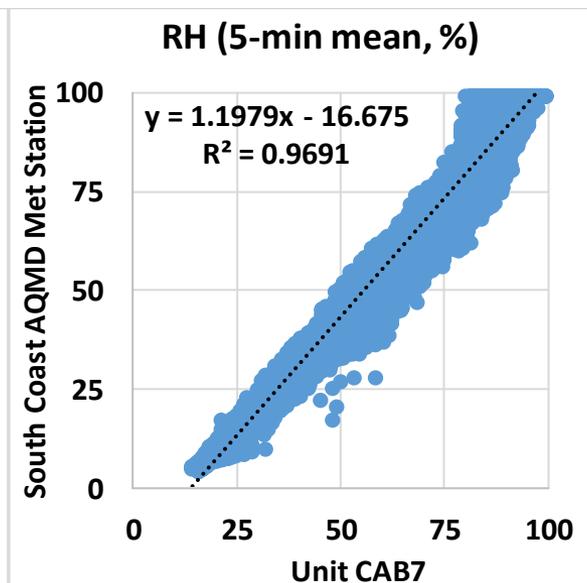
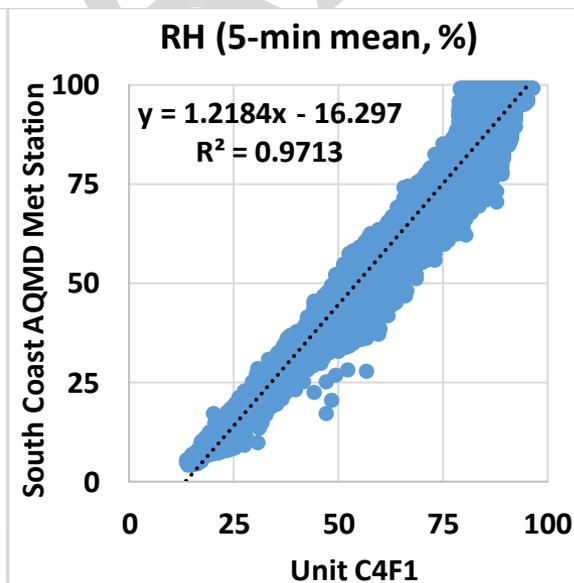
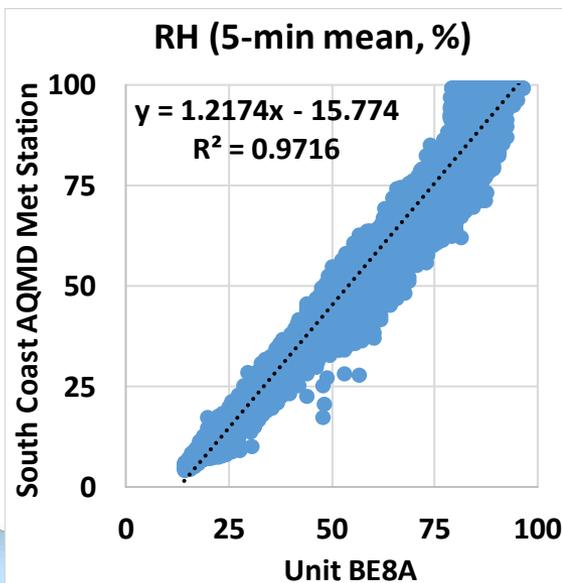
- The Qingping Air Monitor Lite sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ( $0.94 < R^2 < 0.96$ )
- Overall, the Qingping Air Monitor Lite sensors overestimated the temperature measurement as recorded by South Coast AQMD Met Station
- The Qingping Air Monitor Lite sensors seemed to track the diurnal temperature variations as recorded by South Coast AQMD Met Station



# Qingping Air Monitor Lite vs South Coast AQMD Met Station (RH; 5-min mean)



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



# Summary

Average of 3 Sensors, PM <sub>2.5</sub>		Qingping Air Monitor Lite vs FEM GRIMM & FEM T640, PM <sub>2.5</sub>							FEM GRIMM & FEM T640 (PM <sub>2.5</sub> , µg/m <sup>3</sup> )		
	Average (µg/m <sup>3</sup> )	SD (µg/m <sup>3</sup> )	R <sup>2</sup>	Slope	Intercept	MBE <sup>1</sup> (µg/m <sup>3</sup> )	MAE <sup>2</sup> (µg/m <sup>3</sup> )	RMSE <sup>3</sup> (µg/m <sup>3</sup> )	Ref. Average	Ref. SD	Range during the field evaluation
<b>5-min</b>	9.8	7.5	0.85 to 0.93	0.96 to 1.15	1.7 to 1.8	-3.2 to -1.3	1.8 to 3.6	2.5 to 4.9	11.5 to 12.8	7.8 to 9.0	0.3 to 102.7
<b>1-hr</b>	9.8	7.3	0.89 to 0.95	0.97 to 1.18	1.4 to 1.5	-3.2 to -1.3	1.7 to 3.5	2.2 to 4.5	11.5 to 12.8	7.6 to 8.7	0.4 to 43.9
<b>24-hr</b>	9.8	5.0	0.91 to 0.96	0.96 to 1.18	1.4 to 1.6	-3.2 to -1.2	1.5 to 3.3	1.7 to 3.7	11.5 to 12.9	5.1 to 5.8	2.7 to 27.9
Average of 3 Sensors, PM <sub>10</sub>		Qingping Air Monitor Lite vs GRIMM & T640, PM <sub>10</sub>							GRIMM & T640 (PM <sub>10</sub> , µg/m <sup>3</sup> )		
	Average (µg/m <sup>3</sup> )	SD (µg/m <sup>3</sup> )	R <sup>2</sup>	Slope	Intercept	MBE <sup>1</sup> (µg/m <sup>3</sup> )	MAE <sup>2</sup> (µg/m <sup>3</sup> )	RMSE <sup>3</sup> (µg/m <sup>3</sup> )	Ref. Average	Ref. SD	Range during the field evaluation
<b>5-min</b>	10.2	7.8	0.37 to 0.43	1.49 to 1.63	10.4 to 13.9	-20.1 to -15.9	16.2 to 20.1	22.8 to 25.1	27.1 to 30.3	18.8 to 20.1	0.4 to 160.9
<b>1-hr</b>	10.2	7.5	0.40 to 0.45	1.53 to 1.66	9.8 to 13.6	-20.1 to -15.8	16.1 to 20.1	22.1 to 24.7	27.1 to 30.3	18.1 to 19.2	0.6 to 122.4
<b>24-hr</b>	10.2	5.2	0.43 to 0.45	1.54 to 1.84	7.7 to 13.6	-20.1 to -15.5	15.6 to 20.1	19.0 to 22.6	26.9 to 30.3	12.7 to 13.6	3.7 to 63.6

<sup>1</sup> 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).

<sup>2</sup> 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.

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

# Discussion

- The three **Qingping Air Monitor Lite** sensors' data recovery was ~97% for PM<sub>2.5</sub> and PM<sub>10</sub> mass concentration measurements
- The absolute intra-model variability was ~0.35 and ~0.37 µg/m<sup>3</sup> for PM<sub>2.5</sub> and PM<sub>10</sub>, respectively
- Reference instruments: very strong correlations between FEM GRIMM and FEM T640 for PM<sub>2.5</sub> ( $R^2 \sim 0.97$ , 1-hr mean) and very strong correlations between GRIMM and T640 for PM<sub>10</sub> ( $R^2 \sim 0.97$ , 1-hr mean) mass concentration measurements
- PM<sub>2.5</sub> mass concentrations measured by the Qingping Air Monitor Lite sensors showed strong to very strong correlations with the corresponding FEM GRIMM and FEM T640 data ( $0.89 < R^2 < 0.95$ , 1-hr mean). The sensors underestimated PM<sub>2.5</sub> mass concentrations as measured by FEM GRIMM and FEM T640
- PM<sub>10</sub> mass concentrations measured by the Qingping Air Monitor Lite sensors showed weak correlations with the corresponding GRIMM and T640 data ( $0.39 < R^2 < 0.46$ ; 1-hr mean). The sensors underestimated PM<sub>10</sub> 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