Field Evaluation
A.U.G. Signals Ltd – AirSENCE Standard AS400X

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 08/17/2023 to 10/12/2023, three **A.U.G. Signals Ltd. – AirSENCE Standard AS400X (hereinafter AirSENCE)** multi-sensor units were deployed at the South Coast AQMD stationary ambient monitoring site in Rubidoux and were run side-by-side with Federal Equivalent Method (FEM) and Federal Reference Method (FRM) instruments measuring the same pollutants.

- **AirSENCE Standard AS400X (*3 units tested*):**
  - Gas Sensors: Electrochemical (Alphasense B model, non-FEM)
  - $PM_{2.5}$ – Optical (Plantower 7003, non-FEM)
  - Each unit measures: O_3 (ppb), NO (ppb), NO_2 (ppb), CO (ppb), $PM_{1.0}$ (µg/m^3), $PM_{2.5}$ (µg/m^3), PM_{10}(µg/m^3), T (°C), RH (%)
  - Unit cost: $4,000 as-tested + $20/month/device
  - Time resolution: 1-min
  - Units IDs: 0299, 0306, and 0310

- **South Coast AQMD Reference instruments:**
  - O_3 instrument (Teledyne T400, hereinafter FEM T400); cost: ~$7,000
    - Time resolution; 1-min
  - CO instrument (Horiba APMA 370, hereinafter FRM Horiba); cost: ~$10,000
    - Time resolution; 1-min
  - NO/NO_2 instrument (Teledyne T200, hereinafter FRM T200); cost: ~$11,000
    - Time resolution: 1-min
  - PM instrument (Teledyne API T640; FEM $PM_{2.5}$, hereinafter FEM T640); cost: $21,000
    - Time resolution: 1-min
    - Measures $PM_{1.0}$, $PM_{2.5}$, PM_{10} (µg/m^3)
  - PM instrument (MetOne BAM; FEM $PM_{2.5}$ & PM_{10}); cost: $20,000
    - Time resolution: 1-hr
    - Measures $PM_{2.5}$, PM_{10} (µg/m^3)
  - Met station (T, RH, P, WS, WD); cost: ~$5,000
    - Time resolution: 1-min

Ozone (O_3) in AirSENCE

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 for O_3 from all units was ~ 100%

Note that the sensors have a 5 ppb detection limit for ozone measurements, therefore all values less than 5 ppb were not used in subsequent data analysis.

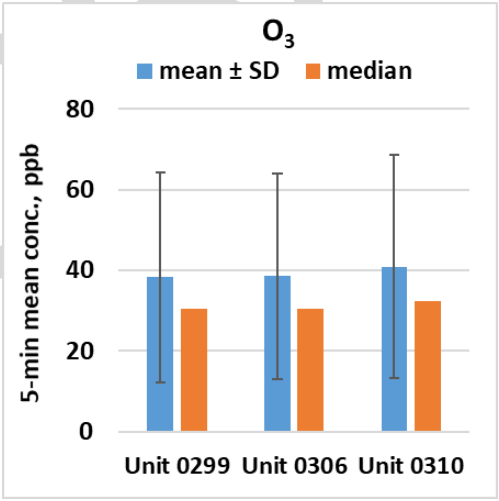
AirSENCE; Intra-model variability

- Absolute intra-model variability was ~ 1.5 ppb for the ozone measurements

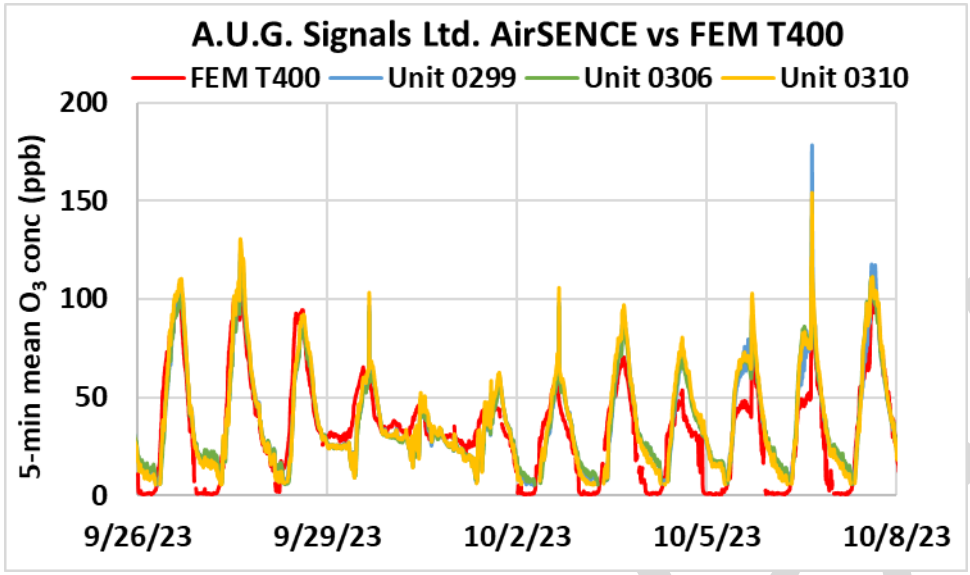
(calculated as the standard deviation of the three sensor means)

- Relative intra-model variability was ~ 3.8% for the ozone measurements

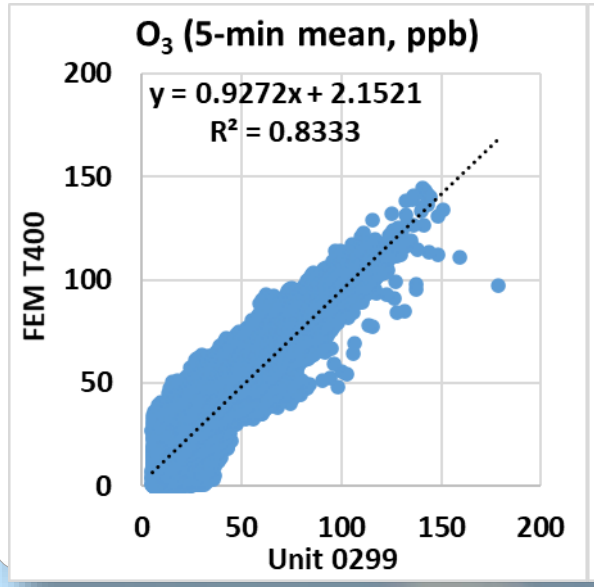
(calculated as the absolute intra-model variability relative to the mean of the three sensor means)

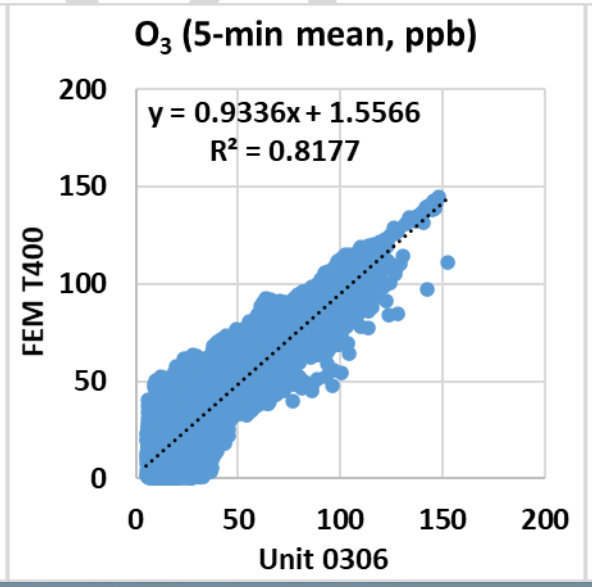


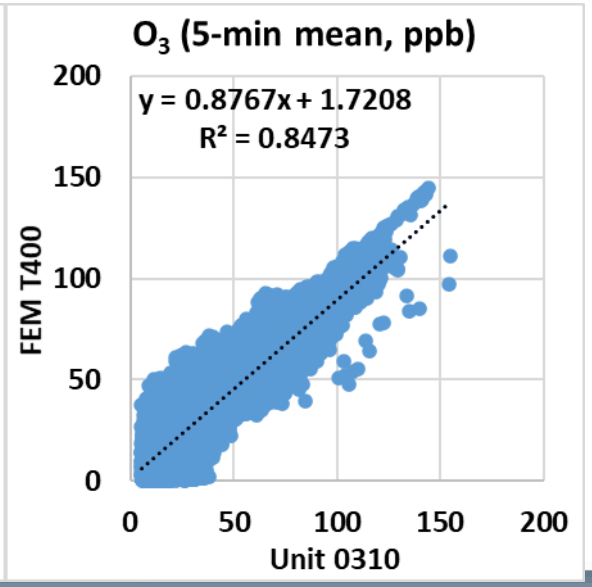
AirSENCE vs FEM T400 (Ozone; 5-min mean)



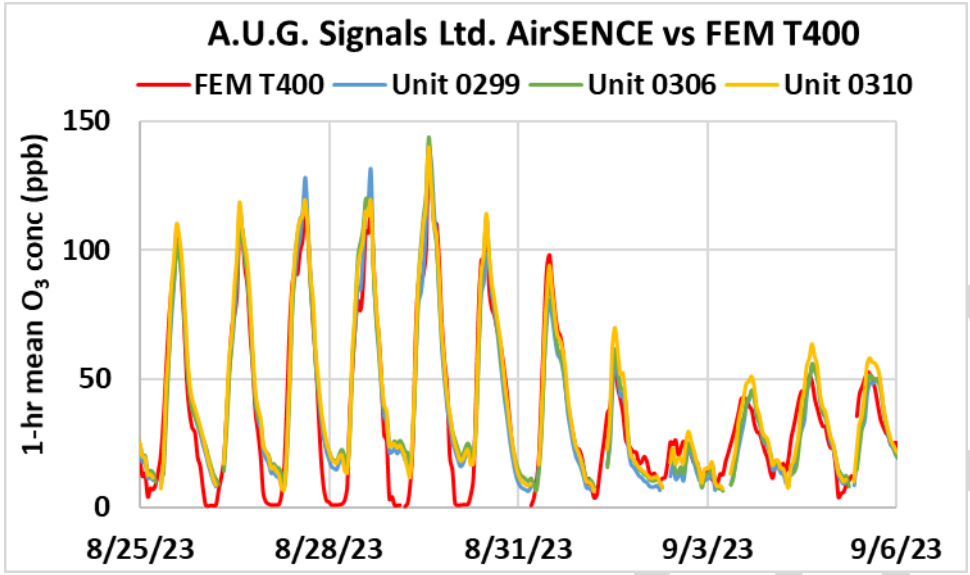
- The AirSENCE sensors showed strong correlations with the corresponding FEM T400 ozone data ($0.81 < R^2 < 0.85$)
- Overall, the AirSENCE sensors overestimated the ozone concentrations as measured by the FEM T400 ozone instrument
- The AirSENCE sensors seemed to track the diurnal ozone variations as recorded by the FEM T400 instrument



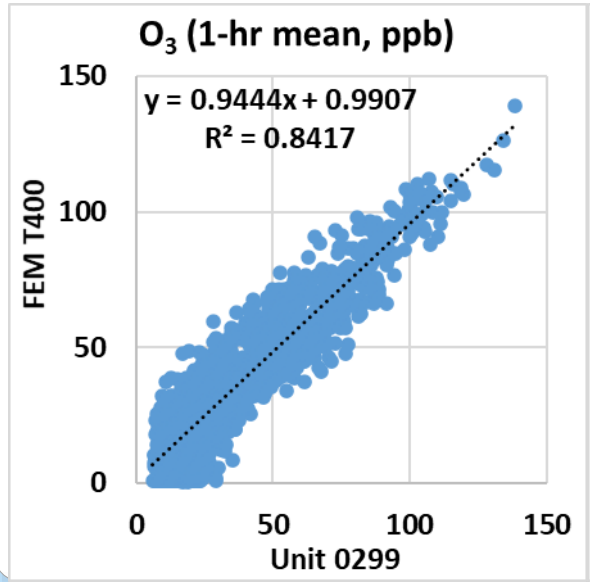


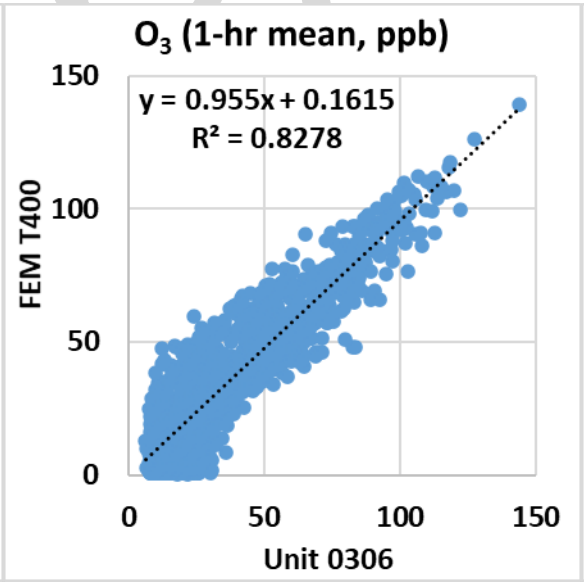


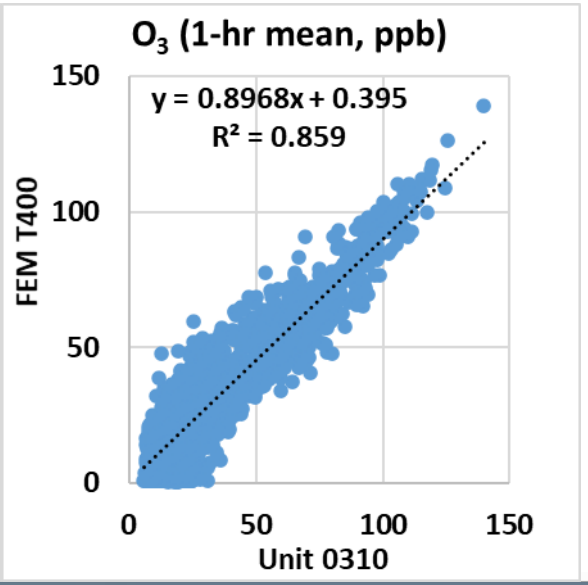
AirSENCE vs FEM T400 (Ozone; 1-hr mean)



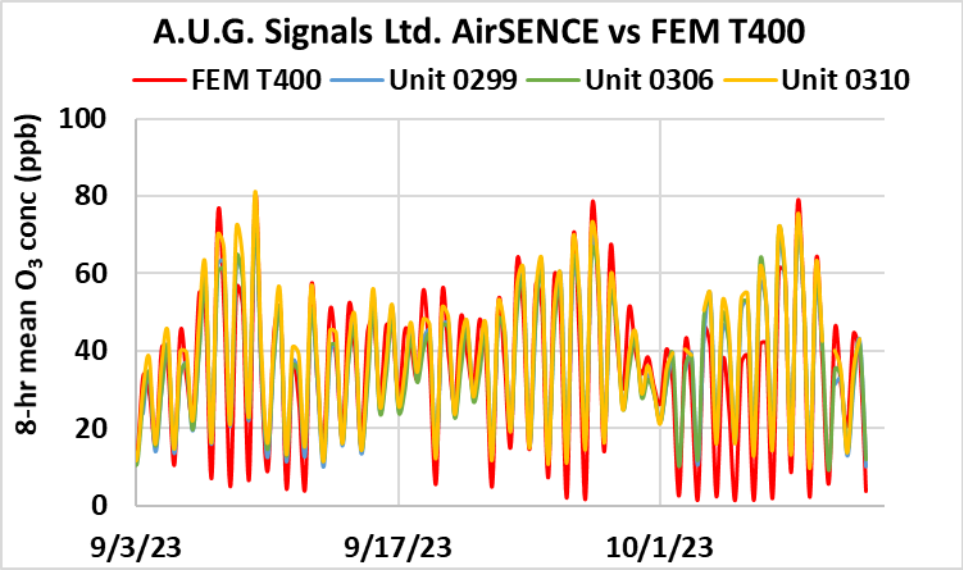
- The AirSENCE sensors showed strong correlations with the corresponding FEM T400 ozone data ($0.82 < R^2 < 0.86$)
- Overall, the AirSENCE sensors overestimated the ozone concentrations as measured by the FEM T400 ozone instrument
- The AirSENCE sensors seemed to track the diurnal ozone variations as recorded by the FEM T400 instrument



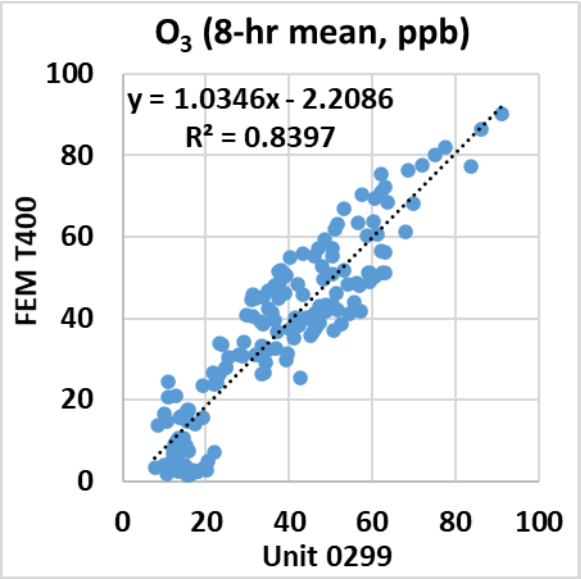


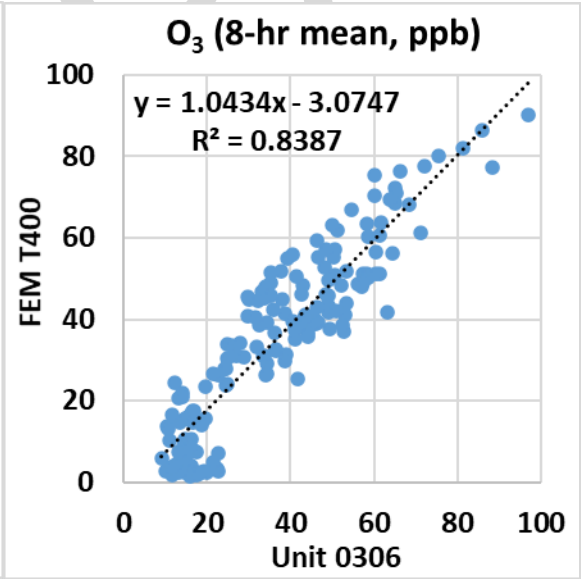


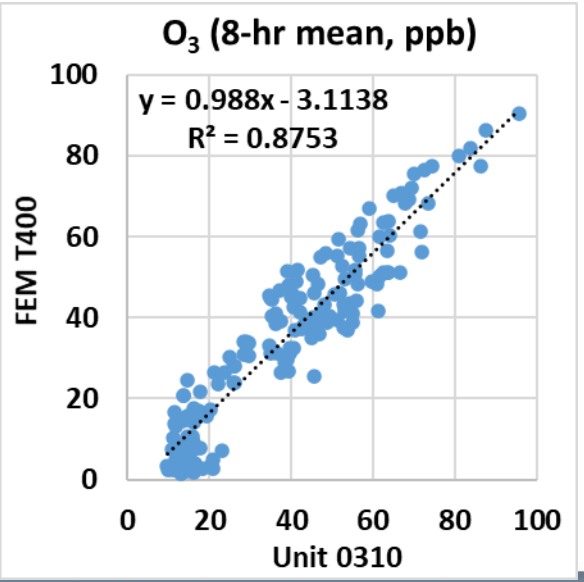
AirSENCE vs FEM T400 (Ozone; 8-hr mean)



- The AirSENCE sensors showed strong correlations with the corresponding FEM T400 ozone data ($0.83 < R^2 < 0.88$)
- Overall, the AirSENCE sensors overestimated the ozone concentrations as measured by the FEM T400 ozone instrument
- The AirSENCE sensors seemed to track the diurnal ozone variations as recorded by the FEM T400 instrument







Summary: Ozone

	Average of 3 Sensors, Ozone		AirSENCE vs FEM T400, Ozone						FEM T400, Ozone (ppb)		
	Average (ppb)	SD (ppb)	R^2	Slope	Intercept	MBE[1] (ppb)	MAE[2] (ppb)	RMSE[3] (ppb)	FEM T400 Average	FEM T400 SD	Range during the field evaluation
5-min	38.4	26.5	0.82 to 0.85	0.88 to 0.93	1.6 to 2.2	0.7 to 3.4	9.0 to 9.3	11.2 to 11.8	36.9	27.0	0.2 to 144.6
1-hr	38.7	26.3	0.83 to 0.86	0.90 to 0.96	0.2 to 1.0	1.1 to 3.8	8.7 to 9.0	10.8 to 11.3	35.4	26.6	0.4 to 139.1
8-hr	38.4	19.6	0.84 to 0.88	0.99 to 1.04	-3.1 to -2.2	0.9 to 3.6	6.9 to 7.5	9.5 to 9.9	35.4	21.7	1.6 to 90.4

[1] Mean Bias Error (MBE): the difference between the sensors and the reference instruments. MBE indicates the tendency of the sensors to underestimate (negative MBE values) or overestimate (positive MBE values).
[2] Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.
[3] Root Mean Square Error (RMSE): another metric to calculate measurement errors.

Nitric Oxide (NO) in AirSENCE

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 for NO from all units was ~100%

Note that the sensors have a 5 ppb detection limit for NO measurements, therefore all values less than 5 ppb were not used in subsequent data analysis.

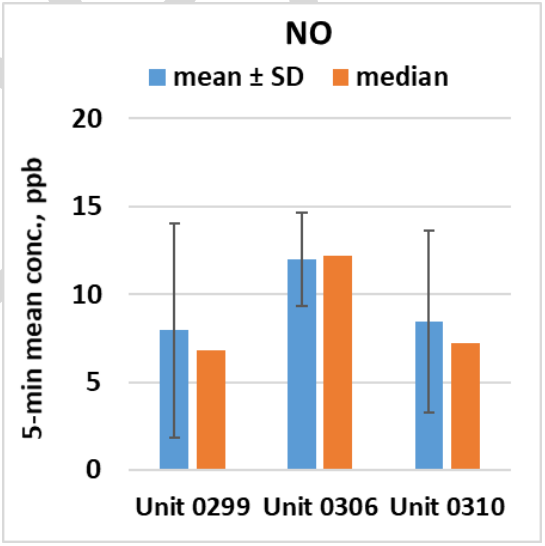
AirSENCE; Intra-model variability

- Absolute intra-model variability was ~ 2.2 ppb for the NO measurements

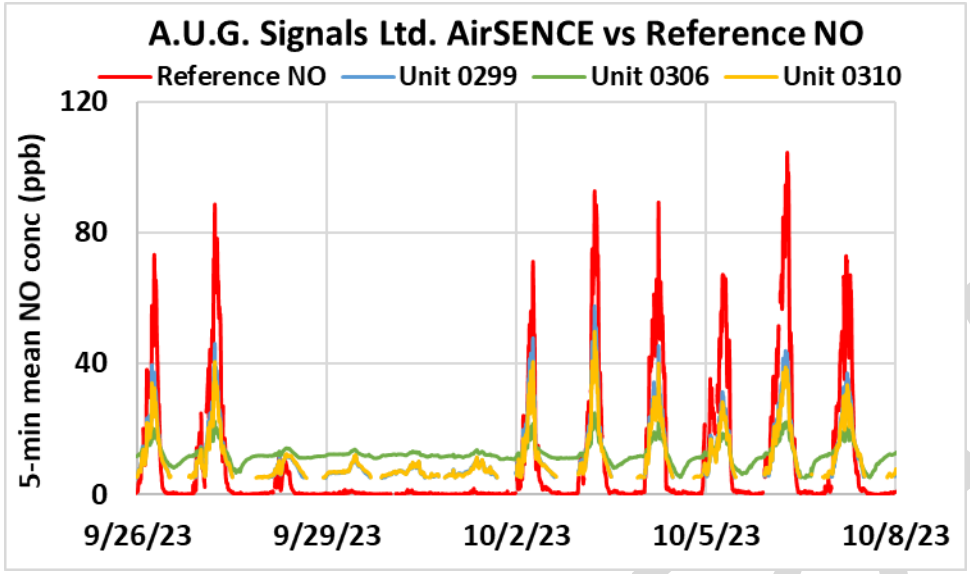
(calculated as the standard deviation of the three sensor means)

- Relative intra-model variability was ~ 23.3% for the NO measurements

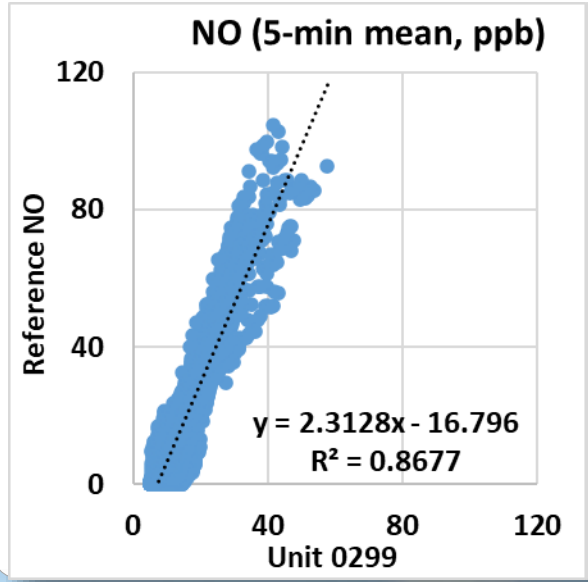
(calculated as the absolute intra-model variability relative to the mean of the three sensor means)

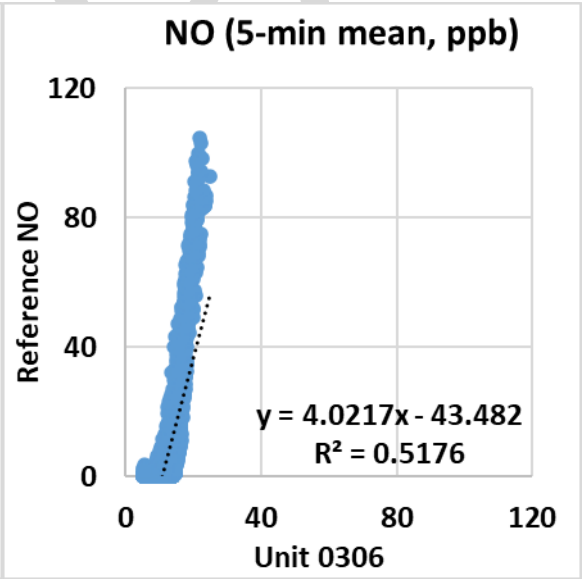


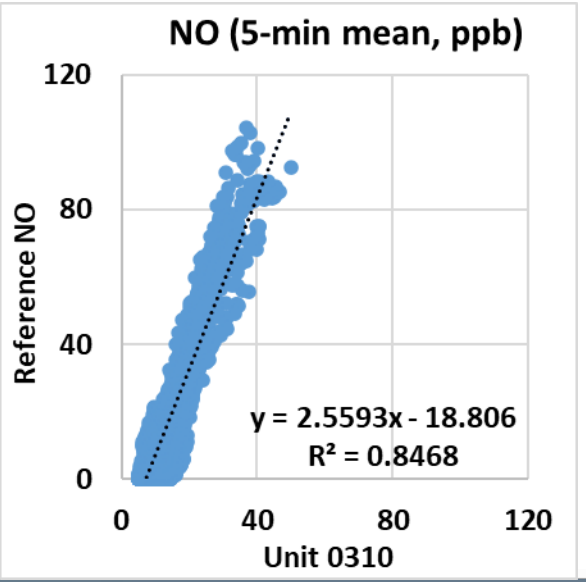
AirSENCE vs FRM T200 (NO; 5-min mean)



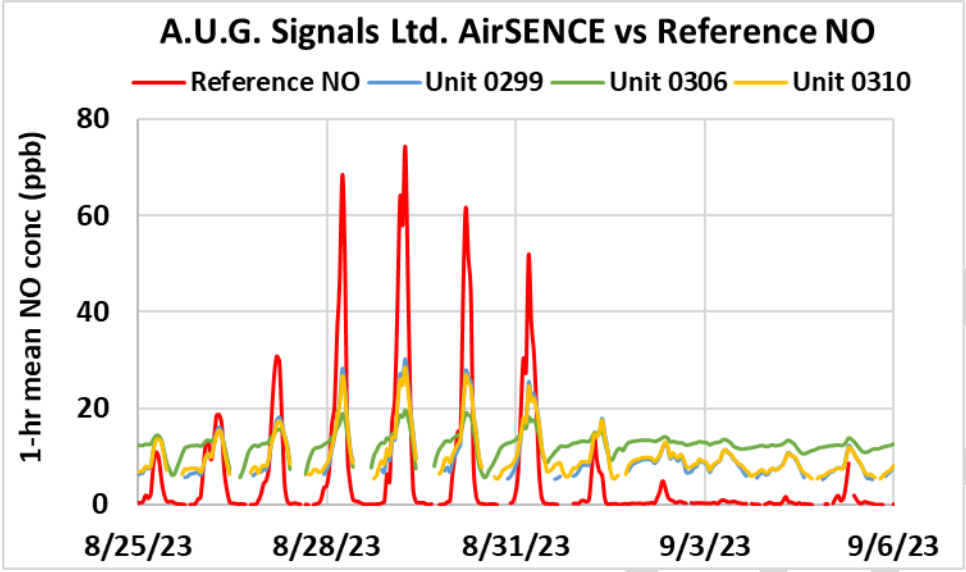
- The AirSENCE sensors showed moderate to strong correlations with the corresponding reference NO data ($0.51 < R^2 < 0.87$)
- Overall, the AirSENCE sensors overestimated the NO concentration as measured by the reference instrument
- The AirSENCE sensors seemed to track the diurnal NO variations as recorded by the reference instrument



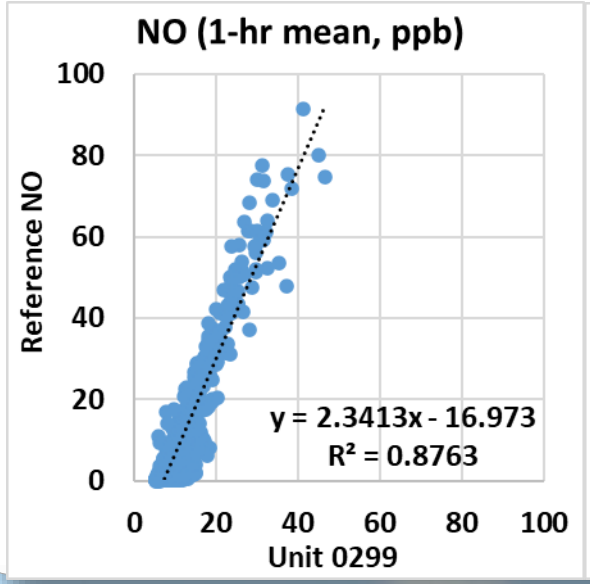


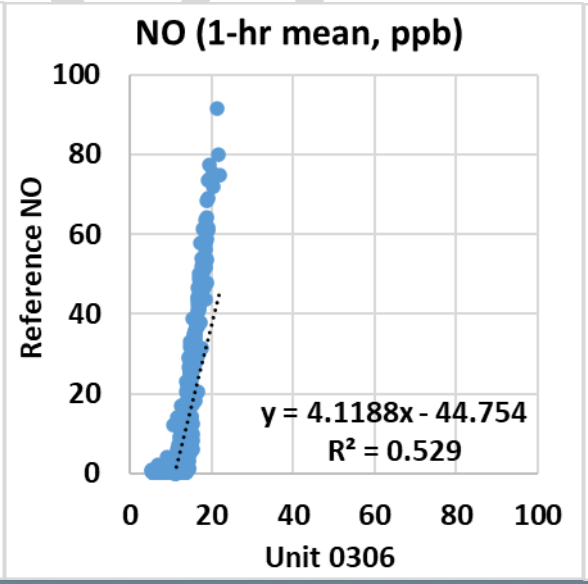


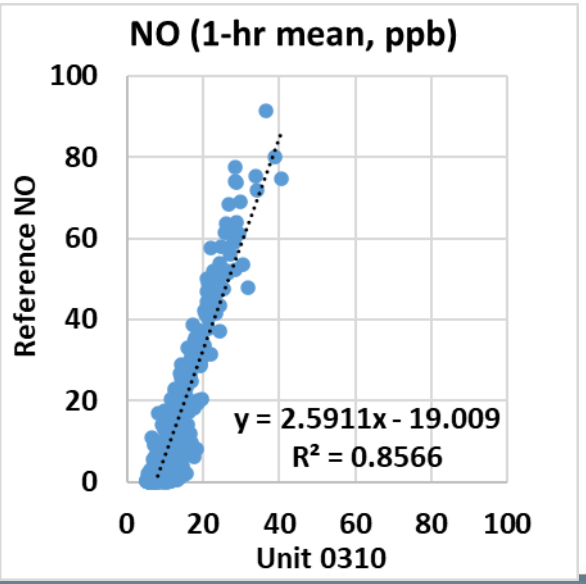
AirSENCE vs FRM T200 (NO; 1-hr mean)



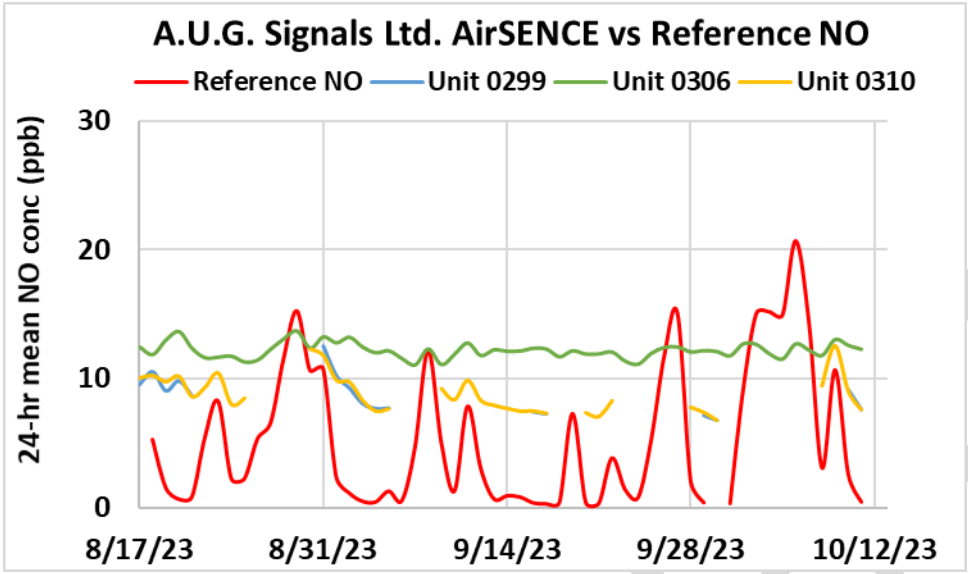
- The AirSENCE sensors showed moderate to strong correlations with the corresponding reference NO data ($0.52 < R^2 < 0.88$)
- Overall, the AirSENCE sensors overestimated the NO concentration as measured by the reference instrument
- The AirSENCE sensors sometimes seemed to track the diurnal NO variations as recorded by the reference instrument



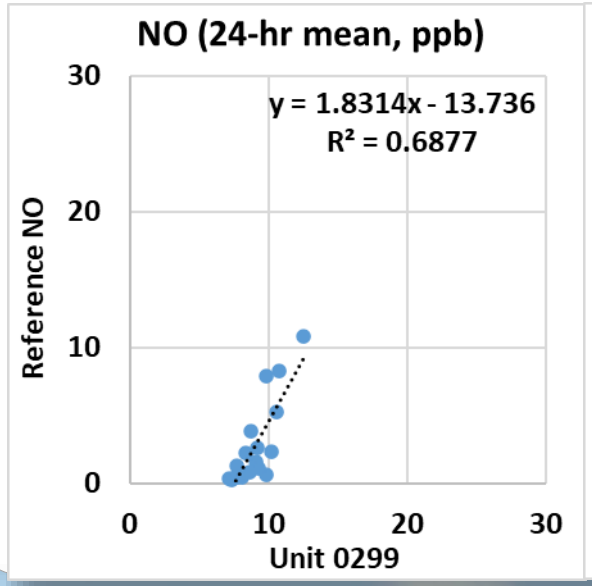


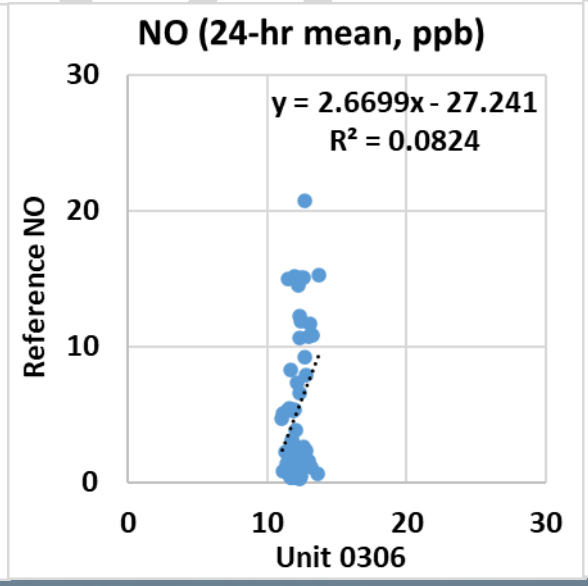


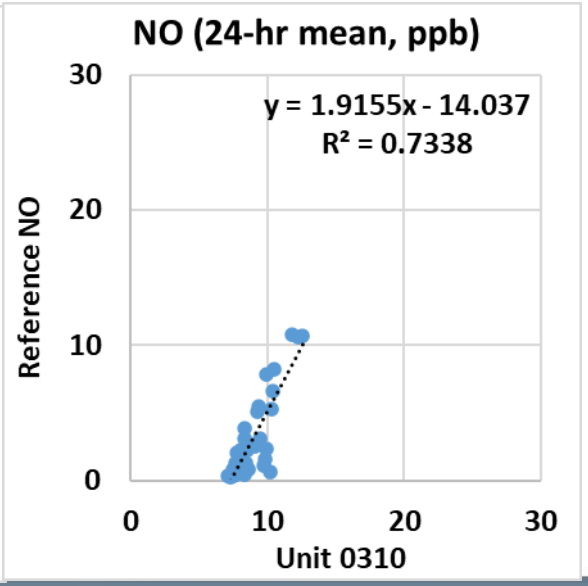
AirSENCE vs FRM T200 (NO; 24-hr mean)



- The AirSENCE sensors showed no to strong correlations with the corresponding reference NO data ($0.08 < R^2 < 0.74$)
- Overall, the AirSENCE sensors overestimated the NO concentration as measured by the reference instrument
- The AirSENCE sensors did not seem to track the daily NO variations as recorded by the reference instrument







Summary: NO

	Average of 3 Sensors, NO		AirSENCE vs Reference NO						Reference NO (ppb)		
	Average (ppb)	SD (ppb)	R^2	Slope	Intercept	MBE[1] (ppb)	MAE[2] (ppb)	RMSE[3] (ppb)	Ref NO Average	Ref NO SD	Range during the field evaluation
5-min	10.7	4.4	0.52 to 0.87	2.31 to 4.02	-43.5 to -16.8	3.3 to 6.7	8.1 to 11.5	10.2 to 13.5	5.4	13.2	0 to 104.5
1-hr	10.8	4.3	0.53 to 0.88	2.34 to 4.12	-44.8 to -17.0	2.7 to 6.5	8.0 to 11.4	9.9 to 13.2	5.7	13.0	0.1 to 91.5
24-hr	10.0	1.2	0.08 to 0.73	1.83 to 2.67	-27.2 to -13.7	5.9 to 6.9	5.9 to 7.8	6.2 to 8.7	5.3	5.5	0.3 to 20.7

[1] Mean Bias Error (MBE): the difference between the sensors and the reference instruments. MBE indicates the tendency of the sensors to underestimate (negative MBE values) or overestimate (positive MBE values).
[2] Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.
[3] Root Mean Square Error (RMSE): another metric to calculate measurement errors.

Nitrogen Dioxide (NO_2) in AirSENCE

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 for NO_2 from all units was ~100%

Note that the sensors have a 5 ppb detection limit for NO_2 measurements, therefore all values less than 5 ppb were not used in subsequent data analysis.

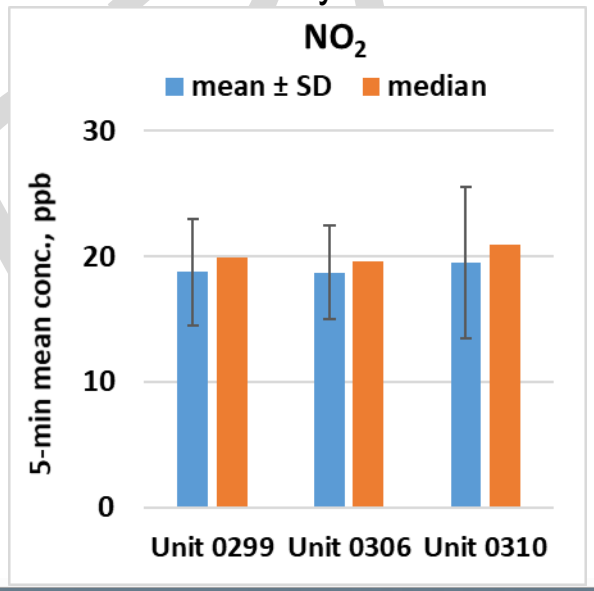
AirSENCE; Intra-model variability

- Absolute intra-model variability was ~ 0.5 ppb for the NO_2 measurements

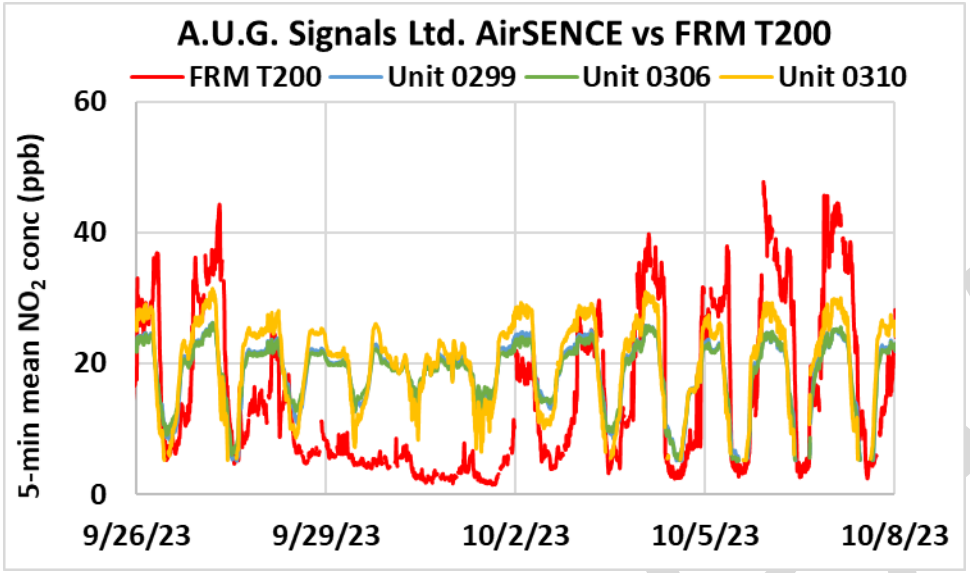
(calculated as the standard deviation of the three sensor means)

- Relative intra-model variability was ~ 2.5% for the NO_2 measurements

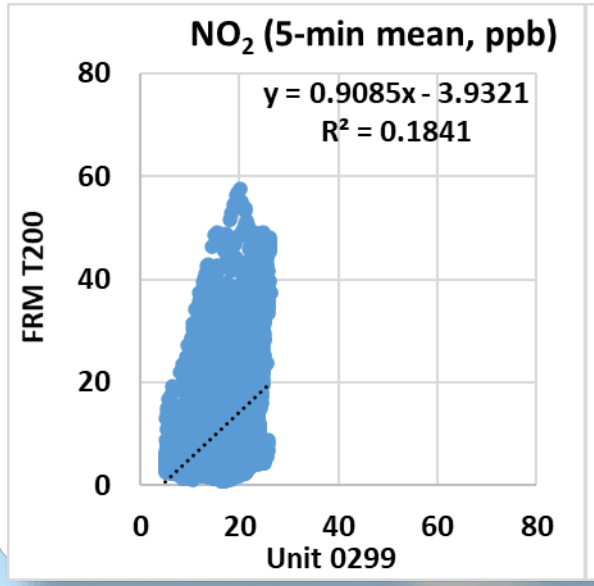
(calculated as the absolute intra-model variability relative to the mean of the three sensor means)

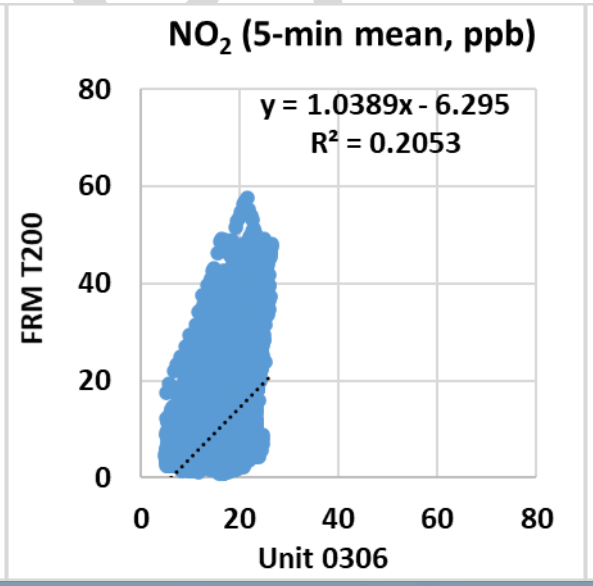


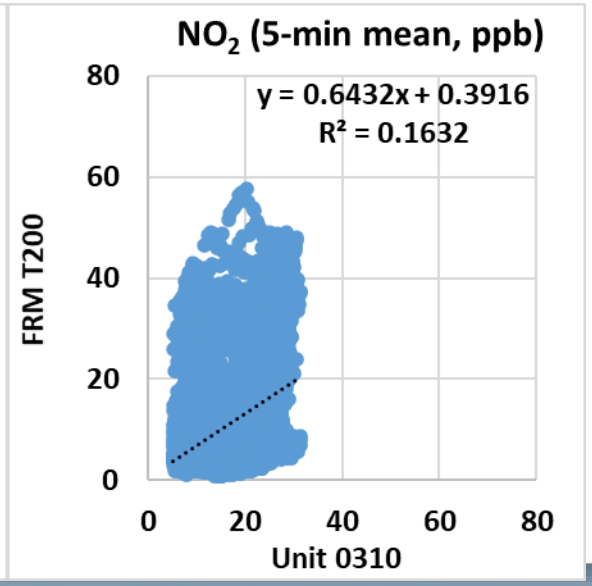
AirSENCE vs FRM T200 (NO_2; 5-min mean)



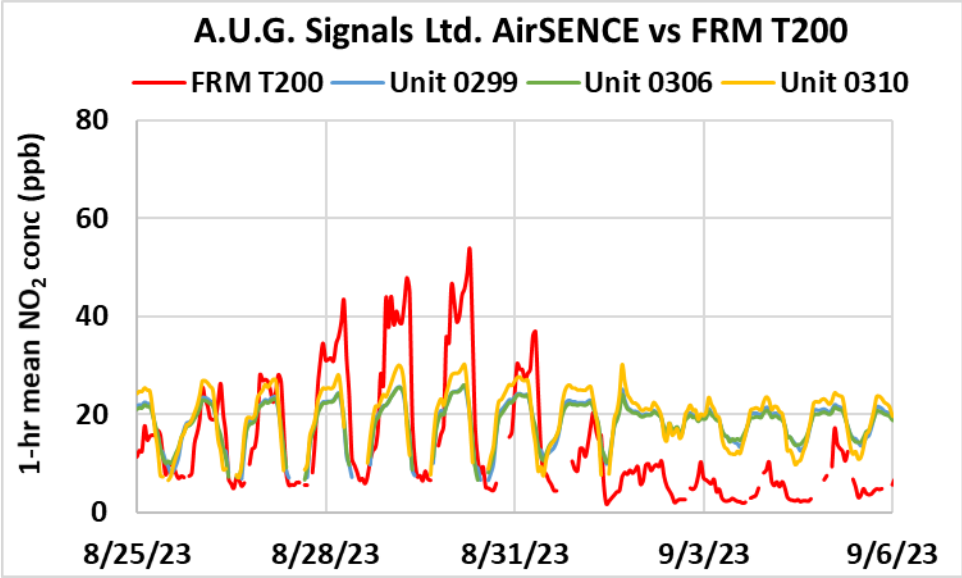
- The AirSENCE sensors showed very weak correlations with the corresponding FRM T200 NO_2 data ($0.16 < R^2 < 0.21$)
- Overall, the AirSENCE sensors overestimated the NO_2 concentration as measured by the FRM T200 instrument
- The AirSENCE sensors sometimes seemed to track the diurnal NO_2 variations as recorded by the FRM T200 instrument



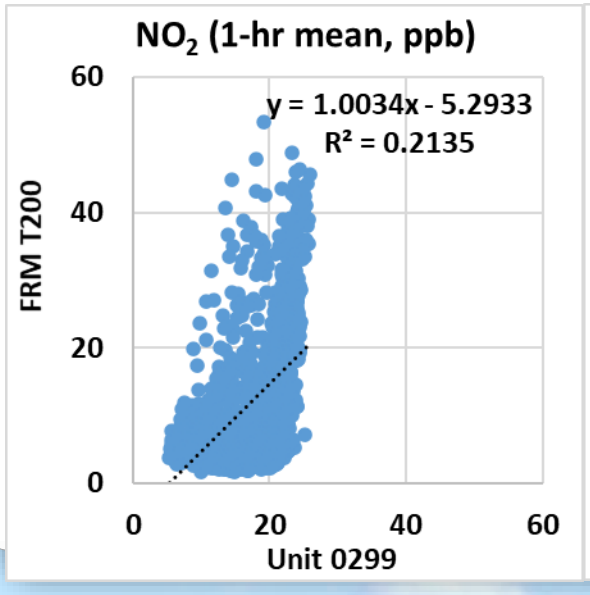


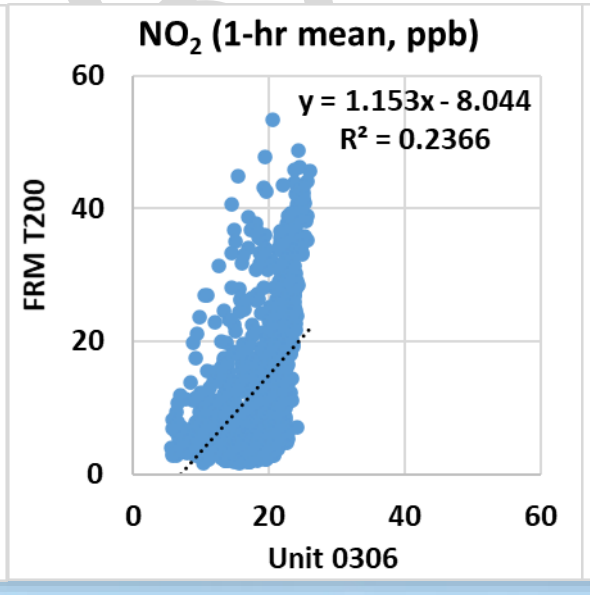


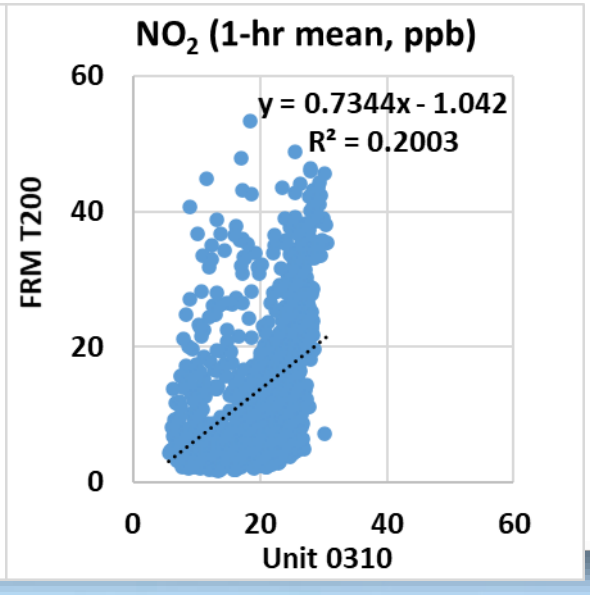
AirSENCE vs FRM T200 (NO_2; 1-hr mean)



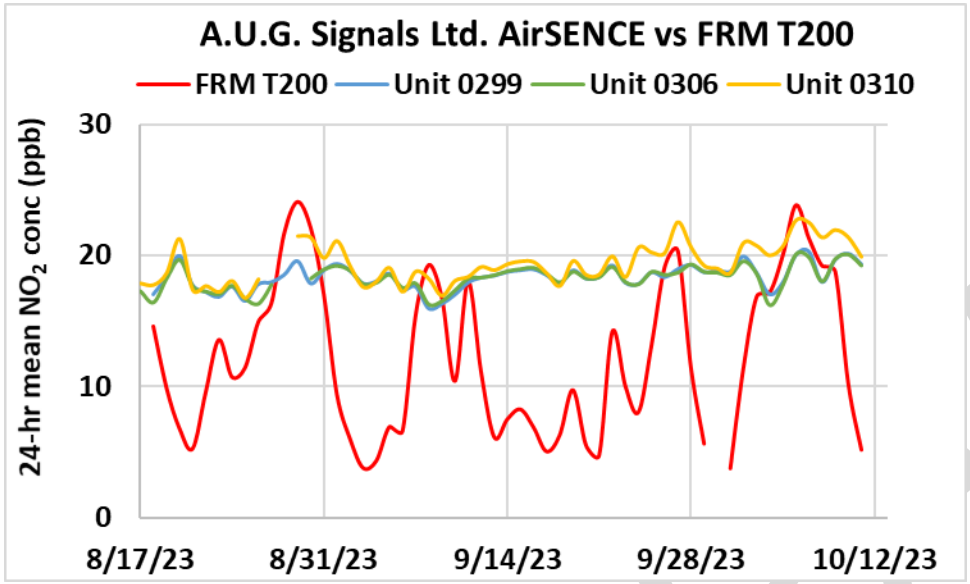
- The AirSENCE sensors showed very weak correlations with the corresponding FRM T200 NO_2 data ($0.20 < R^2 < 0.24$)
- Overall, the AirSENCE sensors overestimated the NO_2 concentration as measured by the FRM T200 instrument
- The AirSENCE sensors sometimes seemed to track the diurnal NO_2 variations as recorded by the FRM T200 instrument



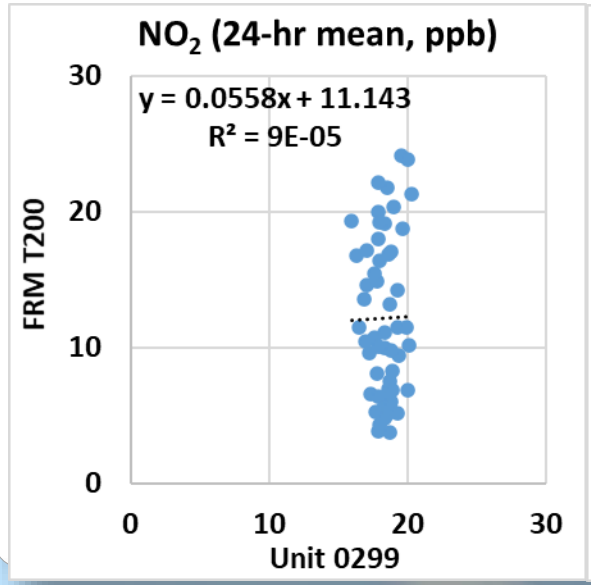


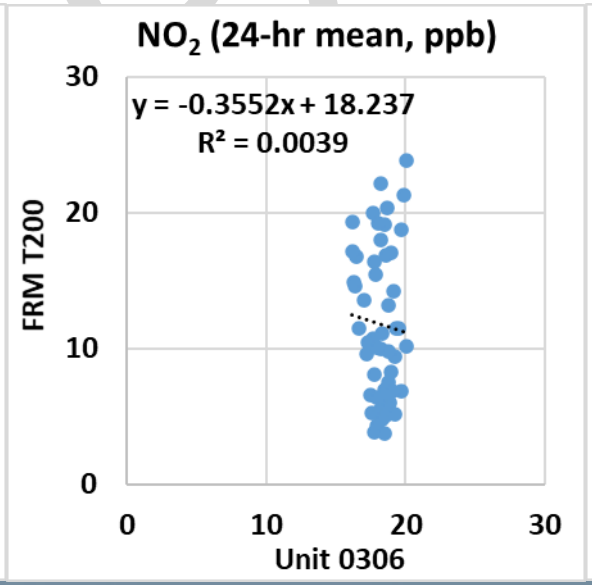


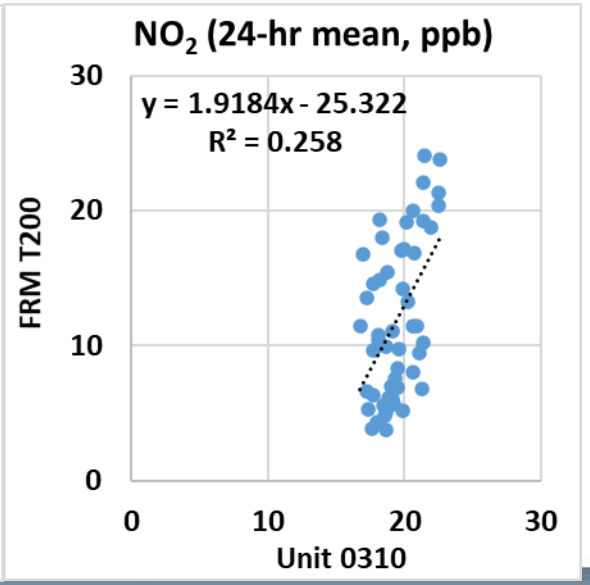
AirSENCE vs FRM T200 (NO_2; 24-hr mean)



- The AirSENCE sensors showed no to very weak correlations with the corresponding FRM T200 NO_2 data ($0 < R^2 < 0.26$)
- Overall, the AirSENCE sensors overestimated the NO_2 concentration as measured by the FRM T200 instrument
- The AirSENCE sensors did not seem to track the daily NO_2 variations as recorded by the FRM T200 instrument







Summary: NO_2

	Average of 3 Sensors, NO_2		AirSENCE vs FRM T200, NO_2						FRM T200, NO_2 (ppb)		
	Average (ppb)	SD (ppb)	R^2	Slope	Intercept	MBE[1] (ppb)	MAE[2] (ppb)	RMSE[3] (ppb)	FRM T200 Average	FRM T200 SD	Range during the field evaluation
5-min	18.7	5.0	0.16 to 0.21	0.64 to 1.04	-6.3 to 0.4	5.6 to 6.4	9.2 to 9.8	10.5 to 11.4	12.2	9.9	0.9 to 57.5
1-hr	18.8	4.8	0.20 to 0.24	0.73 to 1.15	-8.0 to -1.0	5.2 to 6.2	9.0 to 9.6	10.3 to 11.1	12.8	10.0	1.6 to 53.4
24-hr	18.7	1.2	0 to 0.26	-0.36 to 1.92	-25.3 to 18.2	6.2 to 7.5	7.2 to 7.7	8.6 to 9.1	12.2	5.9	3.8 to 24.1

[1] Mean Bias Error (MBE): the difference between the sensors and the reference instruments. MBE indicates the tendency of the sensors to underestimate (negative MBE values) or overestimate (positive MBE values).
[2] Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.
[3] Root Mean Square Error (RMSE): another metric to calculate measurement errors.

Carbon Monoxide (CO) in AirSENCE

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 for CO from all units was ~100%

Note that the sensors have a 20 ppb detection limit for CO measurements, therefore all values less than 20 ppb were not used in subsequent data analysis.

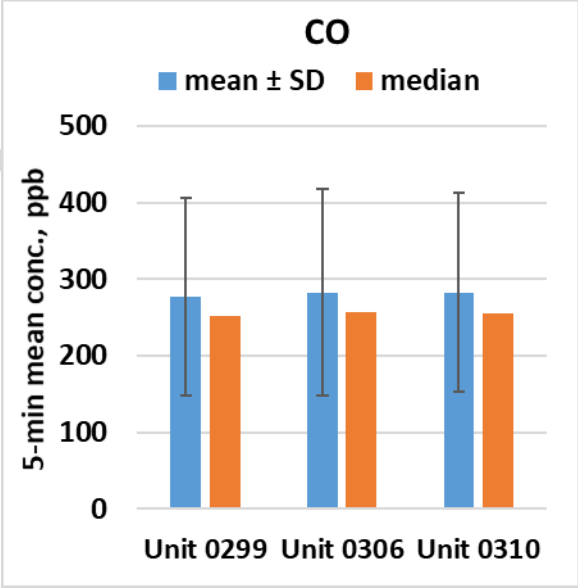
AirSENCE; Intra-model variability

- Absolute intra-model variability was ~ 3.1 ppb for the CO measurements

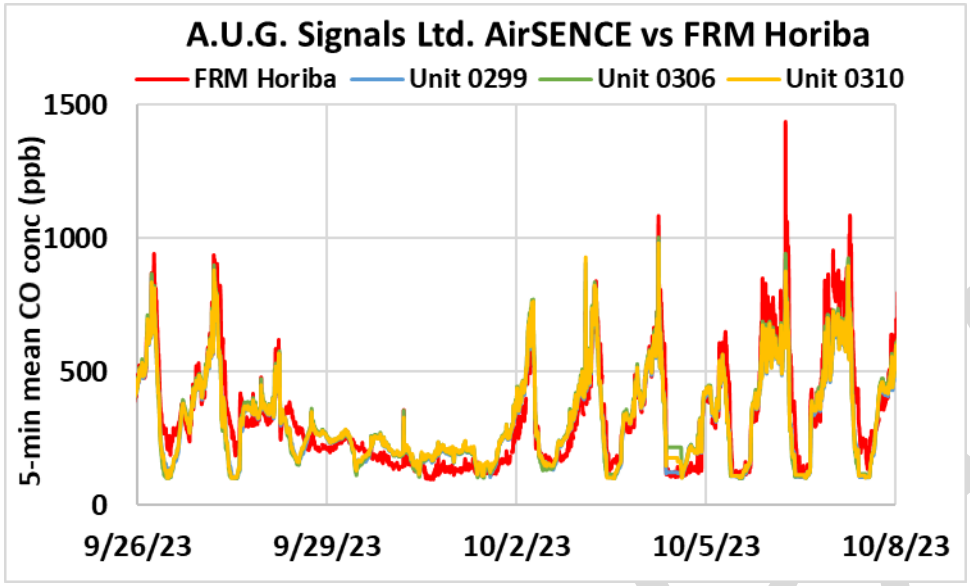
(calculated as the standard deviation of the three sensor means)

- Relative intra-model variability was ~ 1.1% for the CO measurements

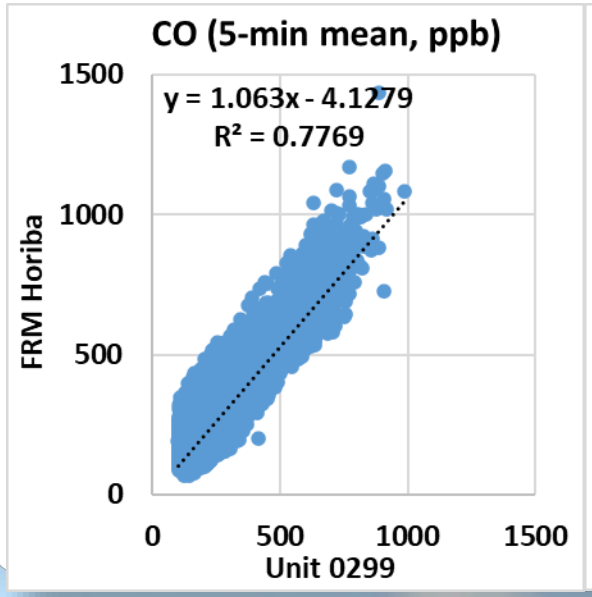
(calculated as the absolute intra-model variability relative to the mean of the three sensor means)

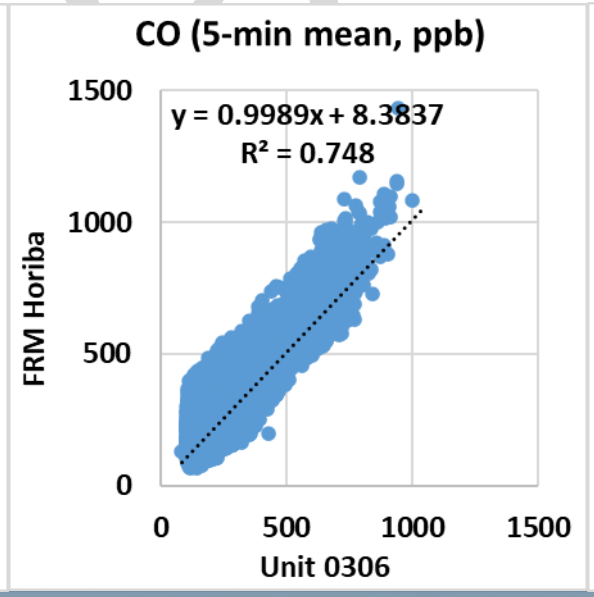


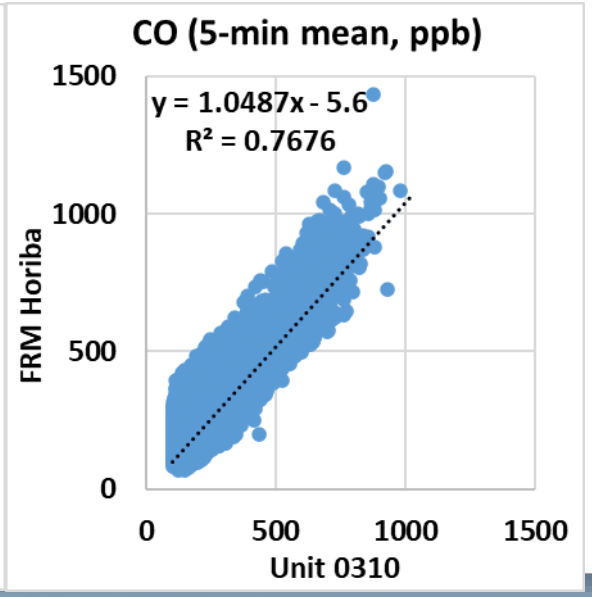
AirSENCE vs FRM Horiba (CO; 5-min mean)



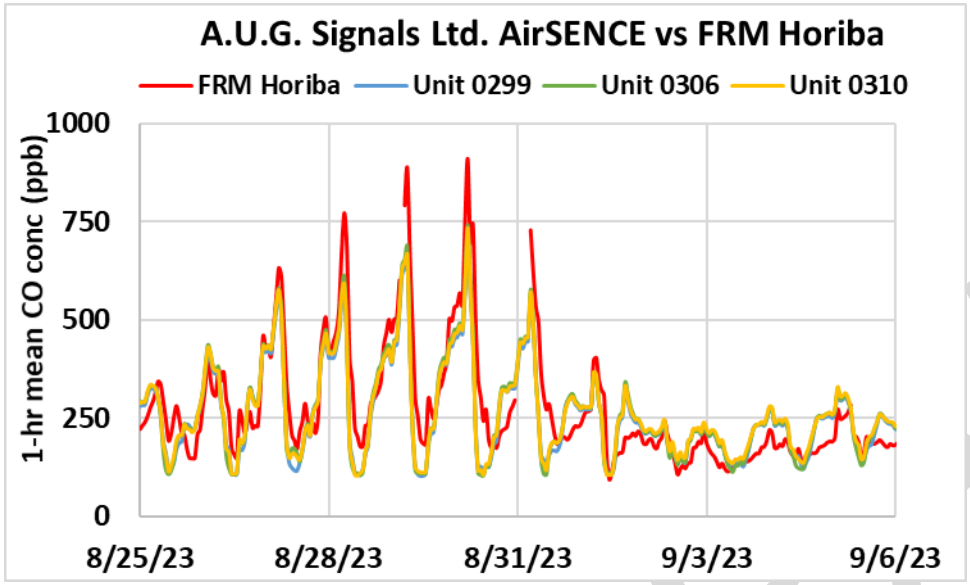
- The AirSENCE sensors showed strong correlations with the corresponding FRM Horiba CO data ($0.74 < R^2 < 0.78$)
- Overall, the AirSENCE sensors underestimated the CO concentration as measured by the FRM Horiba instrument
- The AirSENCE sensors seemed to track the diurnal CO variations as recorded by the FRM Horiba instrument



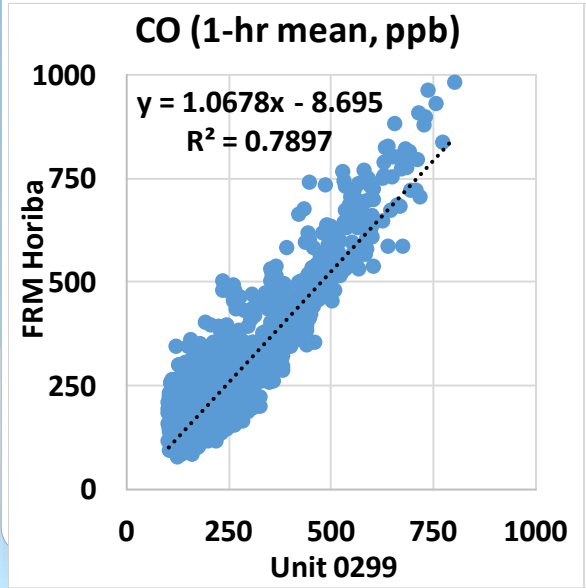


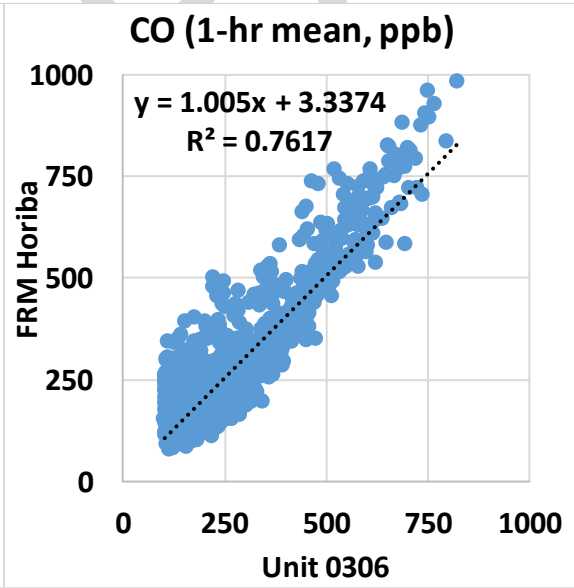


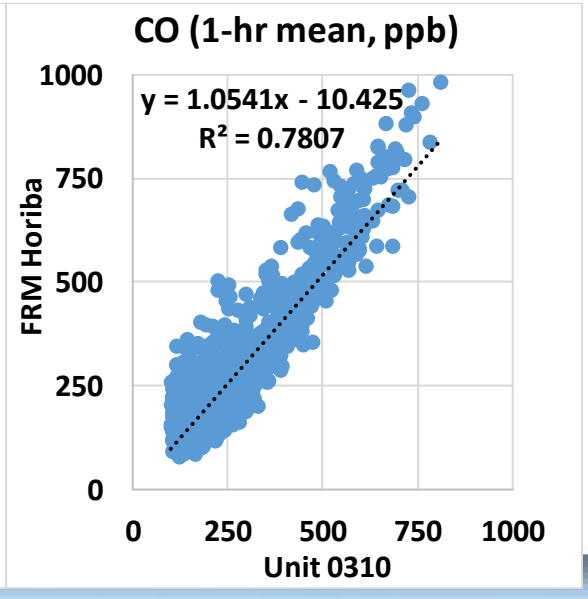
AirSENCE vs FRM Horiba (CO; 1-hr mean)



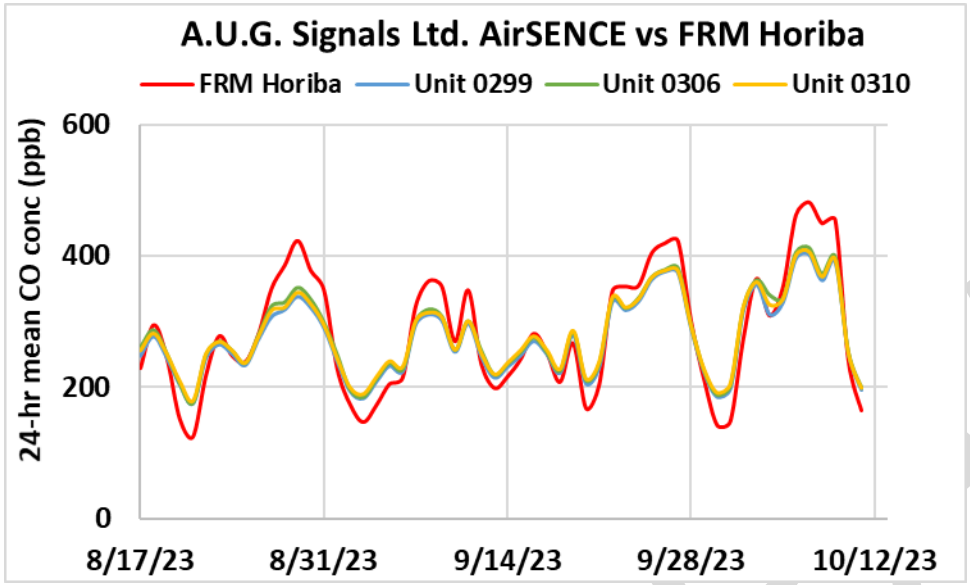
- The AirSENCE sensors showed strong correlations with the corresponding FRM Horiba CO data ($0.76 < R^2 < 0.79$)
- Overall, the AirSENCE sensors underestimated the CO concentration as measured by the FRM Horiba instrument
- The AirSENCE sensors seemed to track the diurnal CO variations as recorded by the FRM Horiba instrument



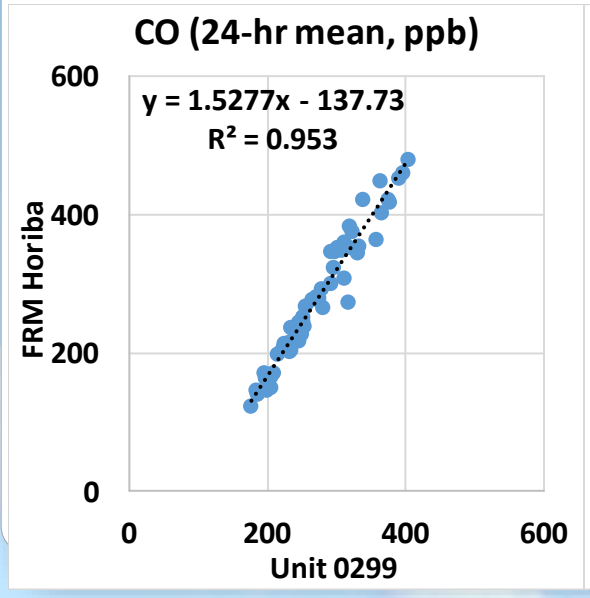


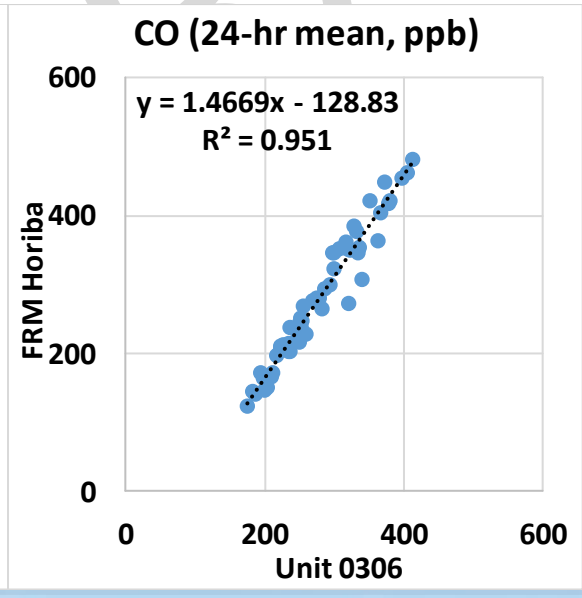


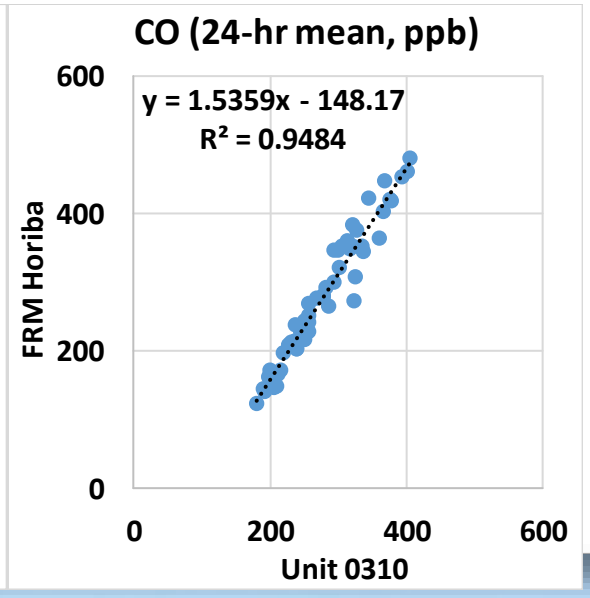
AirSENCE vs FRM Horiba (CO; 24-hr mean)



- The AirSENCE sensors showed very strong correlations with the corresponding FRM Horiba CO data ($0.94 < R^2 < 0.96$)
- Overall, the AirSENCE sensors underestimated the CO concentration as measured by the FRM Horiba instrument
- The AirSENCE sensors seemed to track the daily CO variations as recorded by the FRM Horiba instrument







Summary: CO

	Average of 3 Sensors, CO		AirSENCE vs FRM Horiba, CO						FRM CO, Horiba (ppb)		
	Average (ppm)	SD (ppb)	R^2	Slope	Intercept	MBE[1] (ppb)	MAE[2] (ppb)	RMSE[3] (ppb)	FRM Horiba Average	FRM Horiba SD	Range during the field evaluation
5-min	281.0	131.6	0.75 to 0.78	1.00 to 1.06	-5.6 to 8.4	-13.0 to -7.9	57.7 to 60.9	74.9 to 78.4	284.6	155.3	67.3 to 1436.1
1-hr	281.1	129.4	0.76 to 0.79	1.01 to 1.07	-10.4 to 3.3	-10.1 to -4.8	55.3 to 58.5	71.1 to 74.5	286.5	152.3	80.4 to 986.2
24-hr	279.7	60.7	0.95	1.47 to 1.54	-148.2 to -128.8	-8.0 to -2.6	29.9 to 31.9	35.6 to 38.2	284.1	94.0	124.0 to 481.8

[1] Mean Bias Error (MBE): the difference between the sensors and the reference instruments. MBE indicates the tendency of the sensors to underestimate (negative MBE values) or overestimate (positive MBE values).
[2] Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.
[3] Root Mean Square Error (RMSE): another metric to calculate measurement errors.

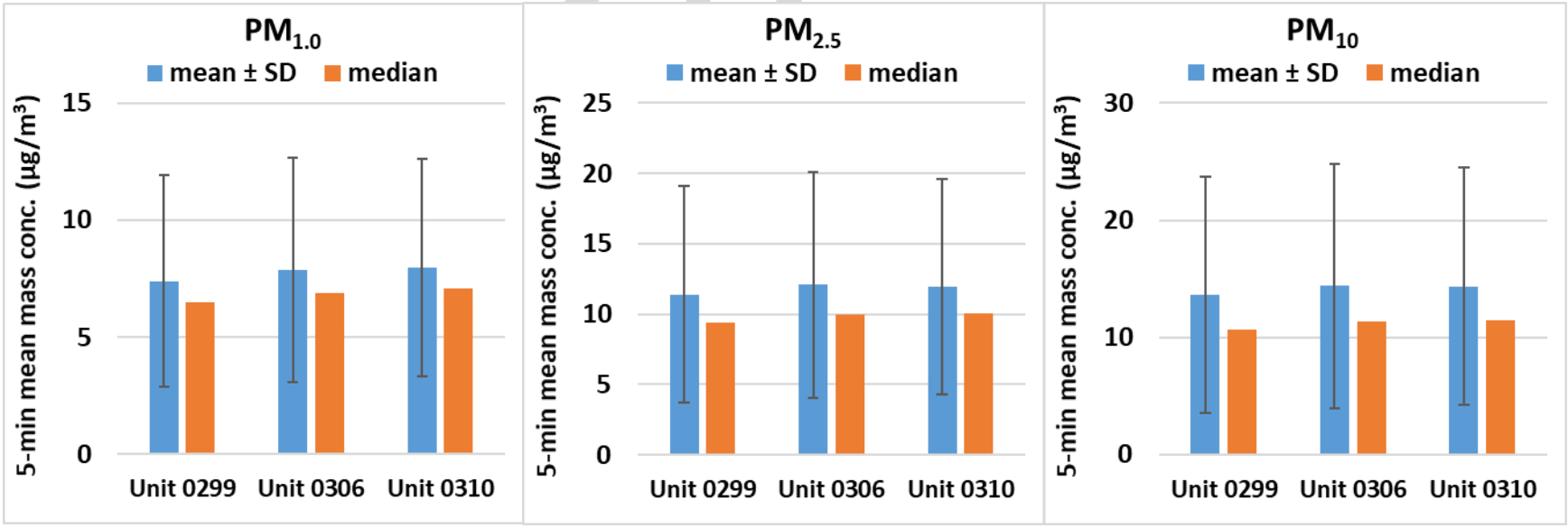
Particulate Matter (PM) in AirSENCE

Data validation & recovery

- Basic QA/QC procedures were used to validate the collected data (i.e. obvious outliers, negative values and invalid data-points were eliminated from the data-set)
- Data recovery from all units was ~100% for all PM measurements

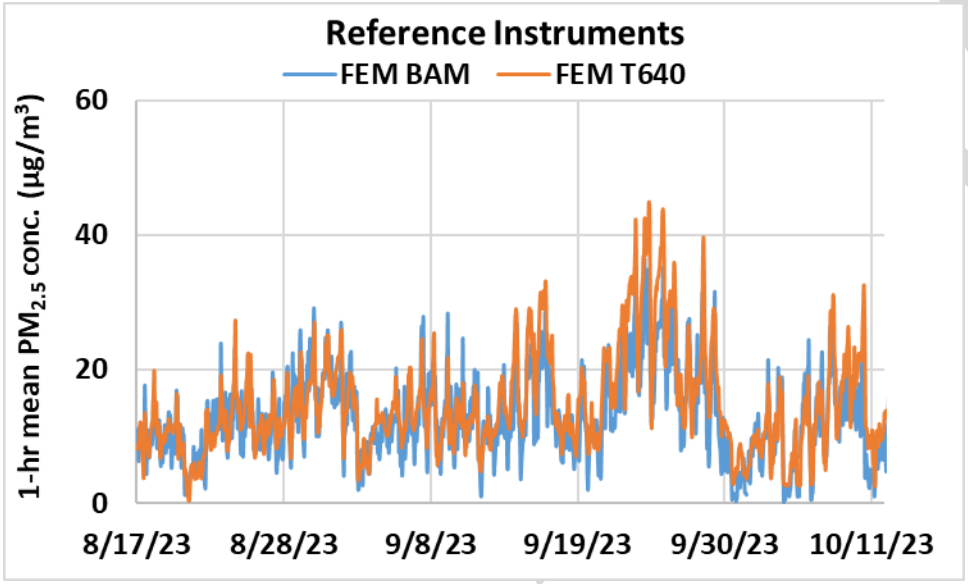
AirSENCE; intra-model variability

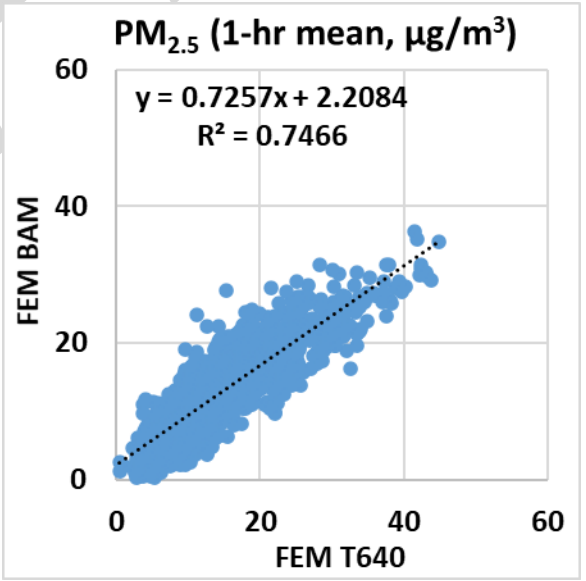
- Absolute intra-model variability was ~0.31, ~0.35 and ~0.42 µg/m^3 for $PM_{1.0}$, $PM_{2.5}$ and $PM_{10,}$ respectively (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~4.0%, ~3.0% and ~2.9% for $PM_{1.0}$, $PM_{2.5}$ and $PM_{10,}$ respectively (calculated as the absolute intra-model variability relative to the mean of the three sensor means)



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

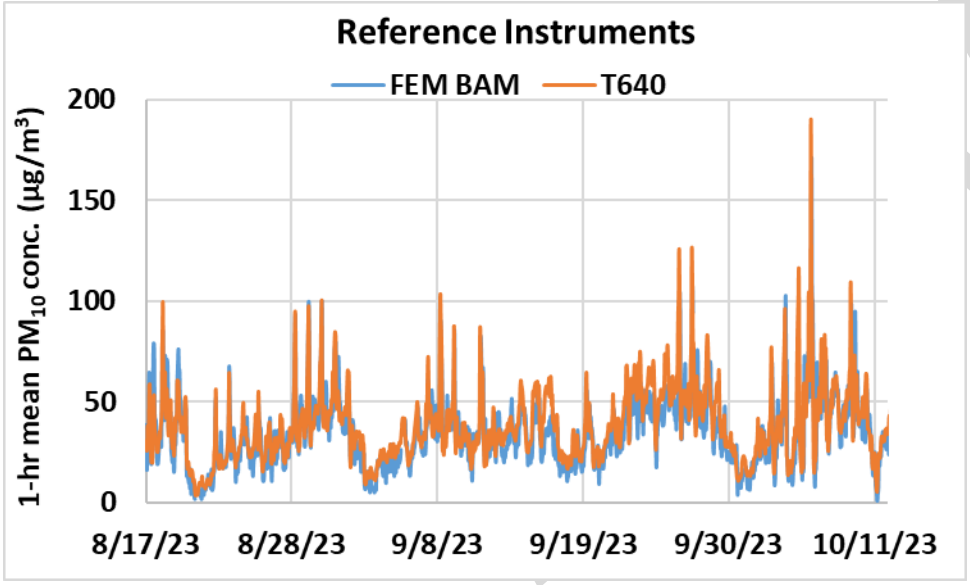
- Data recovery for $PM_{2.5}$ from FEM BAM and FEM T640 was 98.9% and ~100%, respectively.
- Strong correlations between the reference instruments for $PM_{2.5}$ measurements (R^2 ~ 0.75) were observed.

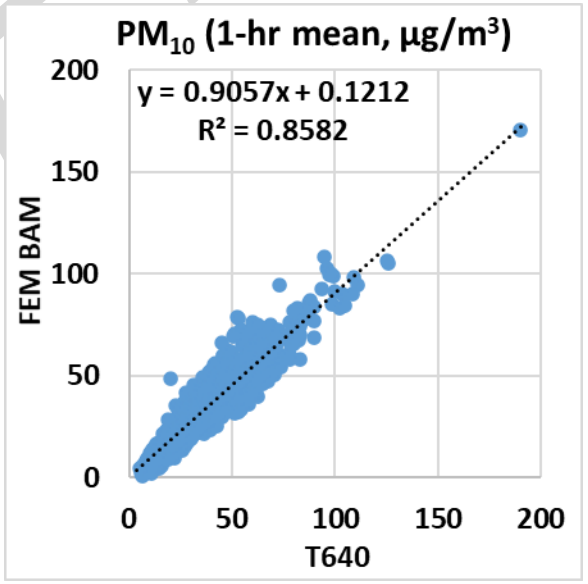




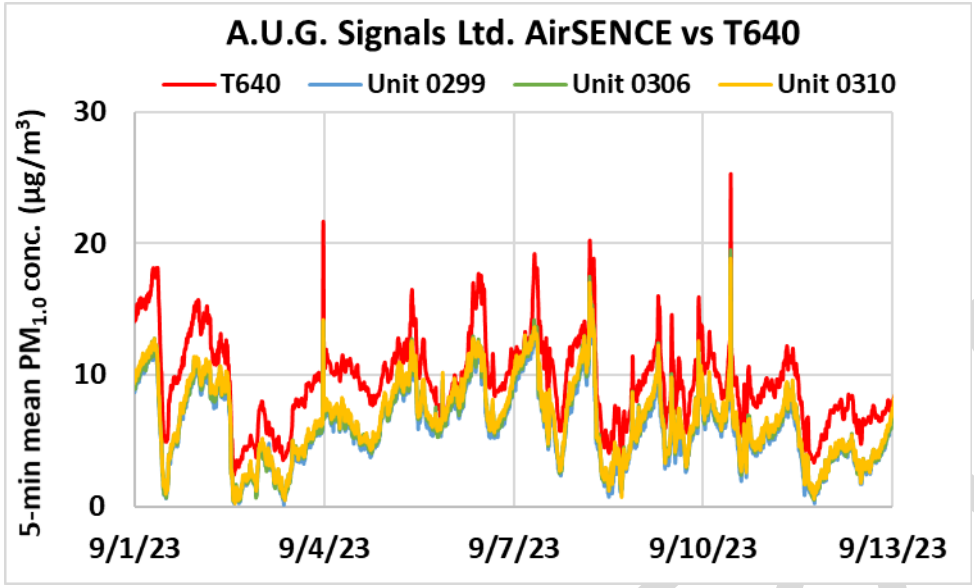
Reference Instruments: PM_{10} FEM BAM and T640

- Data recovery for PM_{10} from FEM BAM and T640 was 98.9% and 99.9%, respectively.
- Strong correlations between the reference instruments for PM_{10} measurements (R^2 ~ 0.86) were observed.

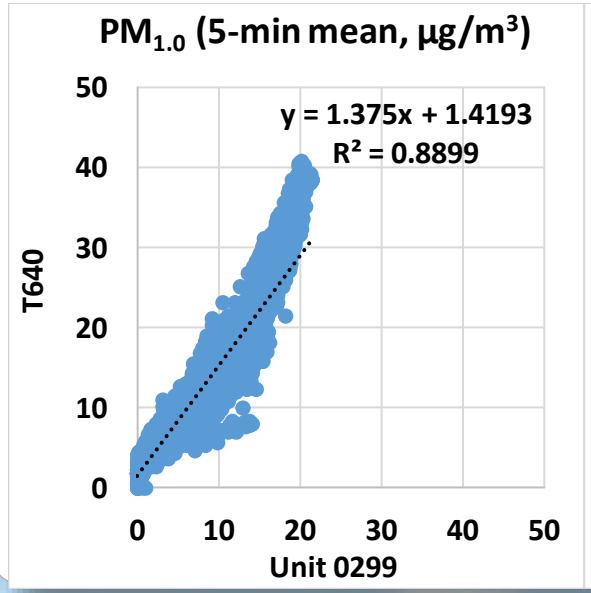


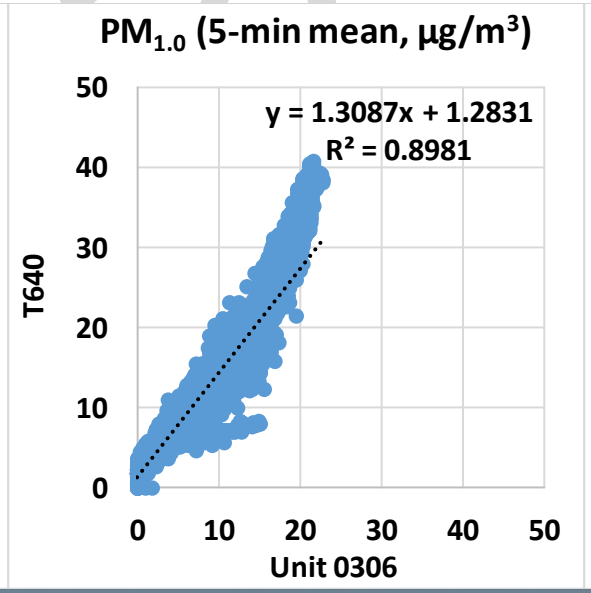


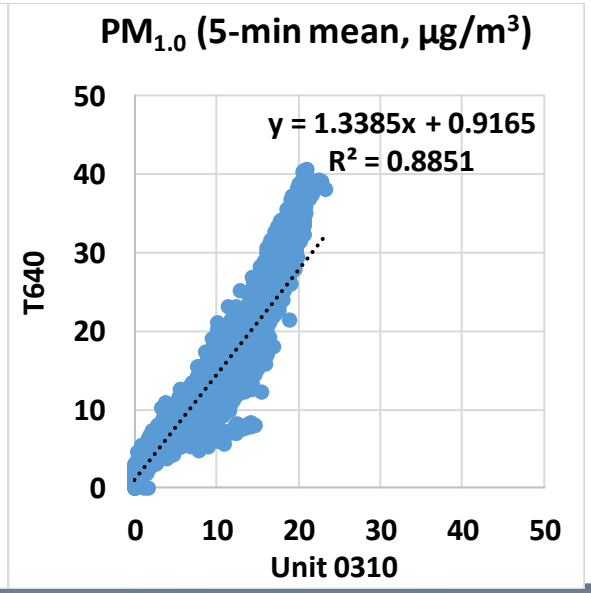
AirSENCE vs T640 ($PM_{1.0}$; 5-min mean)



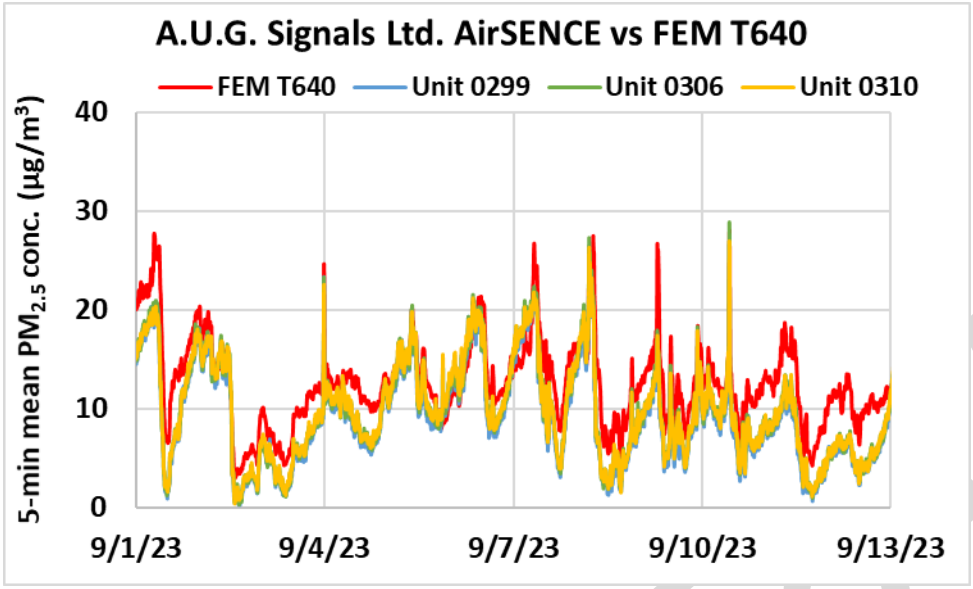
- The AirSENCE sensors showed strong correlations with the corresponding T640 data ($0.88 < R^2 < 0.90$)
- Overall, the AirSENCE sensors underestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The AirSENCE sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640



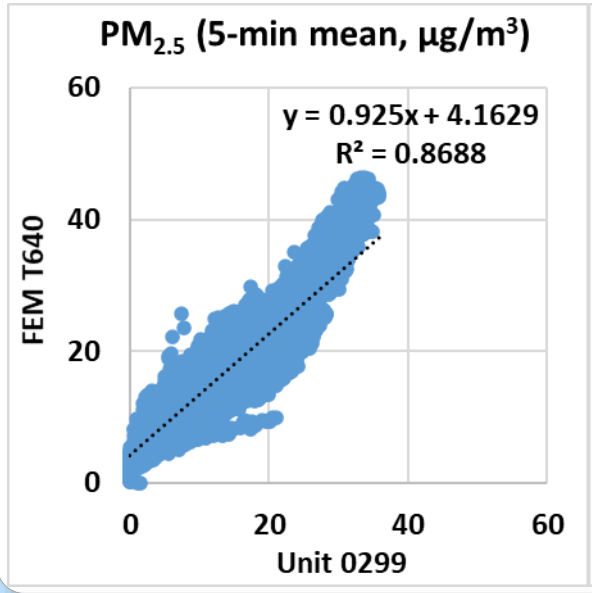


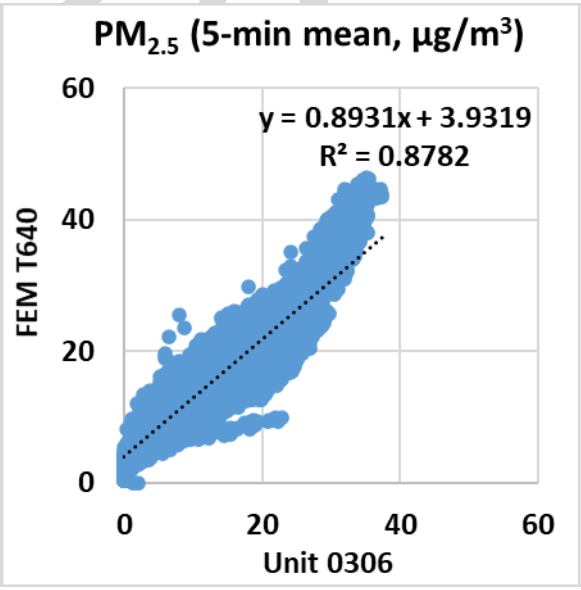


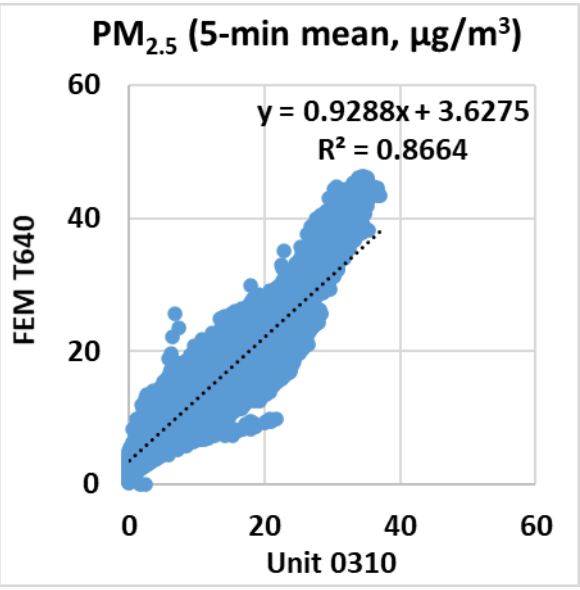
AirSENCE vs FEM T640 ($PM_{2.5}$; 5-min mean)



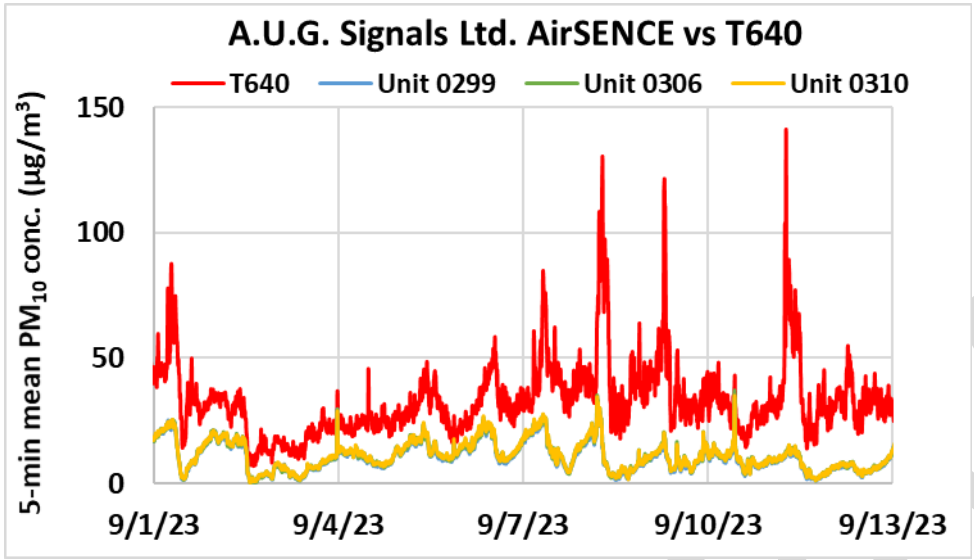
- The AirSENCE sensors showed strong correlations with the corresponding FEM T640 data ($0.86 < R^2 < 0.88$)
- Overall, the AirSENCE sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The AirSENCE sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



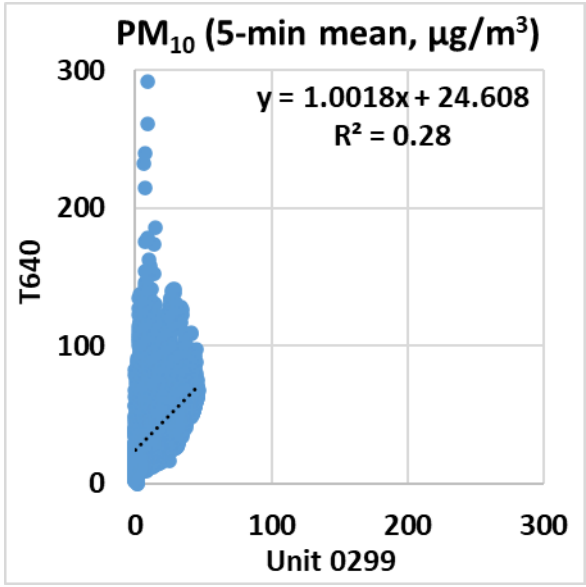


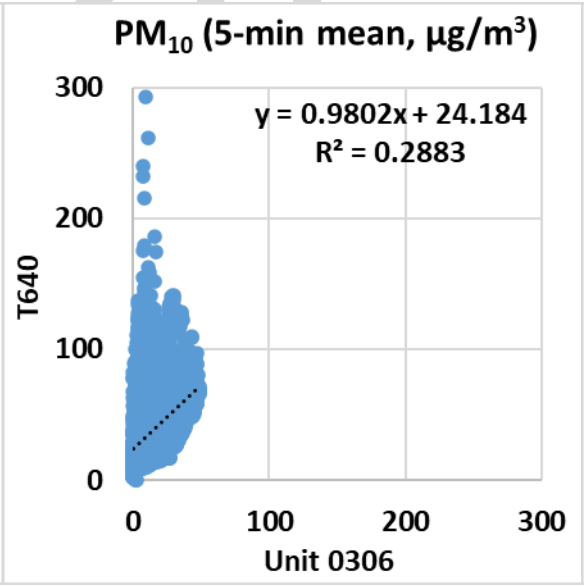


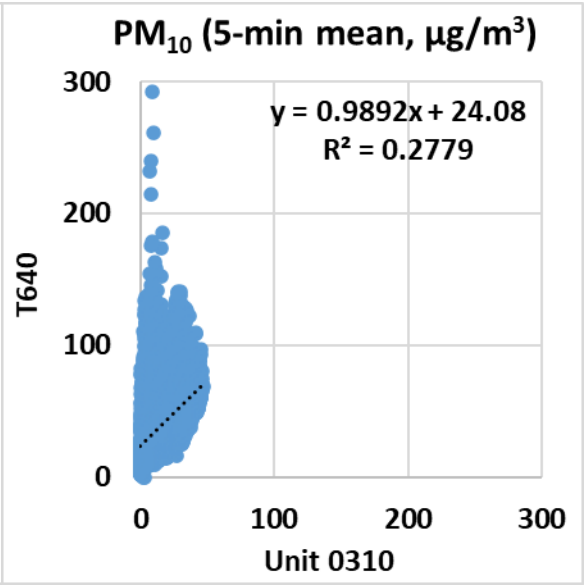
AirSENCE vs T640 (PM_{10}; 5-min mean)



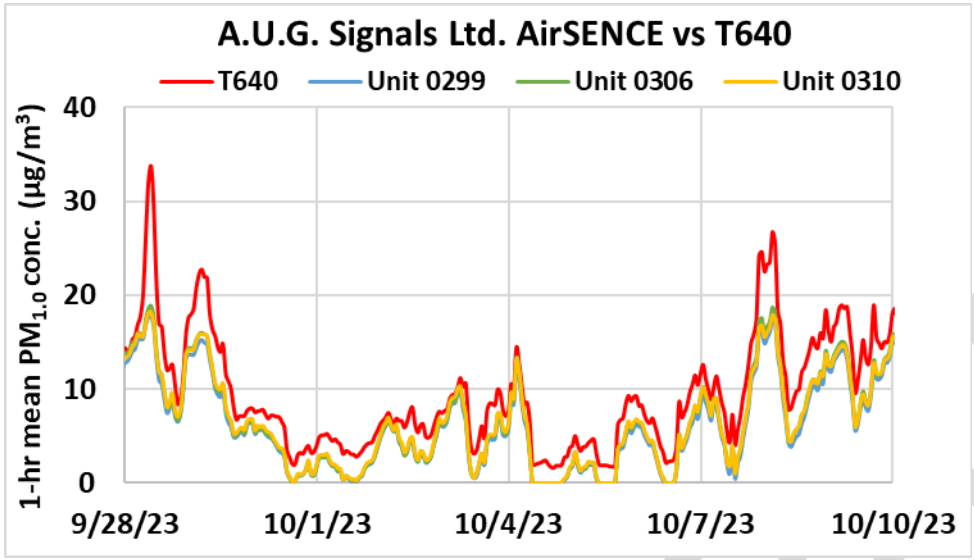
- The AirSENCE sensors showed very weak correlations with the corresponding T640 data ($0.27 < R^2 < 0.29$)
- Overall, the AirSENCE sensors underestimated the PM_{10} mass concentrations as measured by T640
- The AirSENCE sensors sometimes seemed to track the PM_{10} diurnal variations as recorded by T640



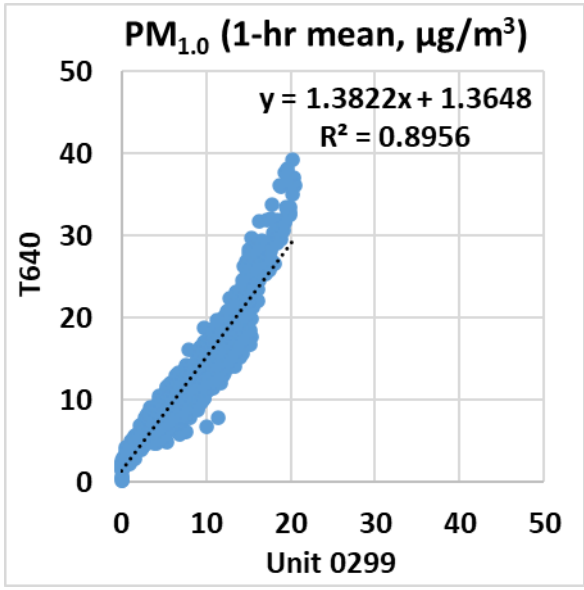


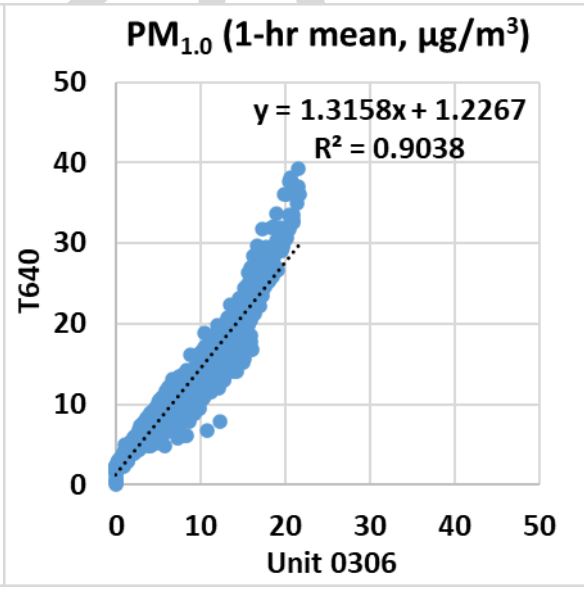


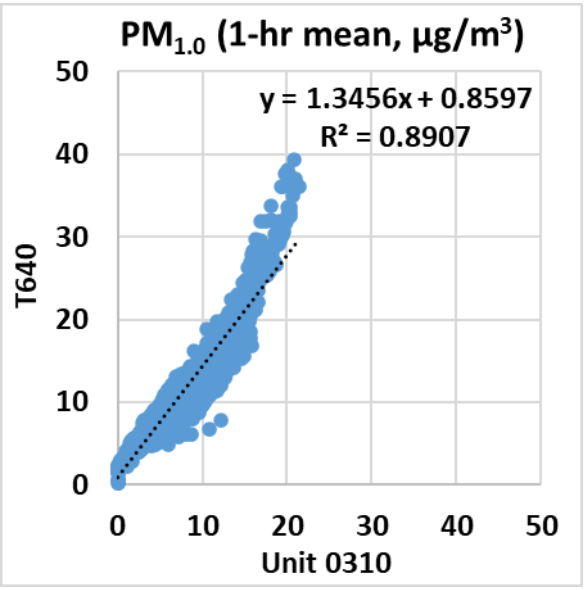
AirSENCE vs T640 ($PM_{1.0}$; 1-hr mean)



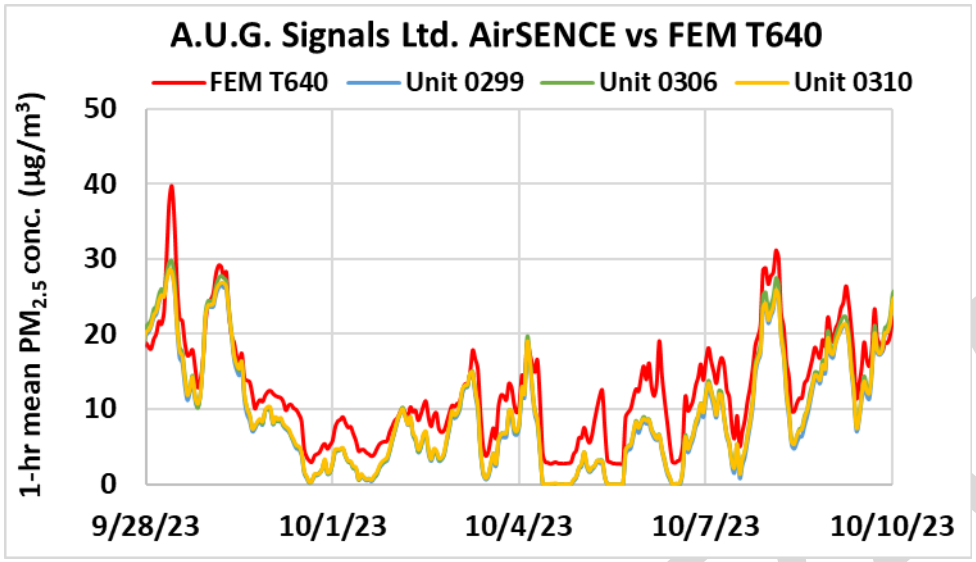
- The AirSENCE sensors showed strong to very strong correlations with the corresponding T640 data ($0.89 < R^2 < 0.91$)
- Overall, the AirSENCE sensors underestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The AirSENCE sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640



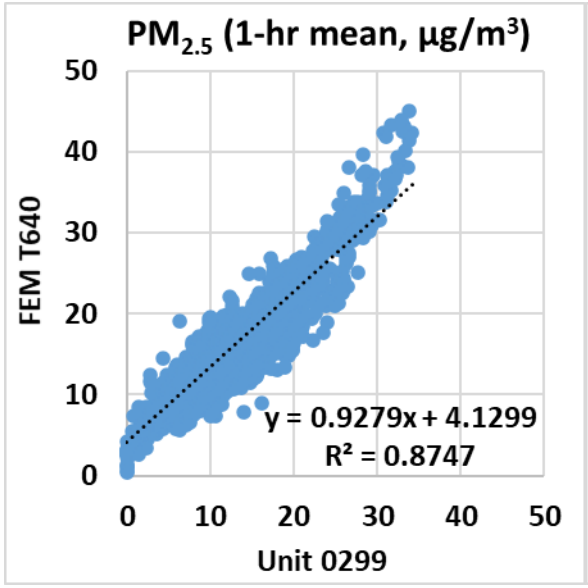


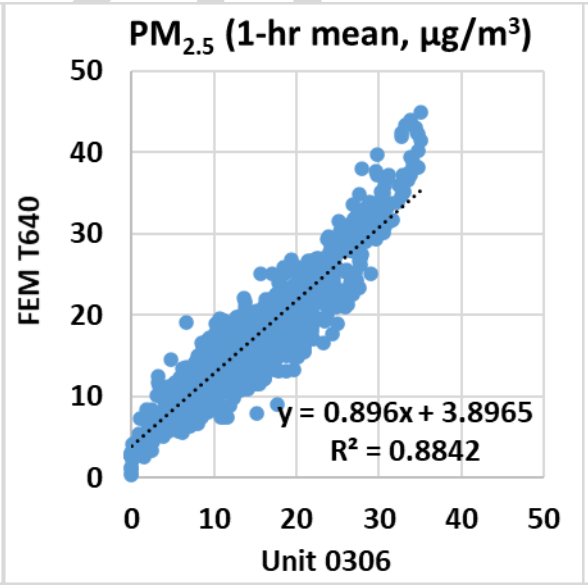


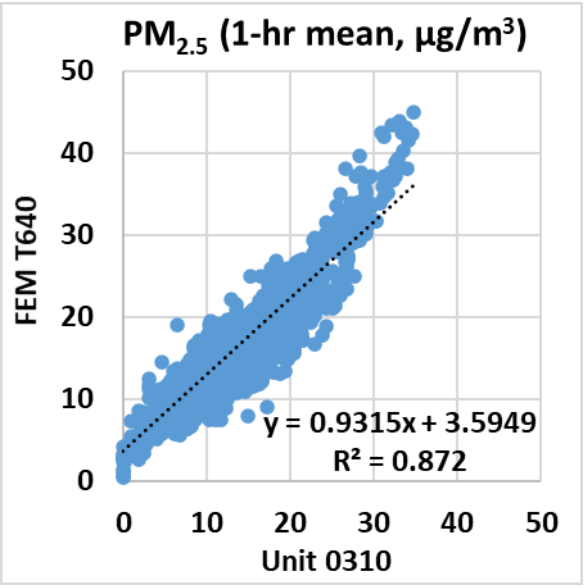
AirSENCE vs FEM T640 ($PM_{2.5}$; 1-hr mean)



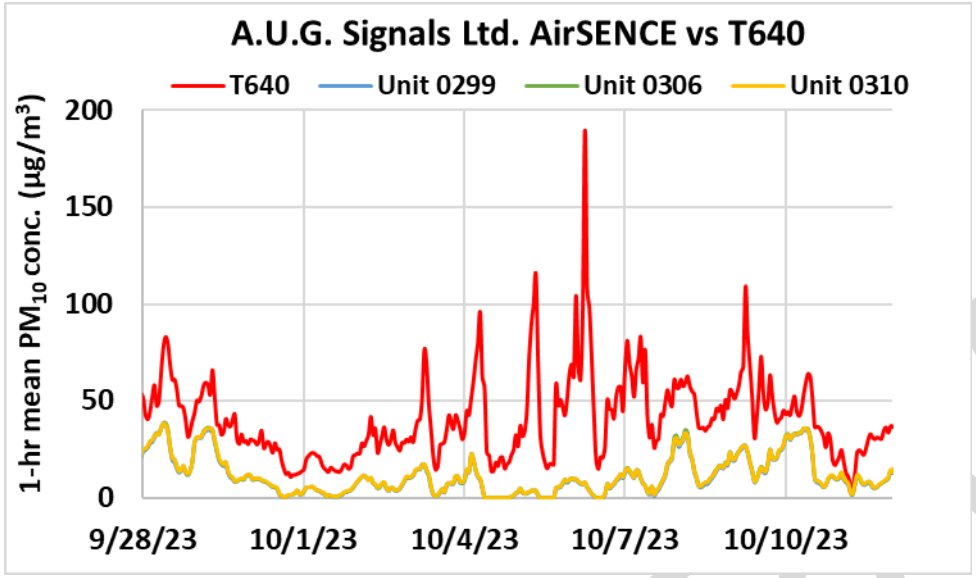
- The AirSENCE sensors showed strong correlations with the corresponding FEM T640 data ($0.87 < R^2 < 0.89$)
- Overall, the AirSENCE sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The AirSENCE sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



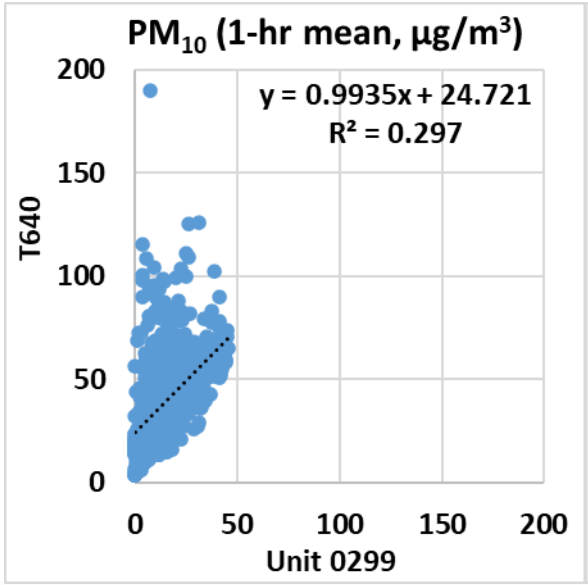


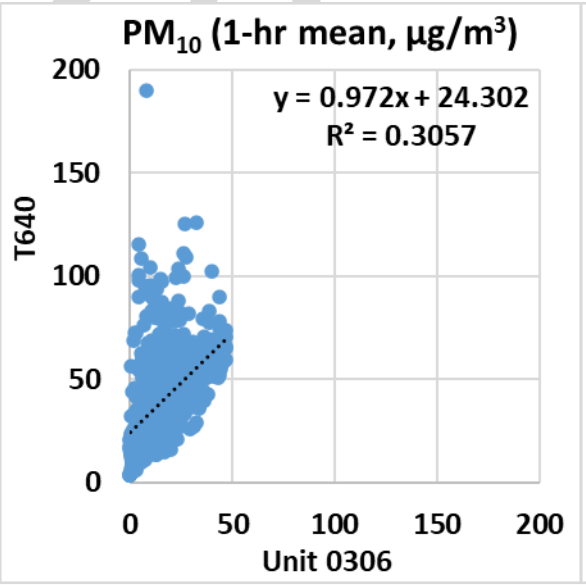


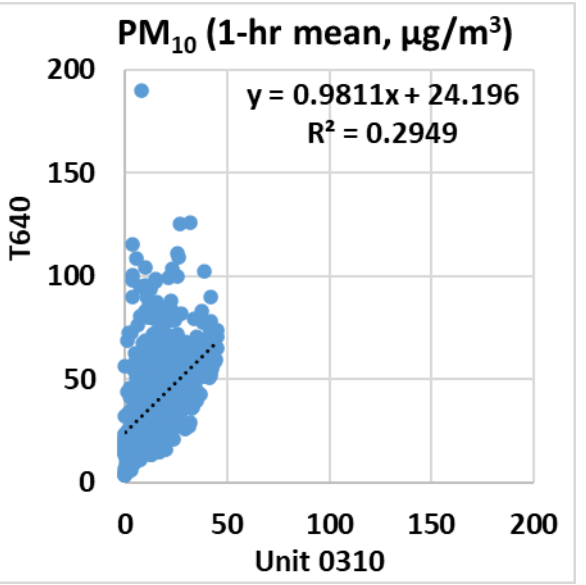
AirSENCE vs T640 (PM_{10}; 1-hr mean)



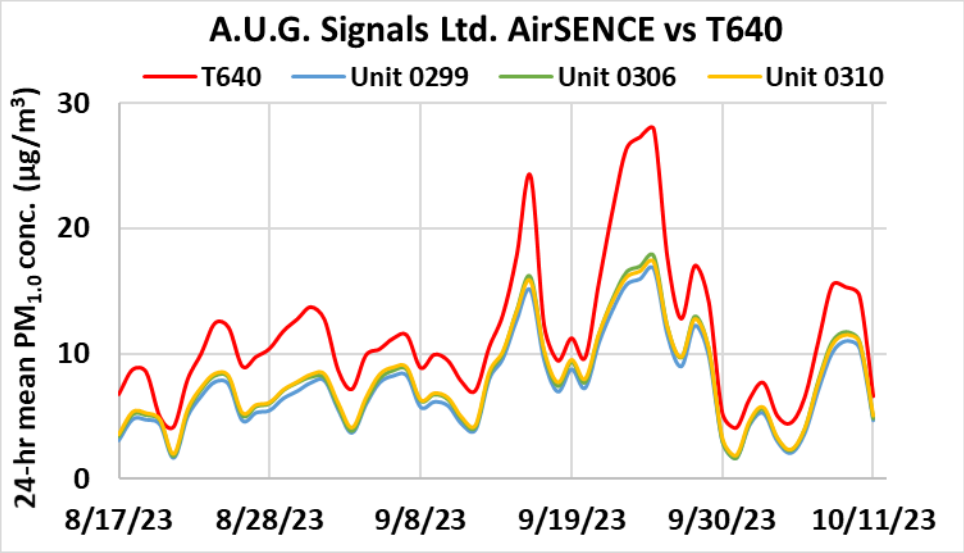
- The AirSENCE sensors showed very weak to weak correlations with the corresponding T640 data ($0.29 < R^2 < 0.31$)
- Overall, the AirSENCE sensors underestimated the PM_{10} mass concentrations as measured by T640
- The AirSENCE sensors sometimes seemed to track the PM_{10} diurnal variations as recorded by T640



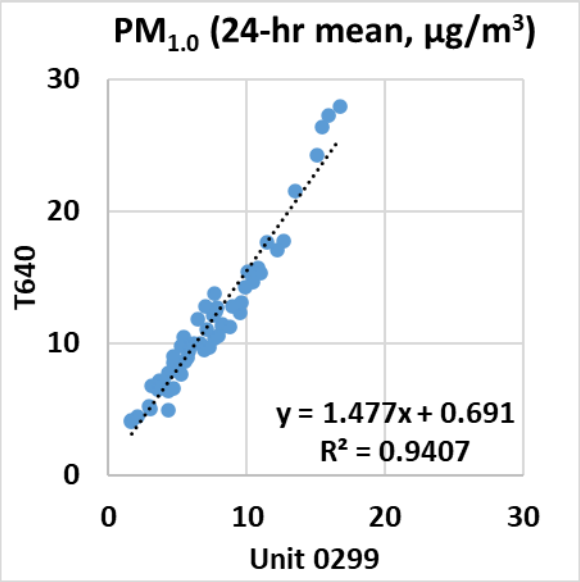


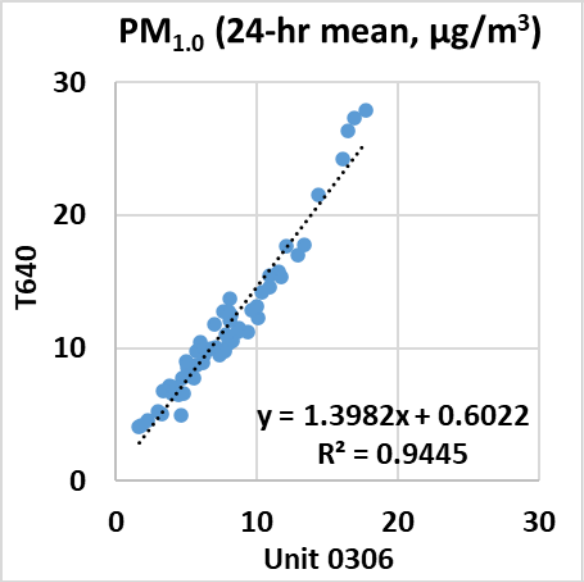


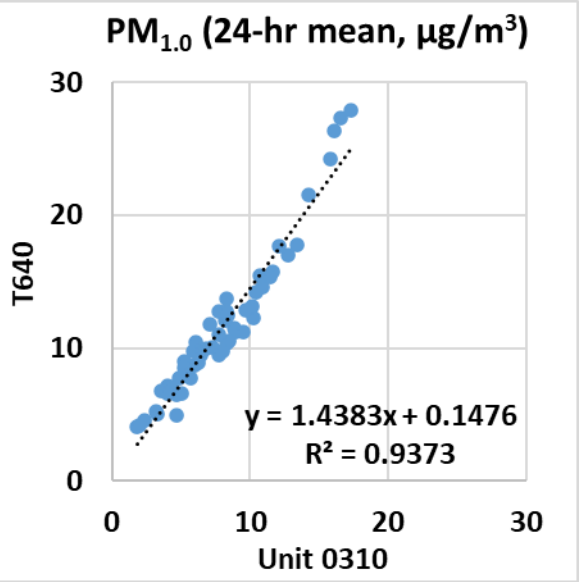
AirSENCE vs T640 ($PM_{1.0}$; 24-hr mean)



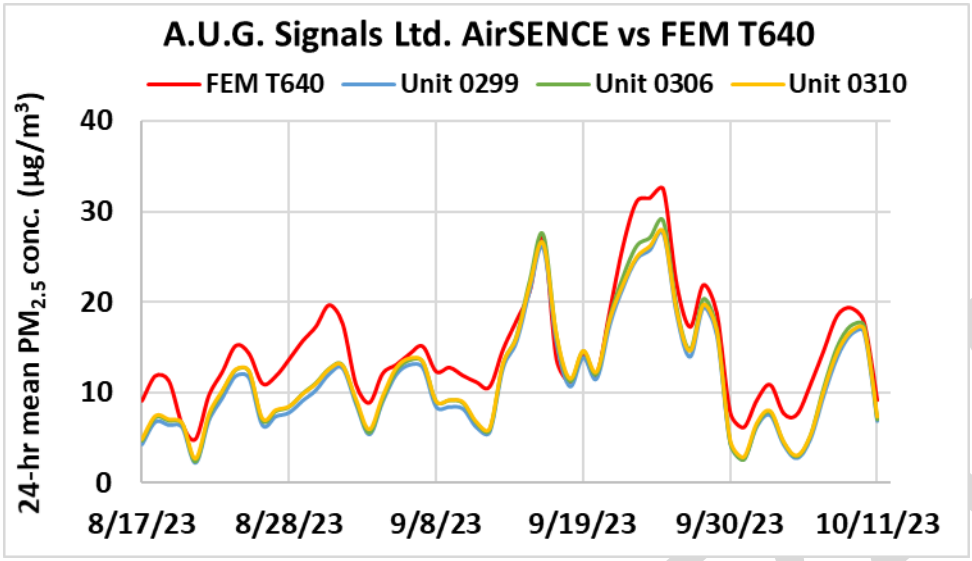
- The AirSENCE sensors showed very strong correlations with the corresponding T640 data ($0.93 < R^2 < 0.95$)
- Overall, the AirSENCE sensors underestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The AirSENCE sensors seemed to track the $PM_{1.0}$ daily variations as recorded by T640



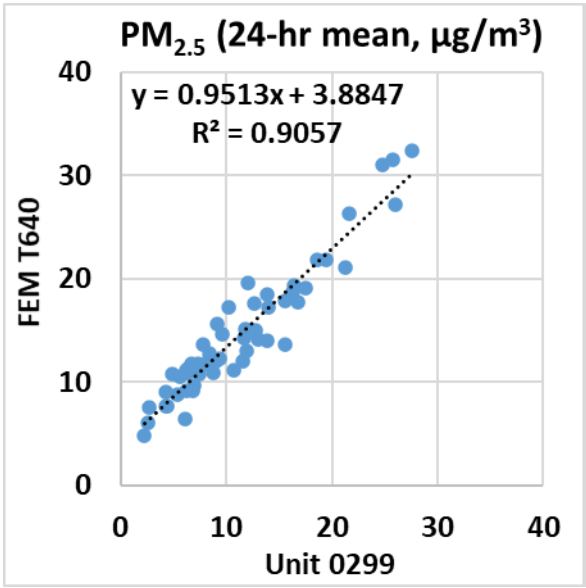


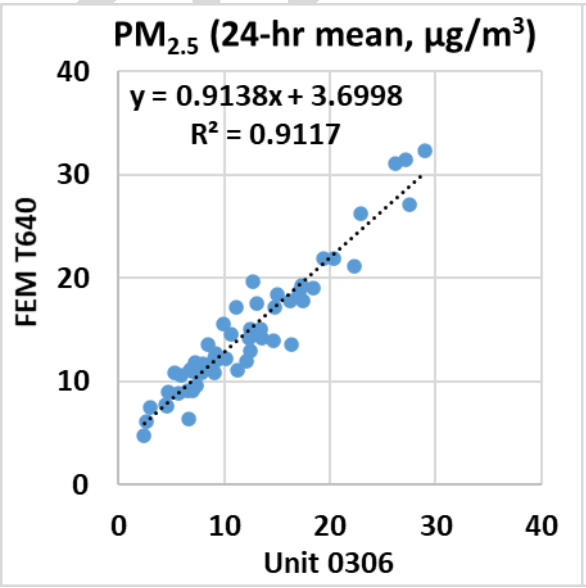


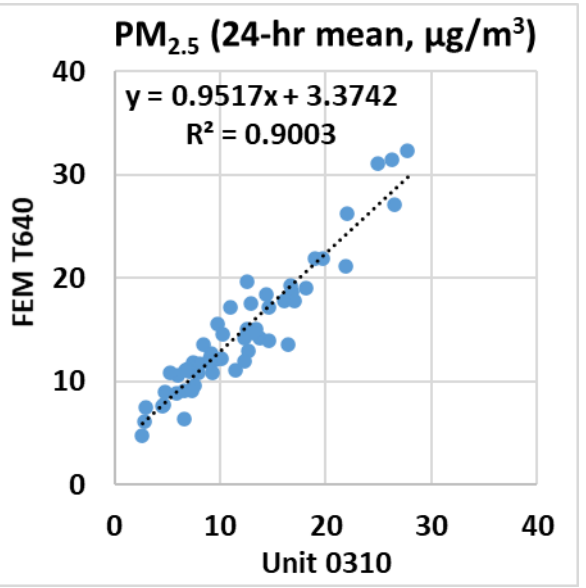
AirSENCE vs FEM T640 ($PM_{2.5}$; 24-hr mean)



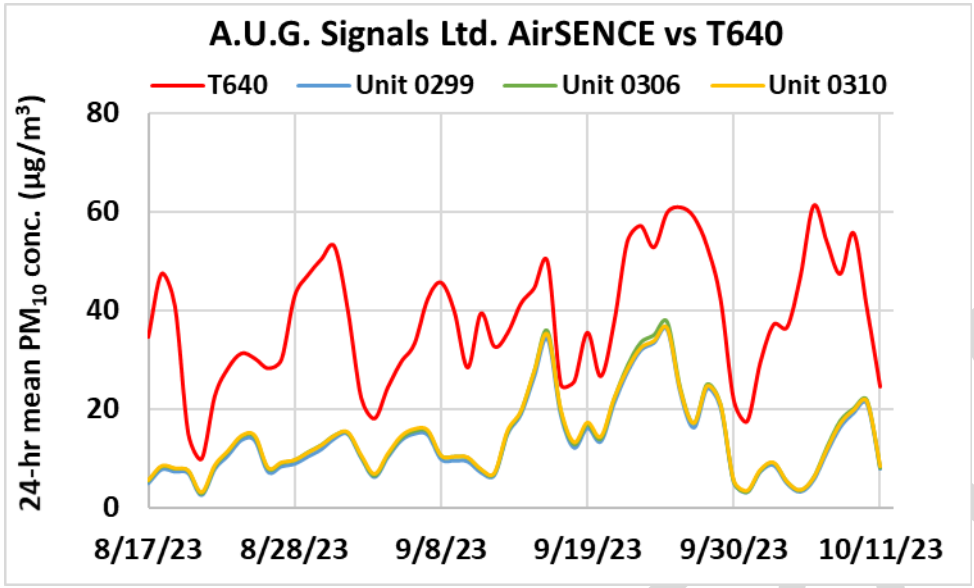
- The AirSENCE sensors showed very strong correlations with the corresponding FEM T640 data ($0.90 < R^2 < 0.92$)
- Overall, the AirSENCE sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The AirSENCE sensors seemed to track the $PM_{2.5}$ daily variations as recorded by FEM T640



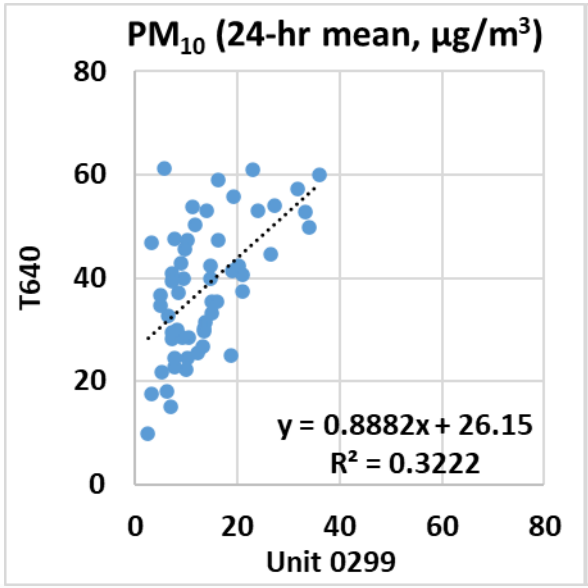


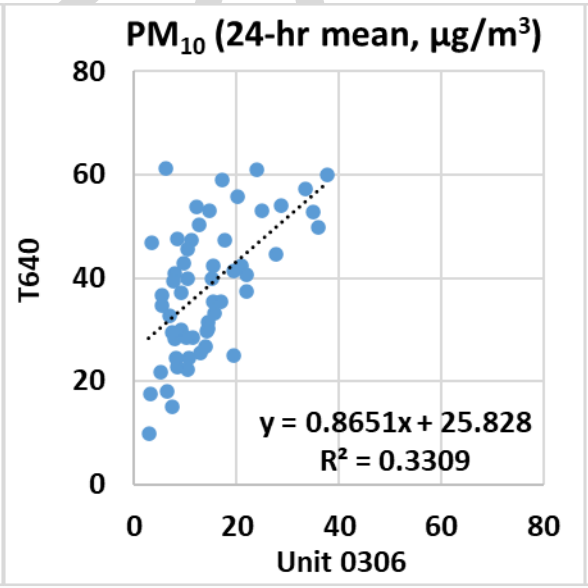


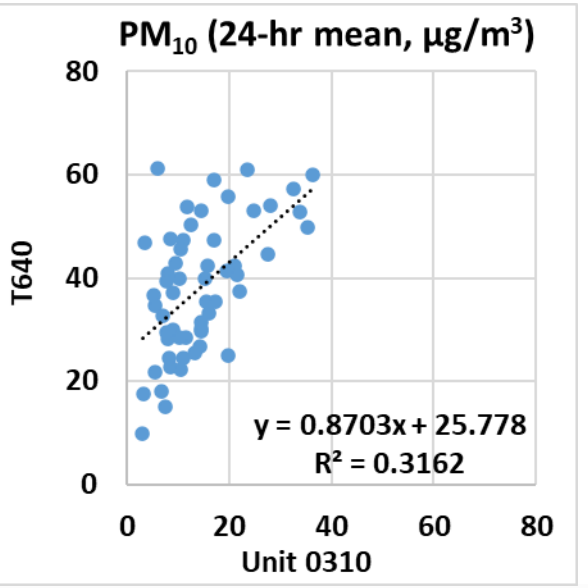
AirSENCE vs T640 (PM_{10}; 24-hr mean)



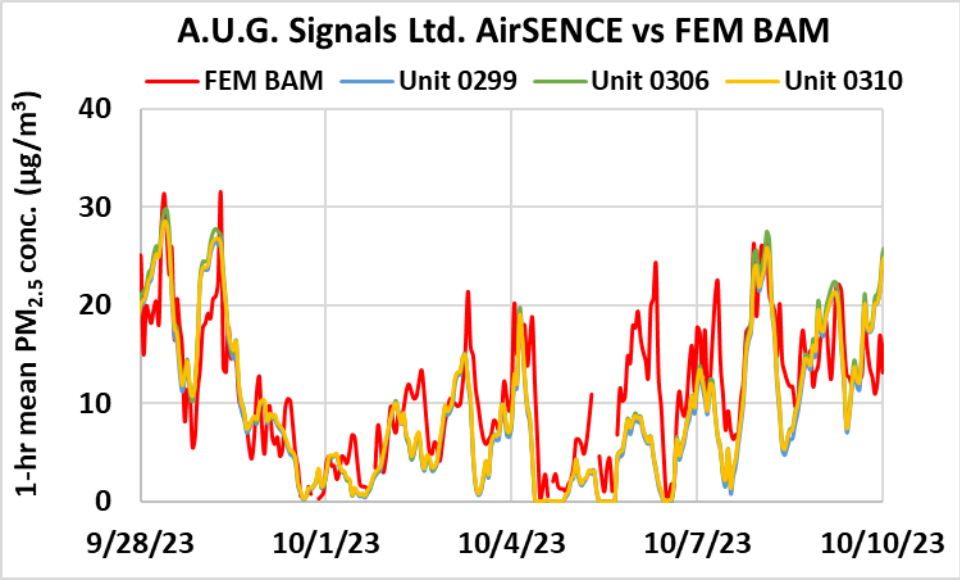
- The AirSENCE sensors showed weak correlations with the corresponding T640 data ($0.31 < R^2 < 0.34$)
- Overall, the AirSENCE sensors underestimated the PM_{10} mass concentrations as measured by T640
- The AirSENCE sensors did not seem to track the PM_{10} daily variations as recorded by T640



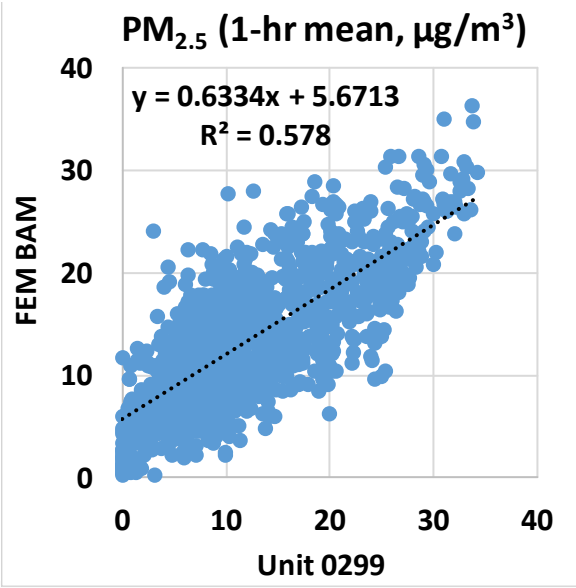


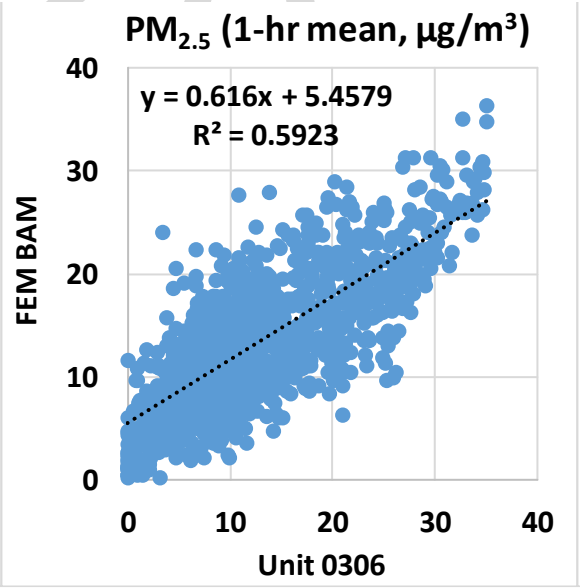


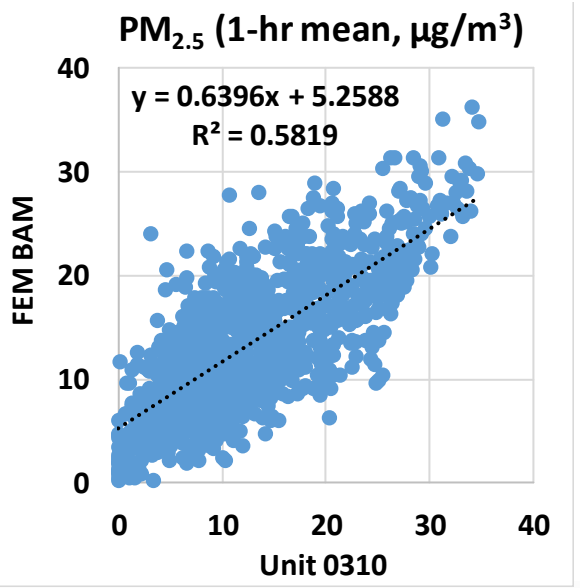
AirSENCE vs FEM BAM ($PM_{2.5}$; 1-hr mean)



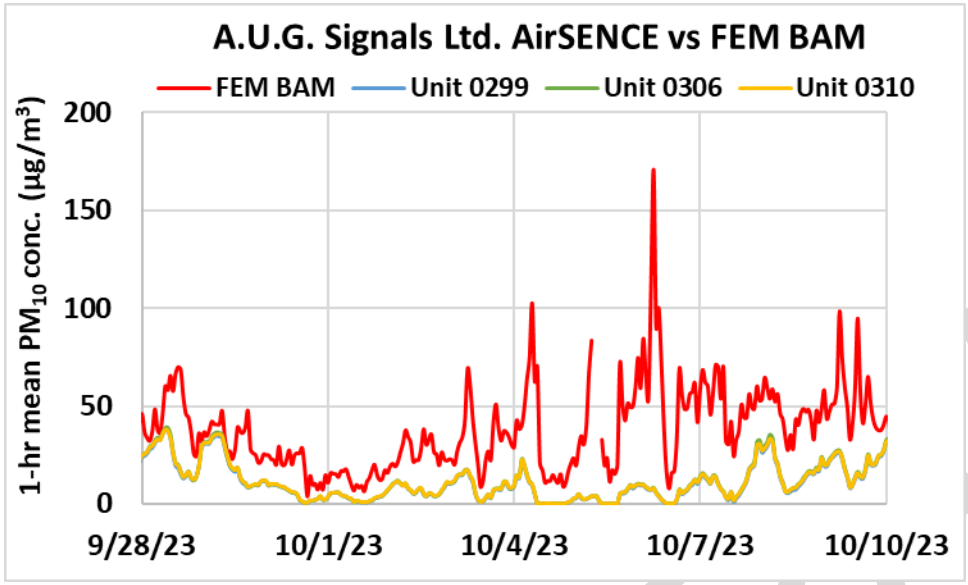
- The AirSENCE sensors showed moderate correlations with the corresponding FEM BAM data ($0.57 < R^2 < 0.60$)
- Overall, the AirSENCE sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM BAM
- The AirSENCE sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM BAM



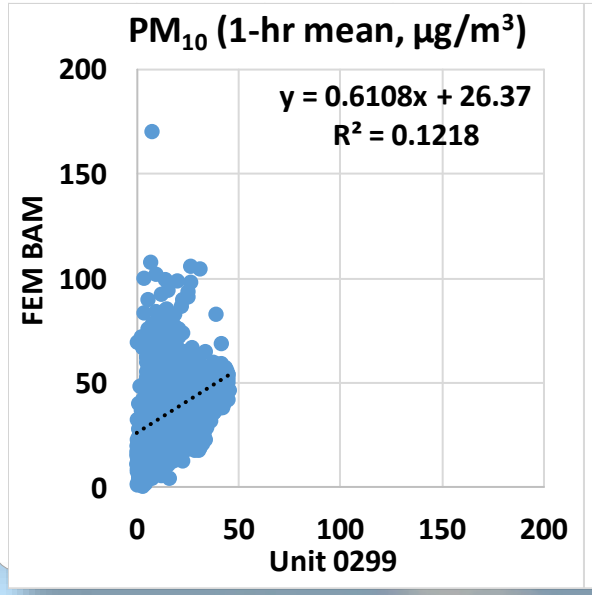


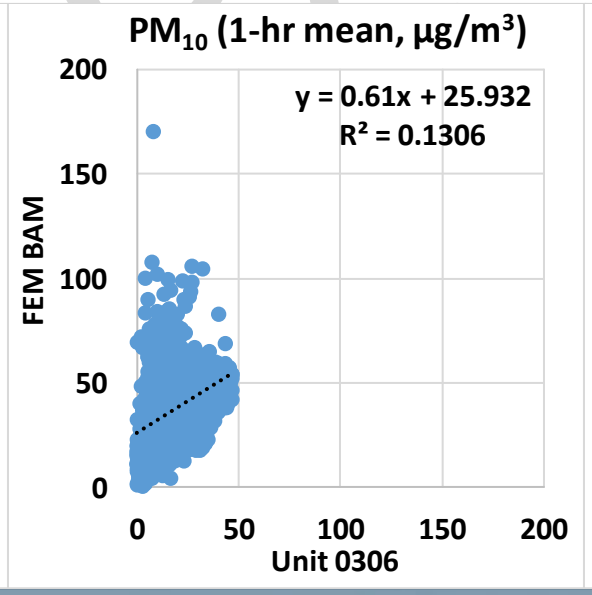


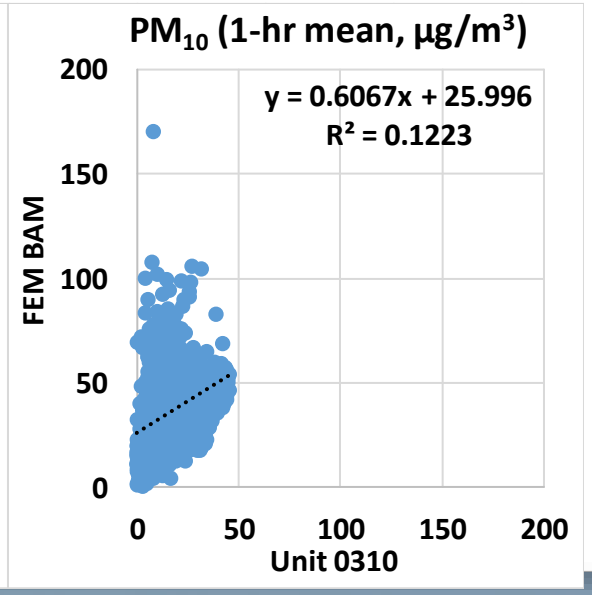
AirSENCE vs FEM BAM (PM_{10}; 1-hr mean)



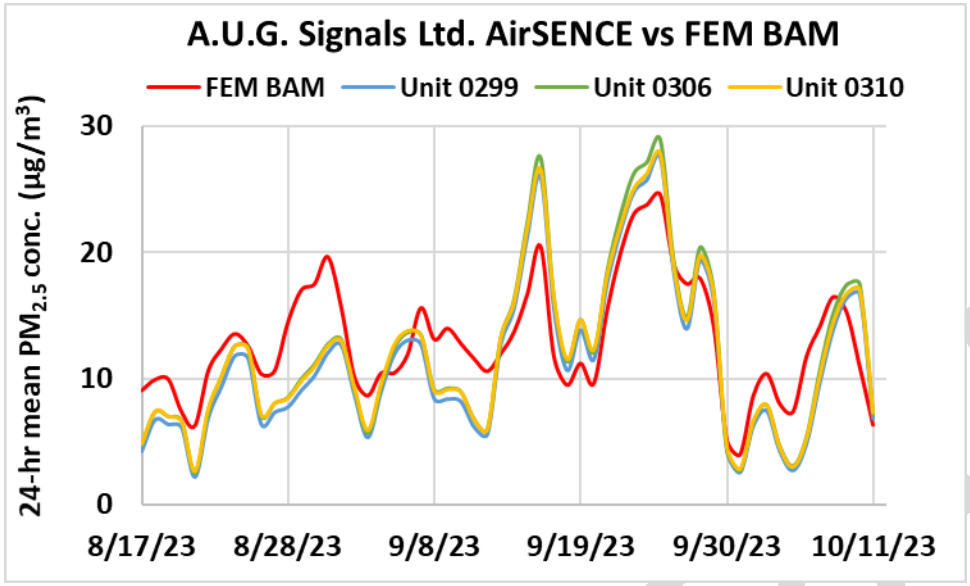
- The AirSENCE sensors showed very weak correlations with the corresponding FEM BAM data ($0.12 < R^2 < 0.14$)
- Overall, the AirSENCE sensors underestimated the PM_{10} mass concentrations as measured by FEM BAM
- The AirSENCE sensors did not seem to track the PM_{10} diurnal variations as recorded by FEM BAM



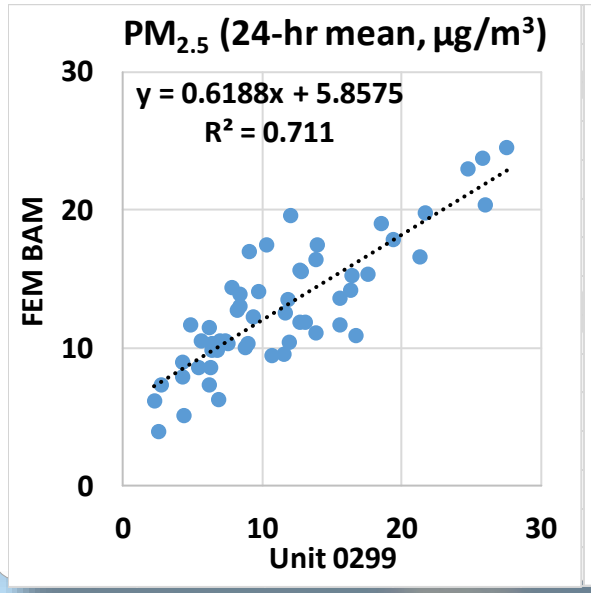


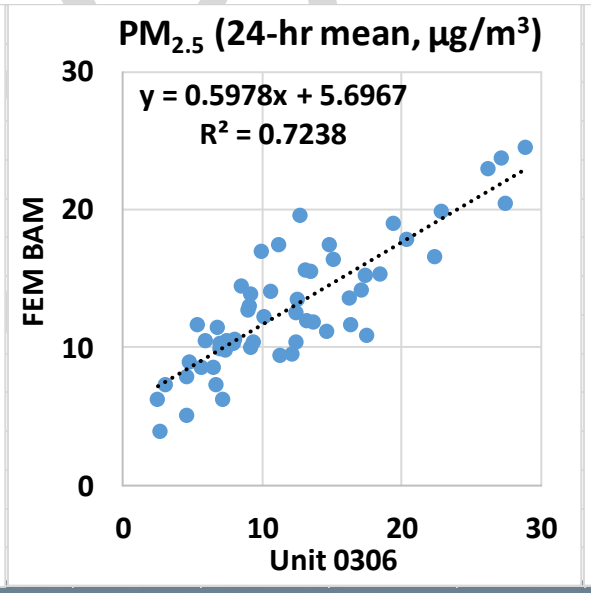


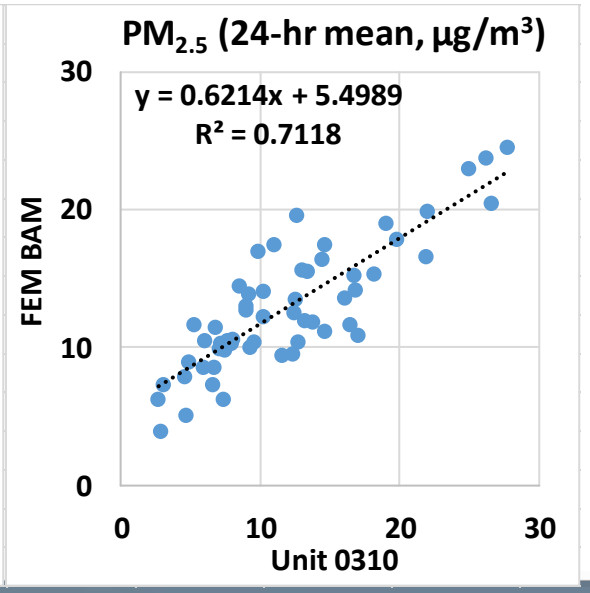
AirSENCE vs FEM BAM ($PM_{2.5}$; 24-hr mean)



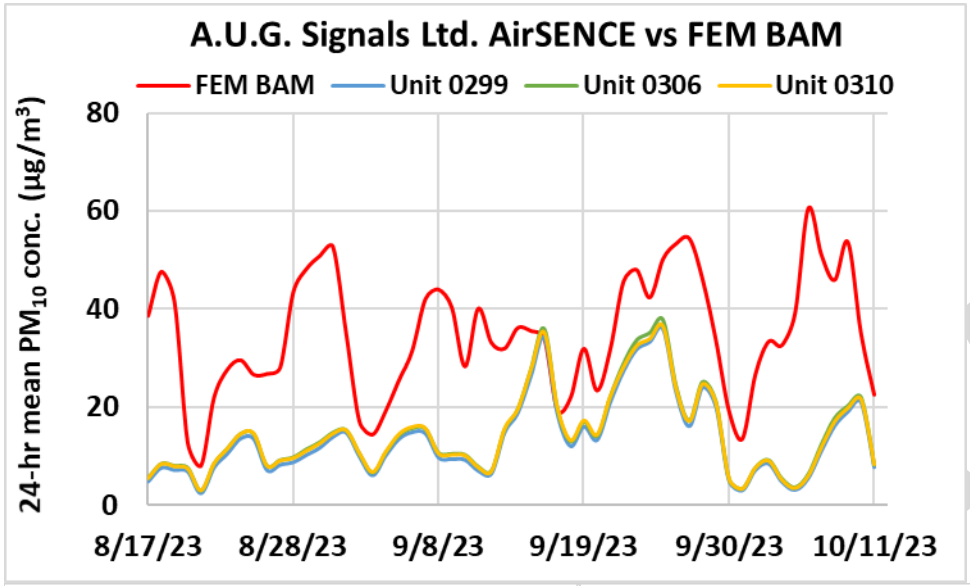
- The AirSENCE sensors showed strong correlations with the corresponding FEM BAM data ($0.71 < R^2 < 0.73$)
- Overall, the AirSENCE sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM BAM
- The AirSENCE sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM BAM



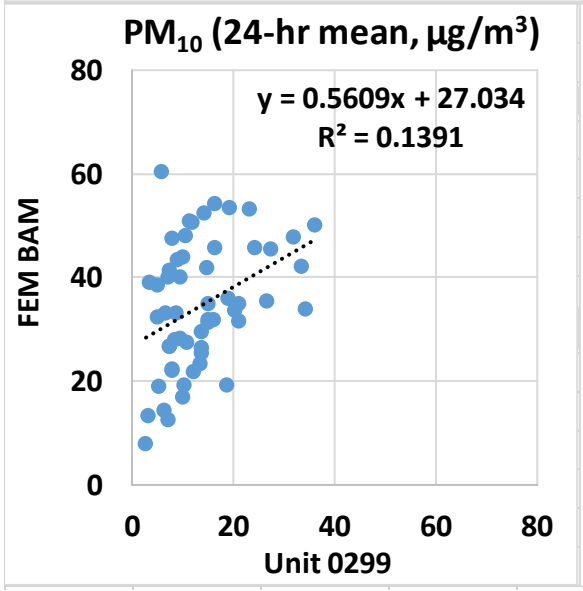


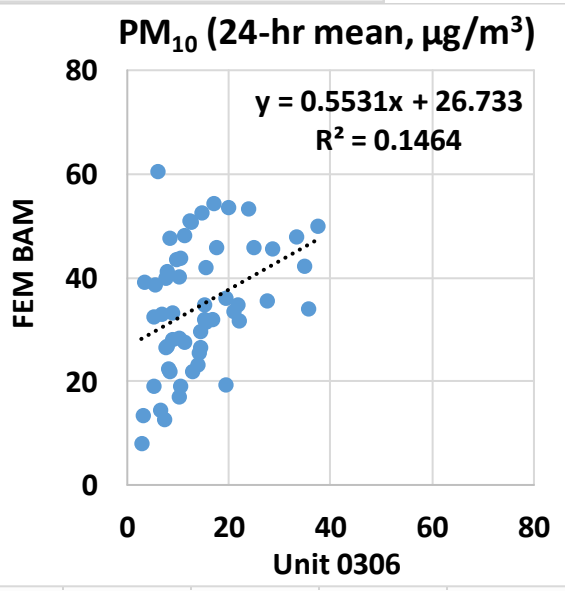


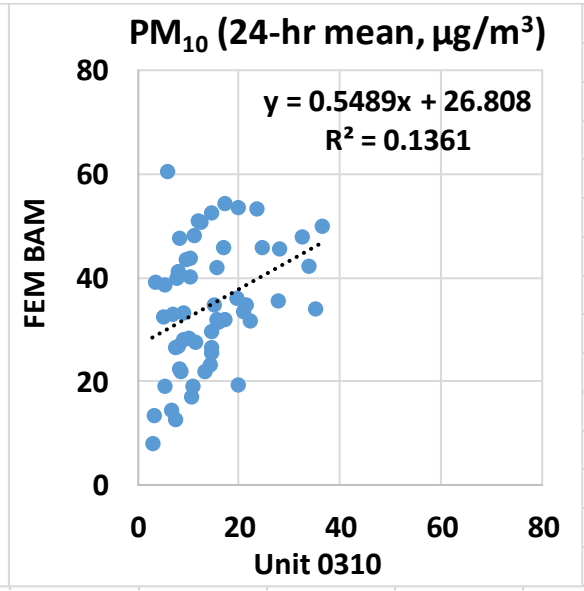
AirSENCE vs FEM BAM (PM_{10}; 24-hr mean)



- The AirSENCE sensors showed very weak correlations with the corresponding FEM BAM data ($0.13 < R^2 < 0.15$)
- Overall, the AirSENCE sensors underestimated the PM_{10} mass concentrations as measured by FEM BAM
- The AirSENCE sensors did not seem to track the PM_{10} diurnal variations as recorded by FEM BAM







Summary: PM

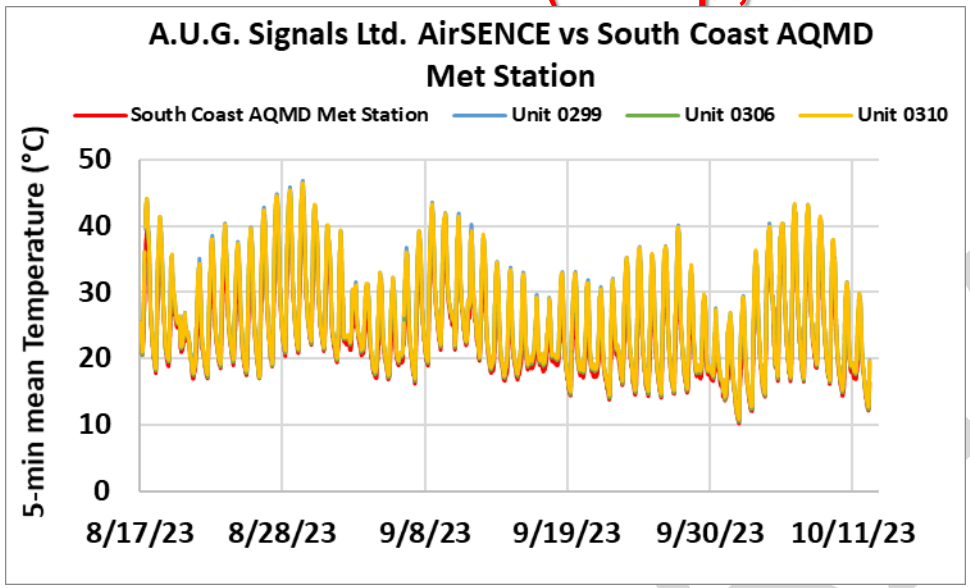
	Average of 3 Sensors, $PM_{1.0}$		AirSENCE vs T640, $PM_{1.0}$						T640 ($PM_{1.0}$, $\mu g/m^3$)		
	Average ($\mu g/m^3$)	SD ($\mu g/m^3$)	R^2	Slope	Intercept	MBE[1] ($\mu g/m^3$)	MAE[2] ($\mu g/m^3$)	RMSE[3] ($\mu g/m^3$)	Ref. Average	Ref. SD	Range during the field evaluation
5-min	7.7	4.7	0.89 to 0.90	1.31 to 1.37	0.9 to 1.4	-4.2 to -3.6	3.7 to 4.2	4.5 to 5.0	11.6	6.6	0 to 40.8
1-hr	7.8	4.6	0.89 to 0.90	1.32 to 1.38	0.9 to 1.4	-4.2 to -3.6	3.6 to 4.2	4.5 to 5.0	11.6	6.6	0.2 to 39.3
24-hr	7.7	3.8	0.94	1.40 to 1.48	0.1 to 0.7	-4.2 to -3.6	3.6 to 4.2	4.2 to 4.7	11.6	5.6	4.1 to 27.9
	Average of 3 Sensors, $PM_{2.5}$		AirSENCE vs FEM BAM & FEM T640, $PM_{2.5}$						FEM BAM & FEM T640 ($PM_{2.5}$, $\mu g/m^3$)		
	Average ($\mu g/m^3$)	SD ($\mu g/m^3$)	R^2	Slope	Intercept	MBE[1] ($\mu g/m^3$)	MAE[2] ($\mu g/m^3$)	RMSE[3] ($\mu g/m^3$)	Ref. Average	Ref. SD	Range during the field evaluation
5-min	11.8	7.8	0.87 to 0.88	0.89 to 0.93	3.6 to 4.2	-3.3 to -2.6	3.4 to 3.8	3.9 to 4.4	14.7	7.7	0 to 46.4
1-hr	11.8	7.7	0.58 to 0.88	0.62 to 0.93	3.6 to 5.7	-3.3 to -0.8	3.3 to 4.2	3.8 to 5.2	13.0 to 14.7	6.3 to 7.6	0.3 to 45.0
24-hr	11.8	6.3	0.71 to 0.91	0.60 to 0.95	3.4 to 5.9	-3.3 to -0.8	2.9 to 3.4	3.3 to 3.8	12.9 to 14.7	4.6 to 6.3	3.9 to 32.4
	Average of 3 Sensors, PM_{10}		AirSENCE vs FEM BAM & T640, PM_{10}						FEM BAM & T640 (PM_{10}, $\mu g/m^3$)		
	Average ($\mu g/m^3$)	SD ($\mu g/m^3$)	R^2	Slope	Intercept	MBE[1] ($\mu g/m^3$)	MAE[2] ($\mu g/m^3$)	RMSE[3] ($\mu g/m^3$)	Ref. Average	Ref. SD	Range during the field evaluation
5-min	14.1	10.2	0.28 to 0.29	0.98 to 1.00	24.1 to 24.6	-24.6 to -23.9	23.9 to 24.7	28.8 to 29.5	38.3	19.0	0 to 292.3
1-hr	14.1	10.1	0.12 to 0.31	0.61 to 0.99	24.2 to 26.4	-24.6 to -20.3	20.7 to 24.6	26.3 to 29.0	34.8 to 38.3	17.5 to 18.2	1.0 to 189.9
24-hr	14.1	8.3	0.14 to 0.33	0.55 to 0.89	25.8 to 27.0	-24.6 to -20.3	20.4 to 24.6	23.5 to 26.8	34.7 to 38.3	12.3 to 12.8	7.9 to 61.3

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

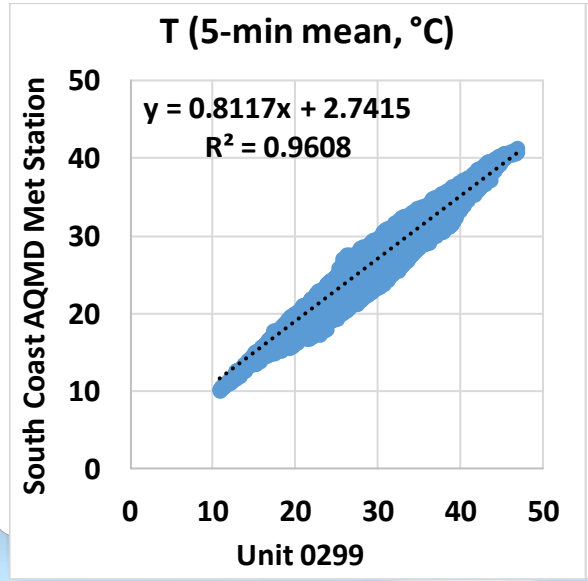
[2] Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.

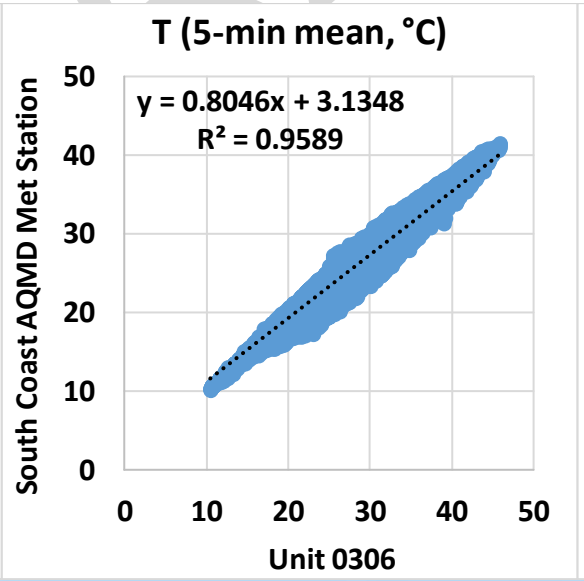
[3] Root Mean Square Error (RMSE): another metric to calculate measurement errors.

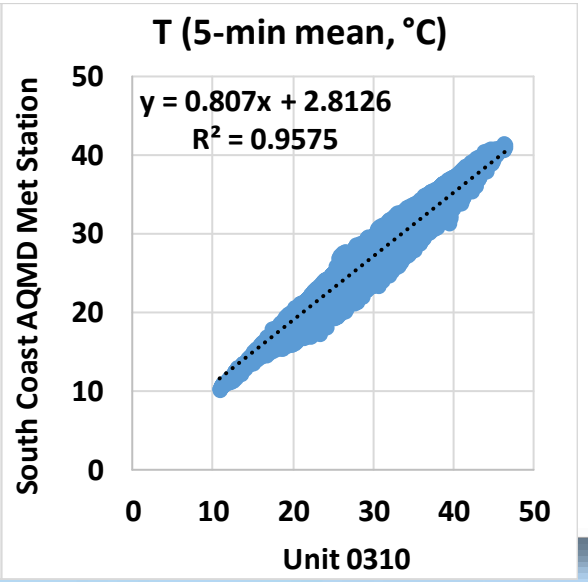
AirSENCE vs South Coast AQMD Met Station (Temp; 5-min mean)



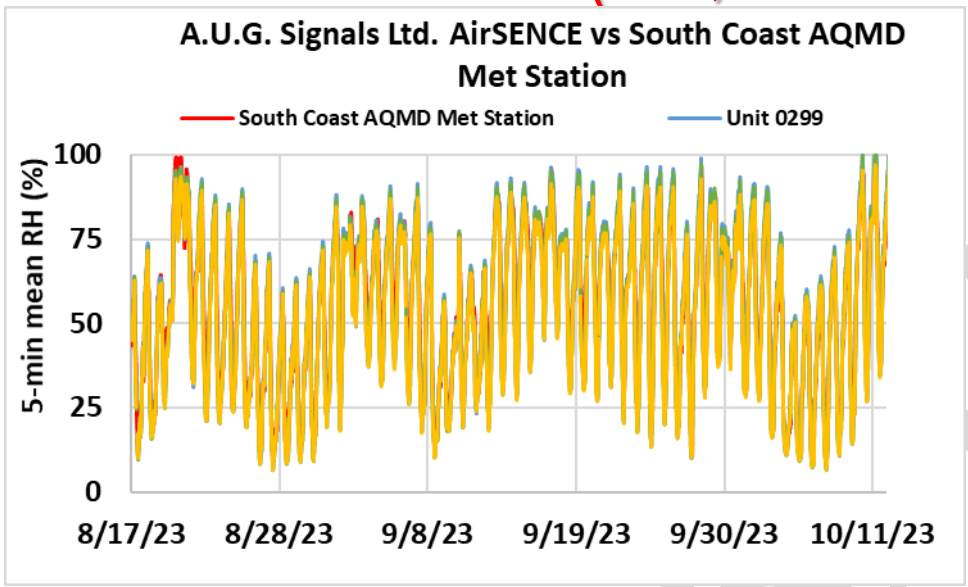
- The AirSENCE sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($0.95 < R^2 < 0.97$)
- Overall, the AirSENCE sensors overestimated the temperature measurement as recorded by South Coast AQMD Met Station
- The AirSENCE sensors seemed to track the diurnal temperature variations as recorded by South Coast AQMD Met Station



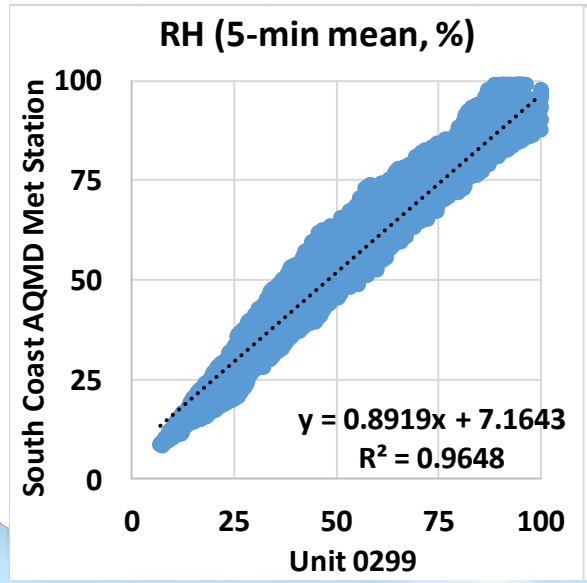


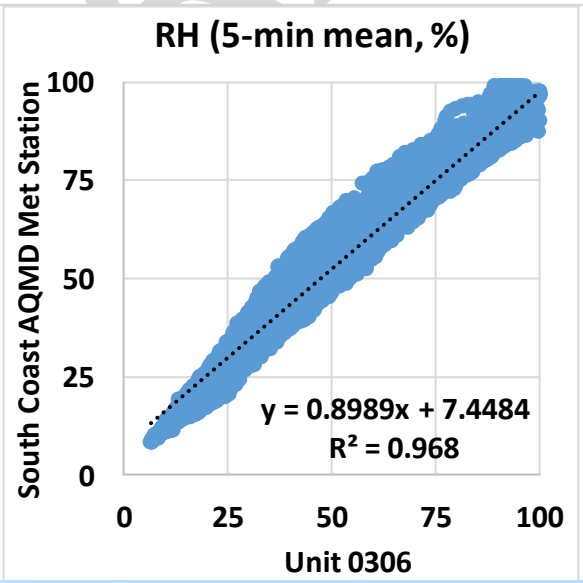


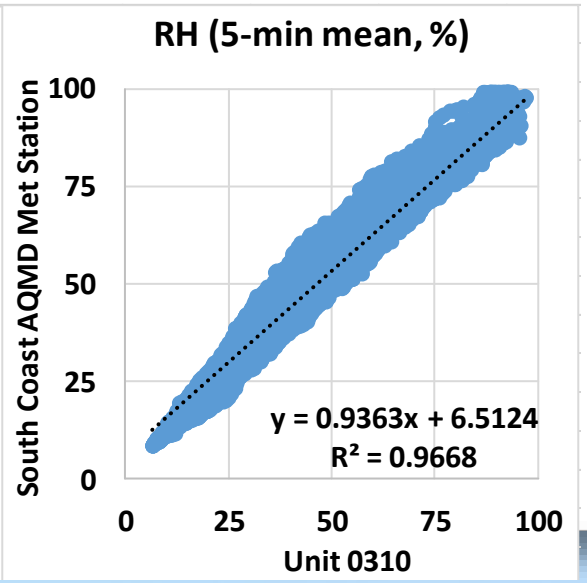
AirSENCE vs South Coast AQMD Met Station (RH; 5-min mean)



- AirSENCE sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($0.96 < R^2 < 0.97$)
- Overall, the AirSENCE sensors underestimated the RH measurement as recorded by South Coast AQMD Met Station
- The AirSENCE sensors seemed to track the diurnal RH variations as recorded by South Coast AQMD Met Station







Discussion

- The three **AirSENCE** sensors' data recovery for all gases (O_3, NO, NO_2 and CO) and all PM fractions was ~100%.
- The absolute intra-model variability for O_3, NO, NO_2 and CO was ~1.5 ppb, ~1.8 ppb, ~0.5ppb and ~3.1ppb, respectively. The absolute intra-model variability was ~0.31, ~0.35 and ~0.42 µg/m^3 for $PM_{1.0}$, $PM_{2.5}$ and $PM_{10,}$ respectively.
- During the entire field deployment testing period:
  - Ozone sensors showed strong correlation with the FEM T400 instrument ($0.81 < R^2 < 0.85$, 5-min mean) and generally overestimated the corresponding FEM T400 data
  - NO sensors showed moderate to strong correlations with the reference NO instrument ($0.51 < R^2 < 0.87$, 5-min mean) and overestimated the corresponding FRM T200 data
  - NO_2 sensors showed very weak correlations with the FRM T200 instrument ($0.16 < R^2 < 0.21$, 5-min mean) and overestimated the corresponding FRM T200 data
  - CO sensors showed strong correlations with the FRM Horiba instrument ($0.74 < R^2 < 0.78$, 5-min mean) and underestimated the corresponding FRM data
  - The AirSENCE sensors showed strong to very strong correlations with the corresponding reference $PM_{1.0}$ data ($0.89 < R^2 < 0.91$, 1-hr mean); moderate to strong correlations with the corresponding reference $PM_{2.5}$ data ($0.57 < R^2 < 0.89$, 1-hr mean) and very weak to weak correlations with the corresponding reference PM_{10} data ($0.12 < R^2 < 0.31$; 1-hr mean). The sensors underestimated $PM_{1.0}$, $PM_{2.5}$ PM_{10} and mass concentrations as measured by the T640 and the BAM
  - Temperature and relative humidity sensors showed very strong correlations with the South Coast AQMD Met Station T and RH data (R^2 ~ 0.96 for T and R^2 ~ 0.96 for RH) and overestimated the T and underestimated the RH data as recorded by the South Coast AQMD Met Station
- 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 controlled T and RH conditions, and known target and interferent pollutants concentrations.
- These results are still preliminary