

# Field Evaluation Piera Systems – Canāree R1



# Background

- From 02/22/2022 to 04/23/2022, three **Piera Systems – Canāree R1** (hereinafter **Canāree R1**) 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
- Canāree R1 (3 units tested):
  - Particle sensor: **optical; non-FEM (Piera IPS-7100)**
  - Each unit reports: PM<sub>1.0</sub>, PM<sub>2.5</sub> and PM<sub>10</sub> (µg/m<sup>3</sup>)
  - **Unit cost: \$299 + \$10/month for AQMS data and cloud services**
  - Time resolution: 1-min
  - Units IDs: 0137, 0147, 0153
- 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

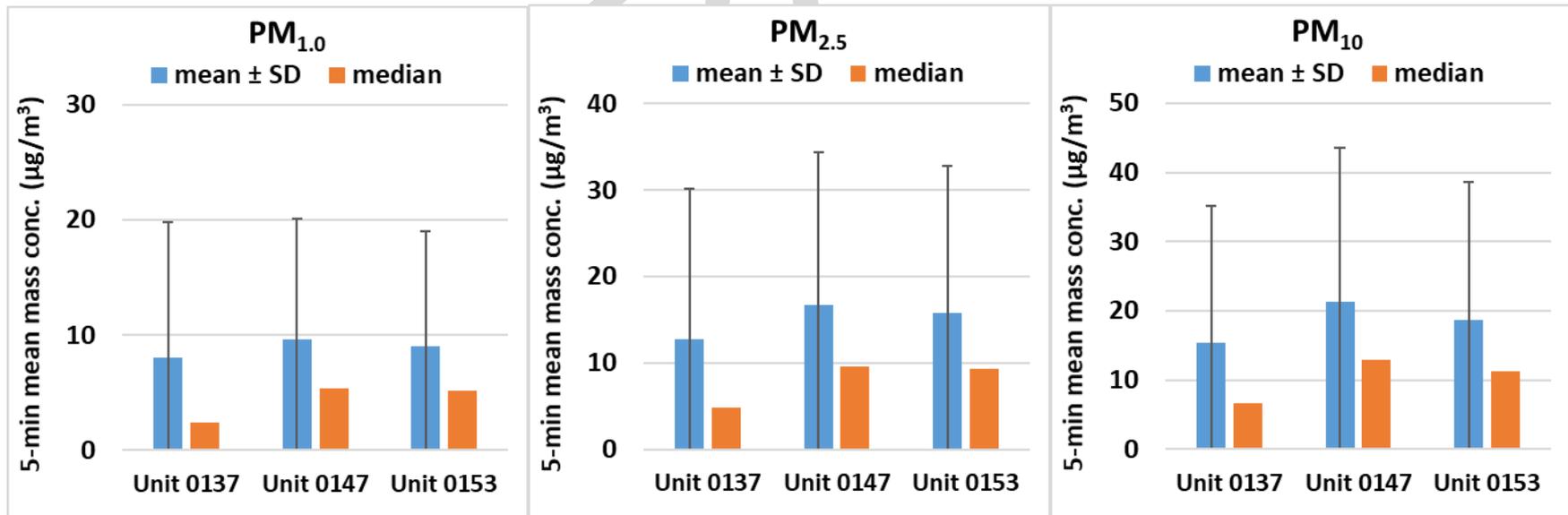


# Data validation & recovery

- 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 Unit 0137, Unit 0147 and Unit 0153 was ~ 100%, ~100% and ~98%, respectively for all PM measurements

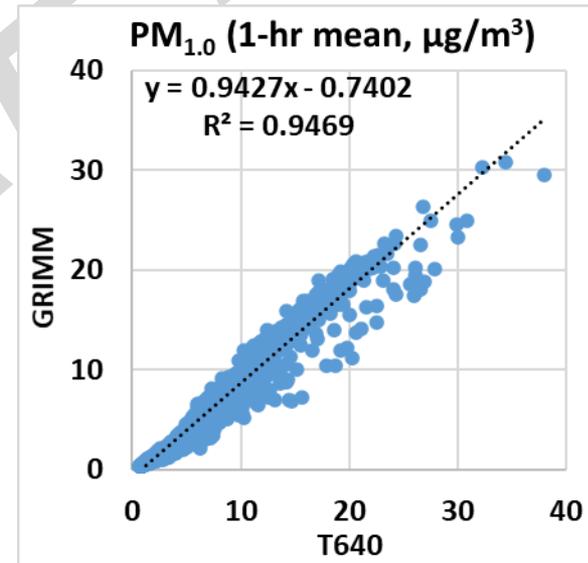
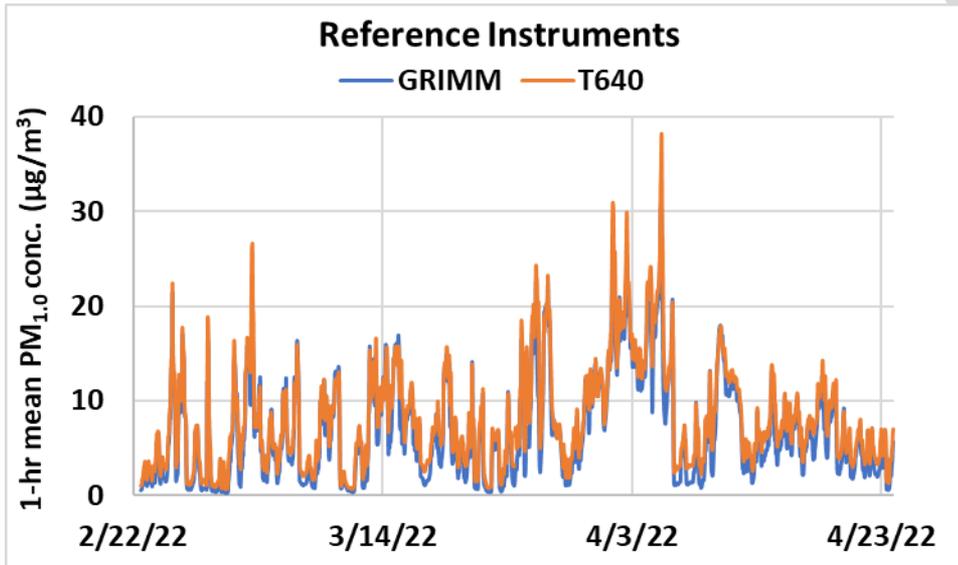
## Canāree R1; intra-model variability

- Absolute intra-model variability was ~ 0.63, 1.65 and 2.47  $\mu\text{g}/\text{m}^3$  for  $\text{PM}_{1.0}$ ,  $\text{PM}_{2.5}$  and  $\text{PM}_{10}$ , respectively (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 7.1%, ~11.0% and ~13.4% for  $\text{PM}_{1.0}$ ,  $\text{PM}_{2.5}$  and  $\text{PM}_{10}$ , respectively (calculated as the absolute intra-model variability relative to the mean of the three sensor means)



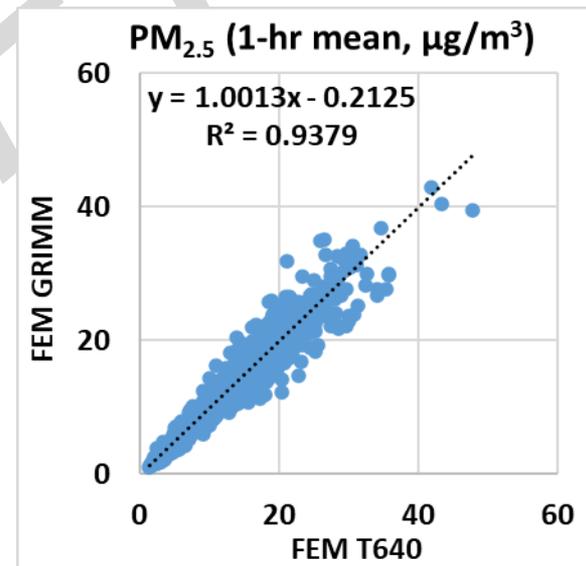
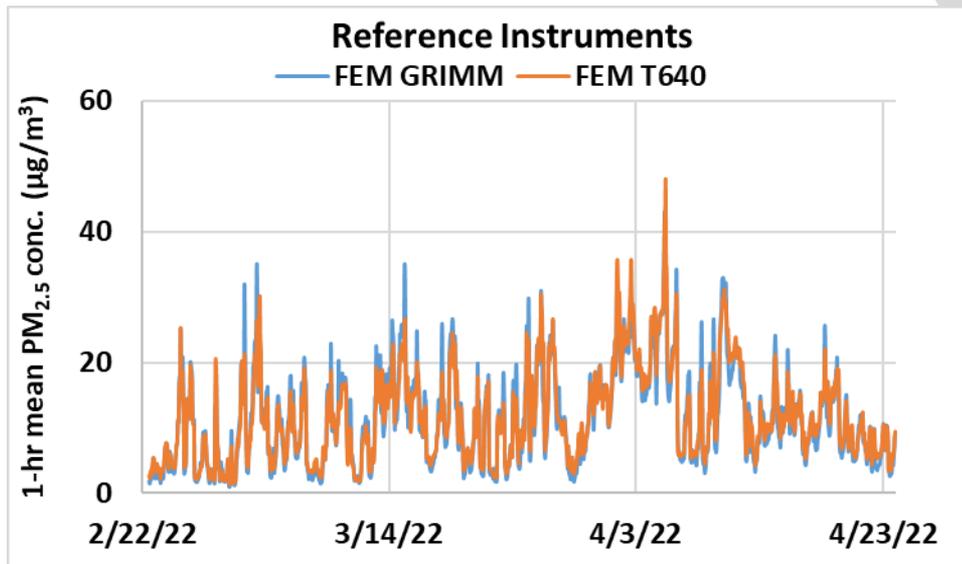
# Reference Instruments: PM<sub>1.0</sub> GRIMM and T640

- Data recovery for PM<sub>1.0</sub> from GRIMM and T640 was ~ 100%.
- Very strong correlations between the reference instruments for PM<sub>1.0</sub> measurements ( $R^2 \sim 0.95$ ) were observed.



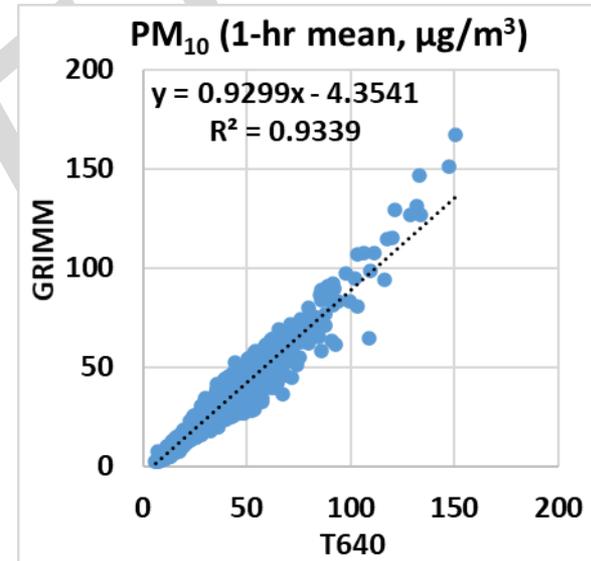
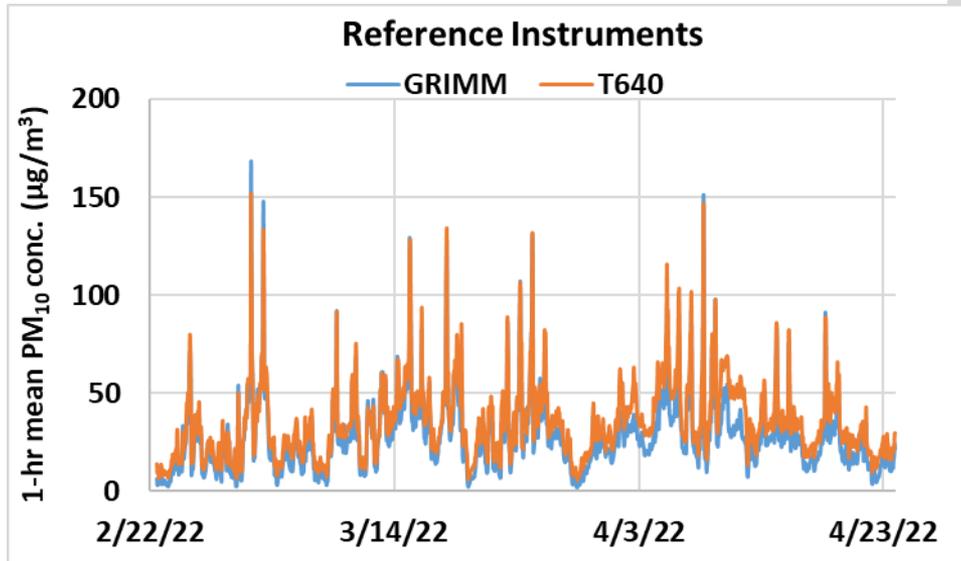
# Reference Instruments: PM<sub>2.5</sub> FEM GRIMM and FEM T640

- Data recovery for PM<sub>2.5</sub> from FEM GRIMM and FEM T640 was ~ 100%.
- Very strong correlations between the reference instruments for PM<sub>2.5</sub> measurements ( $R^2 \sim 0.94$ ) were observed.

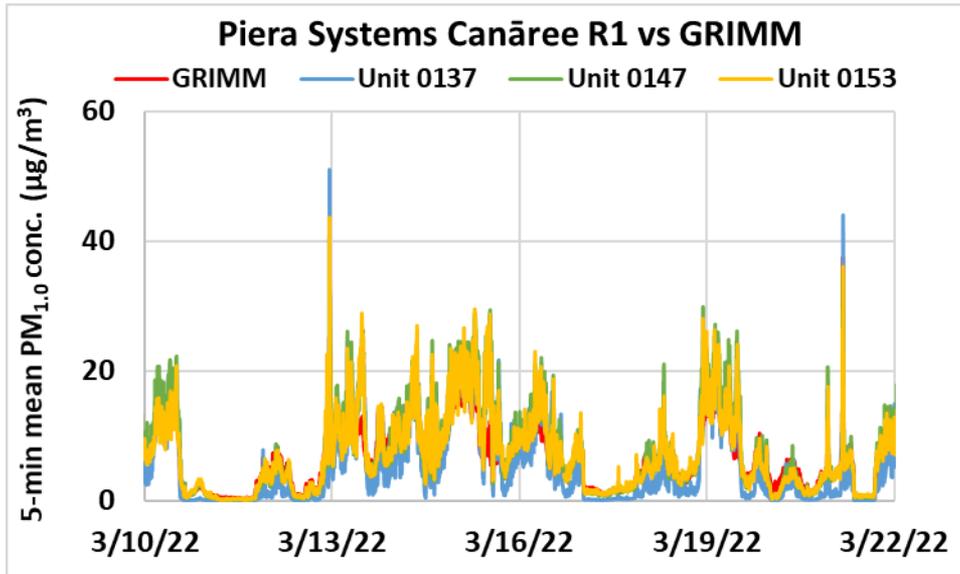


# Reference Instruments: PM<sub>10</sub> GRIMM and T640

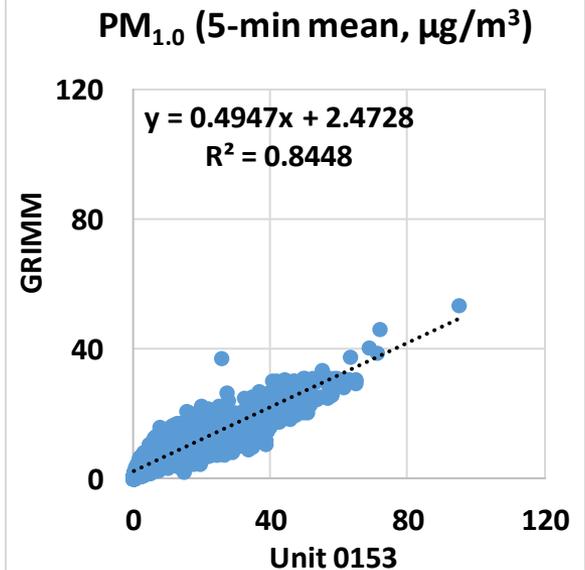
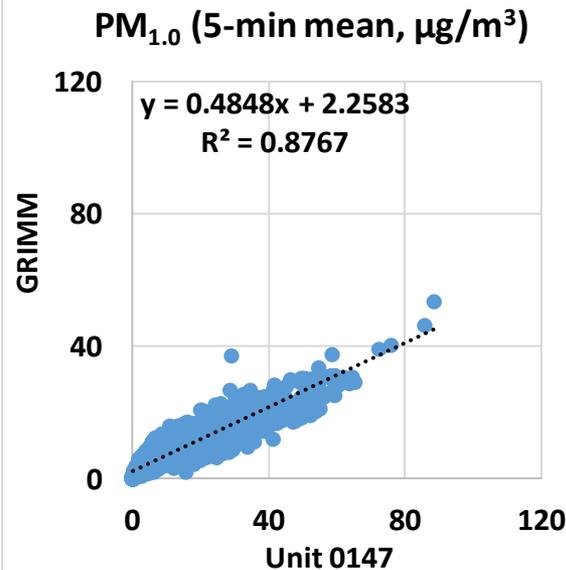
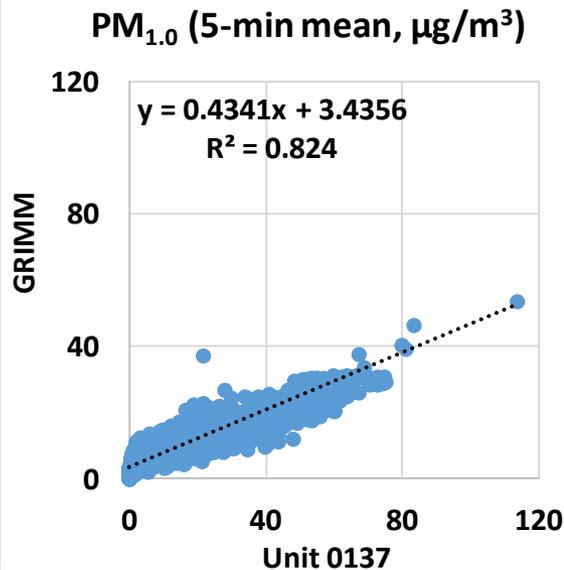
- Data recovery for PM<sub>10</sub> from GRIMM and T640 was ~ 100%.
- Very strong correlations between the reference instruments for PM<sub>10</sub> measurements ( $R^2 \sim 0.93$ ) were observed.



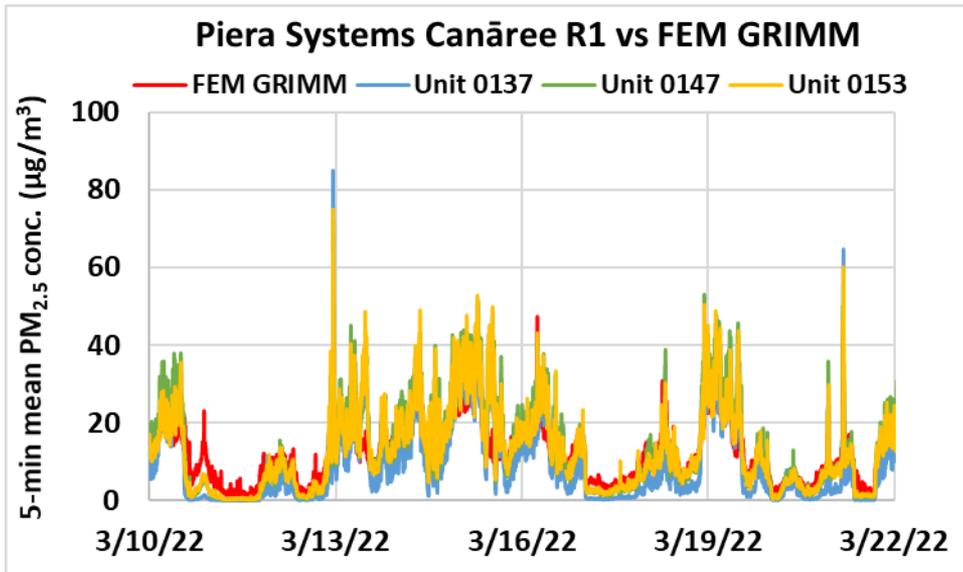
# Canãree R1 vs GRIMM (PM<sub>1.0</sub>; 5-min mean)



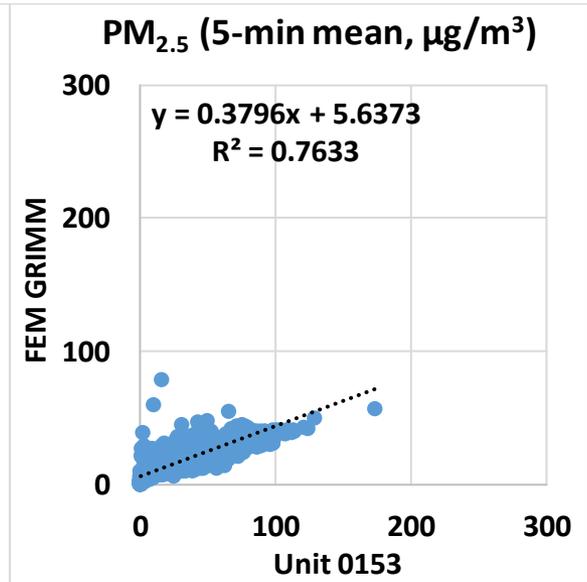
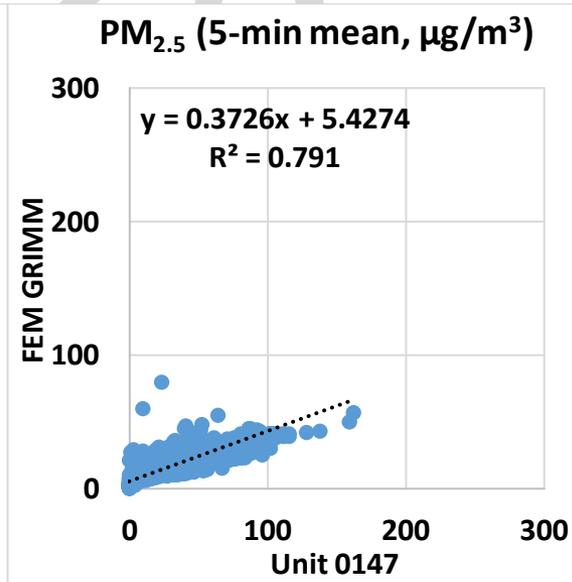
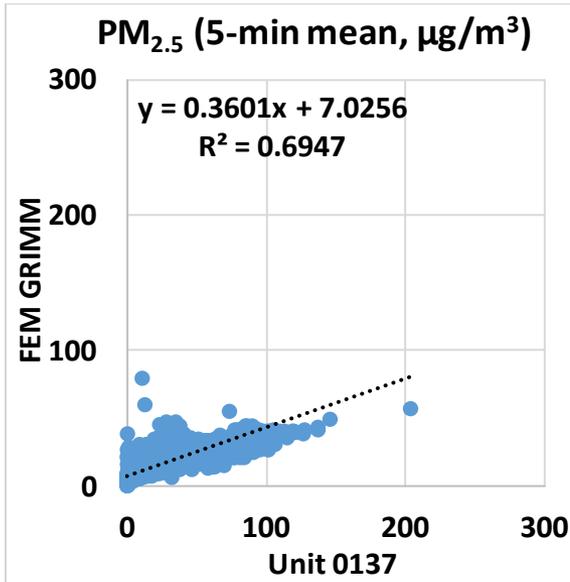
- The Canãree R1 sensors showed strong correlations with the corresponding GRIMM data ( $0.82 < R^2 < 0.88$ )
- Overall, the Canãree R1 sensors overestimated the PM<sub>1.0</sub> mass concentrations as measured by GRIMM
- The Canãree R1 sensors seemed to track the PM<sub>1.0</sub> diurnal variations as recorded by GRIMM



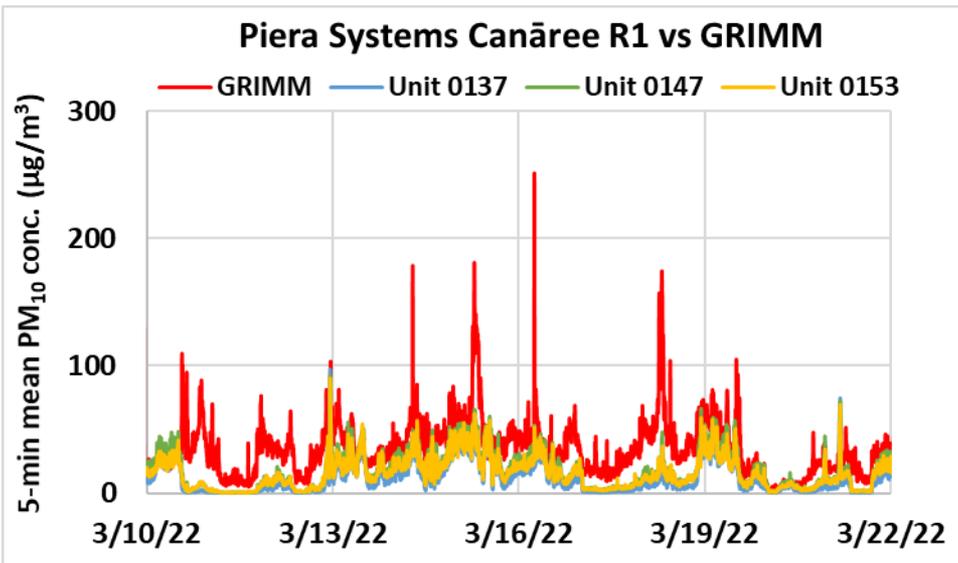
# Canāree R1 vs FEM GRIMM (PM<sub>2.5</sub>; 5-min mean)



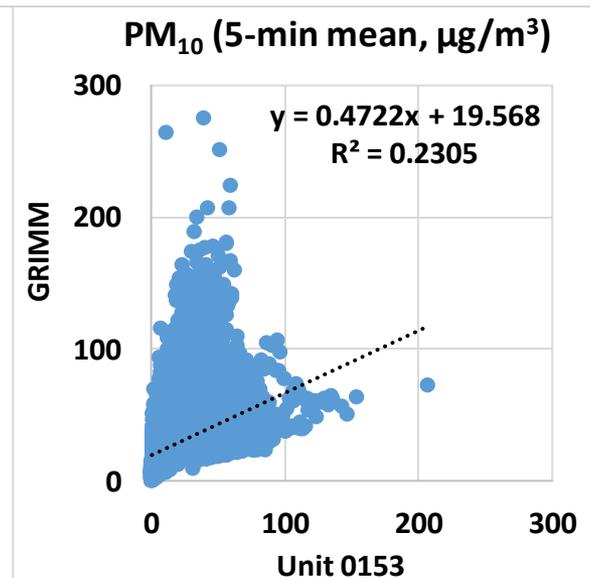
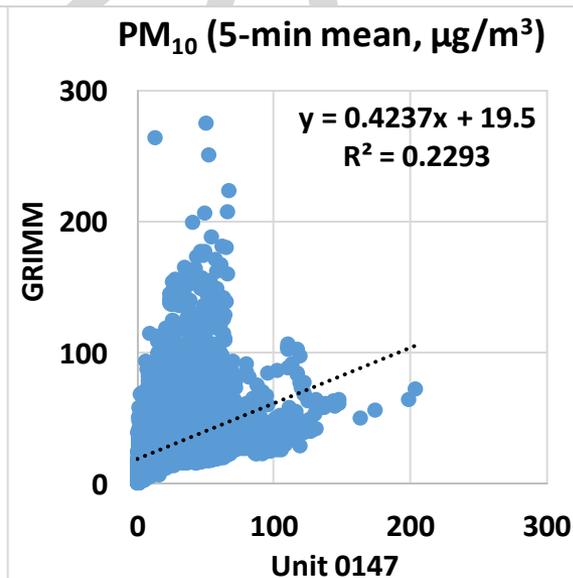
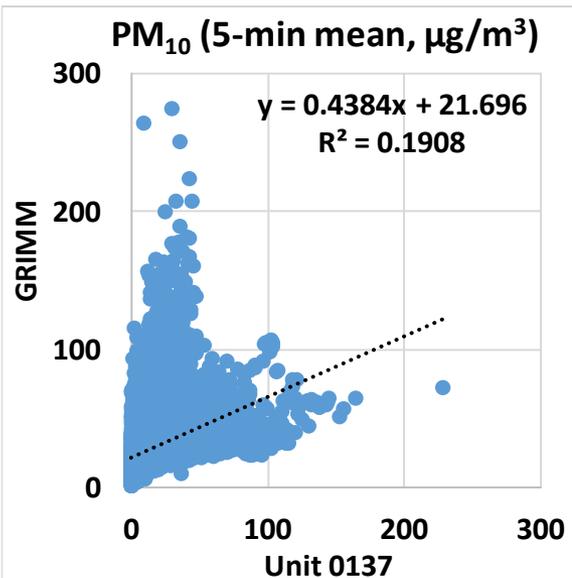
- The Canāree R1 sensors showed moderate to strong correlations with the corresponding FEM GRIMM data ( $0.69 < R^2 < 0.80$ )
- Overall, the Canāree R1 sensors overestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM GRIMM
- The Canāree R1 sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM GRIMM



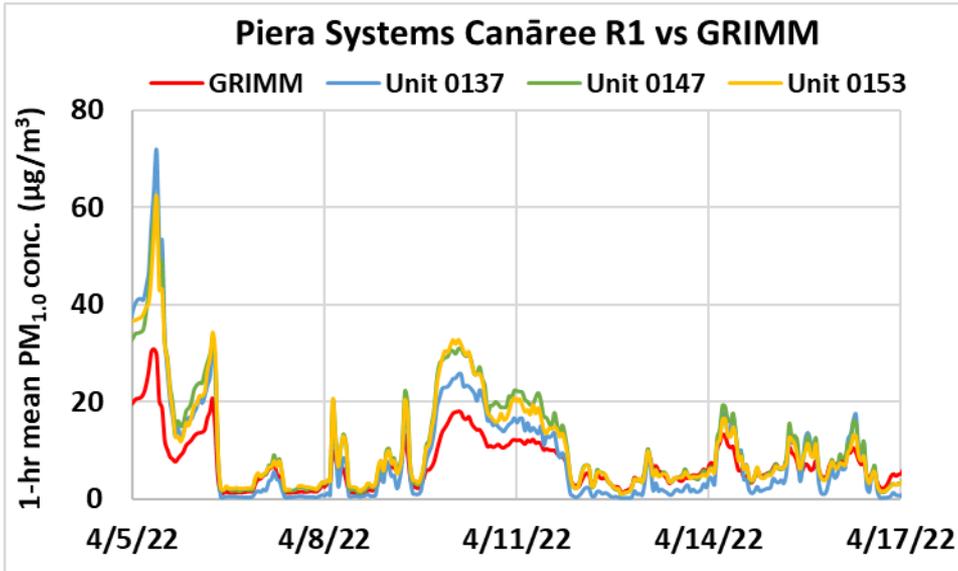
# Canãree R1 vs GRIMM (PM<sub>10</sub>; 5-min mean)



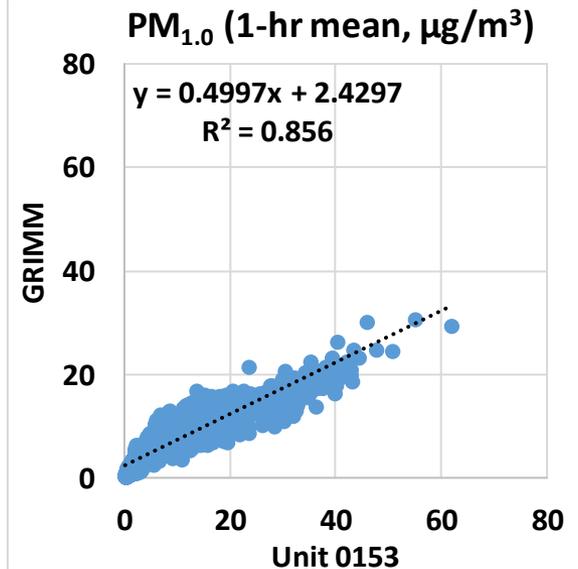
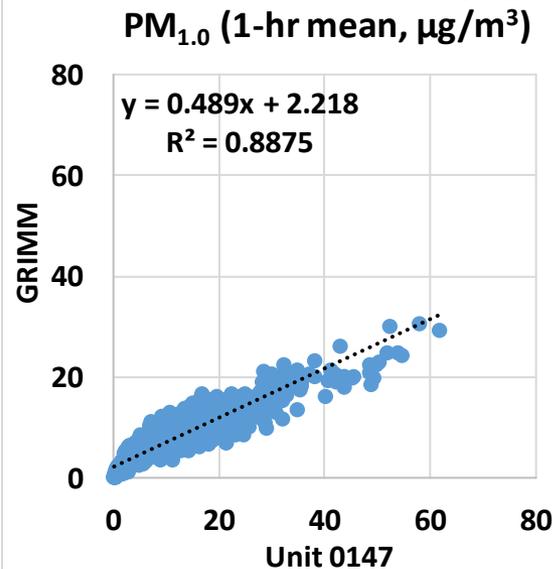
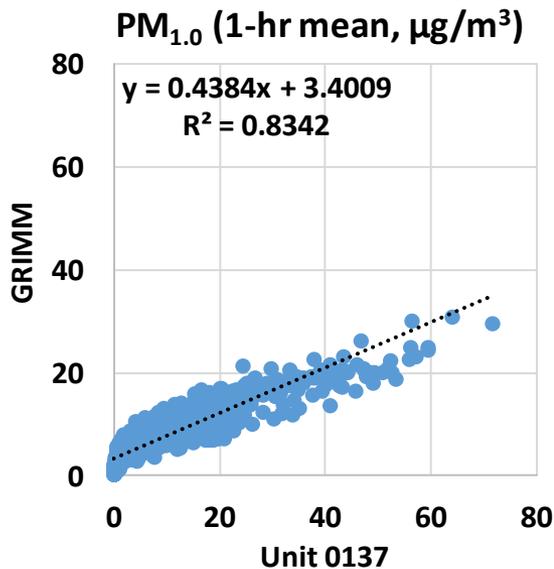
- The Canãree R1 sensors showed very weak correlations with the corresponding GRIMM data ( $0.19 < R^2 < 0.24$ )
- Overall, the Canãree R1 sensors underestimated the PM<sub>10</sub> mass concentrations as measured by GRIMM
- The Canãree R1 sensors did not seem to track the PM<sub>10</sub> diurnal variations as recorded by GRIMM



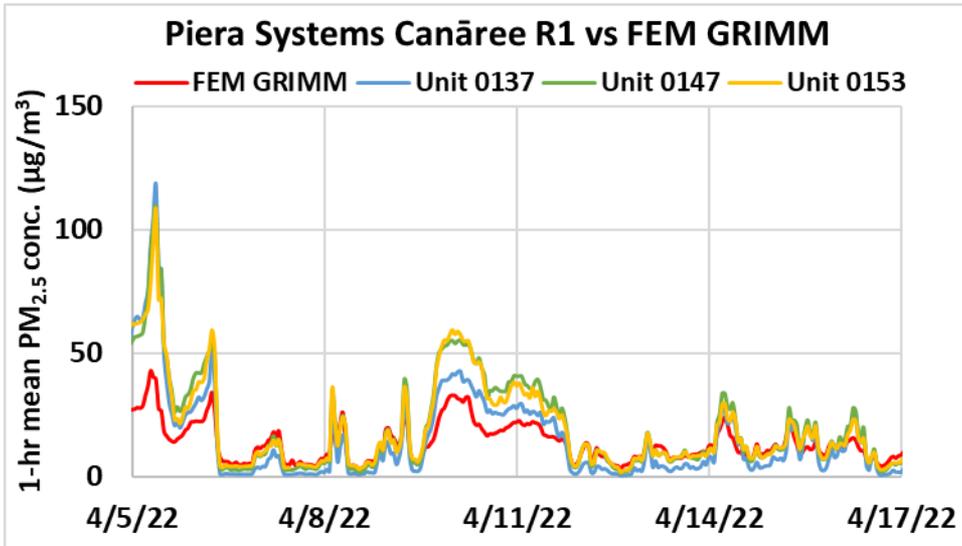
# Canāree R1 vs GRIMM (PM<sub>1.0</sub>; 1-hr mean)



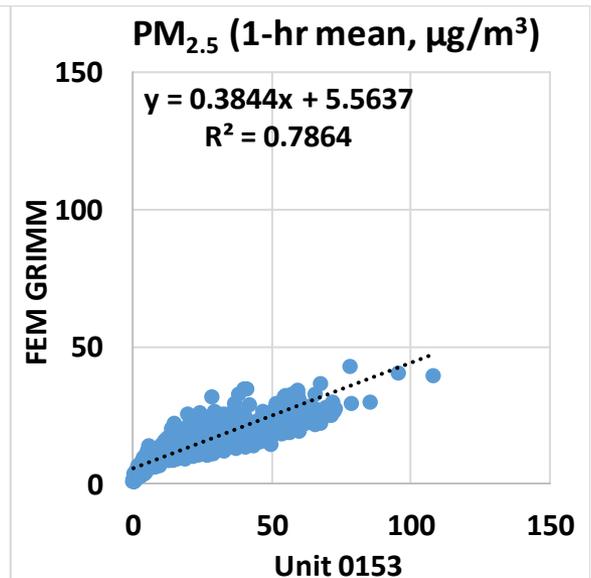
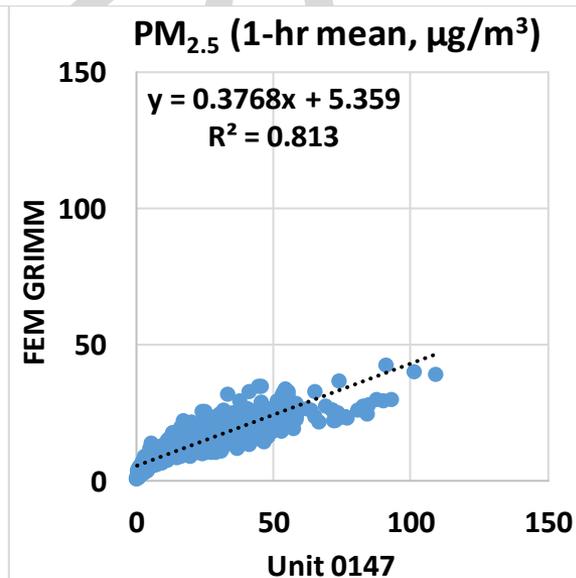
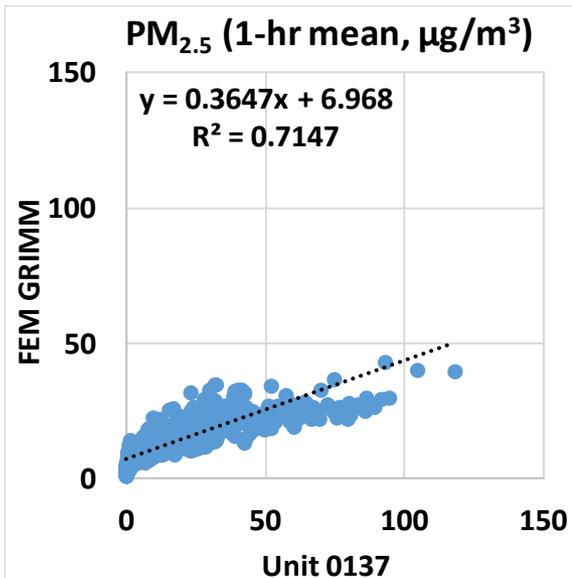
- The Canāree R1 sensors showed strong correlations with the corresponding GRIMM data ( $0.83 < R^2 < 0.89$ )
- Overall, the Canāree R1 sensors overestimated the PM<sub>1.0</sub> mass concentrations as measured by GRIMM
- The Canāree R1 sensors seemed to track the PM<sub>1.0</sub> diurnal variations as recorded by GRIMM



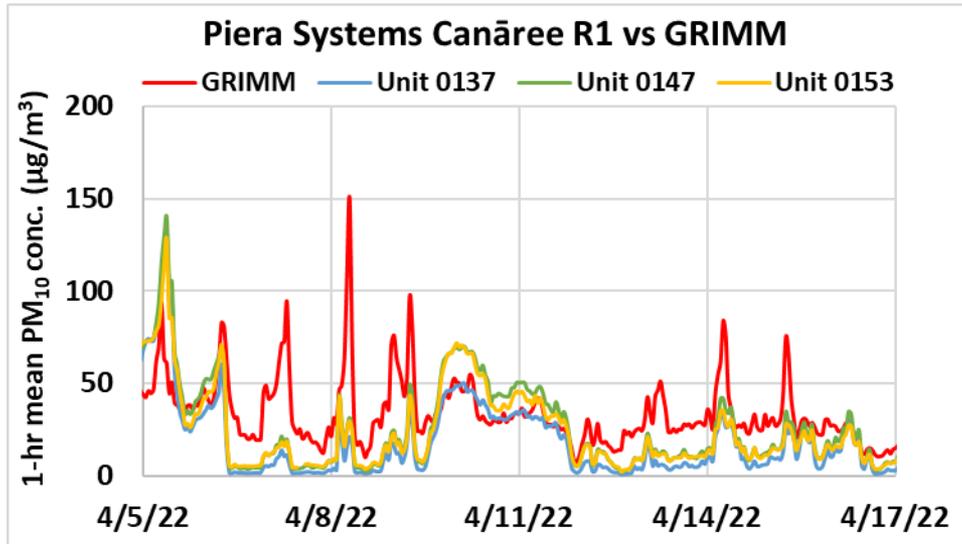
# Canāree R1 vs FEM GRIMM (PM<sub>2.5</sub>; 1-hr mean)



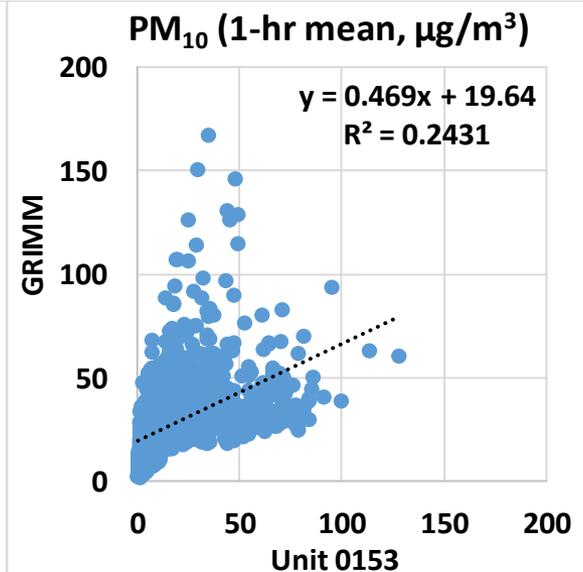
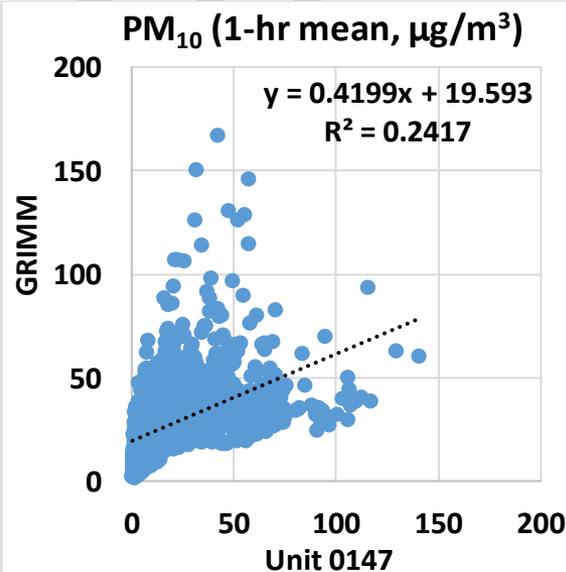
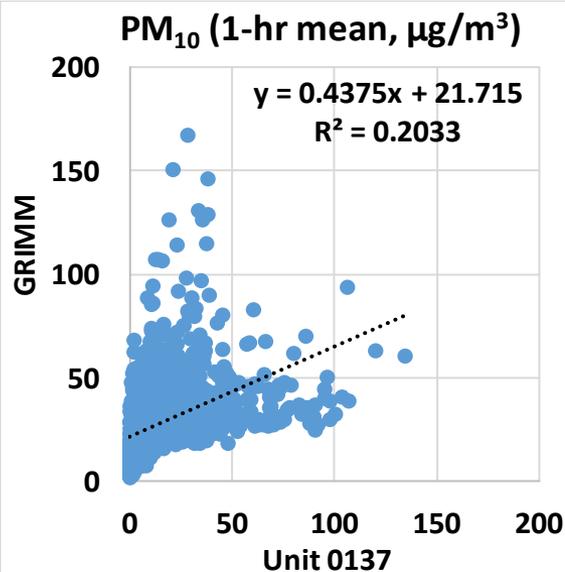
- The Canāree R1 sensors showed strong correlations with the corresponding FEM GRIMM data ( $0.71 < R^2 < 0.82$ )
- Overall, the Canāree R1 sensors overestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM GRIMM
- The Canāree R1 sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM GRIMM



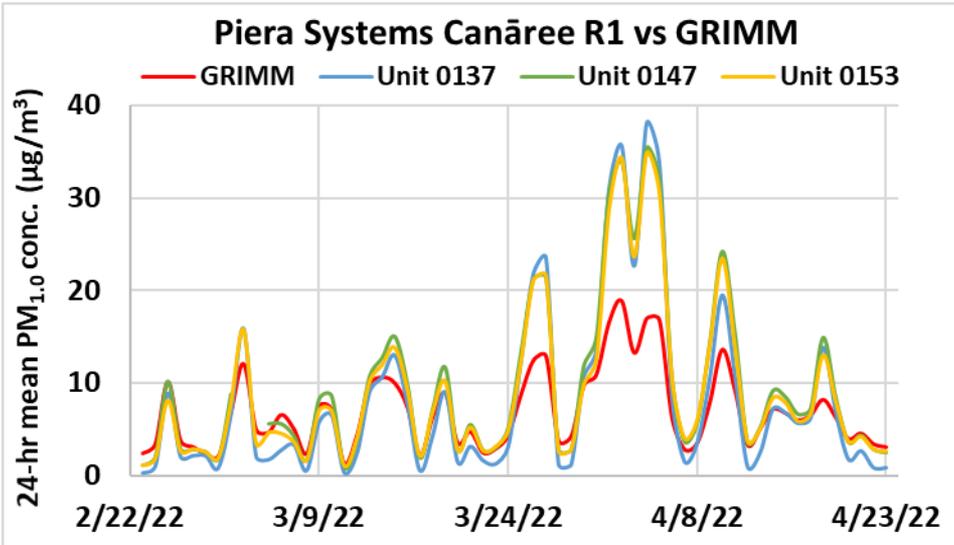
# Canāree R1 vs GRIMM (PM<sub>10</sub>; 1-hr mean)



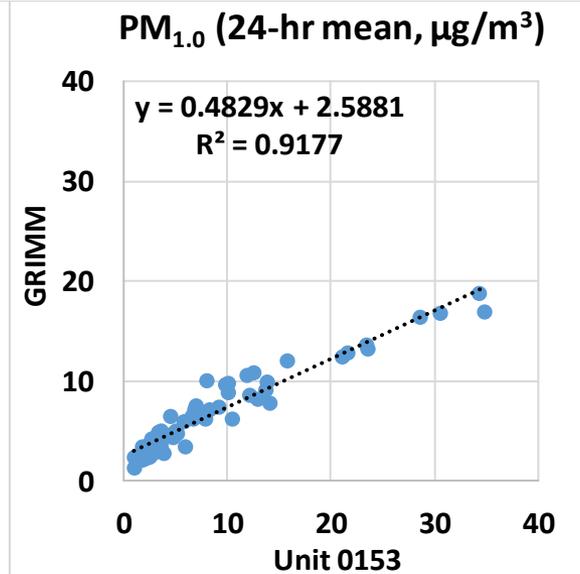
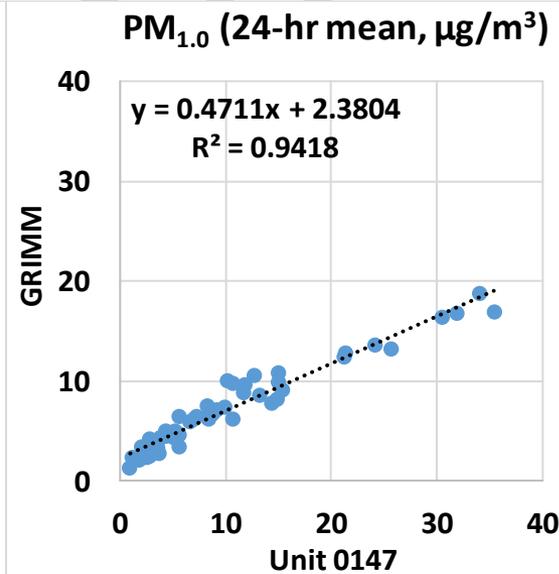
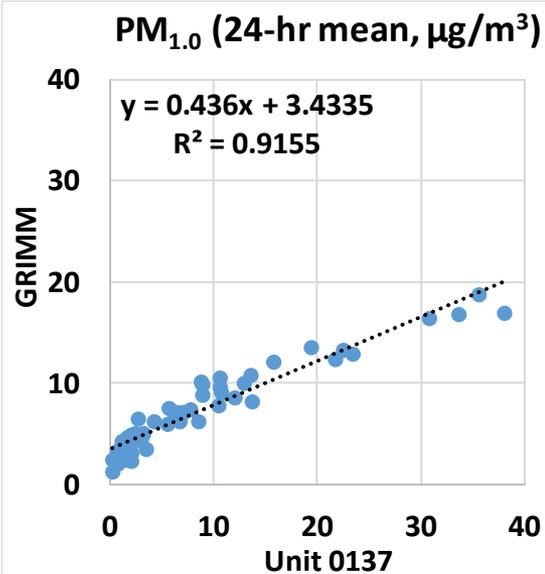
- The Canāree R1 sensors showed very weak correlations with the corresponding GRIMM data ( $0.20 < R^2 < 0.25$ )
- Overall, the Canāree R1 sensors underestimated the PM<sub>10</sub> mass concentrations as measured by GRIMM
- The Canāree R1 sensors did not seem to track the PM<sub>10</sub> diurnal variations as recorded by GRIMM



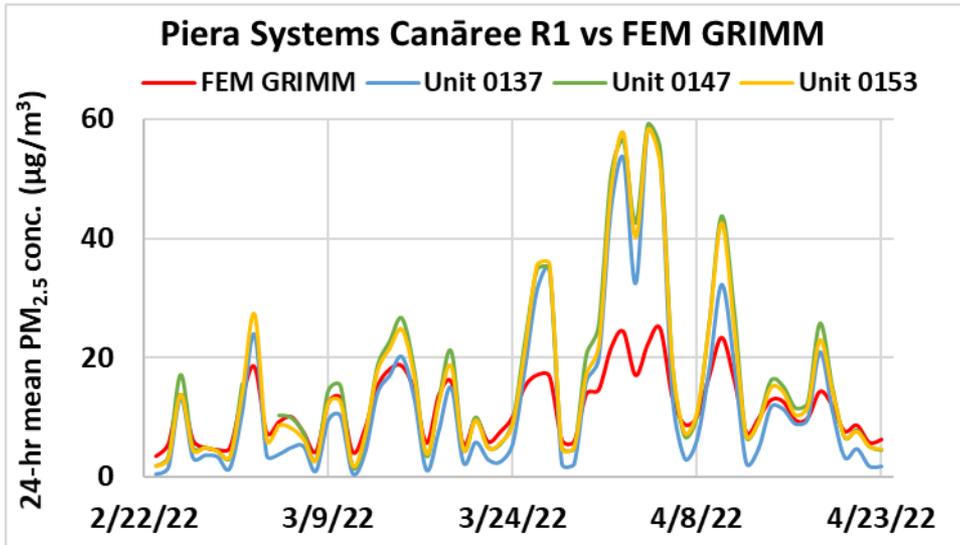
# Canāree R1 vs GRIMM (PM<sub>1.0</sub>; 24-hr mean)



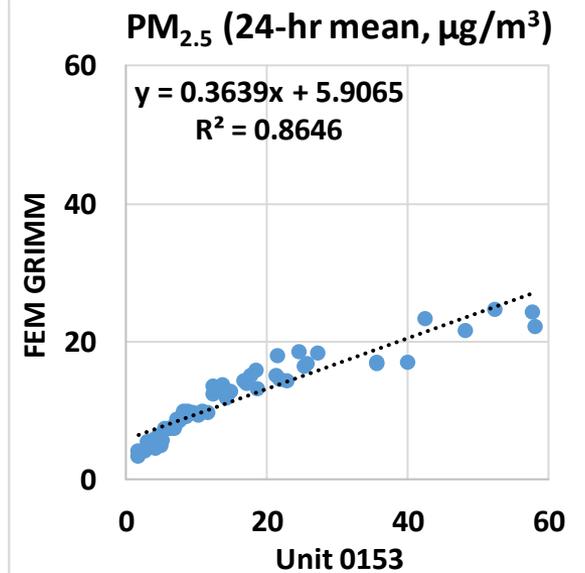
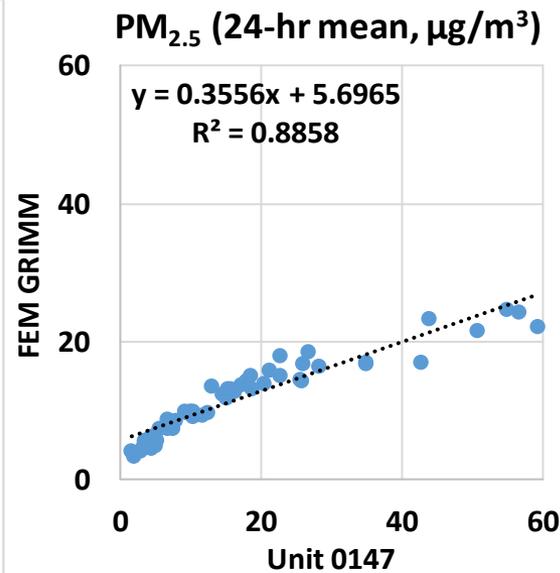
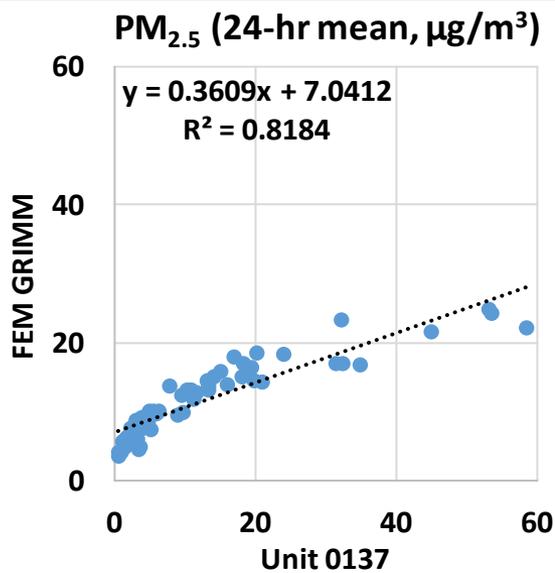
- The Canāree R1 sensors showed very strong correlations with the corresponding GRIMM data ( $0.91 < R^2 < 0.95$ )
- Overall, the Canāree R1 sensors overestimated the PM<sub>1.0</sub> mass concentrations as measured by GRIMM
- The Canāree R1 sensors seemed to track the PM<sub>1.0</sub> diurnal variations as recorded by GRIMM



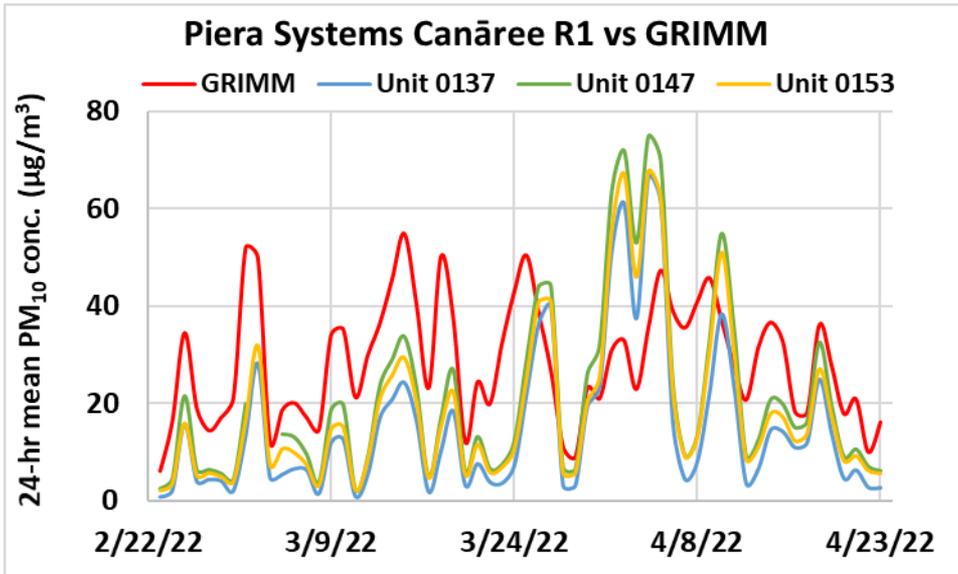
# Canāree R1 vs FEM GRIMM (PM<sub>2.5</sub>; 24-hr mean)



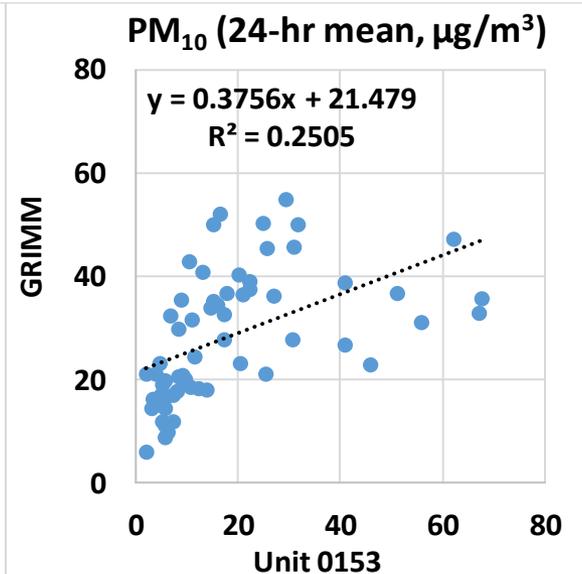
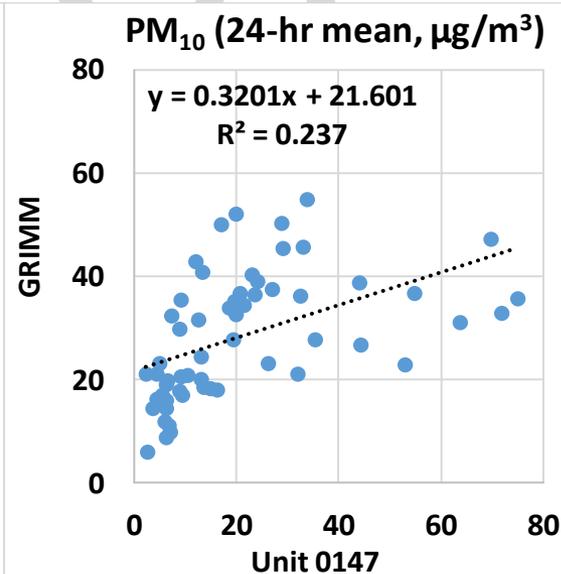
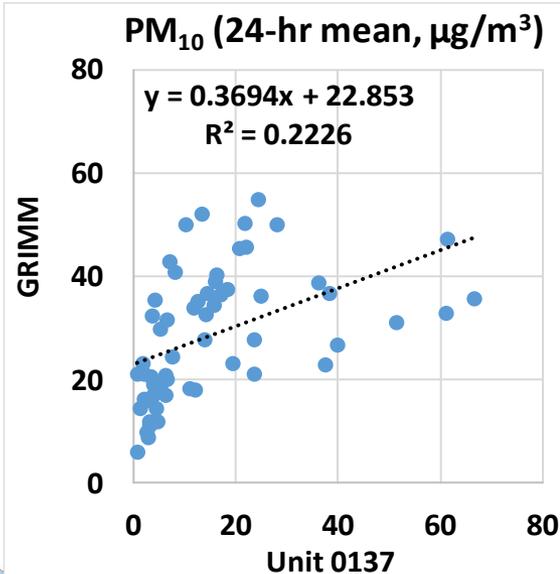
- The Canāree R1 sensors showed strong correlations with the corresponding FEM GRIMM data ( $0.81 < R^2 < 0.89$ )
- Overall, the Canāree R1 sensors overestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM GRIMM
- The Canāree R1 sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM GRIMM



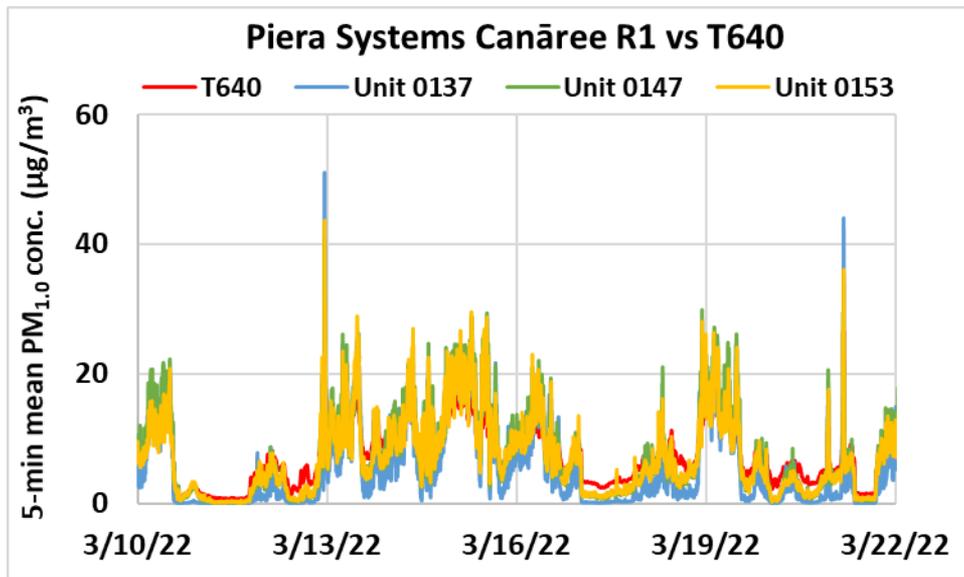
# Canãree R1 vs GRIMM (PM<sub>10</sub>; 24-hr mean)



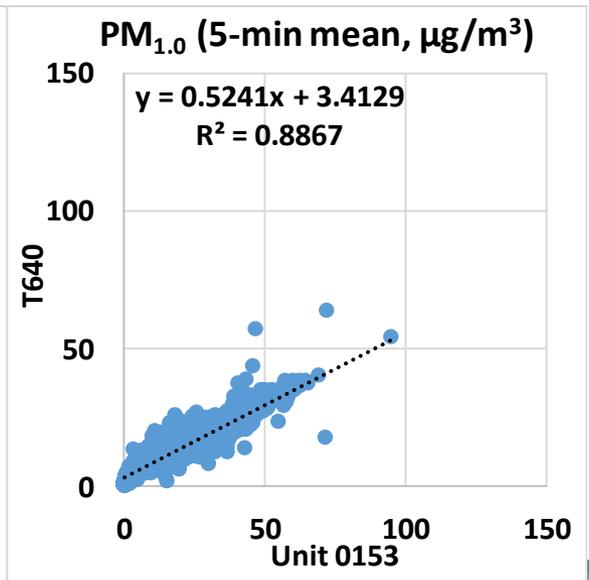
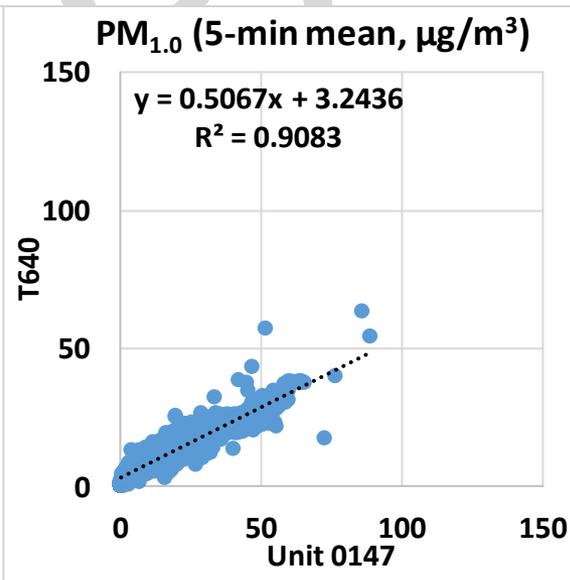
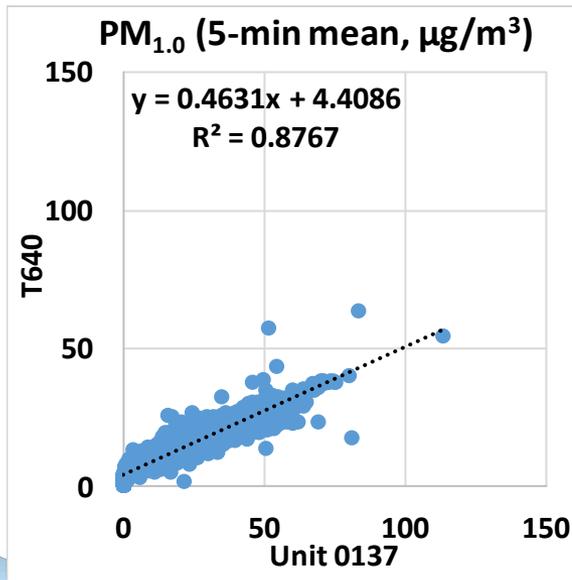
- The Canãree R1 sensors showed very weak correlations with the corresponding GRIMM data ( $0.22 < R^2 < 0.26$ )
- Overall, the Canãree R1 sensors underestimated the PM<sub>10</sub> mass concentrations as measured by GRIMM
- The Canãree R1 sensors seemed to track the PM<sub>10</sub> diurnal variations as recorded by GRIMM



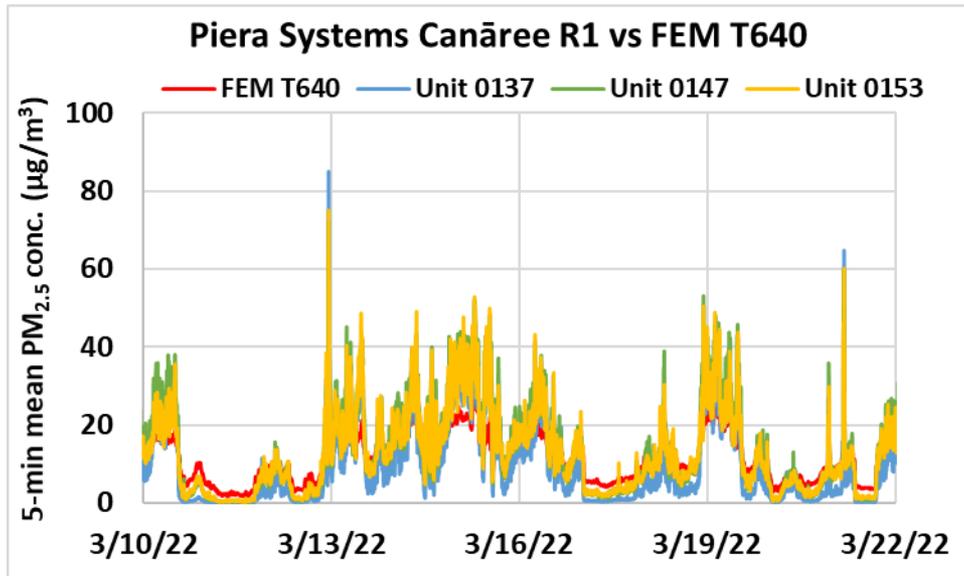
# Canāree R1 vs T640 (PM<sub>1.0</sub>; 5-min mean)



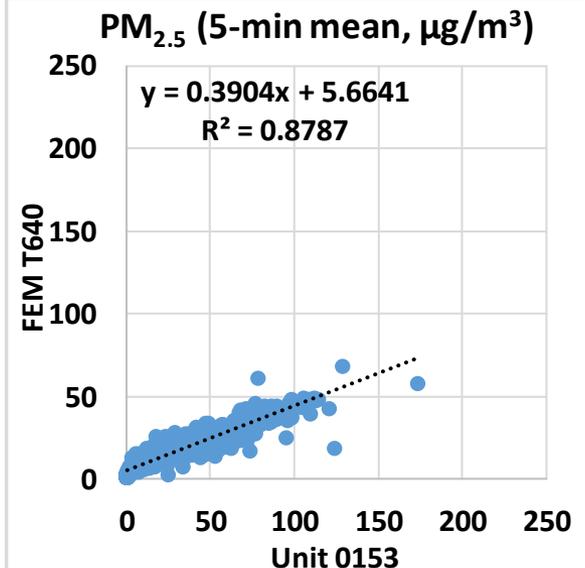
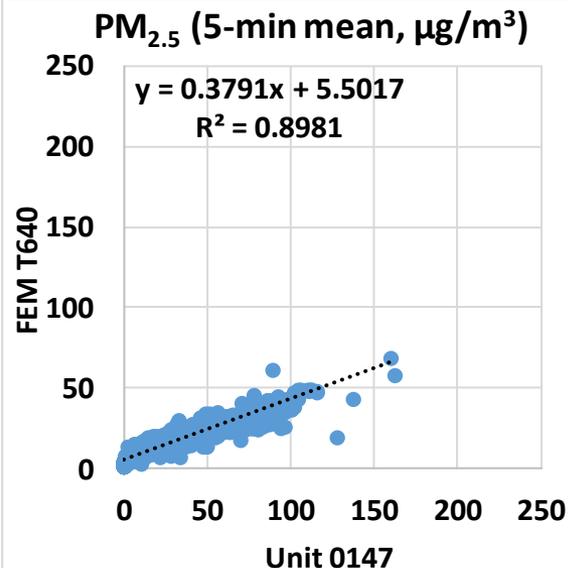
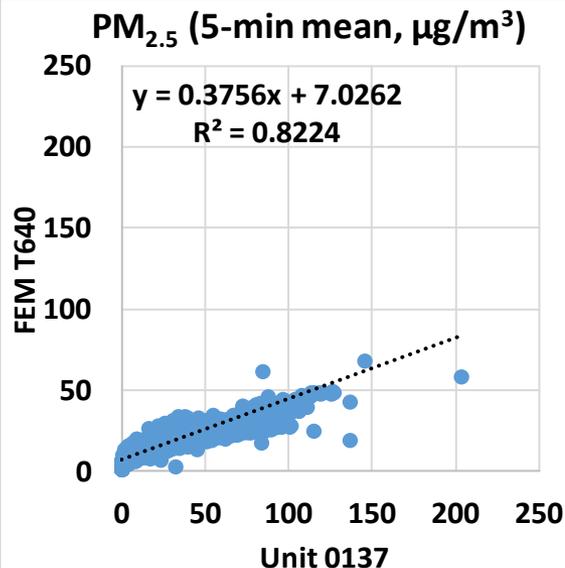
- The Canāree R1 sensors showed strong to very strong correlations with the corresponding T640 data ( $0.87 < R^2 < 0.91$ )
- Overall, the Canāree R1 sensors overestimated the PM<sub>1.0</sub> mass concentrations as measured by T640
- The Canāree R1 sensors seemed to track the PM<sub>1.0</sub> diurnal variations as recorded by T640



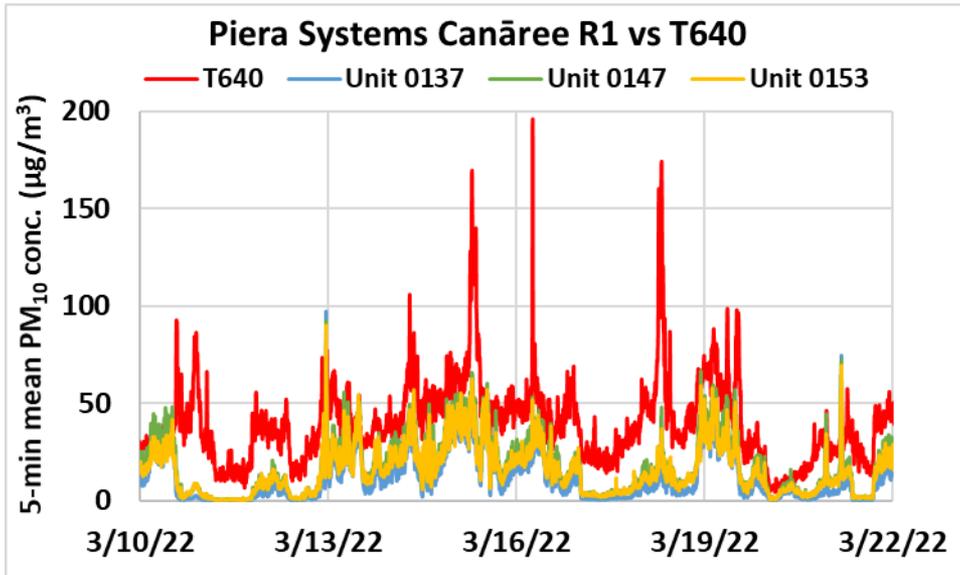
# Canāree R1 vs FEM T640 (PM<sub>2.5</sub>; 5-min mean)



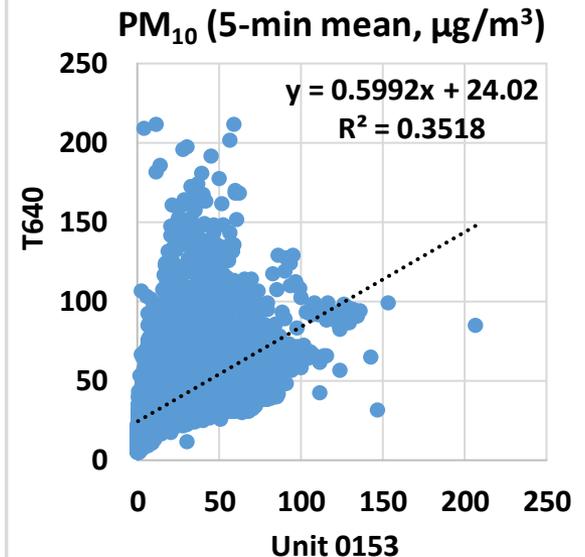
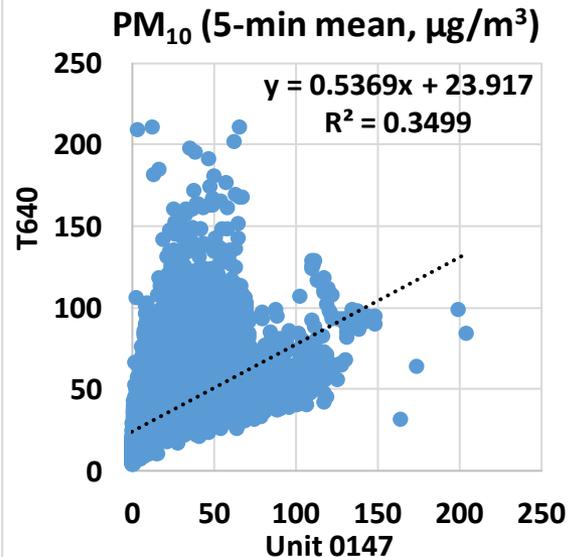
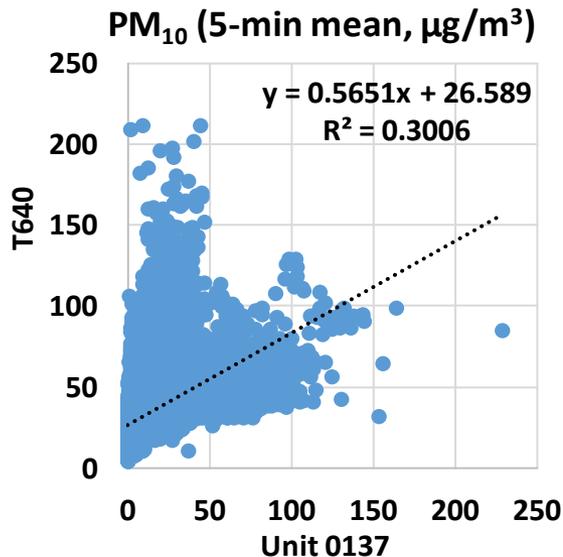
- The Canāree R1 sensors showed strong correlations with the corresponding FEM T640 data ( $0.82 < R^2 < 0.90$ )
- Overall, the Canāree R1 sensors overestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM T640
- The Canāree R1 sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM T640



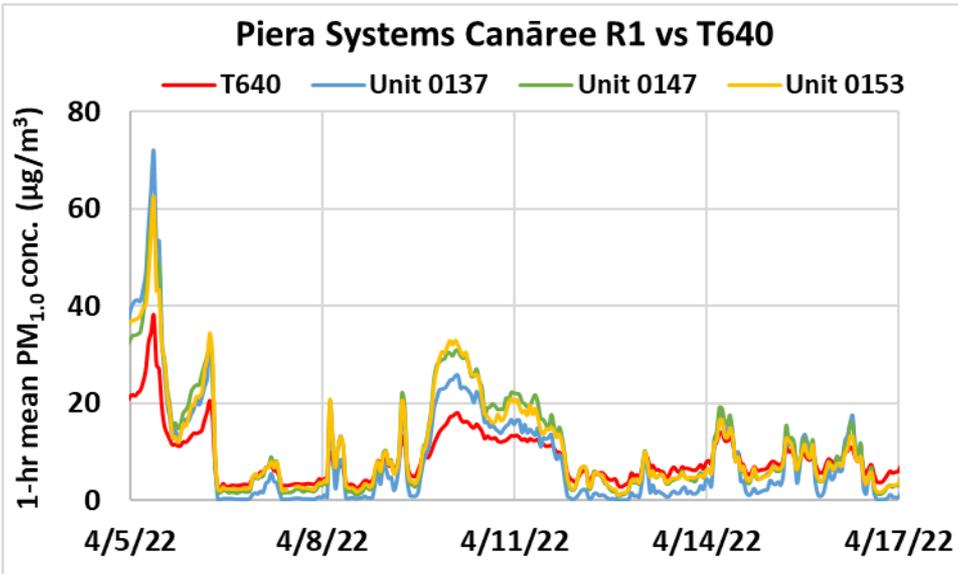
# Canāree R1 vs T640 (PM<sub>10</sub>; 5-min mean)



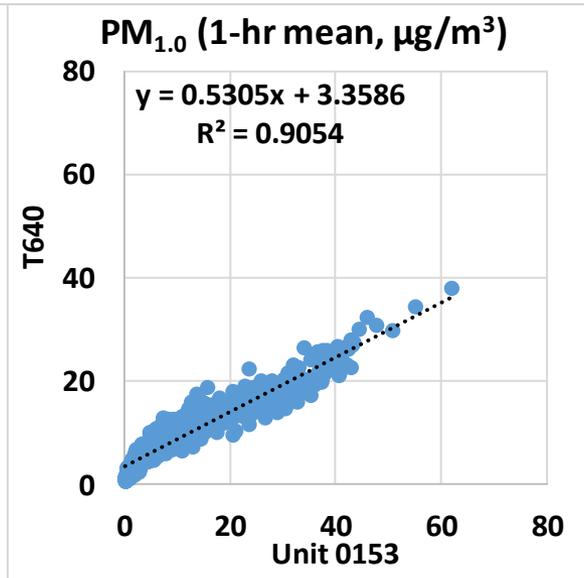
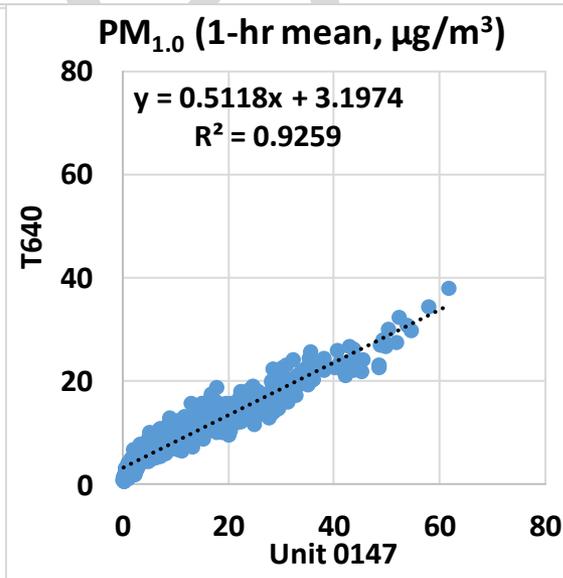
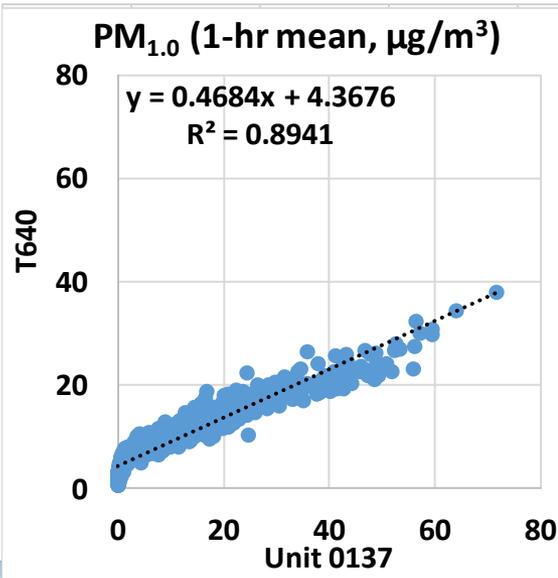
- The Canāree R1 sensors showed weak correlations with the corresponding T640 data ( $0.30 < R^2 < 0.36$ )
- Overall, the Canāree R1 sensors underestimated the PM<sub>10</sub> mass concentrations as measured by T640
- The Canāree R1 sensors did not seem to track the PM<sub>10</sub> diurnal variations as recorded by T640



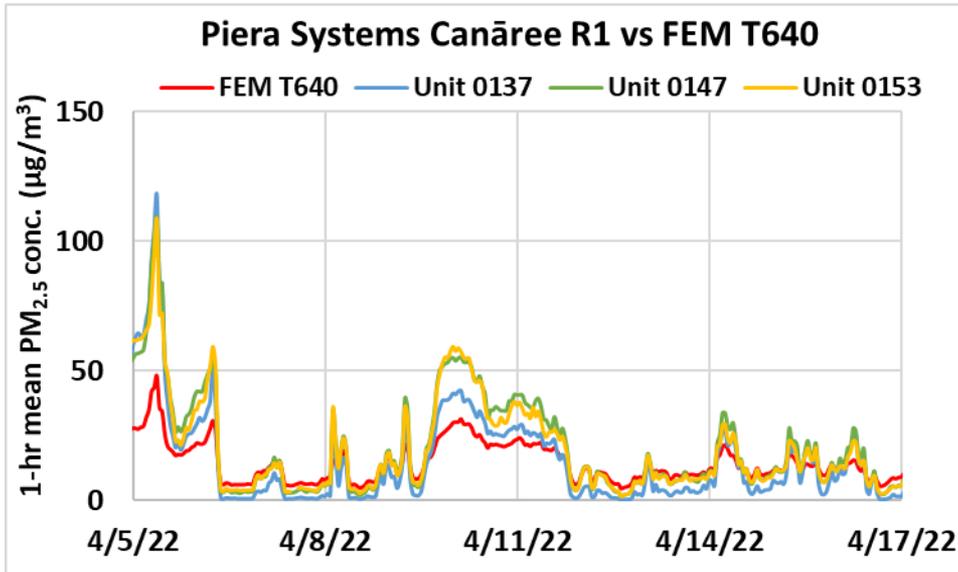
# Canãree R1 vs T640 (PM<sub>1.0</sub>; 1-hr mean)



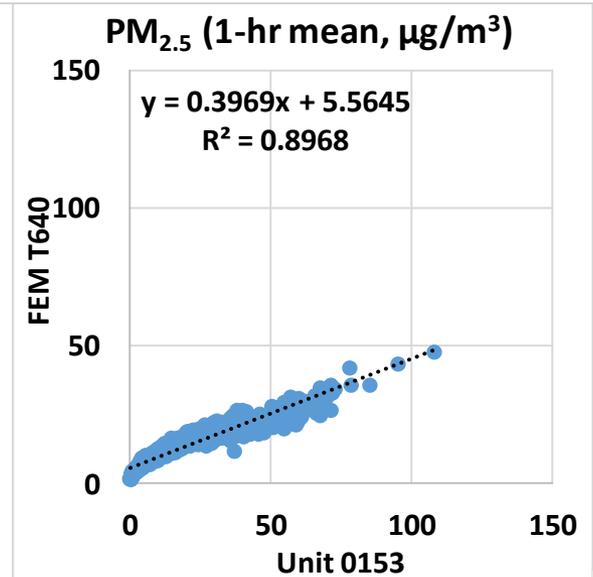
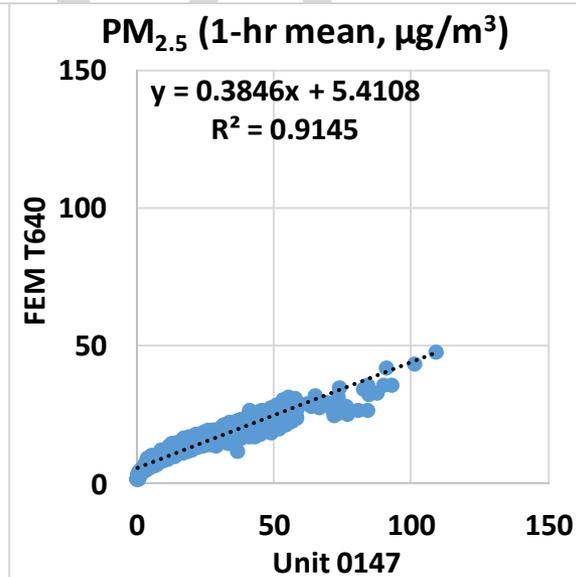
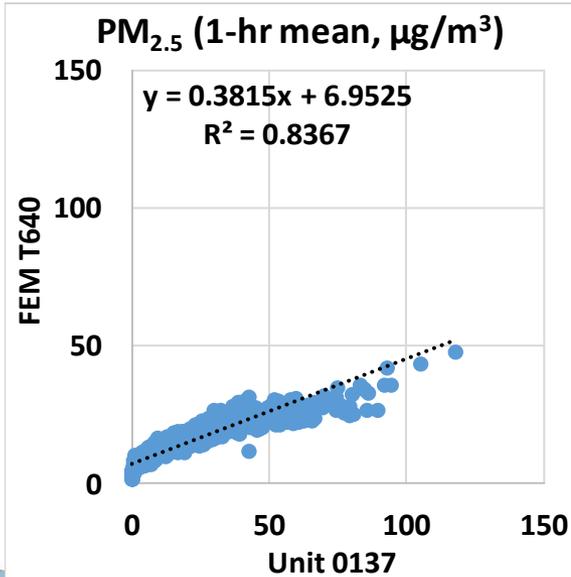
- The Canãree R1 sensors showed strong to very strong correlations with the corresponding T640 data ( $0.89 < R^2 < 0.93$ )
- Overall, the Canãree R1 sensors overestimated the PM<sub>1.0</sub> mass concentrations as measured by T640
- The Canãree R1 sensors seemed to track the PM<sub>1.0</sub> diurnal variations as recorded by T640



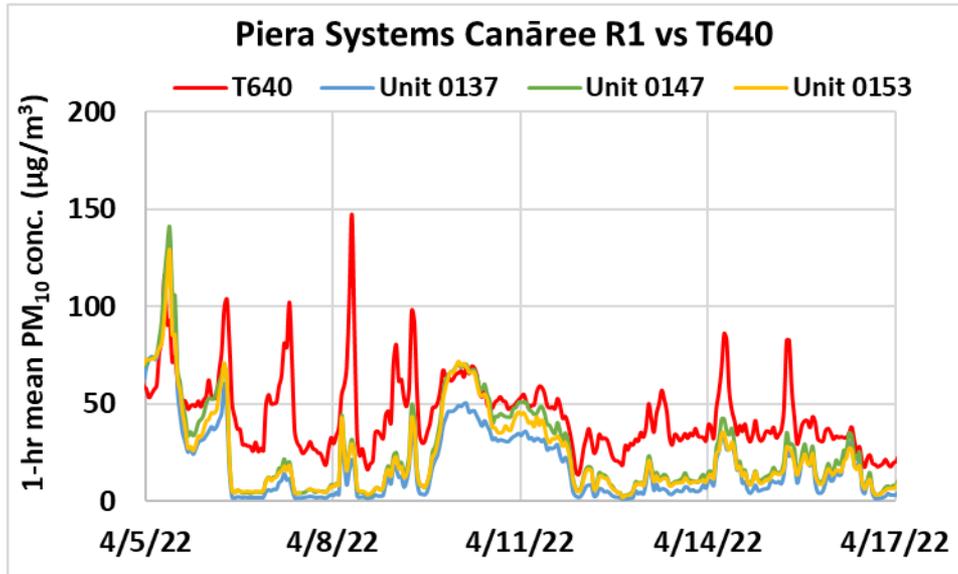
# Canāree R1 vs FEM T640 (PM<sub>2.5</sub>; 1-hr mean)



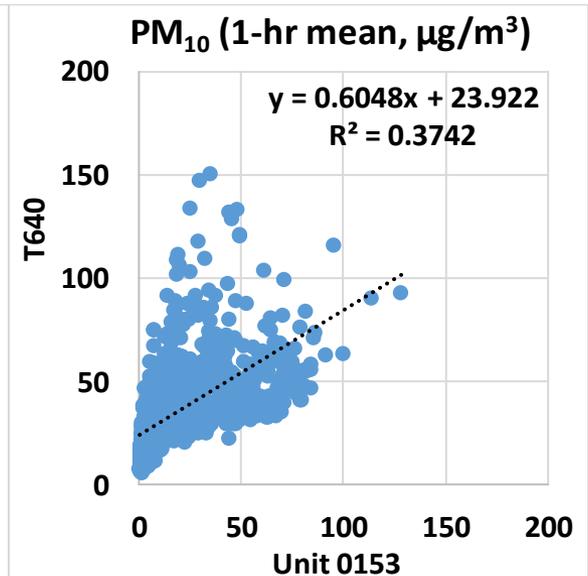
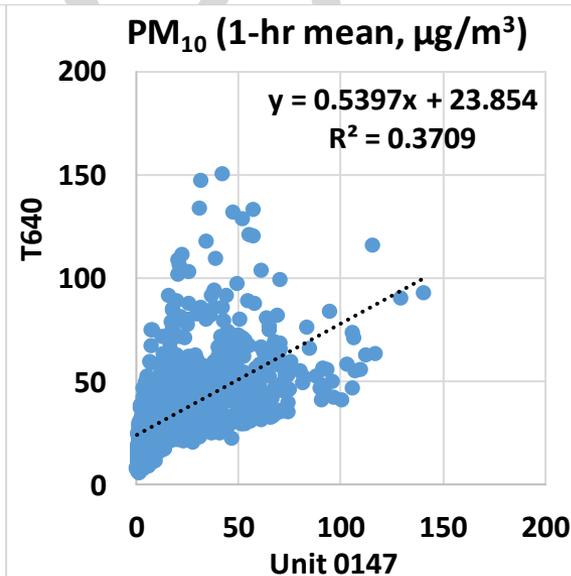
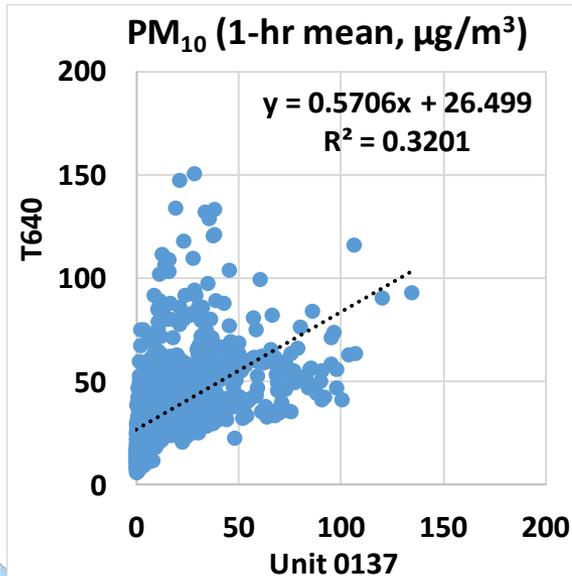
- The Canāree R1 sensors showed strong to very strong correlations with the corresponding FEM T640 data ( $0.83 < R^2 < 0.92$ )
- Overall, the Canāree R1 sensors overestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM T640
- The Canāree R1 sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM T640



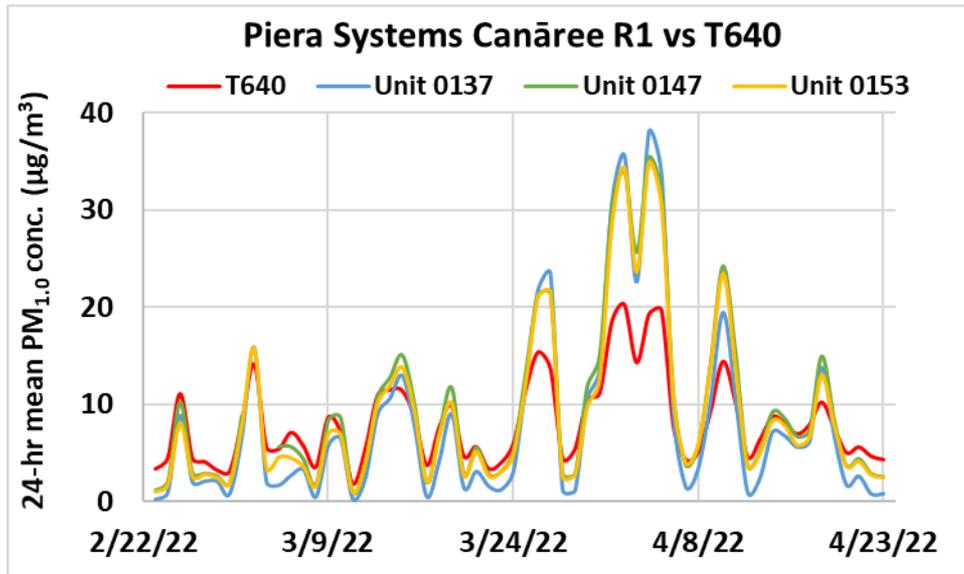
# Canāree R1 vs T640 (PM<sub>10</sub>; 1-hr mean)



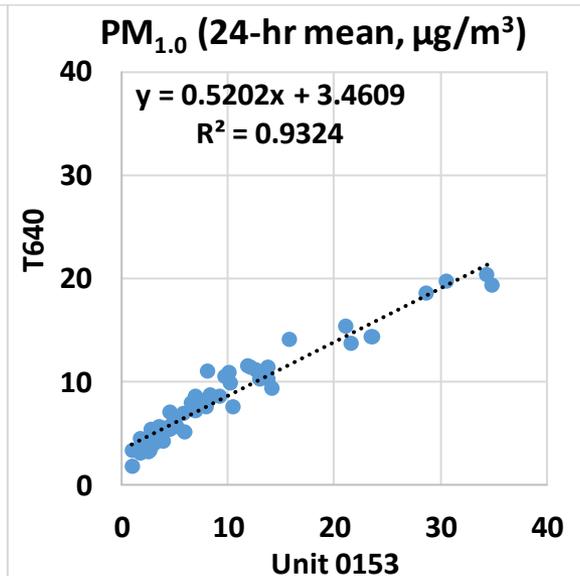
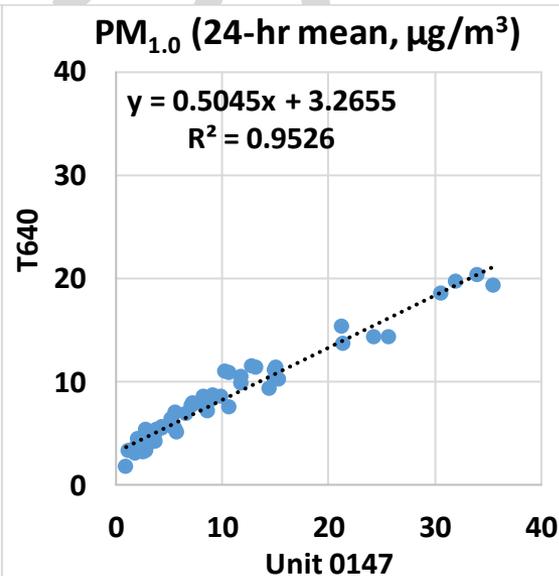
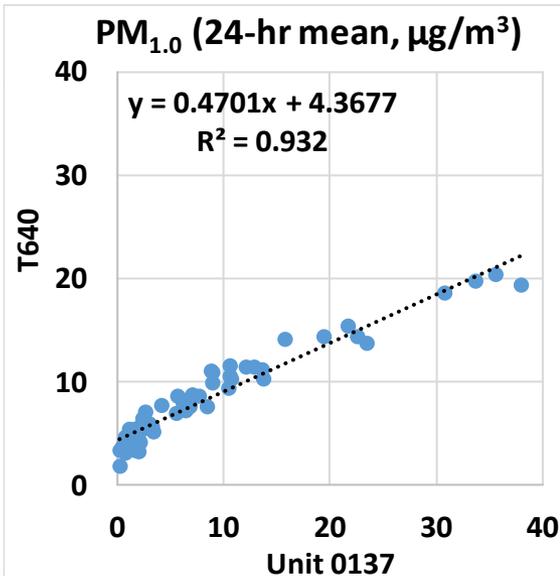
- The Canāree R1 sensors showed weak correlations with the corresponding T640 data ( $0.32 < R^2 < 0.38$ )
- Overall, the Canāree R1 sensors underestimated the PM<sub>10</sub> mass concentrations as measured by T640
- The Canāree R1 sensors did not seem to track the PM<sub>10</sub> diurnal variations as recorded by T640



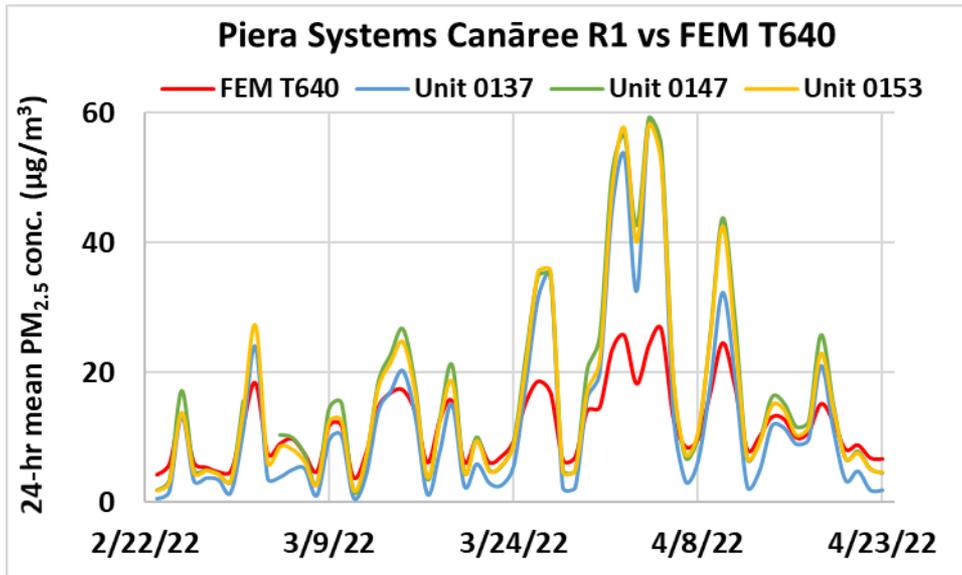
# Canāree R1 vs T640 (PM<sub>1.0</sub>; 24-hr mean)



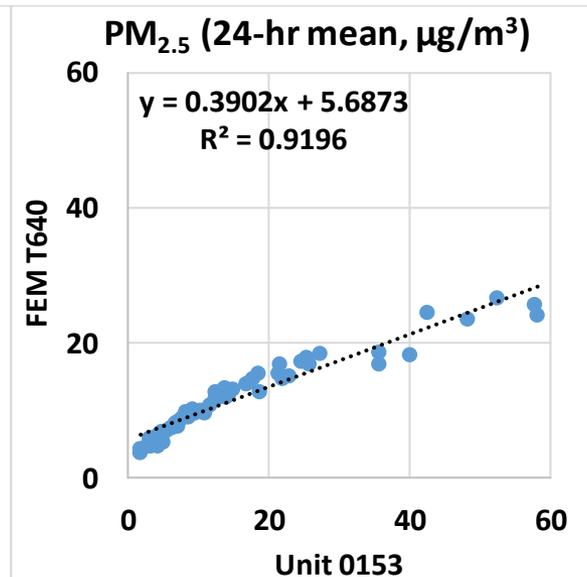
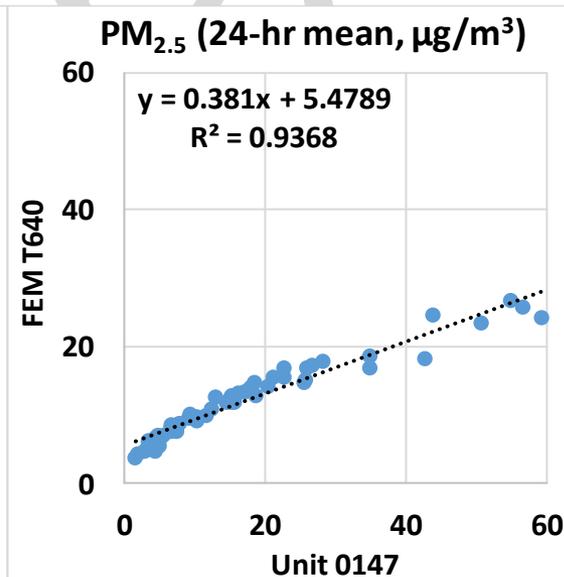
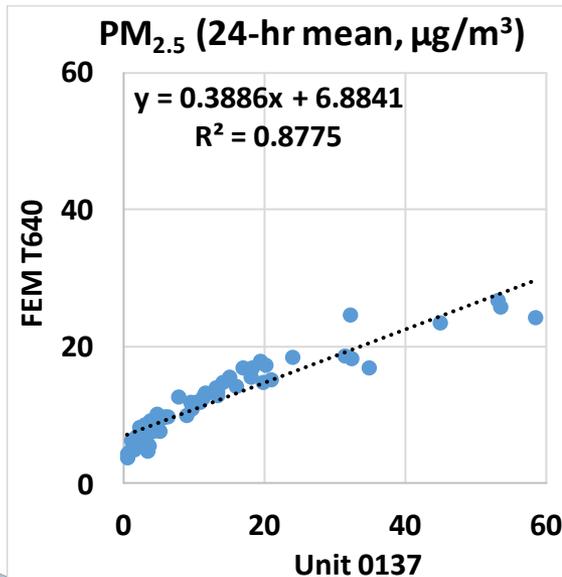
- The Canāree R1 sensors showed very strong correlations with the corresponding T640 data ( $0.93 < R^2 < 0.96$ )
- Overall, the Canāree R1 sensors overestimated the PM<sub>1.0</sub> mass concentrations as measured by T640
- The Canāree R1 sensors seemed to track the PM<sub>1.0</sub> diurnal variations as recorded by T640



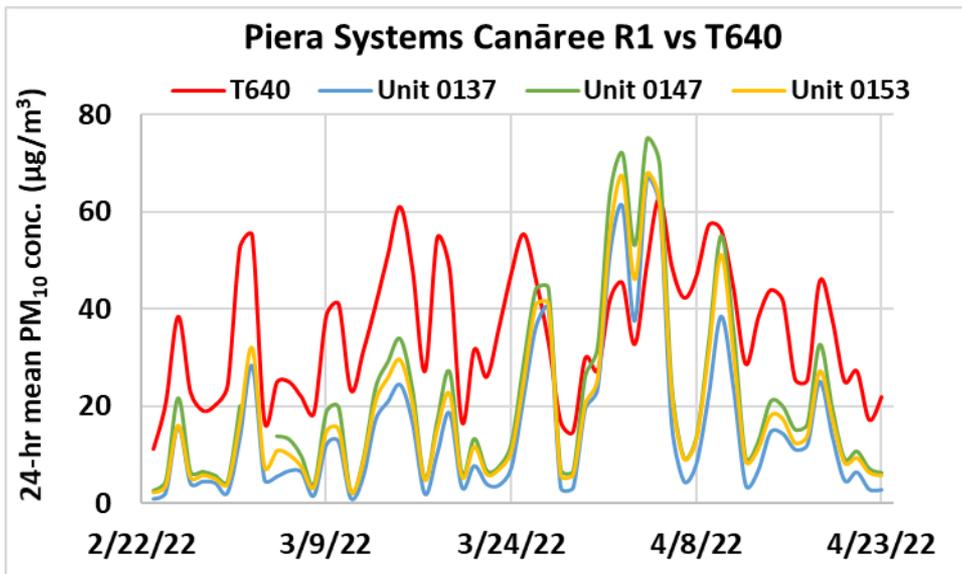
# Canāree R1 vs FEM T640 (PM<sub>2.5</sub>; 24-hr mean)



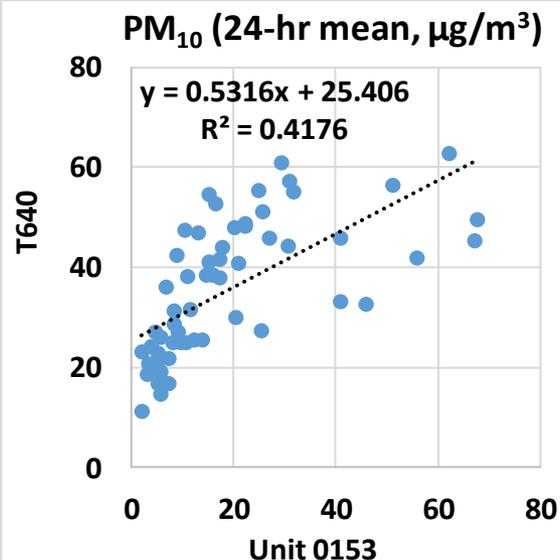
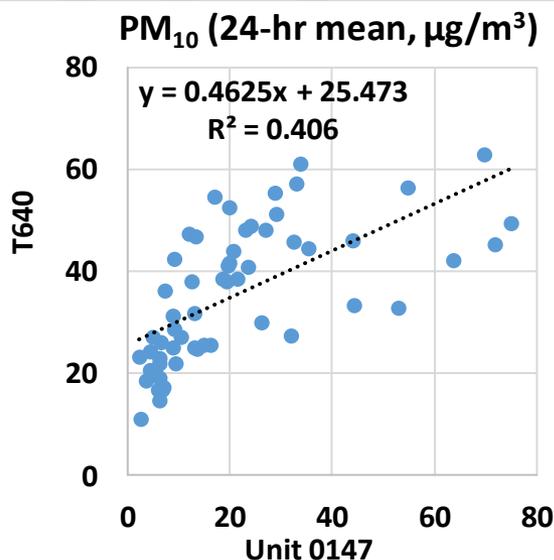
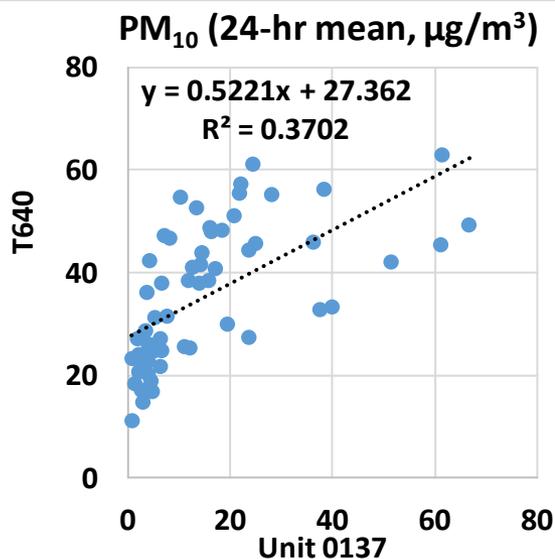
- The Canāree R1 sensors showed strong to very strong correlations with the corresponding FEM T640 data ( $0.87 < R^2 < 0.94$ )
- Overall, the Canāree R1 sensors overestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM T640
- The Canāree R1 sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM T640



# Canāree R1 vs T640 (PM<sub>10</sub>; 24-hr mean)



- The Canāree R1 sensors showed weak correlations with the corresponding T640 data ( $0.37 < R^2 < 0.42$ )
- Overall, the Canāree R1 sensors underestimated the PM<sub>10</sub> mass concentrations as measured by T640
- The Canāree R1 sensors did not seem to track the PM<sub>10</sub> diurnal variations as recorded by T640



# Summary

Average of 3 Sensors, PM <sub>1.0</sub>		Canăree R1 vs GRIMM & T640, PM <sub>1.0</sub>							GRIMM & T640 (PM <sub>1.0</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>	8.8	10.6	0.82 to 0.91	0.43 to 0.52	2.3 to 4.4	-0.1 to 2.7	3.2 to 4.5	5.2 to 6.9	6.9 to 8.1	5.4 to 5.6	0.3 to 64.1
<b>1-hr</b>	8.8	10.4	0.83 to 0.93	0.44 to 0.53	2.2 to 4.4	-0.1 to 2.7	3.1 to 4.3	5.0 to 6.7	6.9 to 8.1	5.3 to 5.4	0.3 to 37.9
<b>24-hr</b>	8.9	8.7	0.92 to 0.95	0.44 to 0.52	2.4 to 4.4	-0.1 to 2.7	2.6 to 3.5	4.2 to 5.4	7.0 to 8.2	4.2 to 4.5	1.4 to 20.3
Average of 3 Sensors, PM <sub>2.5</sub>		Canăree R1 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>	15.0	17.3	0.69 to 0.90	0.36 to 0.39	5.4 to 7.0	0.9 to 5.0	6.3 to 7.2	11.2 to 12.7	11.6 to 11.8	7.1 to 7.4	0.8 to 79.4
<b>1-hr</b>	15.0	16.9	0.71 to 0.91	0.36 to 0.40	5.4 to 7.0	0.9 to 5.0	6.1 to 7.0	10.8 to 12.3	11.6 to 11.8	7.0 to 7.2	1.0 to 47.9
<b>24-hr</b>	15.1	14.1	0.82 to 0.94	0.36 to 0.39	5.5 to 7.0	0.9 to 5.0	5.3 to 6.1	8.7 to 10.8	11.7 to 11.8	5.5 to 5.7	3.5 to 26.7
Average of 3 Sensors, PM <sub>10</sub>		Canăree R1 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>	18.4	20.5	0.19 to 0.35	0.42 to 0.60	19.5 to 26.6	-20.0 to -7.2	16.3 to 22.7	22.4 to 27.5	28.4 to 35.2	19.6 to 20.1	1.4 to 275.4
<b>1-hr</b>	18.4	20.0	0.20 to 0.37	0.42 to 0.60	19.6 to 26.5	-20.0 to -7.2	16.1 to 22.6	21.4 to 26.8	28.4 to 35.2	18.5 to 19.2	2.3 to 167.3
<b>24-hr</b>	18.5	16.7	0.22 to 0.42	0.32 to 0.53	21.5 to 27.4	-20.0 to -7.1	15.0 to 21.9	17.7 to 23.9	28.5 to 35.4	12.3 to 13.4	6.0 to 62.8

<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 **Canāree R1** sensors' data recovery from Unit 0137, Unit 0147 and Unit 0153 was ~ 100%, ~100% and ~98%, respectively for all PM measurements
- The absolute intra-model variability was ~ 0.63, ~1.65 and ~2.47  $\mu\text{g}/\text{m}^3$  for  $\text{PM}_{1.0}$ ,  $\text{PM}_{2.5}$  and  $\text{PM}_{10}$ , respectively
- Regulatory-grade instruments: Very strong correlations between GRIMM and T640 for  $\text{PM}_{1.0}$  ( $R^2 \sim 0.95$ , 1-hr mean); Very strong correlations between FEM GRIMM and FEM T640 for  $\text{PM}_{2.5}$  ( $R^2 \sim 0.94$ , 1-hr mean) and very strong correlations between GRIMM and T640 for  $\text{PM}_{10}$  ( $R^2 \sim 0.93$ , 1-hr mean) mass concentration measurements
- $\text{PM}_{1.0}$  mass concentrations measured by the Canāree R1 sensors showed strong to very strong correlations with the corresponding GRIMM and T640 data ( $0.83 < R^2 < 0.93$ , 1-hr mean). The sensors overestimated  $\text{PM}_{1.0}$  mass concentrations as measured by GRIMM and T640
- $\text{PM}_{2.5}$  mass concentrations measured by the Canāree R1 sensors showed strong to very strong correlations with the corresponding FEM GRIMM and FEM T640 data ( $0.71 < R^2 < 0.92$ , 1-hr mean). The sensors overestimated  $\text{PM}_{2.5}$  mass concentrations as measured by FEM GRIMM and FEM T640
- $\text{PM}_{10}$  mass concentrations measured by the Canāree R1 sensors showed very weak to weak correlations with the corresponding GRIMM and T640 data ( $0.20 < R^2 < 0.38$ ; 1-hr mean). The sensors underestimated  $\text{PM}_{10}$  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