

# Field Evaluation Davis Instruments - Airlink



# Background

- From 04/02/2021 to 06/01/2021, three **Davis Instruments Airlink** (hereinafter **Airlink**) 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
- Airlink (3 units tested):
  - Particle sensor: **optical; non-FEM (PMSA003, Plantower)**
  - Each unit reports: PM<sub>1.0</sub>, PM<sub>2.5</sub> and PM<sub>10</sub> (µg/m<sup>3</sup>), Temperature (°F), RH (%)
  - **Unit cost: \$179**
  - Time resolution: 1-min
  - Units IDs: 023B, 023F, 0206
- GRIMM (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

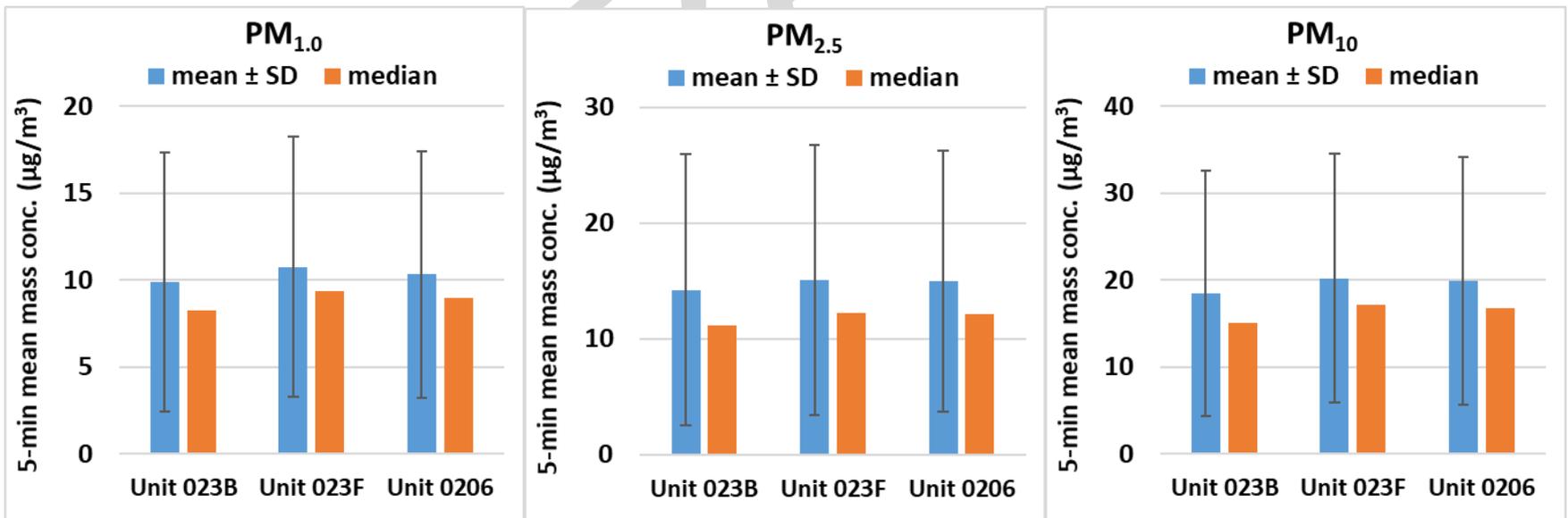


# Data validation & recovery

- 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  $\sim 100\%$  for all PM measurements

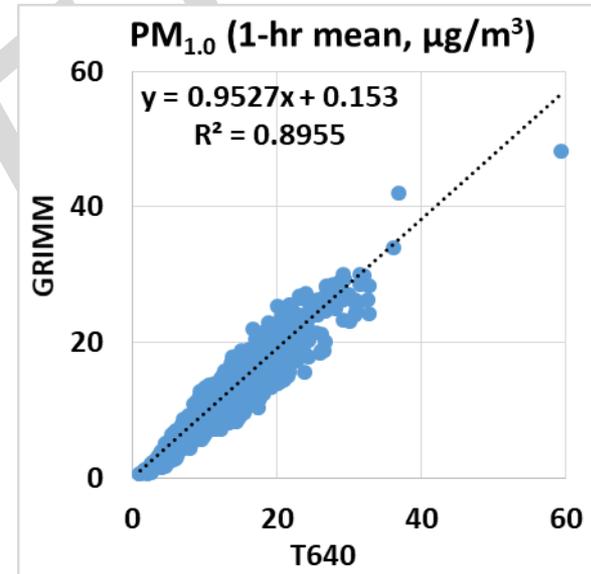
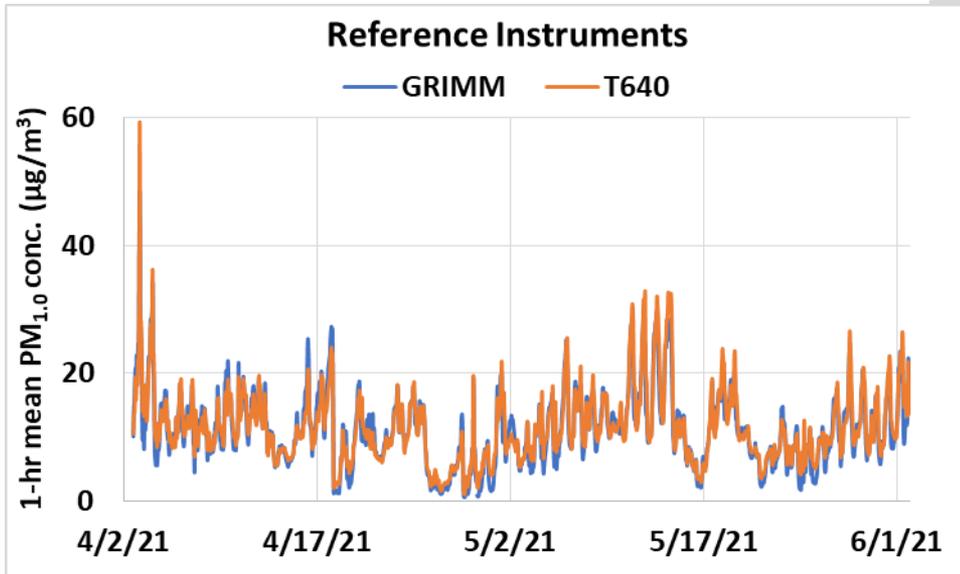
## Airlink; intra-model variability

- Absolute intra-model variability was  $\sim 0.35$ ,  $0.37$  and  $0.75 \mu\text{g}/\text{m}^3$  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  $\sim 3.4\%$ ,  $2.5\%$  and  $3.8\%$  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)



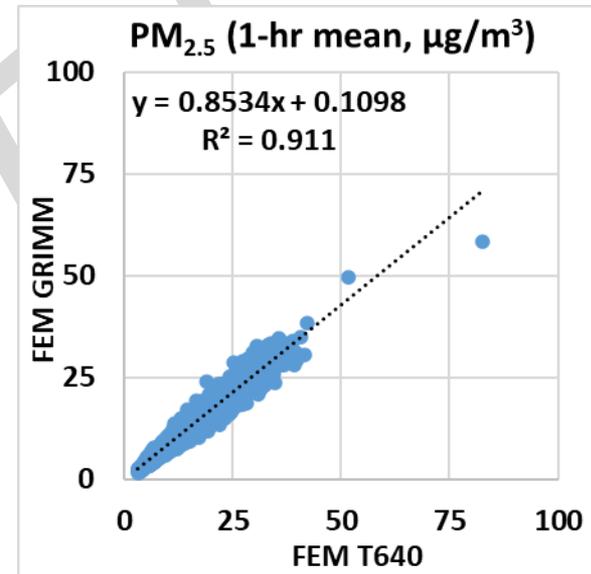
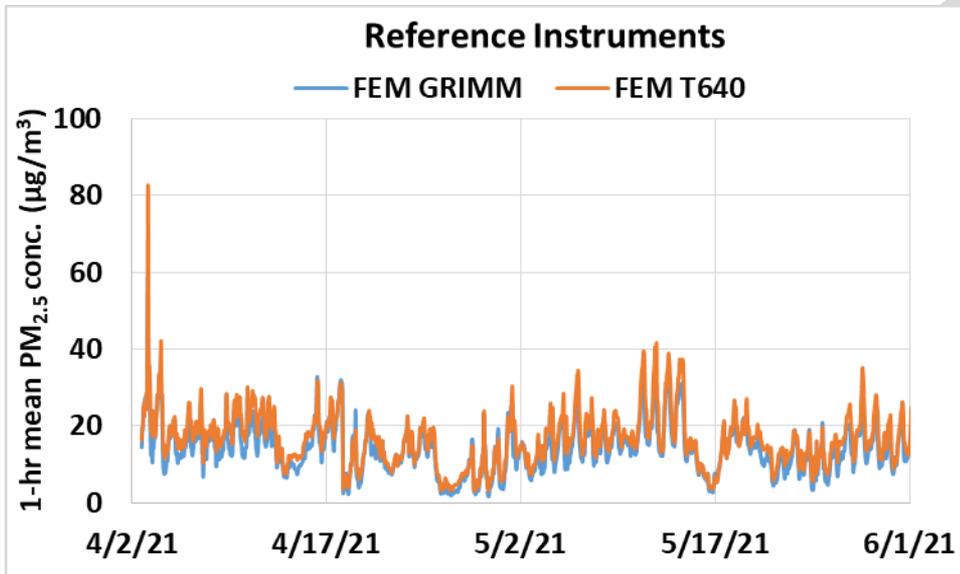
# Reference Instruments: PM<sub>1.0</sub> GRIMM and T640

- Data recovery for PM<sub>1.0</sub> from GRIMM and T640 was ~ 100%.
- Strong correlations between the reference instruments for PM<sub>1.0</sub> measurements ( $R^2 \sim 0.90$ ) were observed.



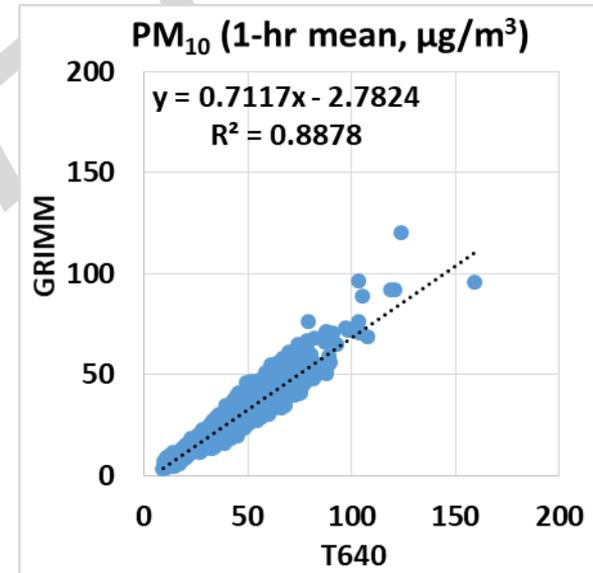
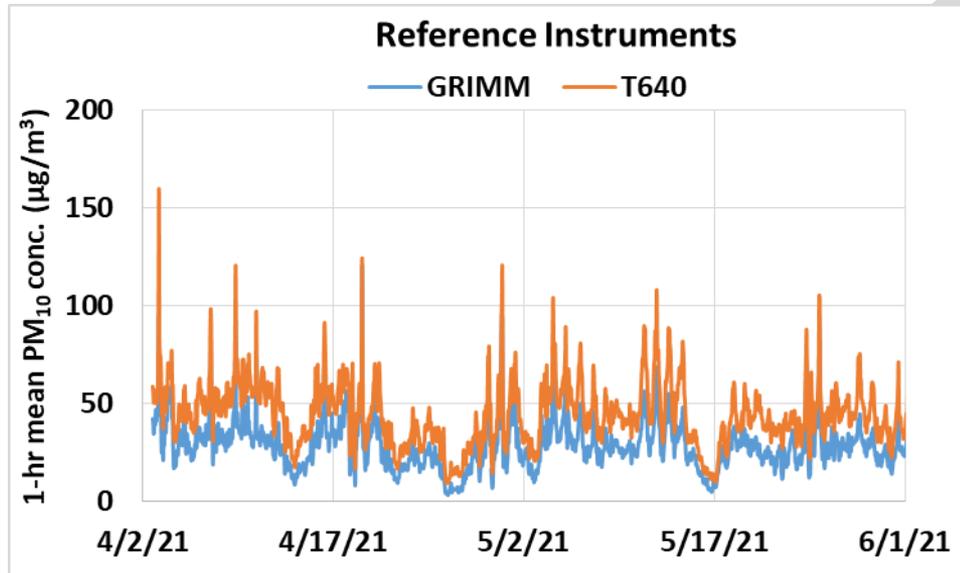
# Reference Instruments: PM<sub>2.5</sub> FEM GRIMM and FEM T640

- 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 ( $R^2 \sim 0.91$ ) were observed.

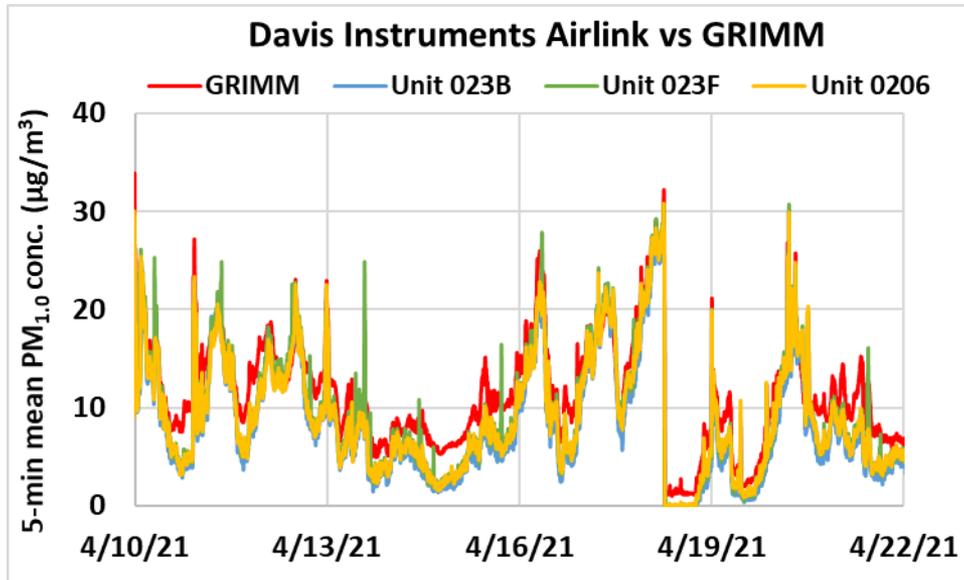


# Reference Instruments: PM<sub>10</sub> GRIMM and T640

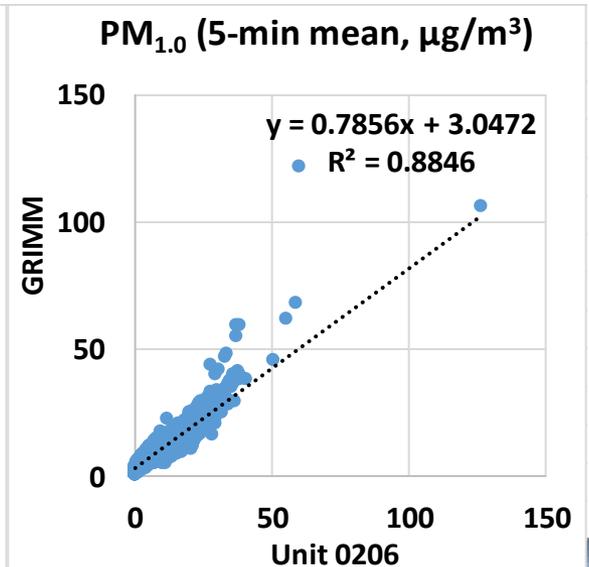
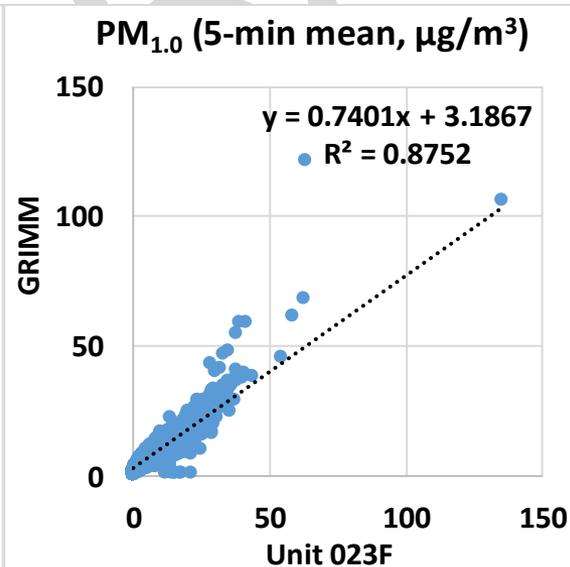
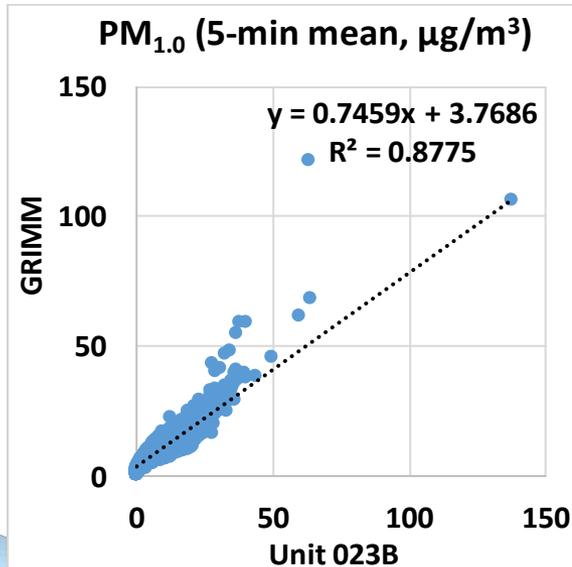
- Data recovery for PM<sub>10</sub> from GRIMM and T640 was ~ 100%.
- Strong correlations between the reference instruments for PM<sub>10</sub> measurements ( $R^2 \sim 0.89$ ) were observed.



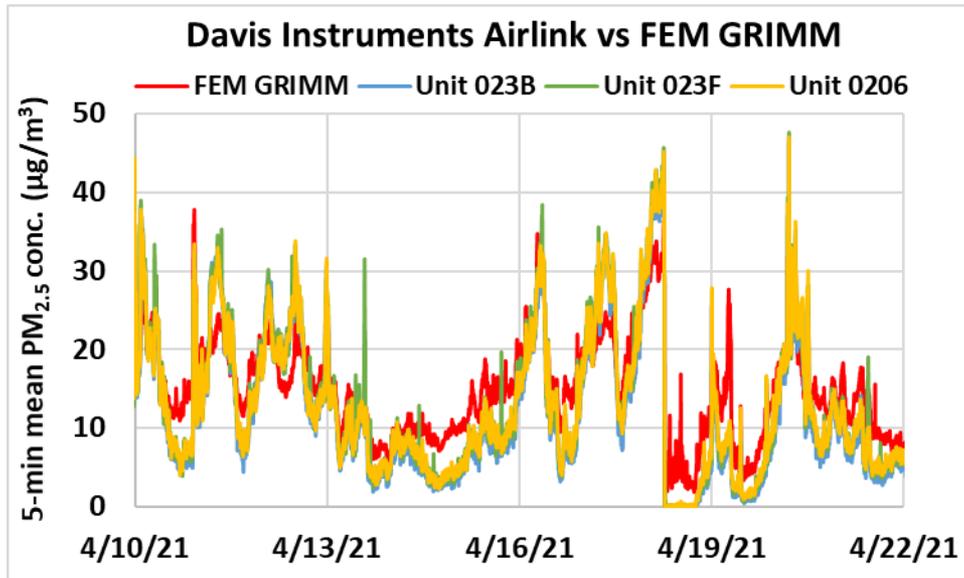
# Airlink vs GRIMM (PM<sub>1.0</sub>; 5-min mean)



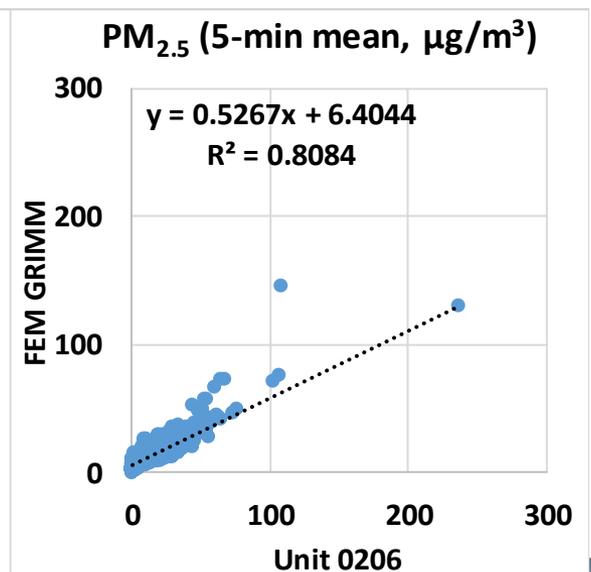
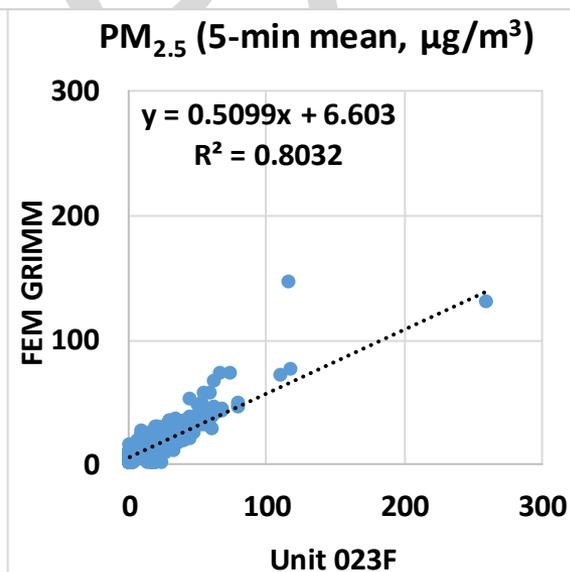
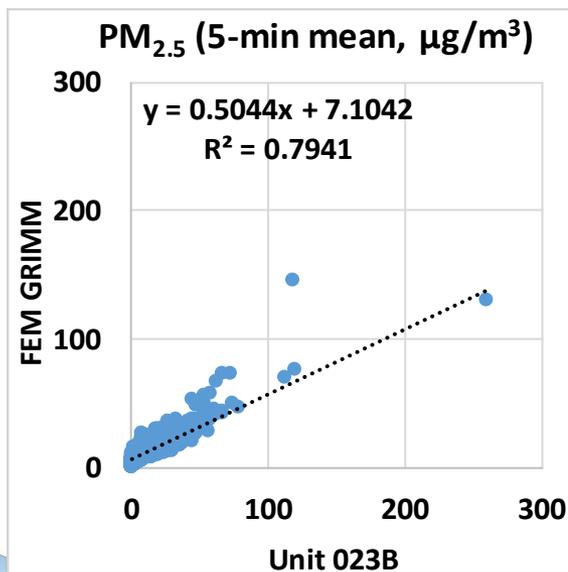
- The Airlink sensors showed strong correlations with the corresponding GRIMM data ( $0.87 < R^2 < 0.89$ )
- Overall, the Airlink sensors underestimated the PM<sub>1.0</sub> mass concentrations as measured by GRIMM
- The Airlink sensors seemed to track the PM<sub>1.0</sub> diurnal variations as recorded by GRIMM



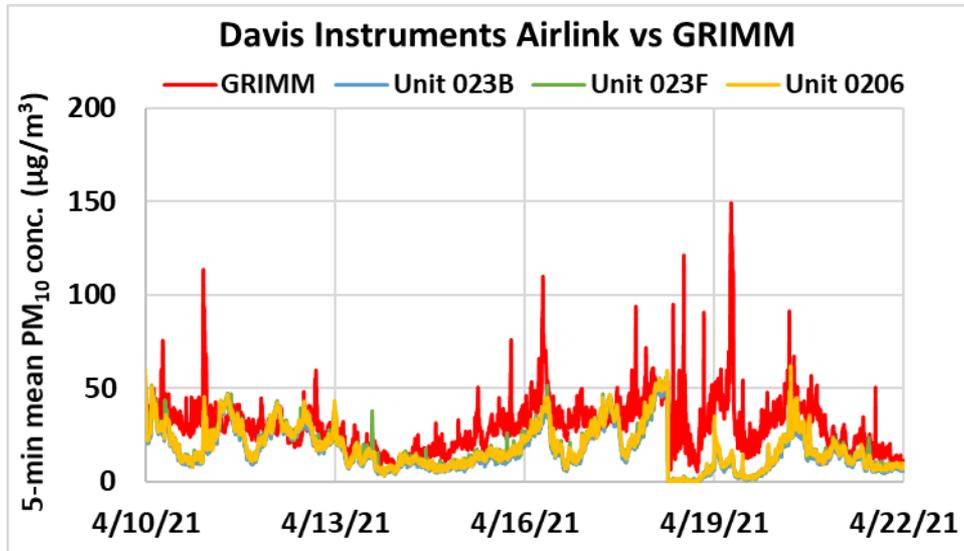
# Airlink vs FEM GRIMM (PM<sub>2.5</sub>; 5-min mean)



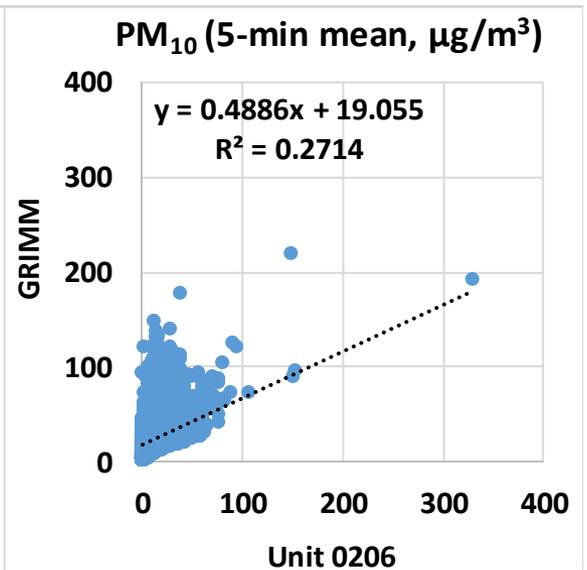
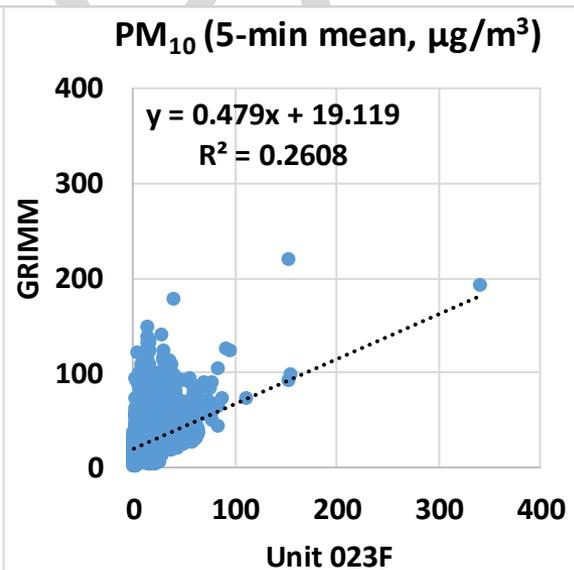
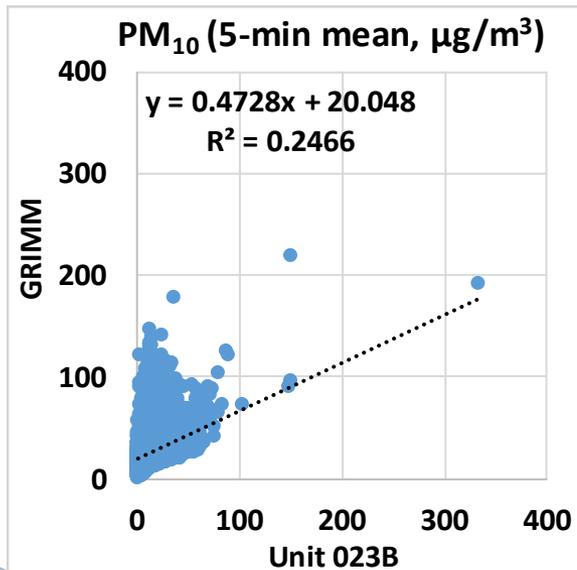
- The Airlink sensors showed strong correlations with the corresponding FEM GRIMM data ( $0.79 < R^2 < 0.81$ )
- Overall, the Airlink sensors overestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM GRIMM
- The Airlink sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM GRIMM



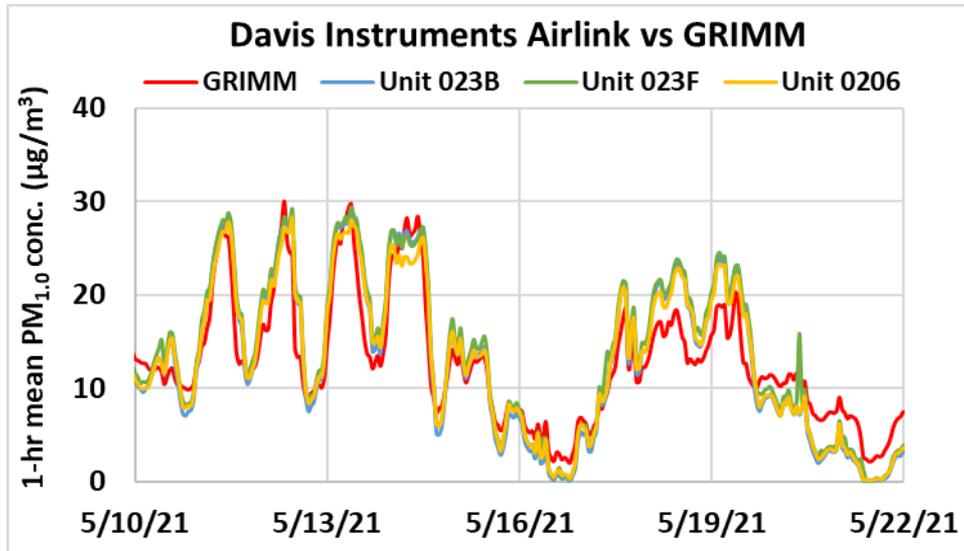
# Airlink vs GRIMM (PM<sub>10</sub>; 5-min mean)



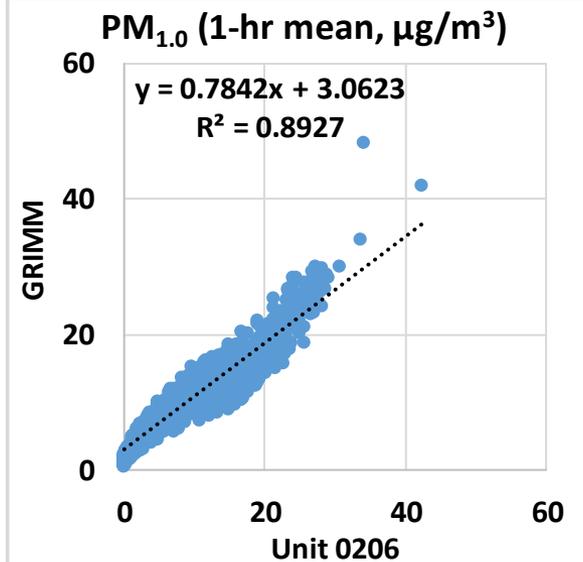
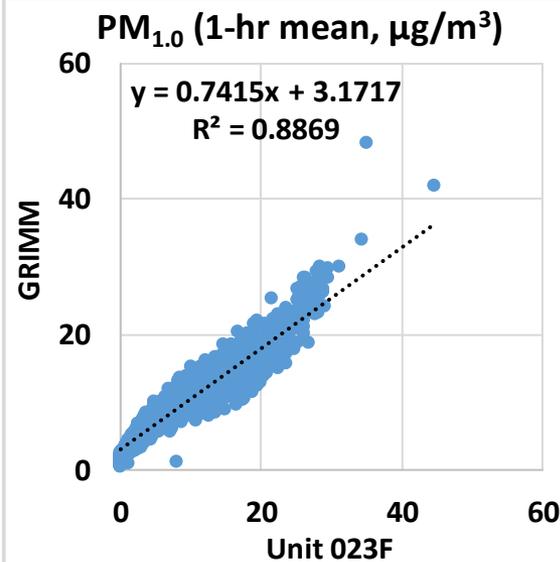
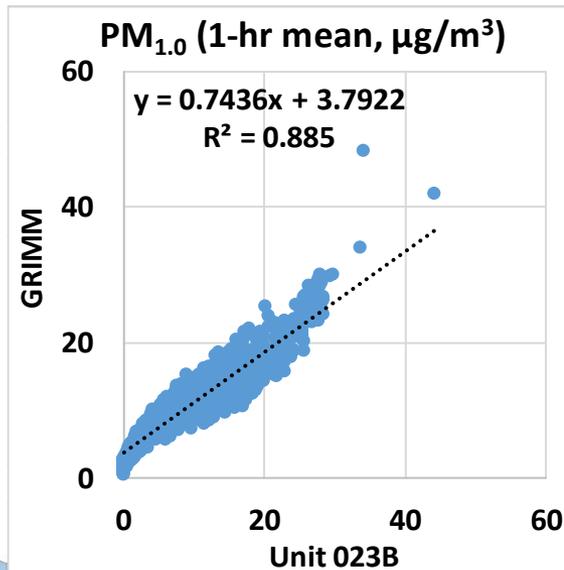
- The Airlink sensors showed very weak correlations with the corresponding GRIMM data ( $0.24 < R^2 < 0.28$ )
- Overall, the Airlink sensors underestimated the PM<sub>10</sub> mass concentrations as measured by GRIMM
- The Airlink sensors did not seem to track the PM<sub>10</sub> diurnal variations as recorded by GRIMM



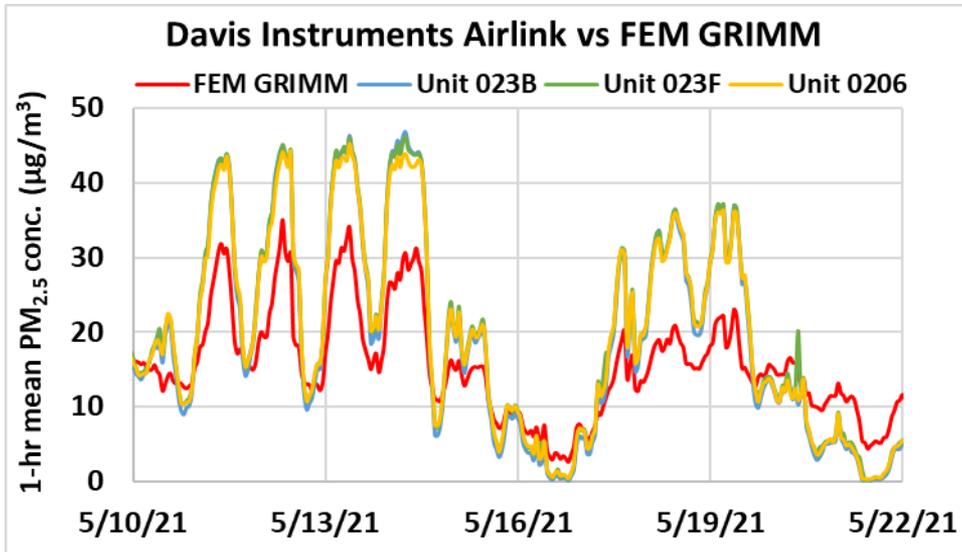
# Airlink vs GRIMM (PM<sub>1.0</sub>; 1-hr mean)



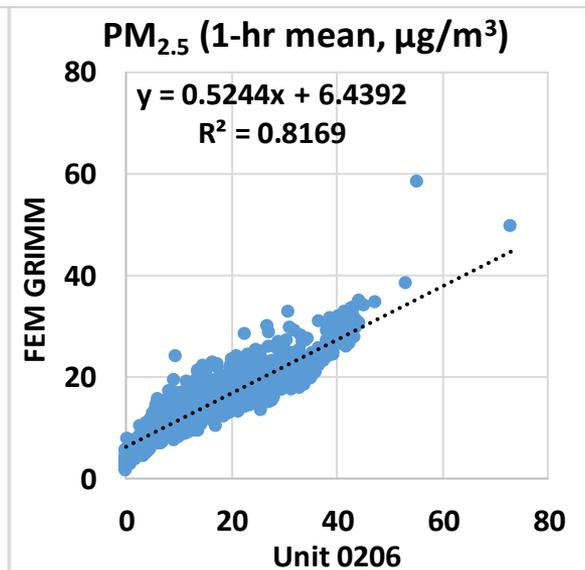
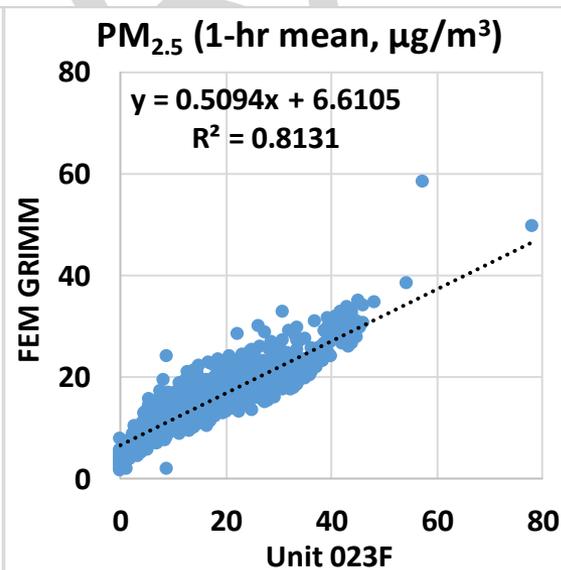
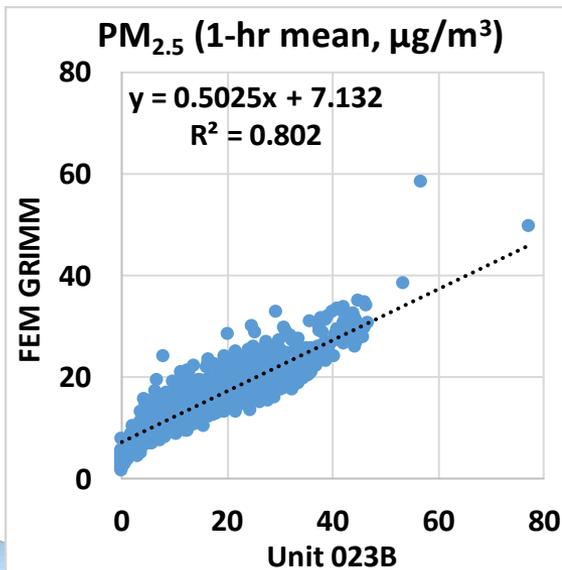
- The Airlink sensors showed strong correlations with the corresponding GRIMM data ( $0.88 < R^2 < 0.90$ )
- Overall, the Airlink sensors underestimated the PM<sub>1.0</sub> mass concentrations as measured by GRIMM
- The Airlink sensors seemed to track the PM<sub>1.0</sub> diurnal variations as recorded by GRIMM



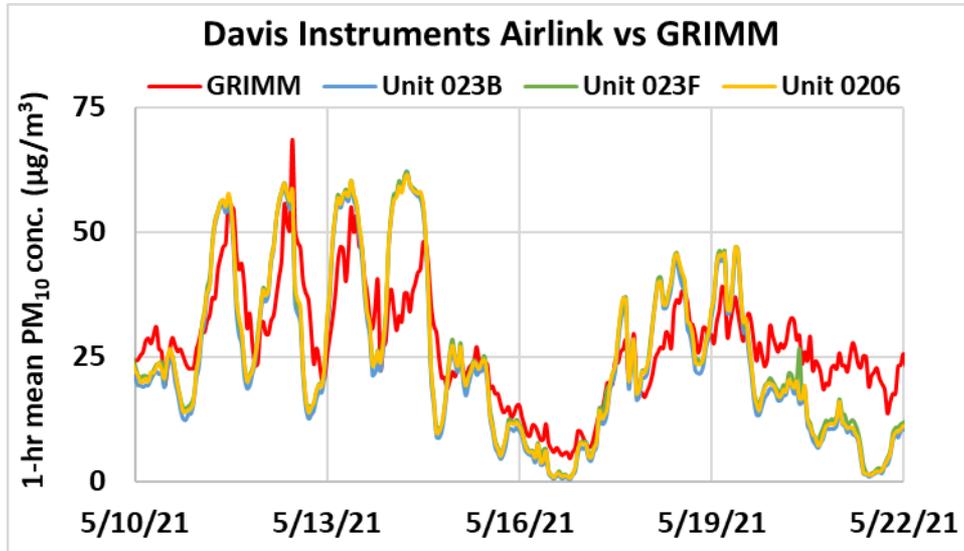
# Airlink vs FEM GRIMM (PM<sub>2.5</sub>; 1-hr mean)



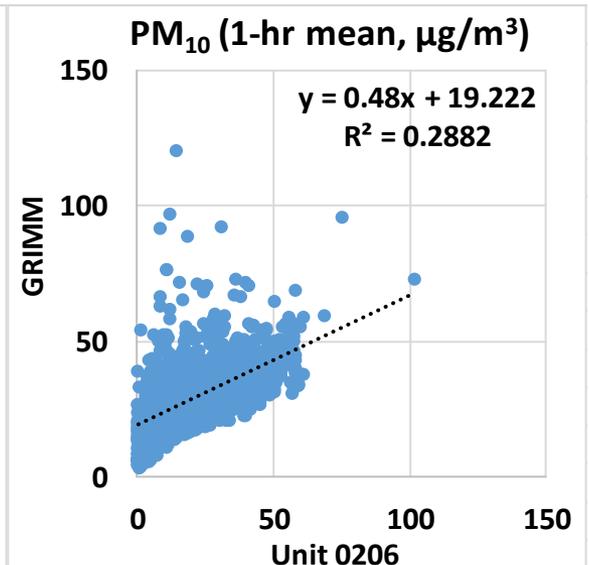
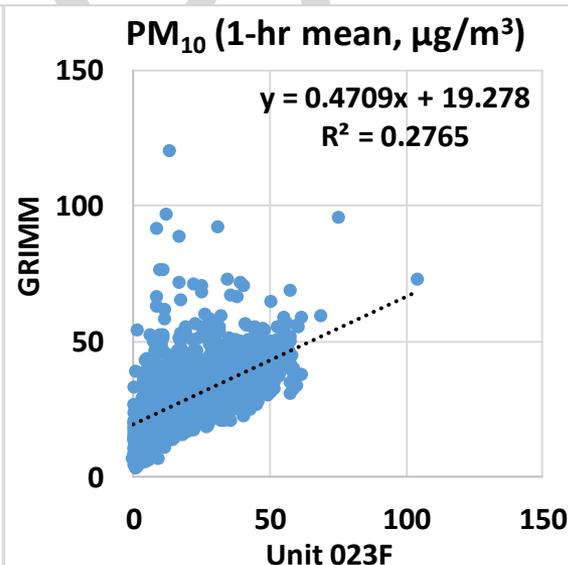
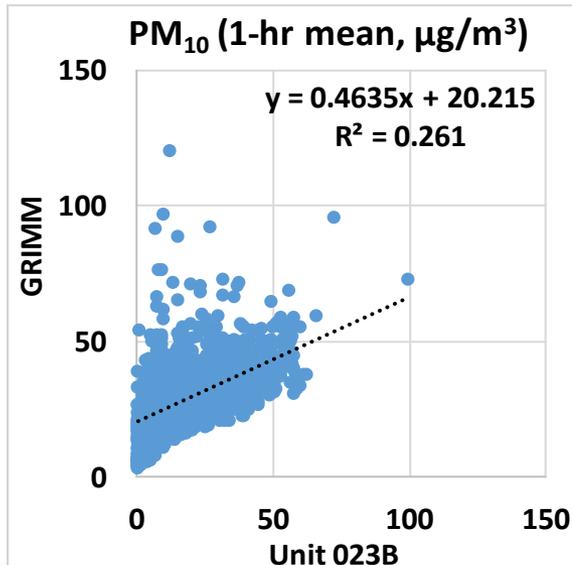
- The Airlink sensors showed strong correlations with the corresponding FEM GRIMM data ( $0.80 < R^2 < 0.82$ )
- Overall, the Airlink sensors overestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM GRIMM
- The Airlink sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM GRIMM



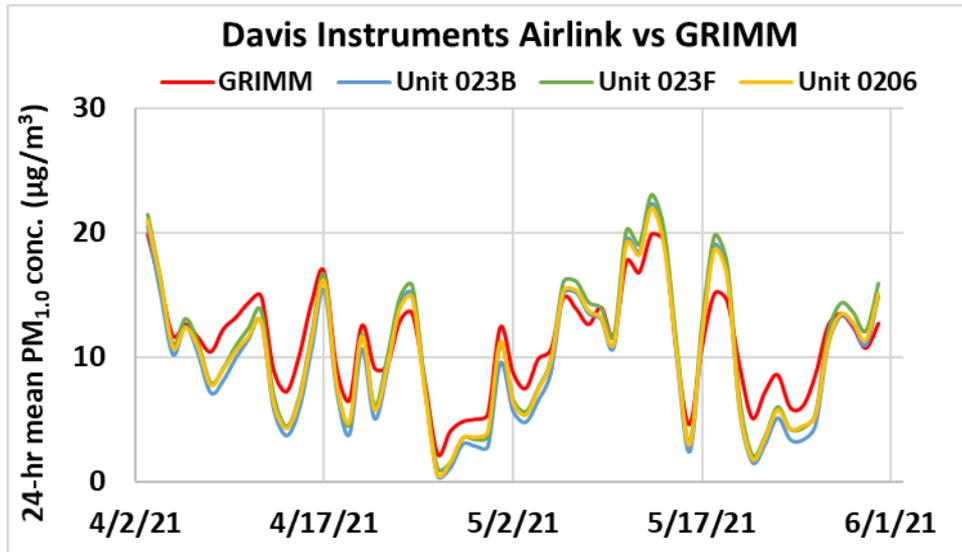
# Airlink vs GRIMM (PM<sub>10</sub>; 1-hr mean)



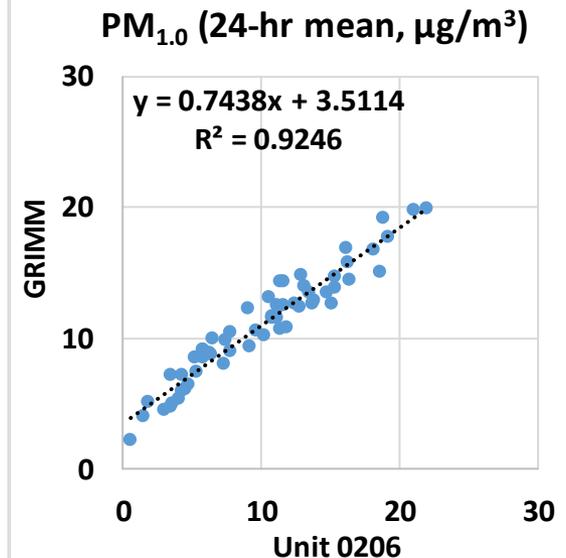
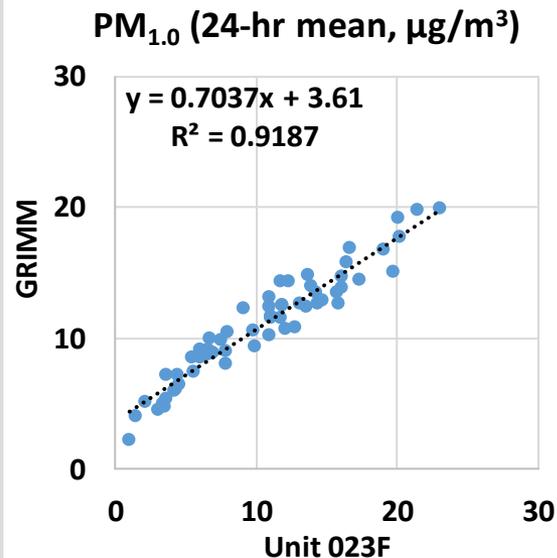
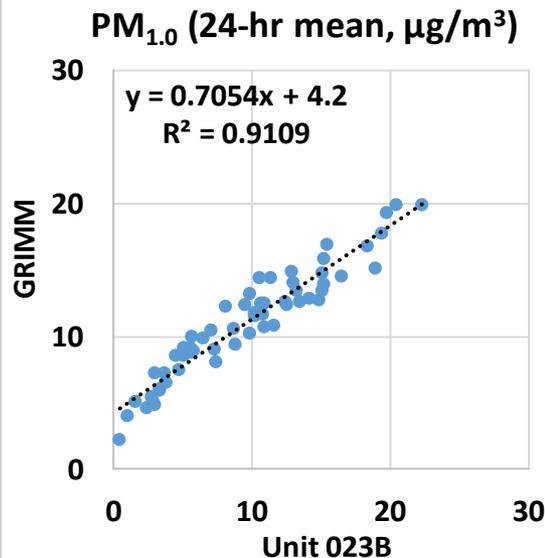
- The Airlink sensors showed very weak correlations with the corresponding GRIMM data ( $0.26 < R^2 < 0.29$ )
- Overall, the Airlink sensors underestimated the PM<sub>10</sub> mass concentrations as measured by GRIMM
- The Airlink sensors did not seem to track the PM<sub>10</sub> diurnal variations as recorded by GRIMM



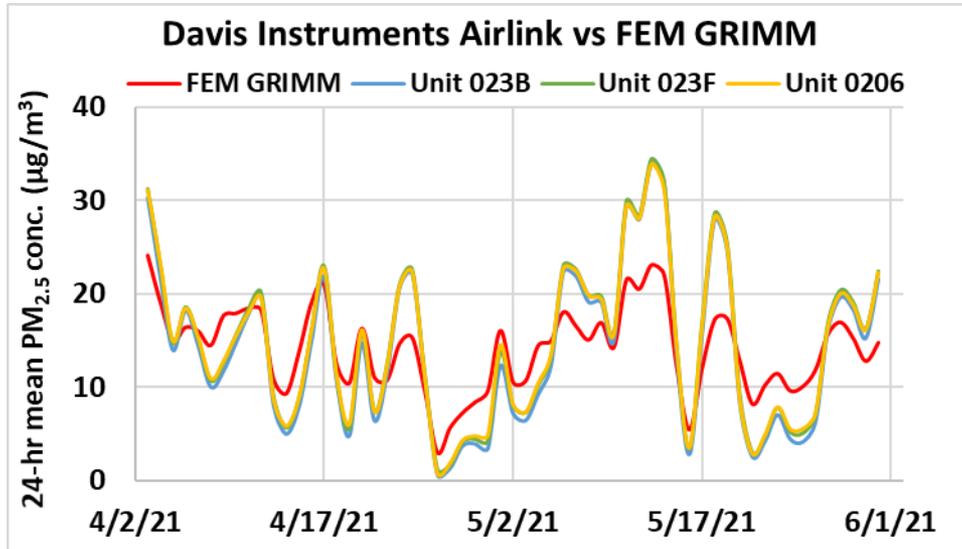
# Airlink vs GRIMM (PM<sub>1.0</sub>; 24-hr mean)



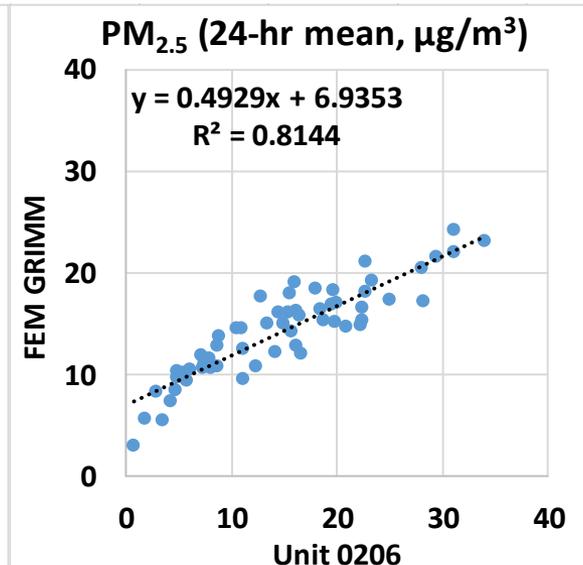
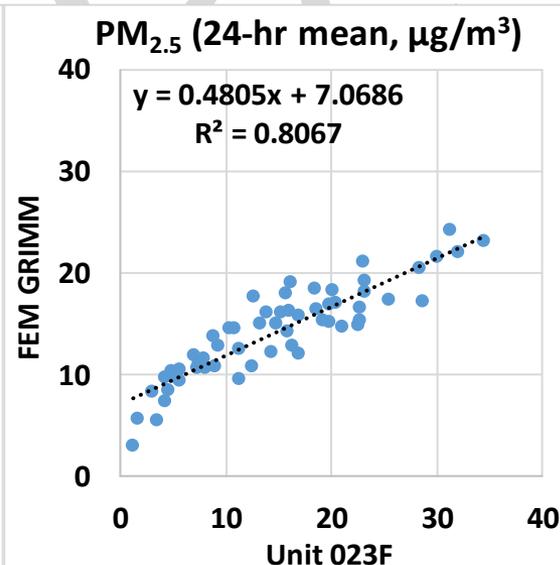
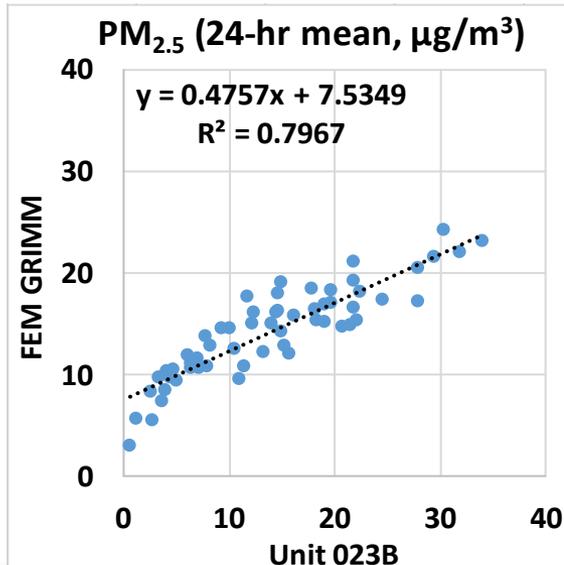
- The Airlink sensors showed very strong correlations with the corresponding GRIMM data ( $0.91 < R^2 < 0.93$ )
- Overall, the Airlink sensors underestimated the PM<sub>1.0</sub> mass concentrations as measured by GRIMM
- The Airlink sensors seemed to track the PM<sub>1.0</sub> diurnal variations as recorded by GRIMM



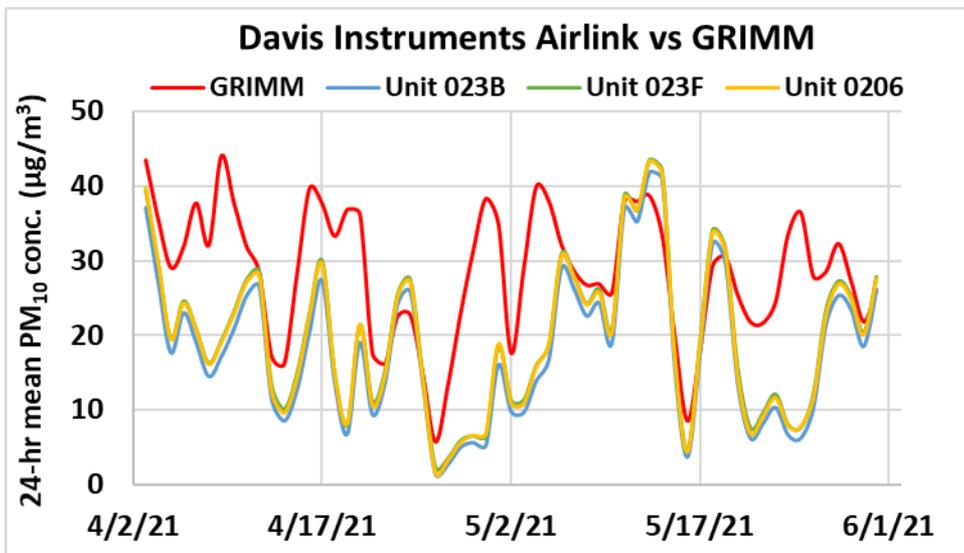
# Airlink vs FEM GRIMM (PM<sub>2.5</sub>; 24-hr mean)



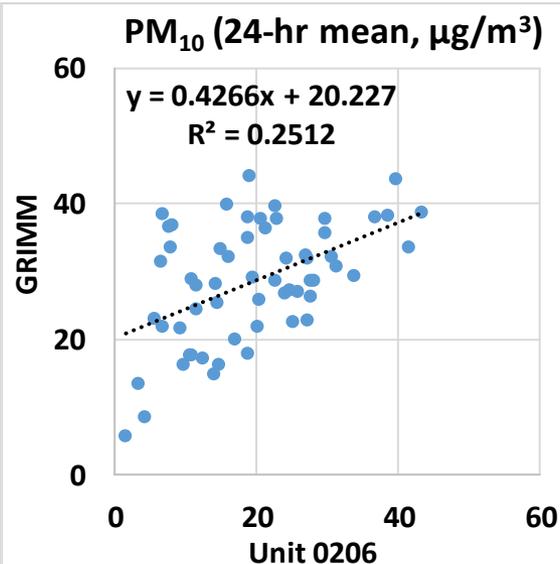
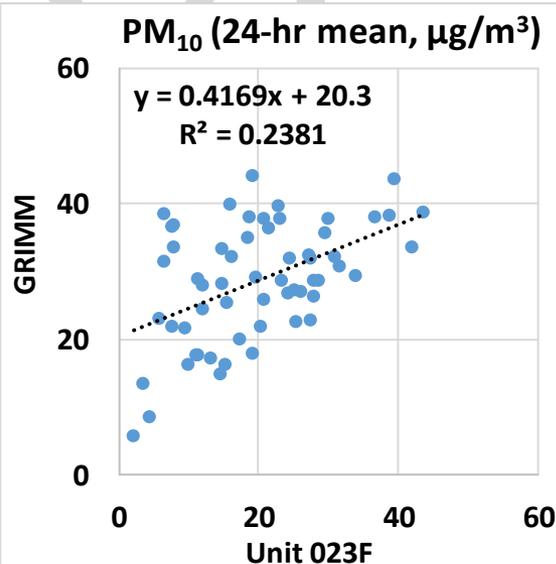
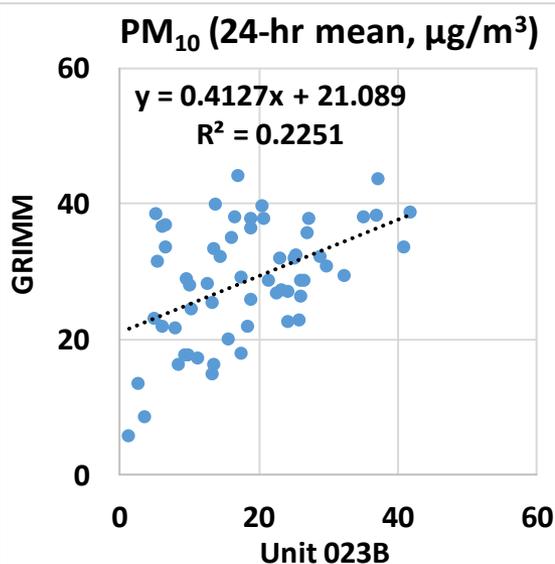
- The Airlink sensors showed strong correlations with the corresponding FEM GRIMM data ( $0.79 < R^2 < 0.82$ )
- Overall, the Airlink sensors overestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM GRIMM
- The Airlink sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM GRIMM



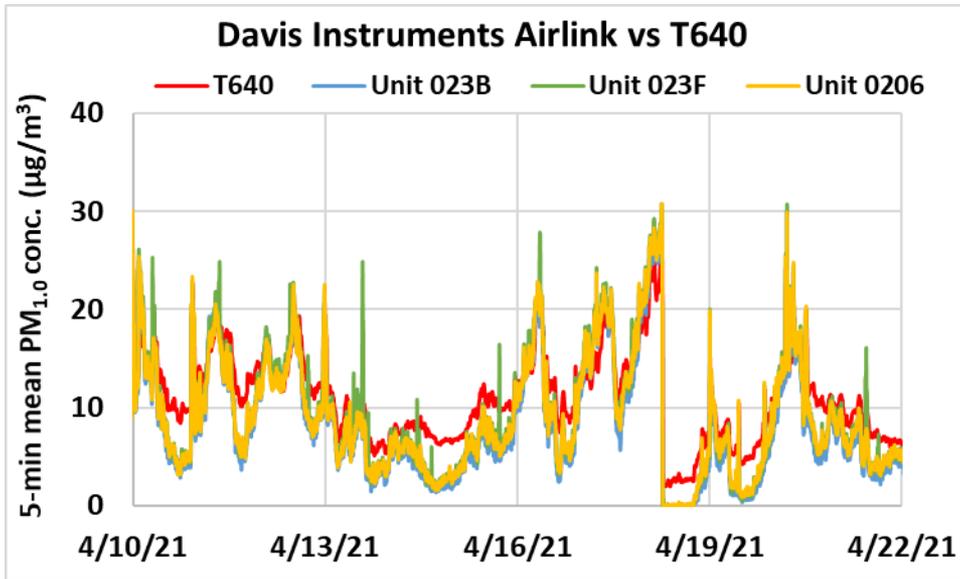
# Airlink vs GRIMM (PM<sub>10</sub>; 24-hr mean)



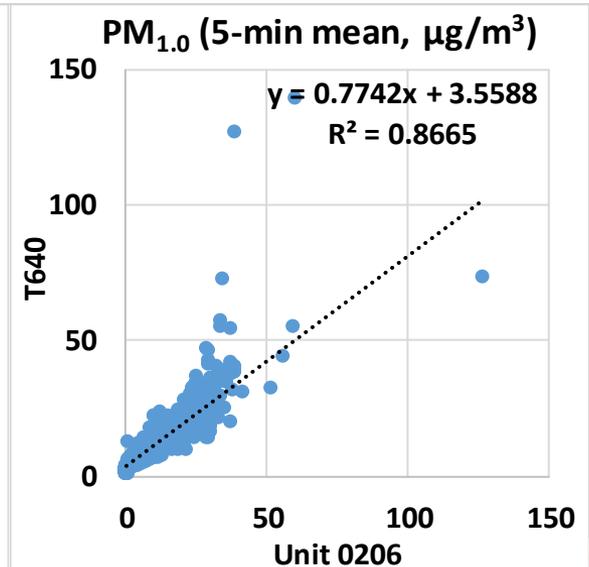
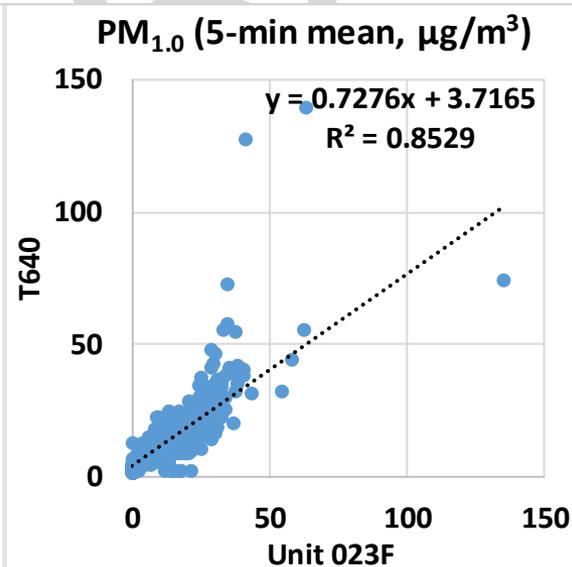
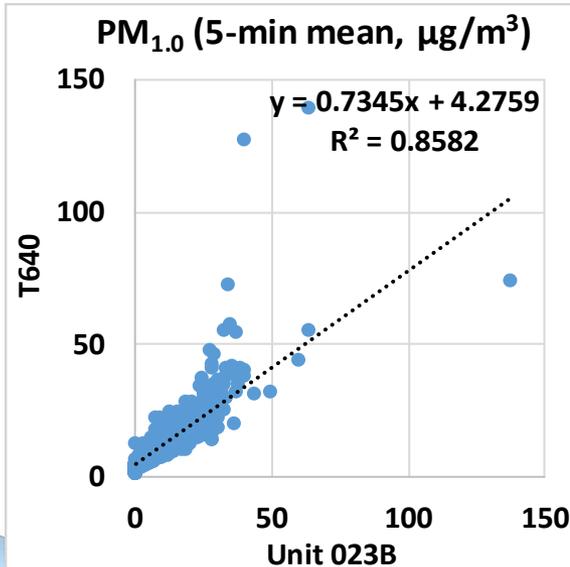
- The Airlink sensors showed very weak correlations with the corresponding GRIMM data ( $0.22 < R^2 < 0.26$ )
- Overall, the Airlink sensors underestimated the PM<sub>10</sub> mass concentrations as measured by GRIMM
- The Airlink sensors did not seem to track the PM<sub>10</sub> diurnal variations as recorded by GRIMM



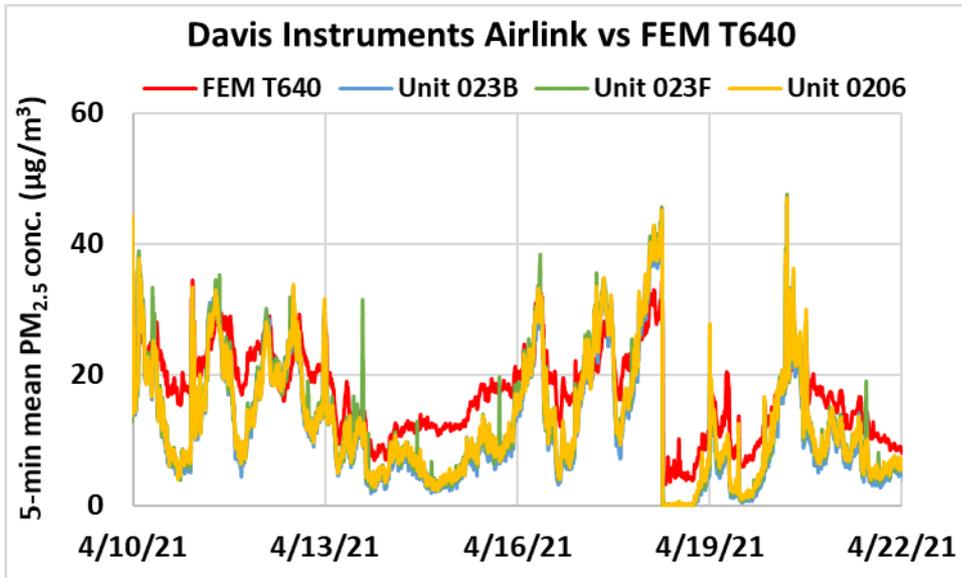
# Airlink vs T640 (PM<sub>1.0</sub>; 5-min mean)



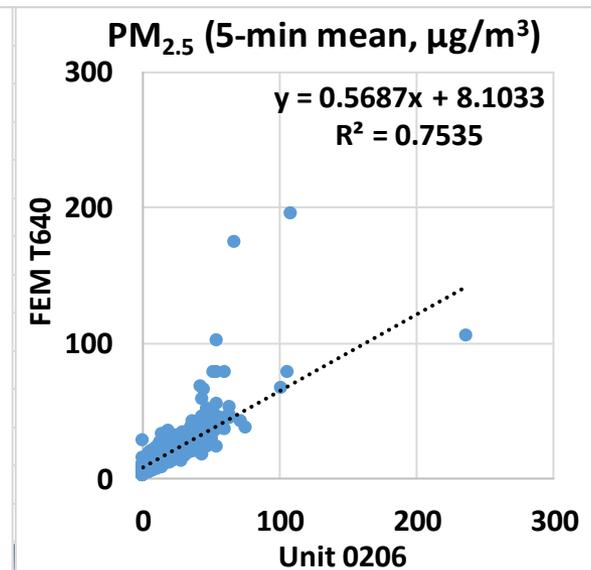
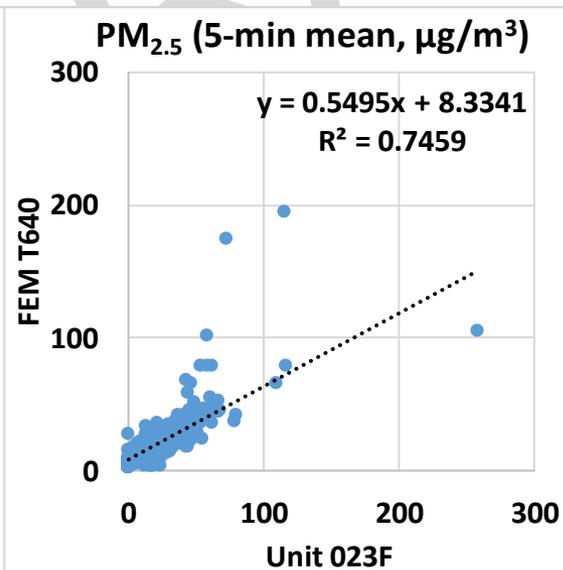
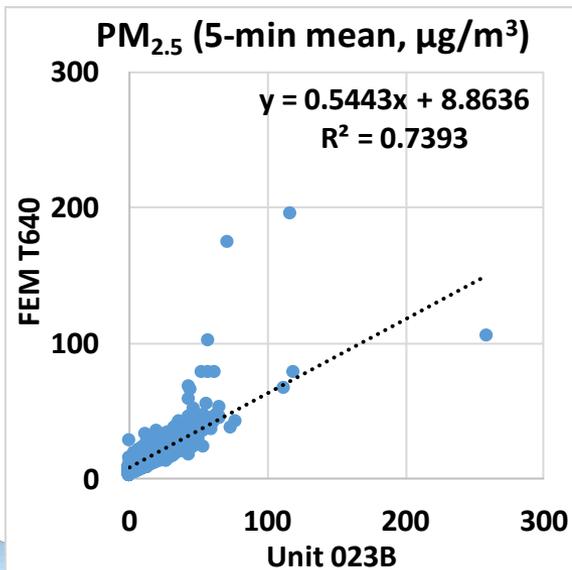
- The Airlink sensors showed strong correlations with the corresponding T640 data ( $0.85 < R^2 < 0.87$ )
- Overall, the Airlink sensors underestimated the PM<sub>1.0</sub> mass concentrations as measured by T640
- The Airlink sensors seemed to track the PM<sub>1.0</sub> diurnal variations as recorded by T640



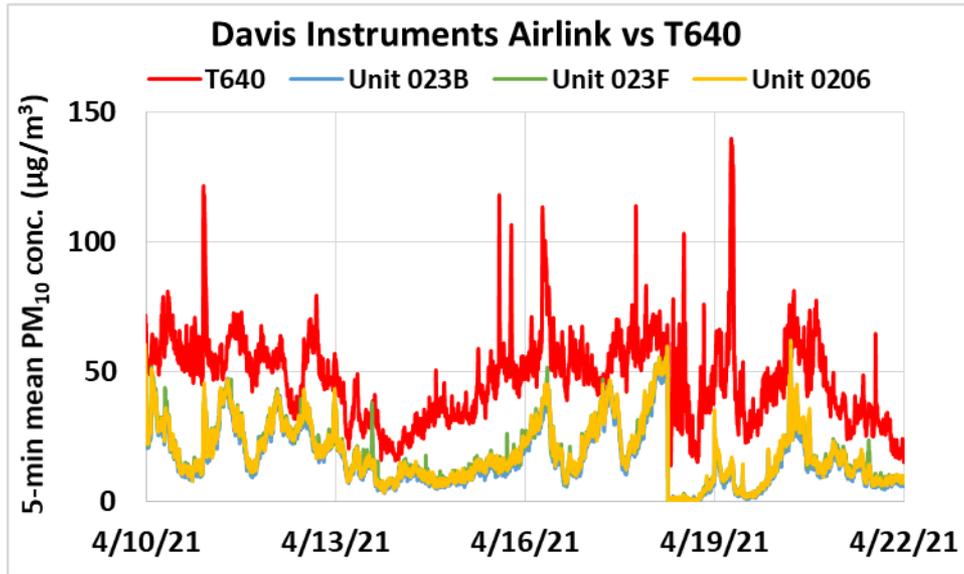
# Airlink vs FEM T640 (PM<sub>2.5</sub>; 5-min mean)



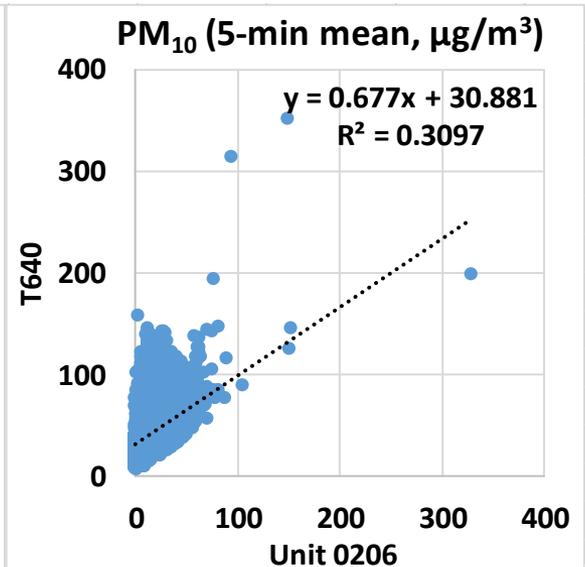
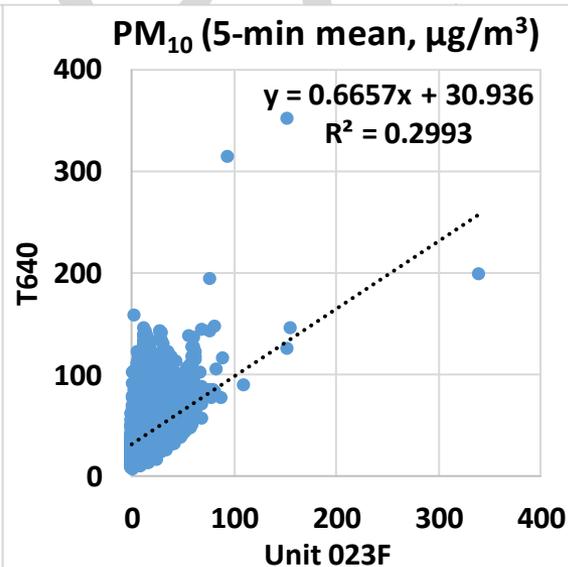
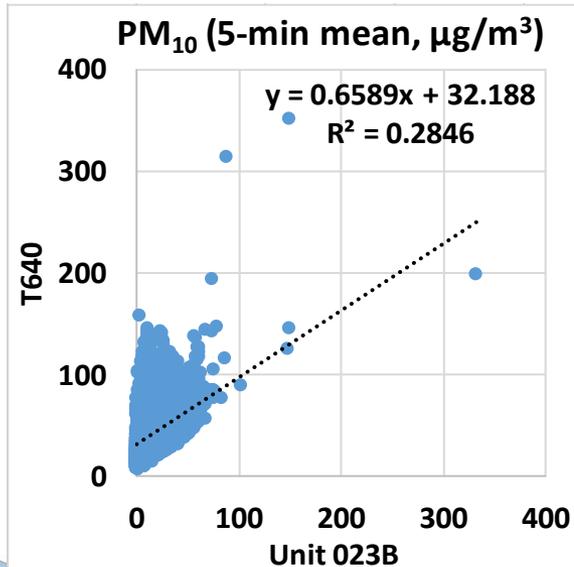
- The Airlink sensors showed strong correlations with the corresponding FEM T640 data ( $0.73 < R^2 < 0.76$ )
- Overall, the Airlink sensors underestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM T640
- The Airlink sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM T640



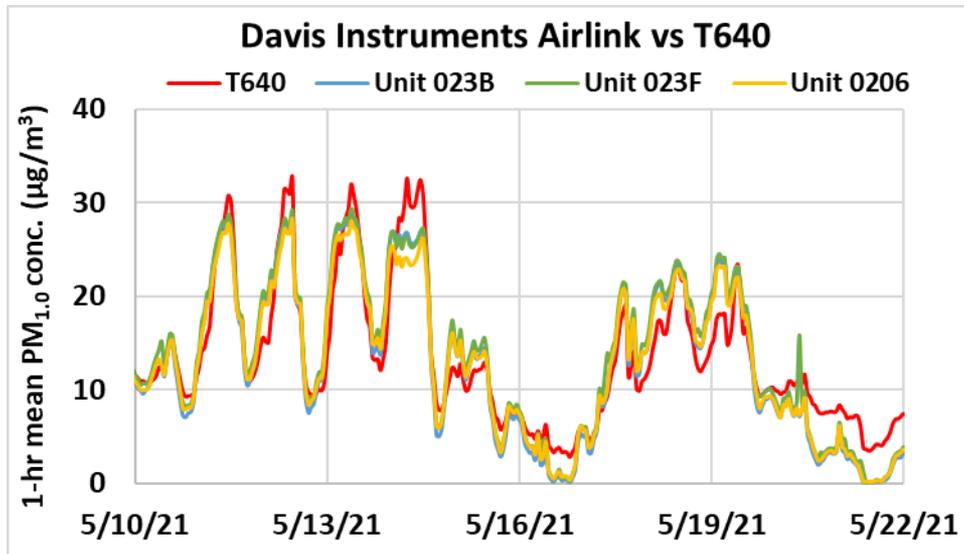
# Airlink vs T640 (PM<sub>10</sub>; 5-min mean)



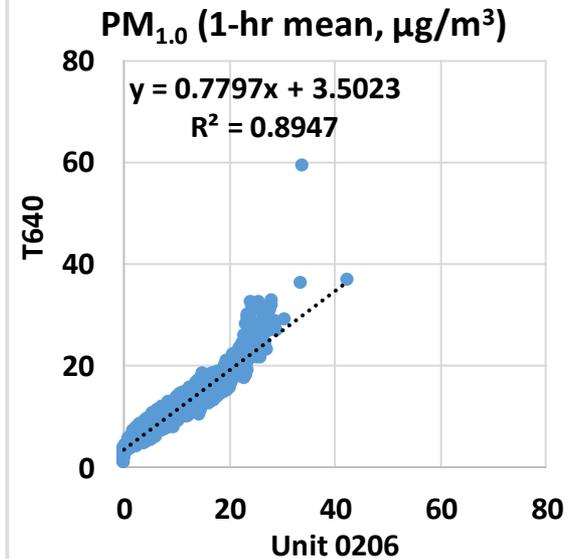
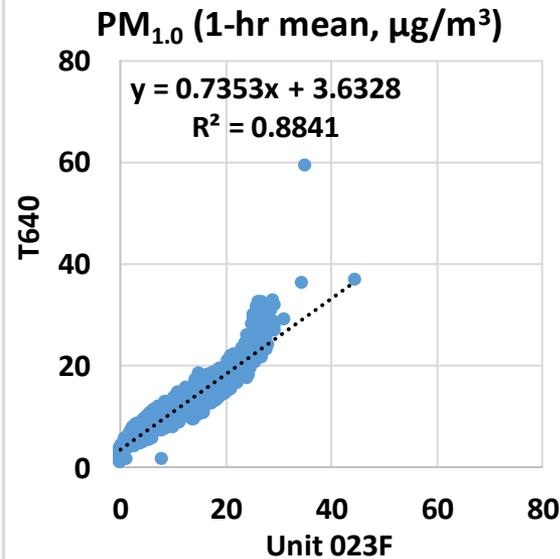
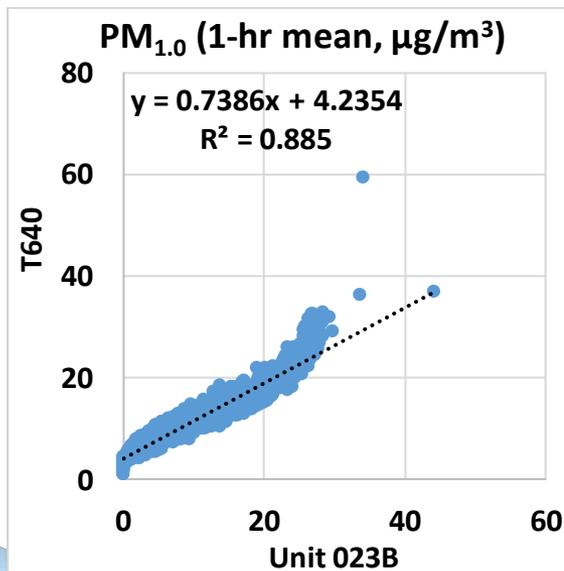
- Airlink sensors showed very weak to weak correlations with the corresponding T640 data ( $0.28 < R^2 < 0.31$ )
- Overall, the Airlink sensors underestimated the PM<sub>10</sub> mass concentrations as measured by T640
- The Airlink sensors did not seem to track the PM<sub>10</sub> diurnal variations as recorded by T640



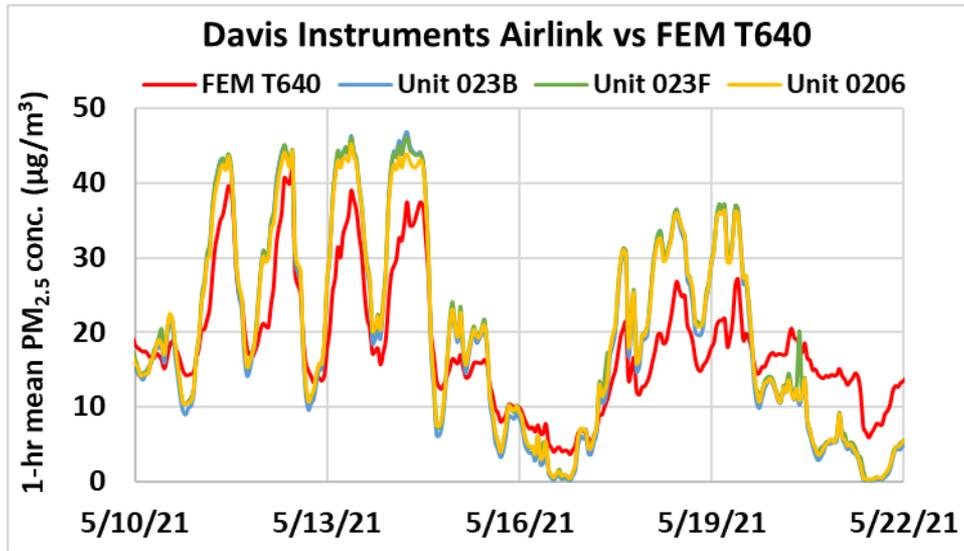
# Airlink vs T640 (PM<sub>1.0</sub>; 1-hr mean)



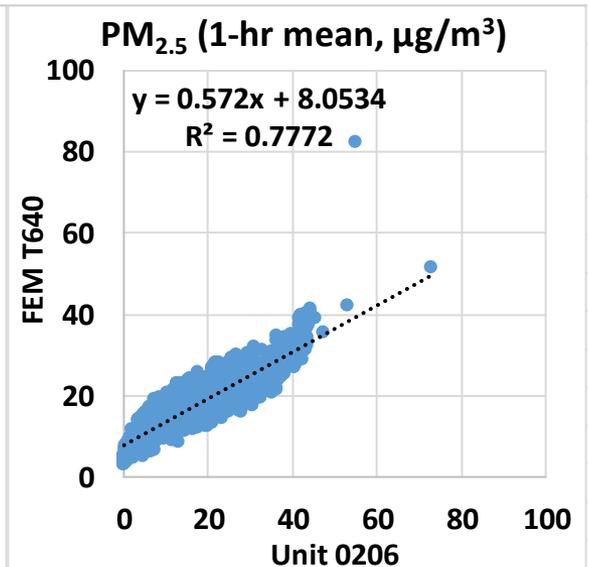
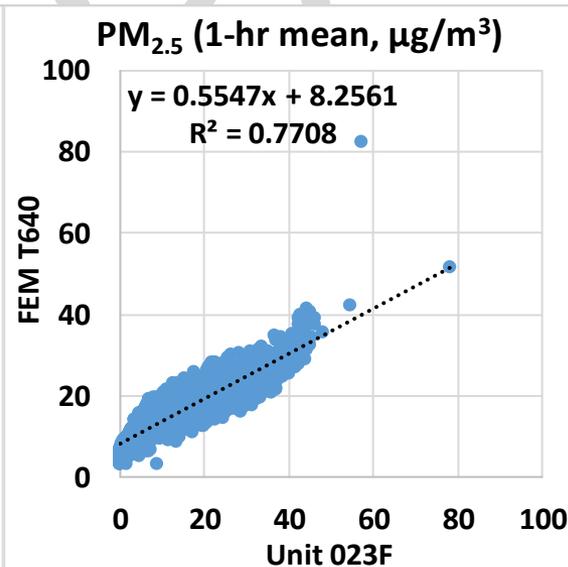
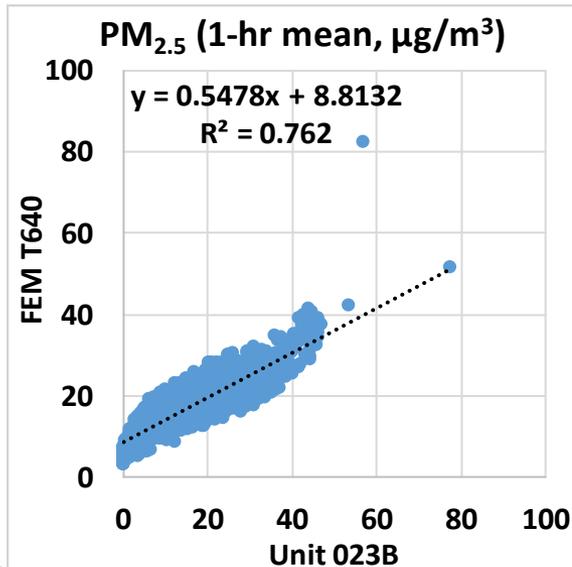
- The Airlink sensors showed strong correlations with the corresponding T640 data ( $0.88 < R^2 < 0.90$ )
- Overall, the Airlink sensors underestimated the PM<sub>1.0</sub> mass concentrations as measured by T640
- The Airlink sensors seemed to track the PM<sub>1.0</sub> diurnal variations as recorded by T640



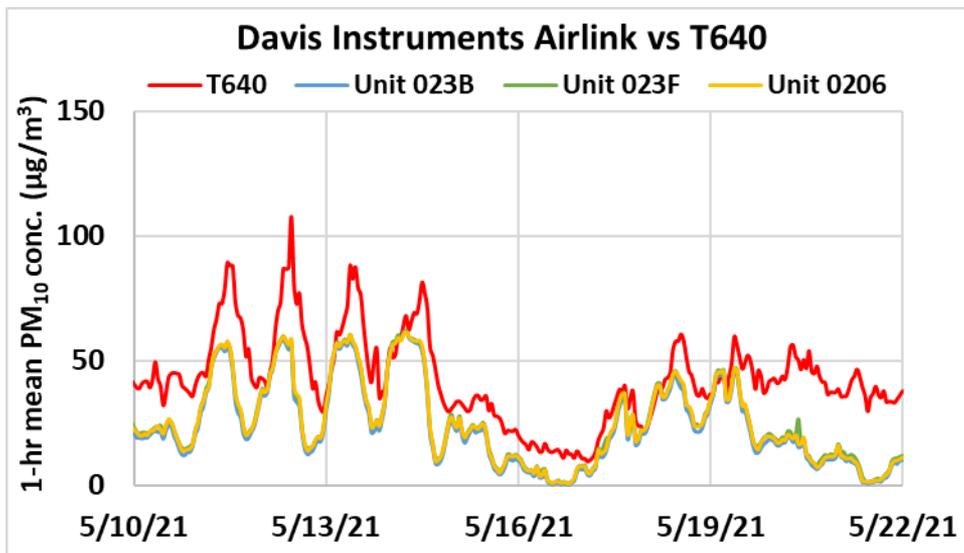
# Airlink vs FEM T640 (PM<sub>2.5</sub>; 1-hr mean)



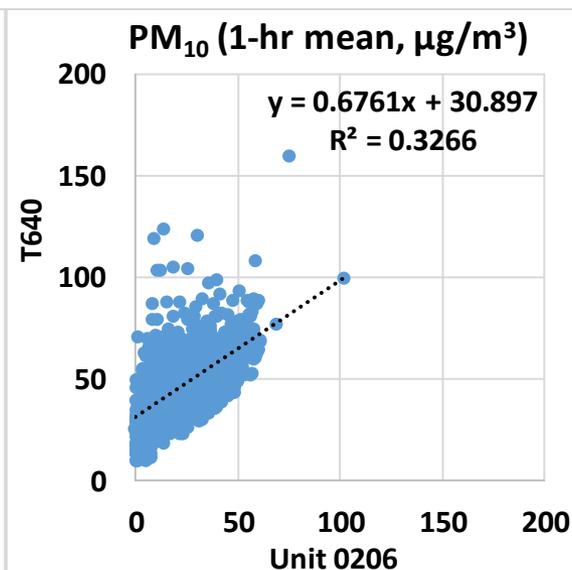
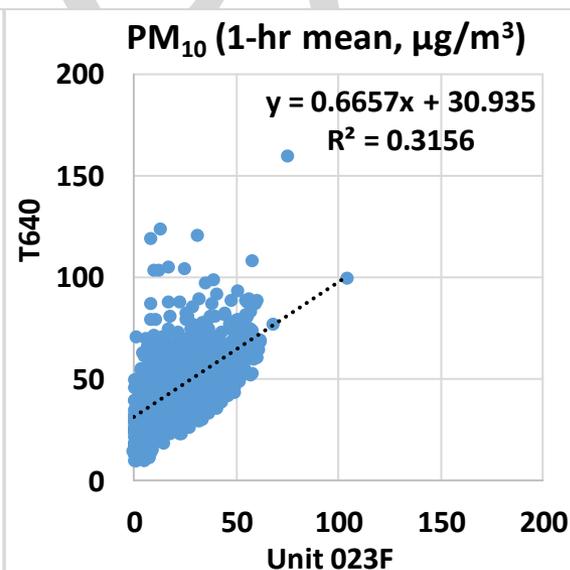
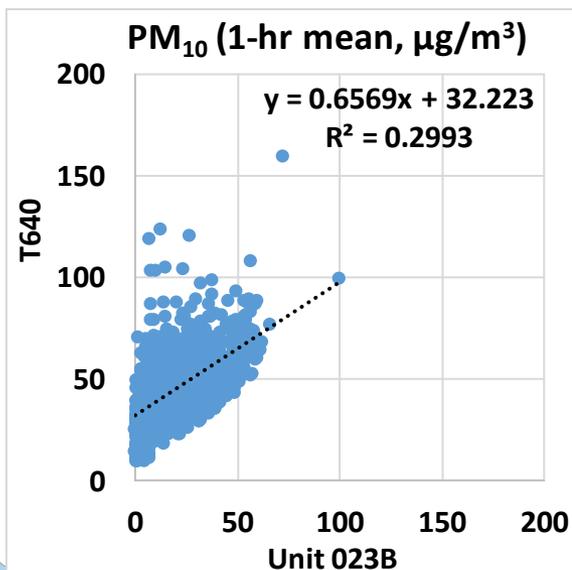
- The Airlink sensors showed strong correlations with the corresponding FEM T640 data ( $0.76 < R^2 < 0.78$ )
- Overall, the Airlink sensors underestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM T640
- The Airlink sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM T640



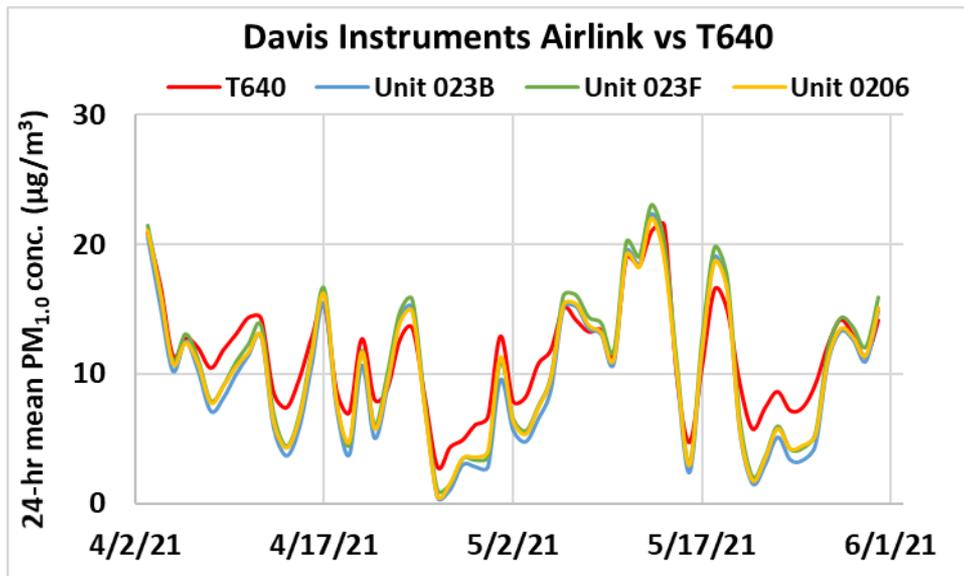
# Airlink vs T640 (PM<sub>10</sub>; 1-hr mean)



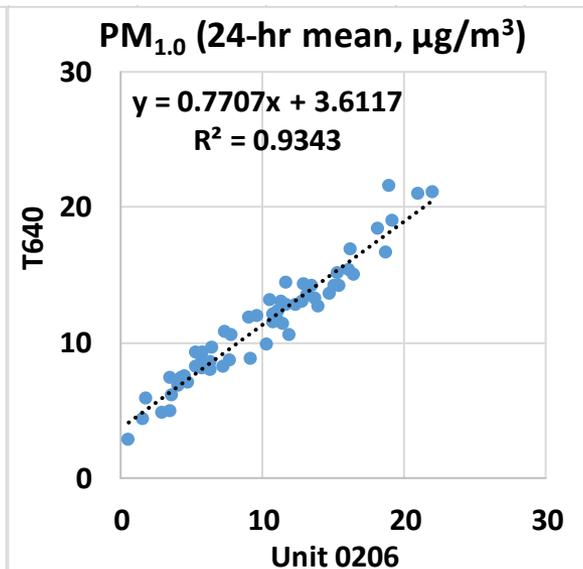
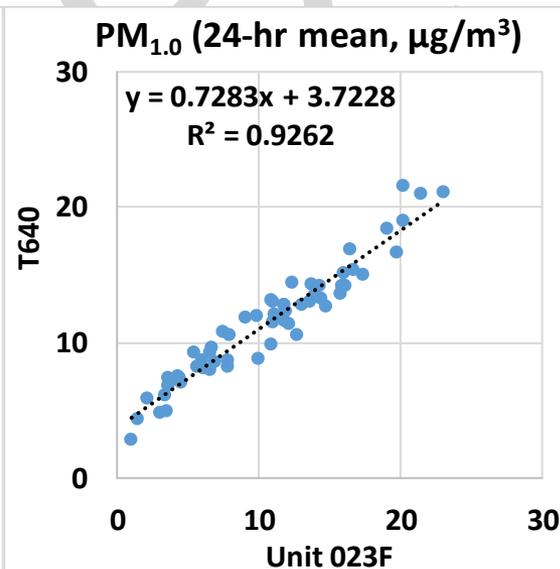
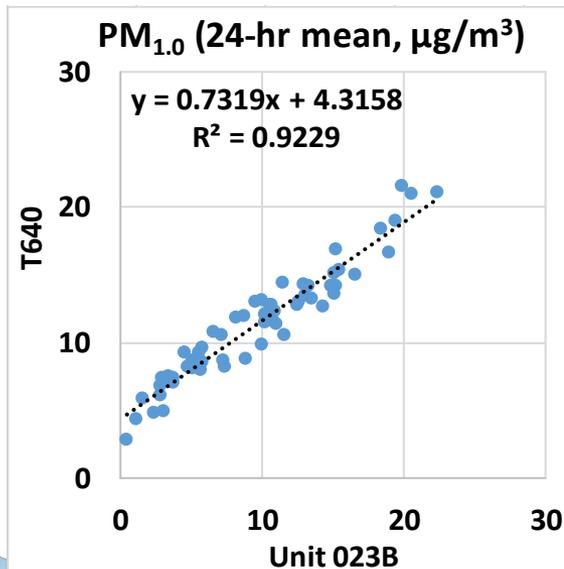
- The Airlink sensors showed very weak to weak correlations with the corresponding T640 data ( $0.29 < R^2 < 0.33$ )
- Overall, the Airlink sensors underestimated the PM<sub>10</sub> mass concentrations as measured by T640
- The Airlink sensors did not seem to track the PM<sub>10</sub> diurnal variations as recorded by T640



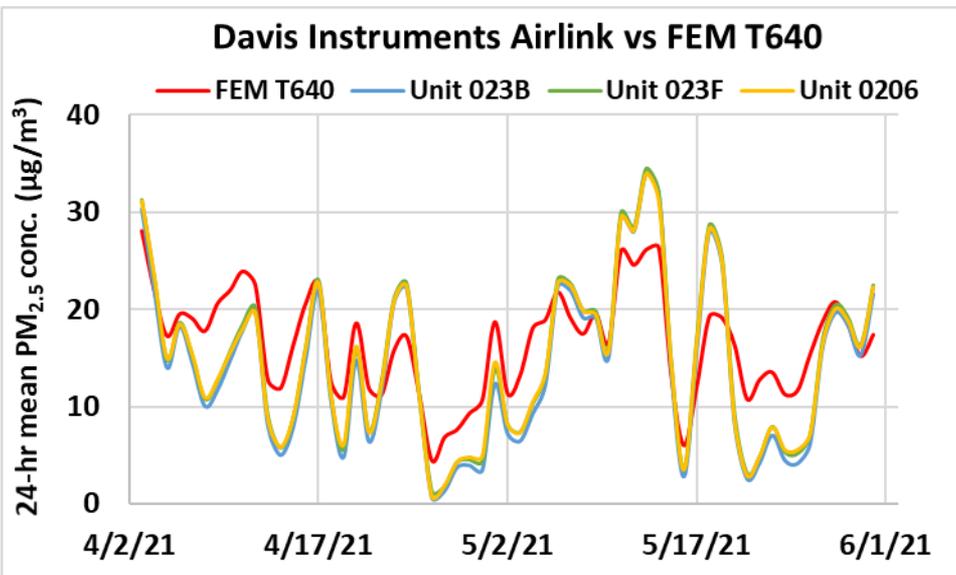
# Airlink vs T640 (PM<sub>1.0</sub>; 24-hr mean)



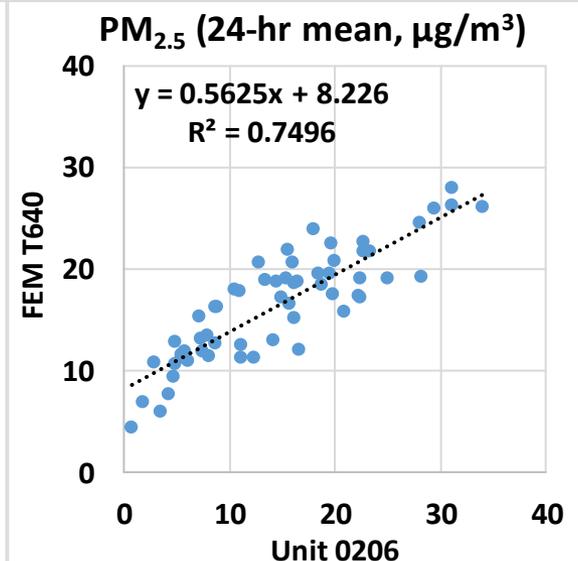
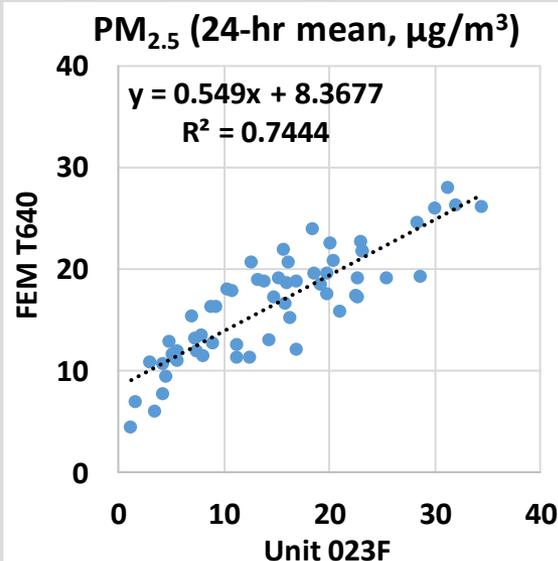
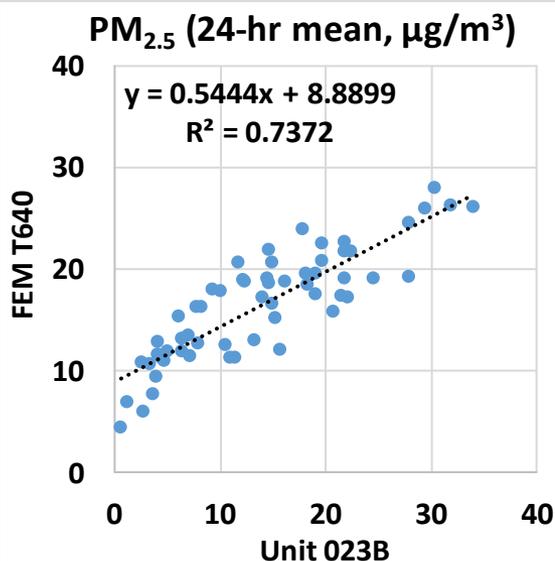
- The Airlink sensors showed very strong correlations with the corresponding T640 data ( $0.92 < R^2 < 0.94$ )
- Overall, the Airlink sensors underestimated the PM<sub>1.0</sub> mass concentrations as measured by T640
- The Airlink sensors seemed to track the PM<sub>1.0</sub> diurnal variations as recorded by T640



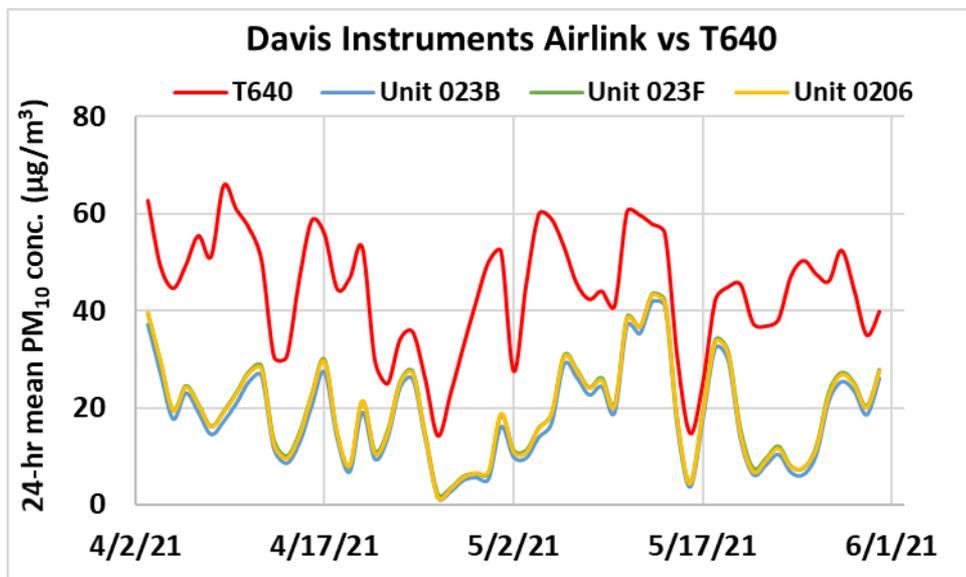
# Airlink vs FEM T640 (PM<sub>2.5</sub>; 24-hr mean)



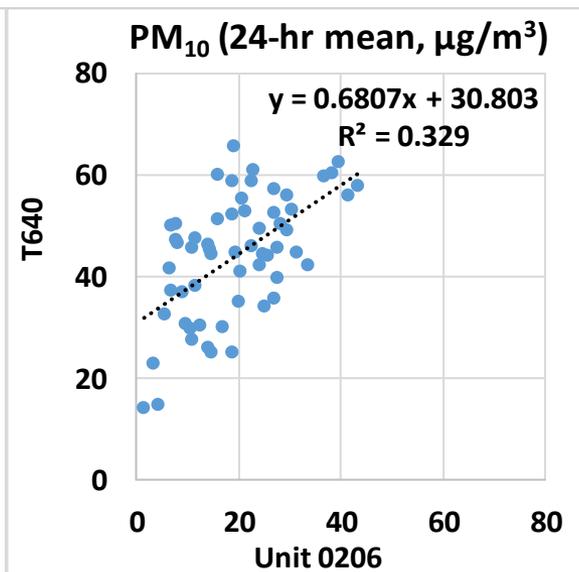
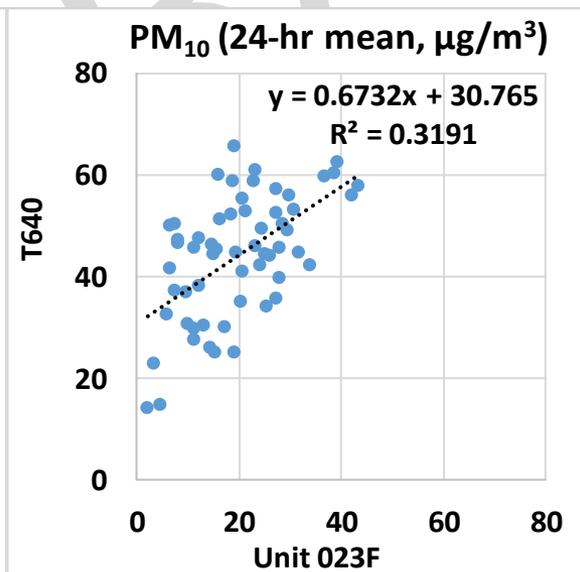
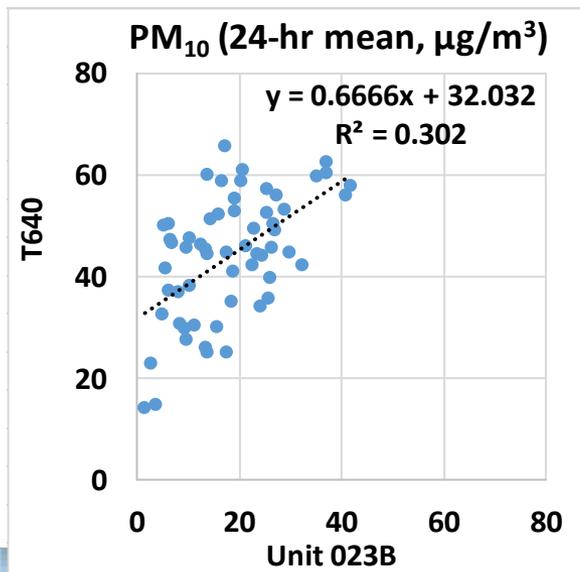
- The Airlink sensors showed strong correlations with the corresponding FEM T640 data ( $0.73 < R^2 < 0.75$ )
- Overall, the Airlink sensors underestimated the PM<sub>2.5</sub> mass concentrations as measured by FEM T640
- The Airlink sensors seemed to track the PM<sub>2.5</sub> diurnal variations as recorded by FEM T640



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



- The Airlink sensors showed weak correlations with the corresponding T640 data ( $0.30 < R^2 < 0.33$ )
- Overall, the Airlink sensors underestimated the PM<sub>10</sub> mass concentrations as measured by T640
- The Airlink sensors did not seem to track the PM<sub>10</sub> diurnal variations as recorded by T640



# Summary

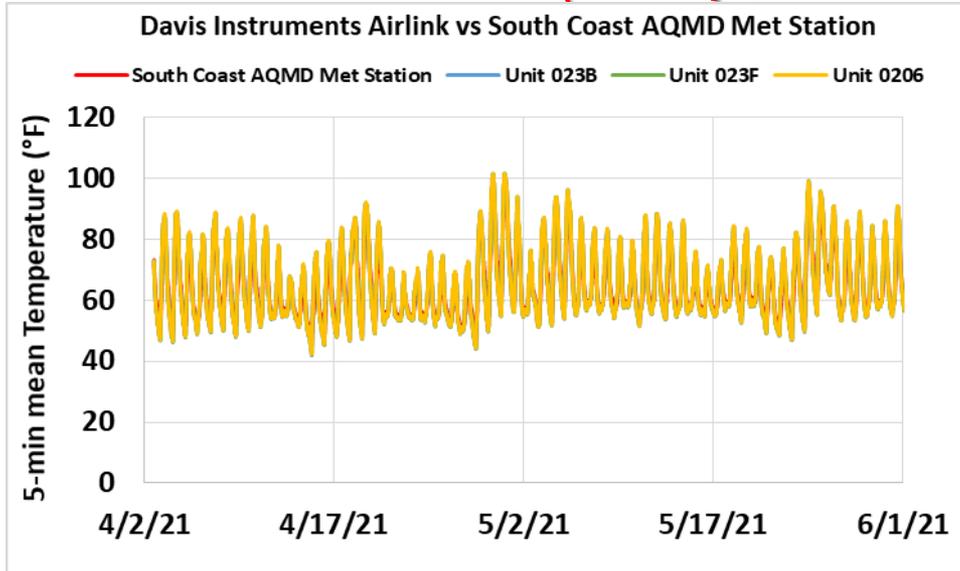
	Average of 3 Sensors, PM <sub>1.0</sub>		Airlink vs GRIMM & T640, PM <sub>1.0</sub>						GRIMM & T640 (PM <sub>1.0</sub> , µg/m <sup>3</sup> )		
	Average (µg/m <sup>3</sup> )	SD (µg/m <sup>3</sup> )	R <sup>2</sup>	Slope	Intercept	MBE <sup>1</sup> (µg/m <sup>3</sup> )	MAE <sup>2</sup> (µg/m <sup>3</sup> )	RMSE <sup>3</sup> (µg/m <sup>3</sup> )	Ref. Average	Ref. SD	Range during the field evaluation
<b>5-min</b>	10.3	7.3	0.85 to 0.88	0.73 to 0.79	3.0 to 4.3	-1.6 to -0.4	2.2 to 2.8	2.7 to 3.4	11.2 to 11.6	5.9	0.4 to 139.9
<b>1-hr</b>	10.3	7.2	0.88 to 0.89	0.74 to 0.78	3.1 to 4.2	-1.6 to -0.4	2.2 to 2.7	2.5 to 3.2	11.2 to 11.6	5.7 to 5.8	0.6 to 59.2
<b>24-hr</b>	10.1	5.4	0.91 to 0.93	0.70 to 0.77	3.5 to 4.3	-1.7 to -0.5	1.7 to 2.1	2.0 to 2.5	11.1 to 11.4	4.0 to 4.2	2.2 to 21.5
	Average of 3 Sensors, PM <sub>2.5</sub>		Airlink 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>	14.8	11.5	0.74 to 0.81	0.50 to 0.57	6.4 to 8.9	-2.4 to 0.8	4.9 to 5.9	6.1 to 7.0	14.3 to 16.6	6.6 to 7.4	1.3 to 195.3
<b>1-hr</b>	14.8	11.3	0.76 to 0.82	0.50 to 0.57	6.4 to 8.8	-2.4 to 0.8	4.8 to 5.8	6.0 to 6.7	14.3 to 16.6	6.4 to 7.2	1.7 to 82.6
<b>24-hr</b>	14.5	8.3	0.74 to 0.81	0.48 to 0.56	6.9 to 8.9	-2.5 to 0.6	3.9 to 4.6	4.6 to 5.3	14.2 to 16.5	4.5 to 5.3	3.1 to 28.0
	Average of 3 Sensors, PM <sub>10</sub>		Airlink vs GRIMM & T640, PM <sub>10</sub>						GRIMM and 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>	19.5	14.2	0.25 to 0.31	0.47 to 0.68	19.1 to 32.2	-25.9 to -8.6	12.1 to 26.0	16.2 to 36.2	28.8 to 44.4	13.4 to 17.4	2.1 to 351.7
<b>1-hr</b>	19.5	13.8	0.26 to 0.33	0.46 to 0.68	19.2 to 32.2	-25.9 to -8.6	11.9 to 26.0	15.5 to 29.7	28.8 to 44.4	12.4 to 16.5	3.0 to 159.5
<b>24-hr</b>	19.2	10.0	0.23 to 0.33	0.41 to 0.68	20.2 to 32.0	-26.0 to -8.7	9.7 to 26.0	12.9 to 28.0	28.6 to 44.1	8.6 to 12.0	5.8 to 65.7

<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).

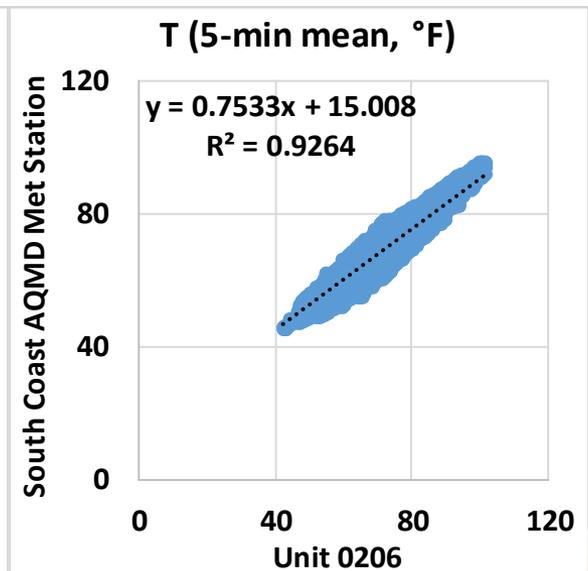
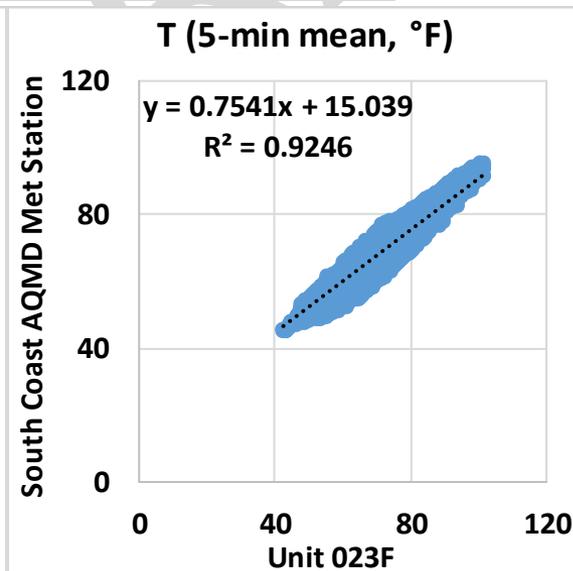
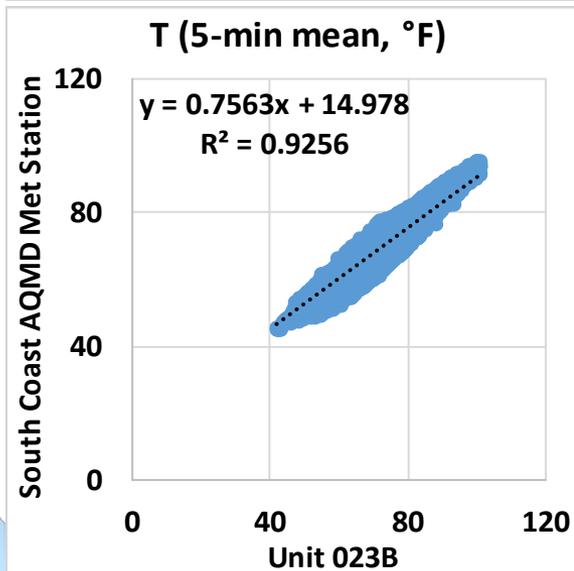
<sup>2</sup> Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.

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

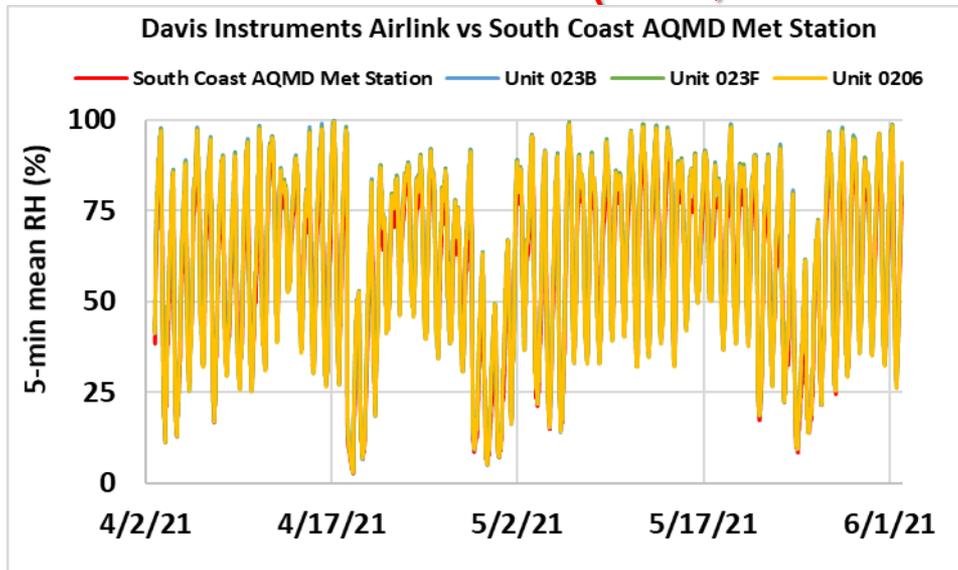
# Airlink vs South Coast AQMD Met Station (Temp; 5-min mean)



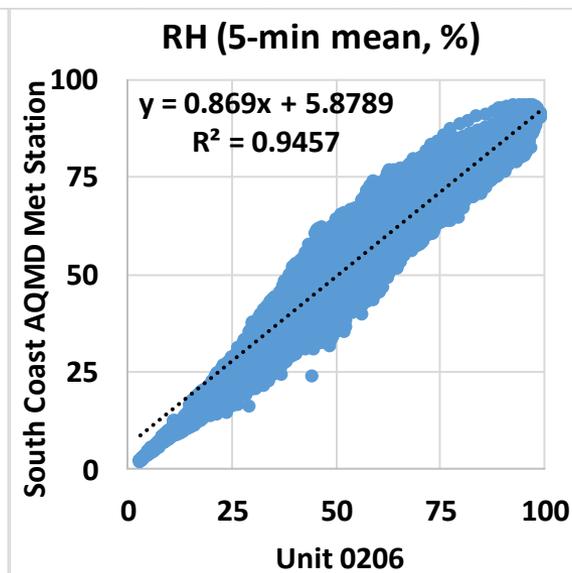
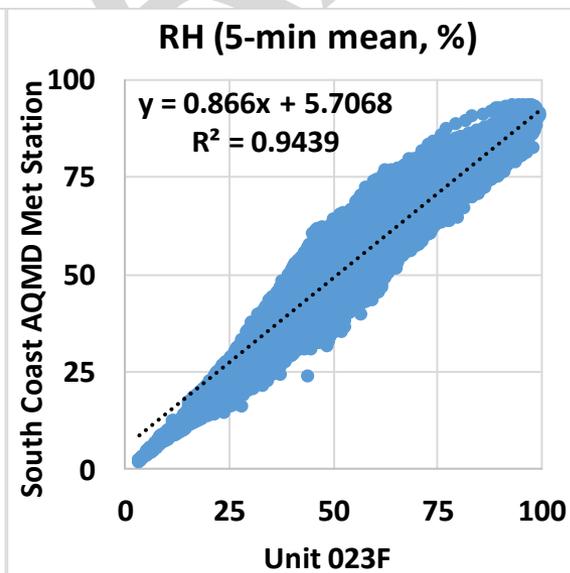
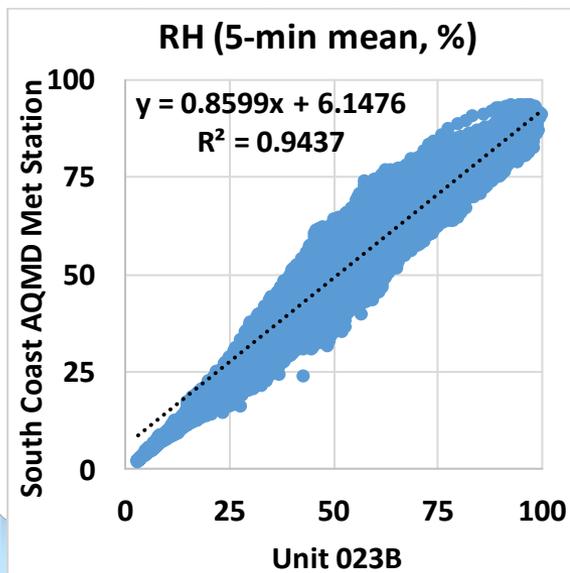
- The Airlink sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ( $0.92 < R^2 < 0.93$ )
- Overall, the Airlink sensors overestimated the temperature measurement as recorded by South Coast AQMD Met Station
- The Airlink sensors seemed to track the diurnal temperature variations as recorded by South Coast AQMD Met Station



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



- The Airlink sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ( $R^2 \sim 0.94$ )
- Overall, the Airlink sensors overestimated the RH measurement as recorded by South Coast AQMD Met Station
- The Airlink sensors seemed to track the diurnal RH variations as recorded by South Coast AQMD Met Station



# Discussion

- The three **Airlink** sensors' data recovery from all units was ~ 100% for all PM measurements
- The absolute intra-model variability was ~ 0.35, 0.37 and 0.75  $\mu\text{g}/\text{m}^3$  for  $\text{PM}_{1.0}$ ,  $\text{PM}_{2.5}$  and  $\text{PM}_{10}$ , respectively
- Strong correlations between GRIMM and T640 for  $\text{PM}_{1.0}$  ( $R^2 \sim 0.90$ , 1-hr mean); very strong correlations between FEM GRIMM and FEM T640 for  $\text{PM}_{2.5}$  ( $R^2 \sim 0.91$ , 1-hr mean) and strong correlations between GRIMM and T640 for  $\text{PM}_{10}$  ( $R^2 \sim 0.89$ , 1-hr mean) mass concentration measurements
- $\text{PM}_{1.0}$  mass concentrations measured by the Airlink sensors showed strong correlations with the corresponding GRIMM and T640 data ( $0.88 < R^2 < 0.90$ , 1-hr mean). The sensors underestimated  $\text{PM}_{1.0}$  mass concentrations as measured by GRIMM and T640
- $\text{PM}_{2.5}$  mass concentrations measured by the Airlink sensors showed strong correlations with the corresponding FEM GRIMM and FEM T640 data ( $0.76 < R^2 < 0.82$ , 1-hr mean). The sensors overestimated  $\text{PM}_{2.5}$  mass concentrations as measured by FEM GRIMM and underestimated  $\text{PM}_{2.5}$  mass concentrations as measured by FEM T640
- $\text{PM}_{10}$  mass concentrations measured by the Airlink sensors showed very weak to weak correlations with the corresponding GRIMM and T640 data ( $0.26 < R^2 < 0.33$ ; 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 prior to the beginning of this test
- Laboratory chamber testing is necessary to fully evaluate the performance of these sensors under known aerosol concentrations and controlled temperature and relative humidity conditions
- All results are still preliminary