Field Evaluation
SGS SmartSense

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 03/07/2024 to 05/07/2024, three **SGS Galson SmartSense (hereinafter SGS SmartSense)** 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.

- SGS SmartSense (*3 units tested*):
  - Gas Sensors: Electrochemical (Alphasense, non-FEM)
  - PM: Optical (Tera Sensor NextPM, non-FEM)
  - Each unit measures: CO (ppm), O_3 (ppb), NO_2 (ppb), $PM_{1.0}$ (µg/m^3), $PM_{2.5}$ (µg/m^3), PM_{10} (µg/m^3), T (°C), RH (%)
  - Unit cost: $1995
  - Time resolution: 1-min
  - Units IDs: 6851, 6946, and 7540

- **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

Carbon Monoxide (CO) in SGS SmartSense

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 Unit 6851, Unit 6946 and Unit 7540 was ~ 97.1%, ~ 99.1% and ~ 96.4%, respectively
- Values below manufacturer stated limit of detection were excluded from further analysis but do not count against data recovery

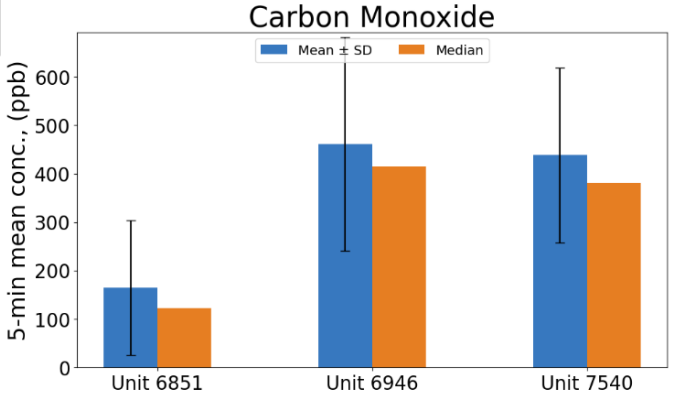
SGS SmartSense; Intra-model variability

- Absolute intra-model variability was ~ 164.7 ppb for the CO measurements

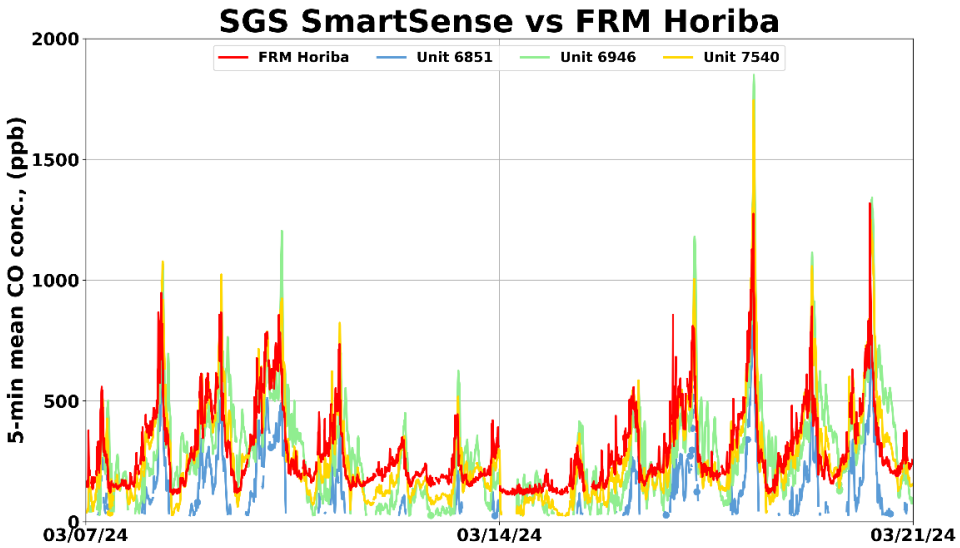
(calculated as the standard deviation of the three sensor means)

- Relative intra-model variability was ~ 46.4% for the CO measurements

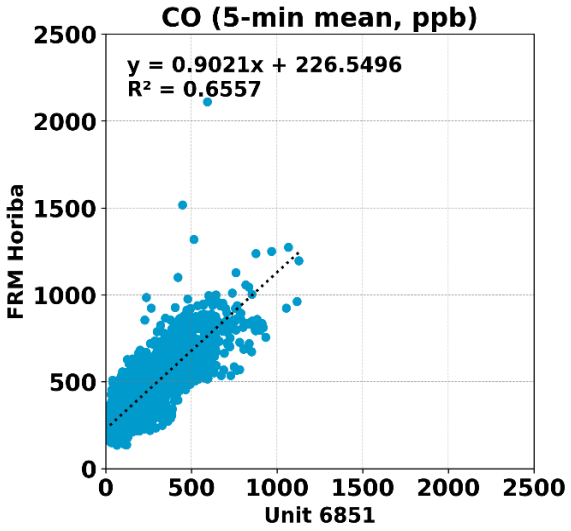
(calculated as the absolute intra-model variability relative to the mean of the three sensor means)

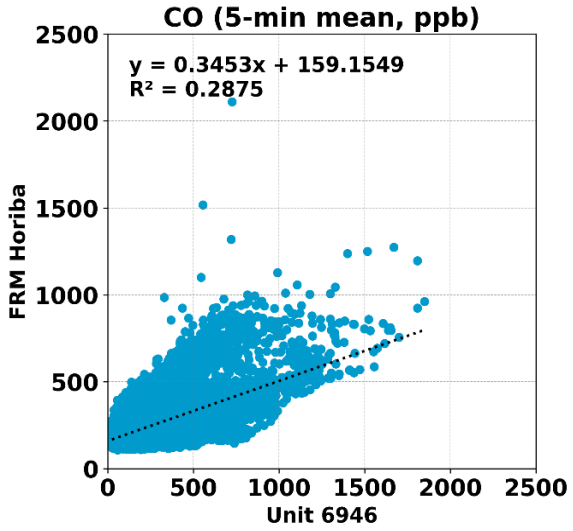


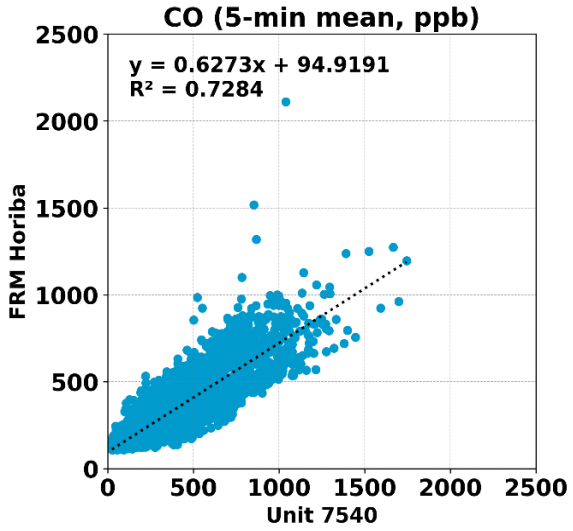
SGS SmartSense vs FRM Horiba (CO; 5-min mean)



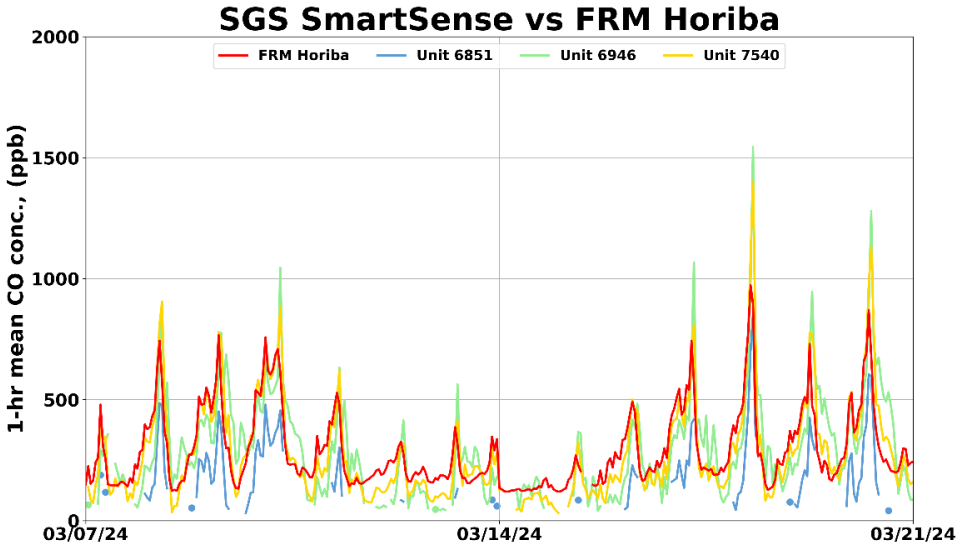
- The SGS SmartSense sensors showed very weak to strong correlation with the corresponding FRM Horiba CO data ($0.28 < R^2 < 0.73$)
- Overall, the SGS SmartSense sensors underestimated the CO concentration as measured by the FRM Horiba CO instrument
- The SGS SmartSense sensors seemed to track the diurnal CO variations as recorded by the FRM Horiba instrument, except for Unit 6946



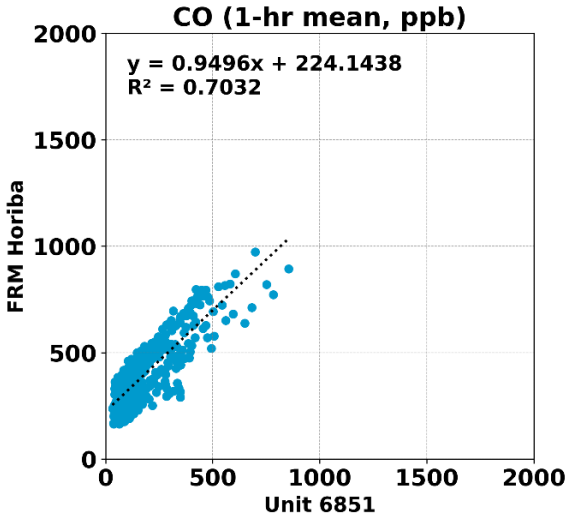


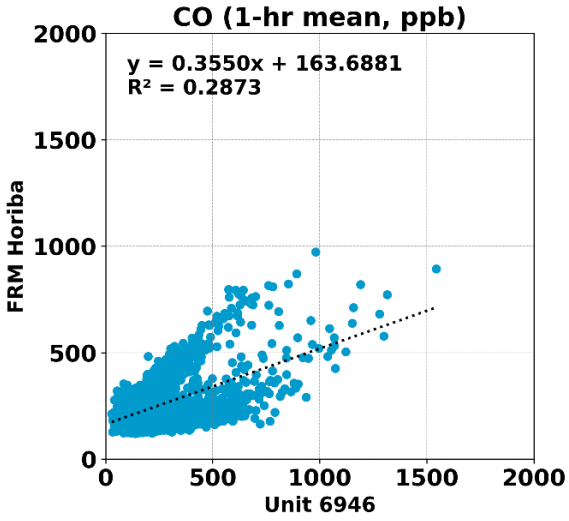


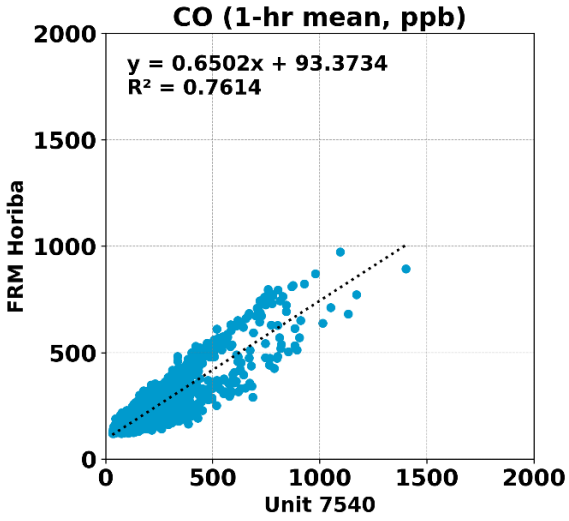
SGS SmartSense vs FRM Horiba (CO; 1-hr mean)



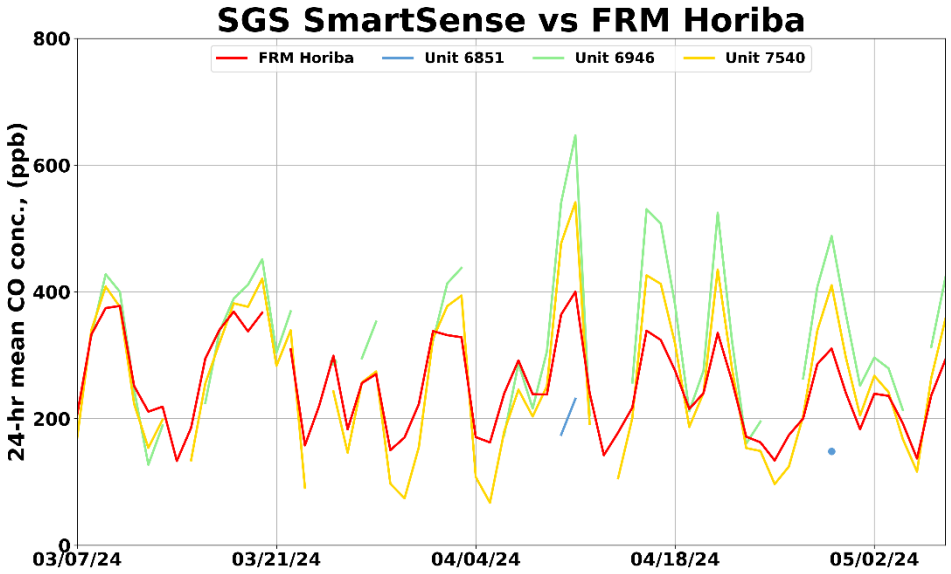
- The SGS SmartSense sensors showed very weak to strong correlation with the corresponding FRM Horiba CO data ($0.28 < R^2 < 0.77$)
- Overall, the SGS SmartSense sensors underestimated the CO concentration as measured by the FRM Horiba CO instrument
- The SGS SmartSense sensors seemed to track the diurnal CO variations as recorded by the FRM Horiba instrument, except for Unit 6946



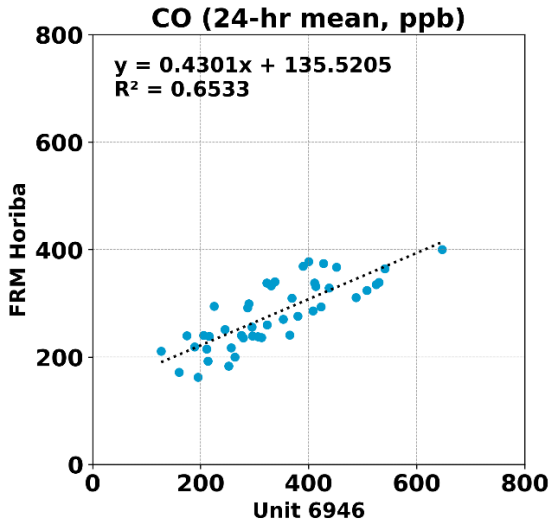


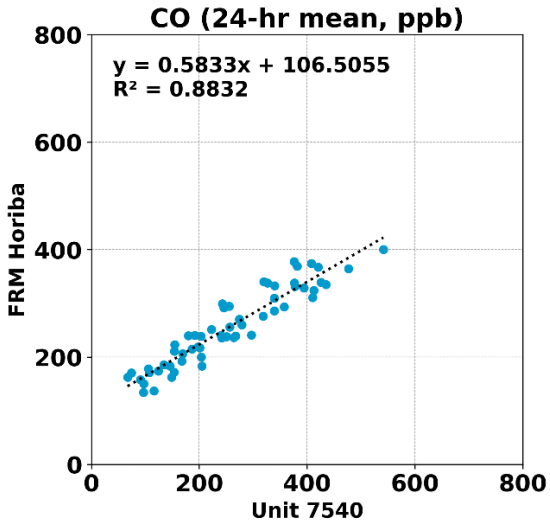


SGS SmartSense vs FRM Horiba (CO; 24-hr mean)



- The SGS SmartSense sensors (Units 6946 and 7540) showed moderate to strong correlation with the corresponding FRM Horiba CO data ($0.65 < R^2 < 0.89$)
- Overall, the SGS SmartSense sensors (Units 6946 and 7540) overestimated the CO concentration as measured by the FRM Horiba CO instrument
- The SGS SmartSense sensors seemed to track the daily CO variations as recorded by the FRM Horiba instrument
- Unit 6851 did not have sufficient data points to calculate the 24-hr averages and was excluded from discussion here





Summary: CO

	Average of 3 Sensors, CO		SGS SmartSense vs FRM Horiba, CO						FRM Horiba, CO (ppb)		
	Average (ppb)	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	241.8	181.5	0.29 to 0.73	0.35 to 0.90	94.9 to 226.5	-210.1 to 44.9	74.3 to 212.1	100.2 to 231.4	250.2	138.2	95.6 to 2111.2
1-hr	249.7	174.8	0.29 to 0.76	0.36 to 0.95	93.4 to 224.1	-215.0 to 37.7	68.7 to 215.5	90.7 to 230.8	253.4	134.3	99.7 to 973.3
***24-hr**	294.7	114.64	0.65 to 0.88	0.43 to 0.58	106.5 to 135.5	-0.2 to 55.2	43.7 to 71.2	53.5 to 92.8	250.8	73.1	133.0 to 400.0

[1] Mean Bias Error (MBE): the difference between the sensors and the reference instruments. MBE indicates the tendency of the sensors to underestimate (negative MBE values) or overestimate (positive MBE values).
[2] Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.
[3] Root Mean Square Error (RMSE): another metric to calculate measurement errors.
* Only results from Units 6946 and 7540 were included

Ozone (O_3) in SGS SmartSense

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 Unit 6851, Unit 6946 and Unit 7540 was ~97.1%, ~99.1% and ~96.4%, respectively
- Values below manufacturer stated limit of detection were excluded from further analysis but do not count against data recovery

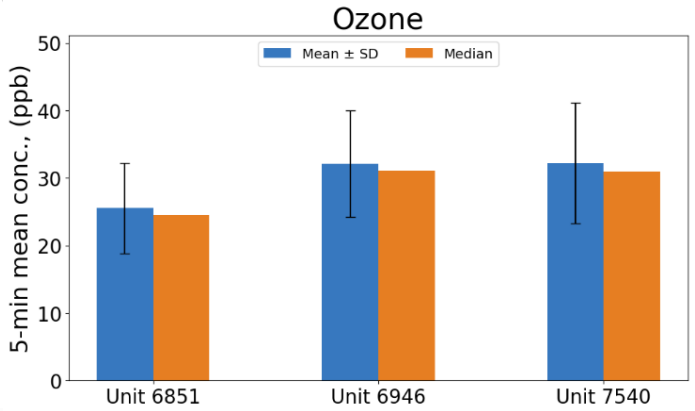
SGS SmartSense; Intra-model variability

- Absolute intra-model variability was ~3.8 ppb for the ozone measurements

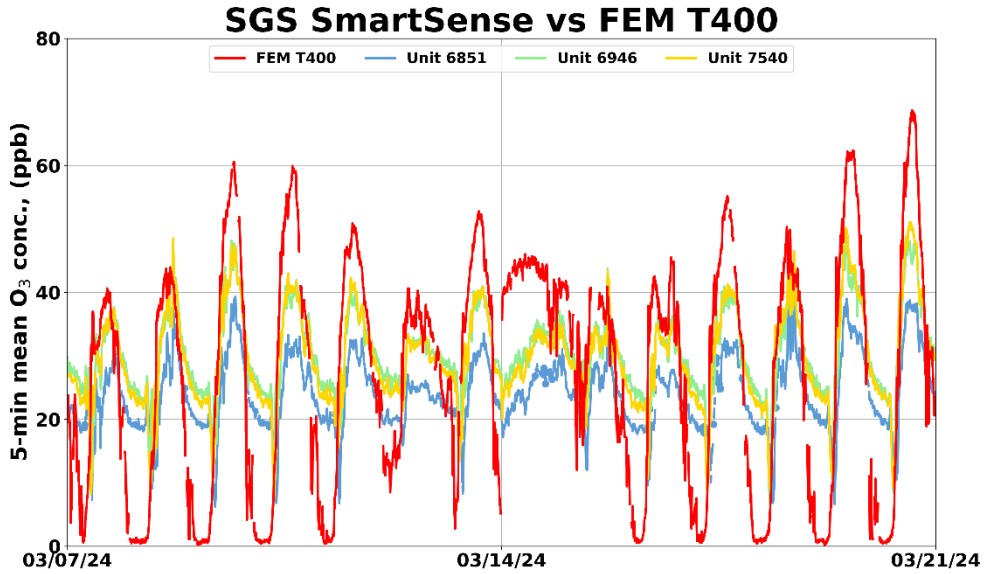
(calculated as the standard deviation of the three sensor means)

- Relative intra-model variability was ~12.7% for the ozone measurements

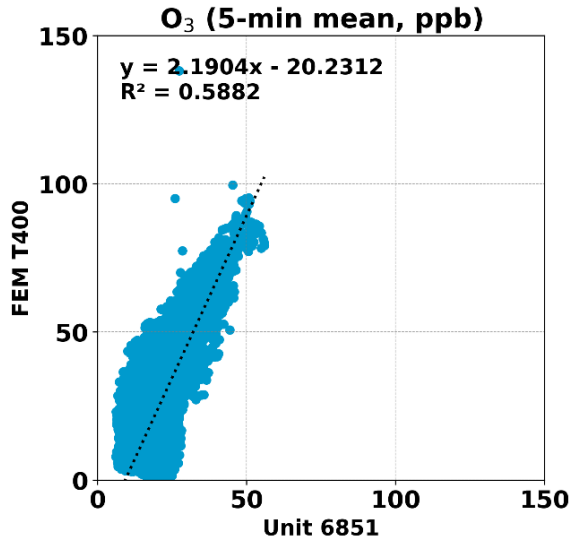
(calculated as the absolute intra-model variability relative to the mean of the three sensor means)

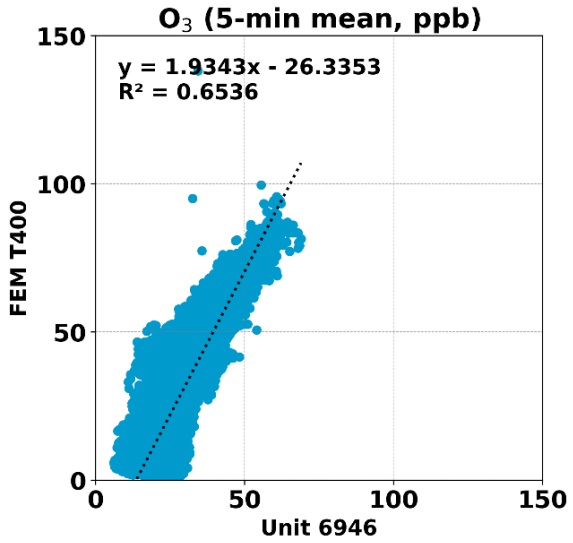


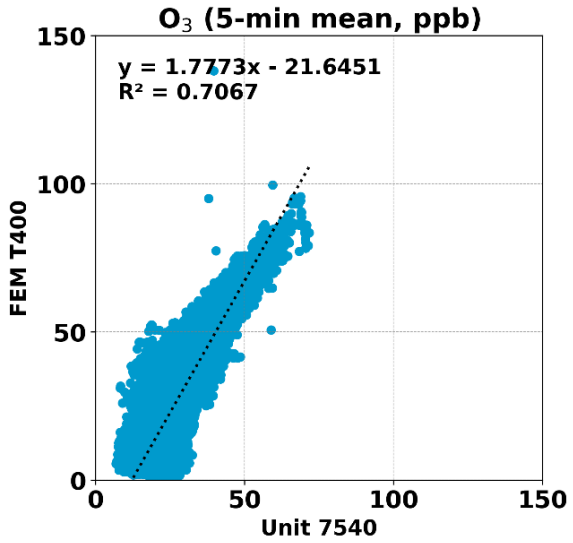
SGS SmartSense vs FEM T400 (Ozone; 5-min mean)



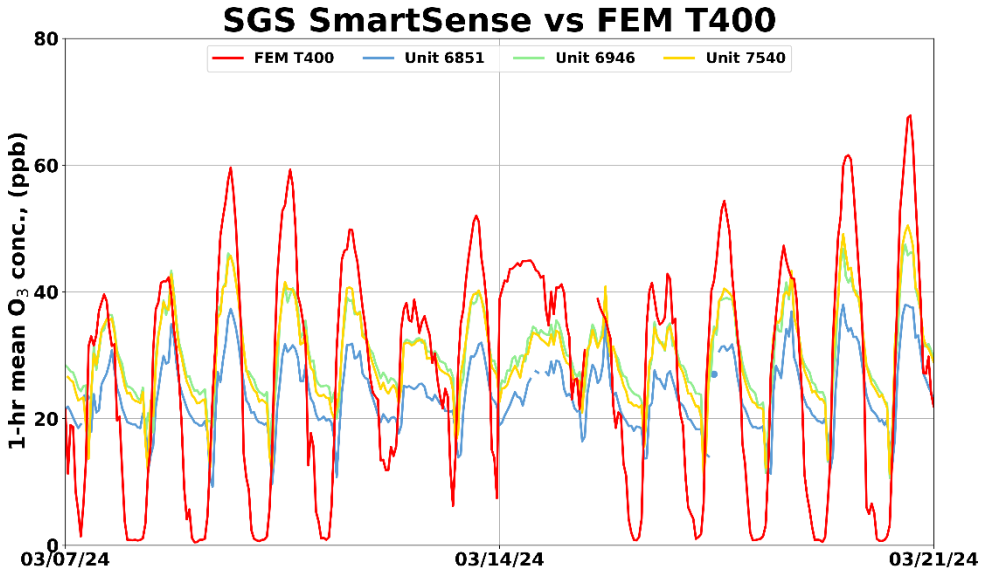
- The SGS SmartSense sensors showed moderate to strong correlation with the corresponding FEM T400 ozone data ($0.58 < R^2 < 0.71$)
- Overall, the SGS SmartSense sensors underestimated the ozone concentration as measured by the FEM T400 ozone instrument
- The SGS SmartSense sensors seemed to track the diurnal ozone variations as recorded by the FEM T400 instrument



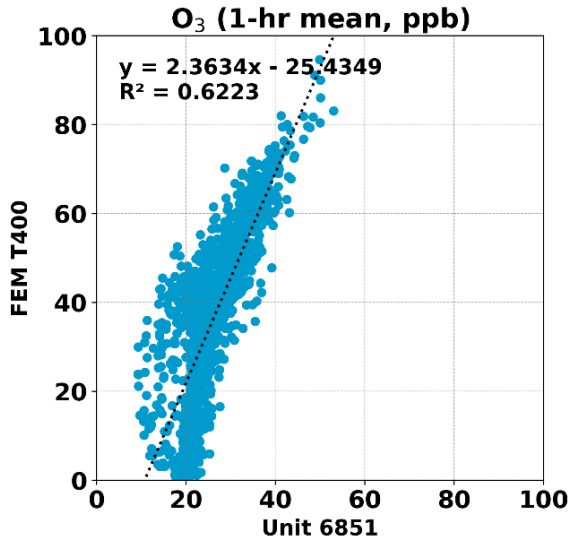


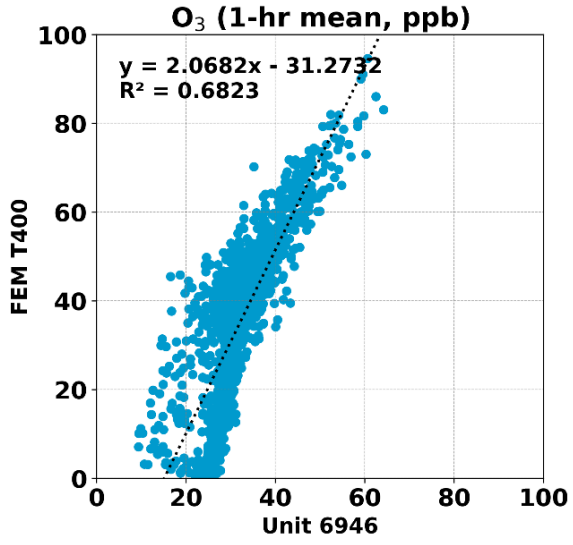


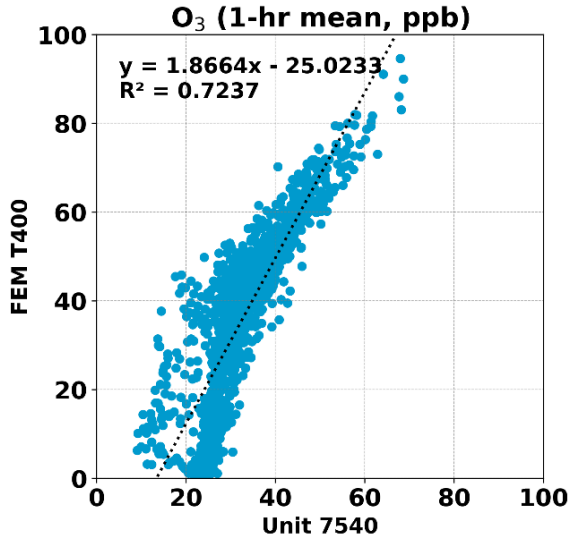
SGS SmartSense vs FEM T400 (Ozone; 1-hr mean)



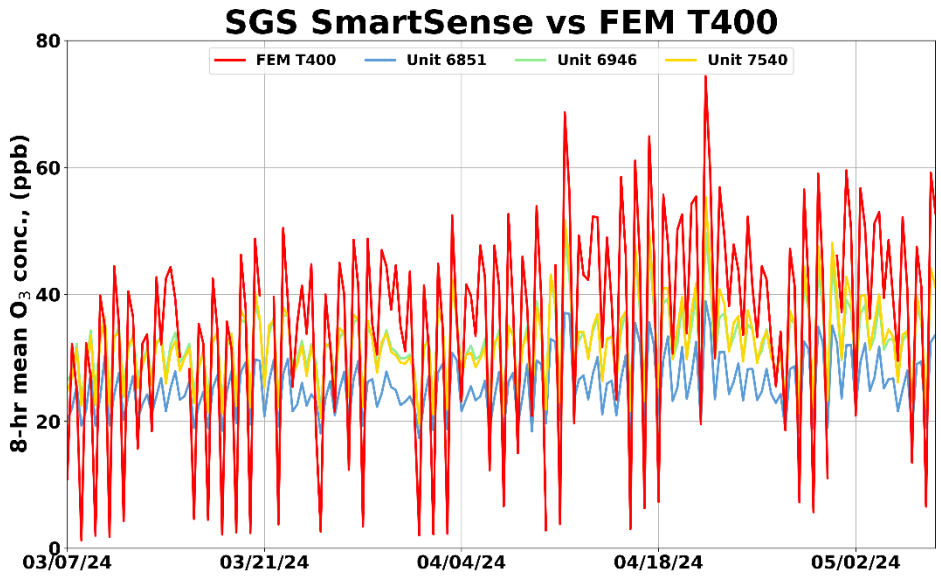
- The SGS SmartSense sensors showed moderate to strong correlation with the corresponding FEM T400 ozone data ($0.62 < R^2 < 0.72$)
- Overall, the SGS SmartSense sensors underestimated the ozone concentration as measured by the FEM T400 ozone instrument
- The SGS SmartSense sensors seemed to track the diurnal ozone variations as recorded by the FEM T400 instrument



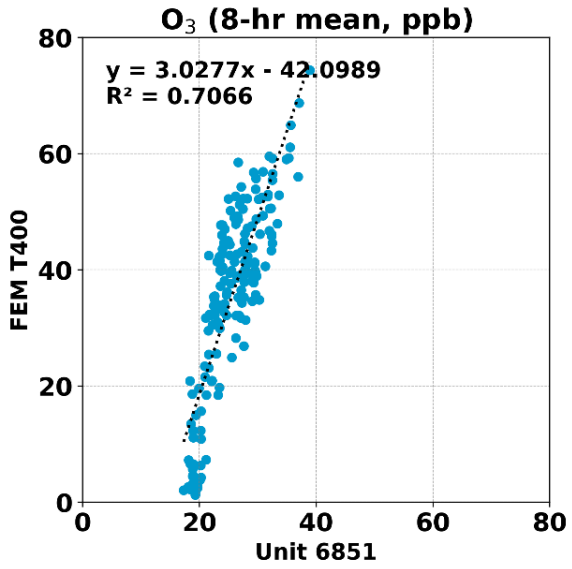


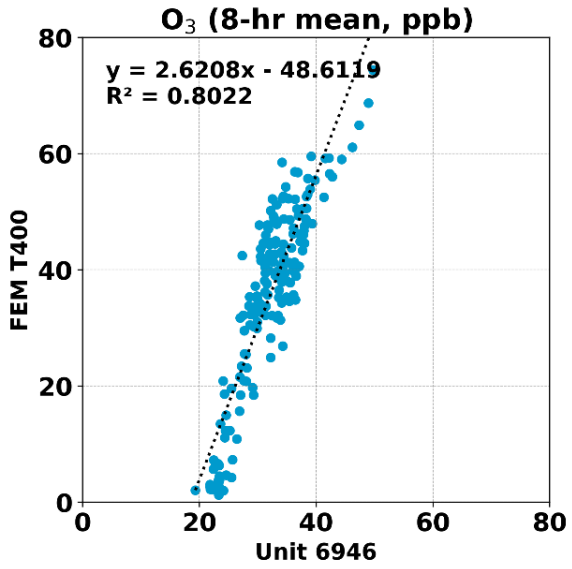


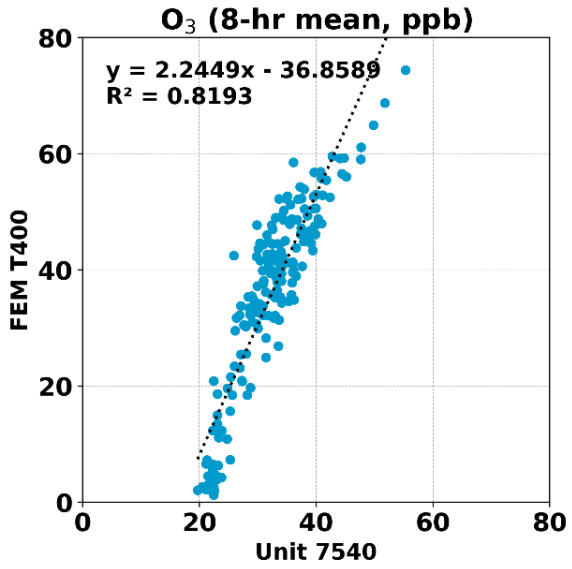
SGS SmartSense vs FEM T400 (Ozone; 8-hr mean)



- The SGS SmartSense sensors showed strong correlation with the corresponding FEM T400 ozone data ($0.70 < R^2 < 0.82$)
- Overall, the SGS SmartSense sensors underestimated the ozone concentration as measured by the FEM T400 ozone instrument
- The SGS SmartSense sensors seemed to track the diurnal ozone variations as recorded by the FEM T400 instrument







Summary: Ozone

	Average of 3 Sensors, Ozone		SGS SmartSense 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	29.9	7.9	0.59 to 0.71	1.78 to 2.19	-26.3 to -20.2	-10.5 to -3.6	11.5 to 16.2	13.4 to 18.3	36.2	19.7	0.1 to 138.1
1-hr	30	7.8	0.62 to 0.72	1.87 to 2.36	-31.3 to -25.0	-9.5 to -2.9	11.3 to 15.7	13.2 to 17.8	35.1	19.6	0.5 to 94.6
8-hr	29.9	5.7	0.71 to 0.82	2.24 to 3.03	-48.6 to -36.9	-9.7 to -3.1	9.7 to 14.4	11.3 to 16.2	35.2	16.6	1.2 to 74.4

[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.

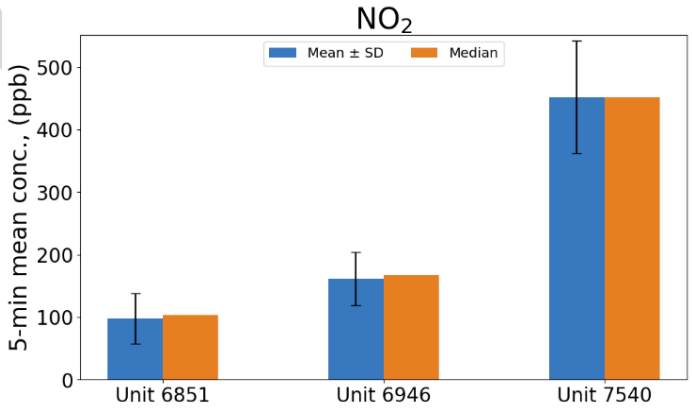
Nitrogen Dioxide (NO_2) in SGS SmartSense

Data validation & recovery

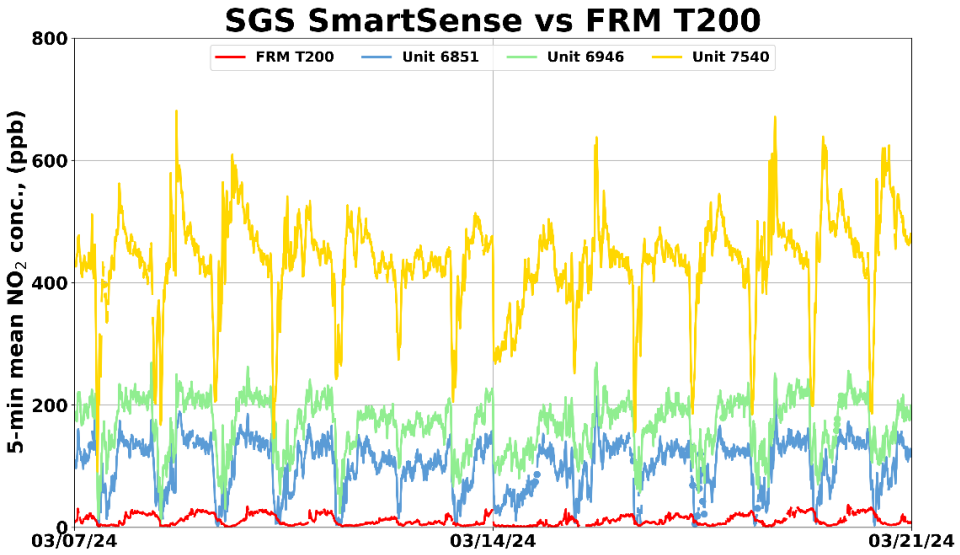
- Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
- Data recovery for NO_2 from Unit 6851, Unit 6946 and Unit 7540 was ~97.1%, ~99.1% and ~96.4%, respectively
- Values below manufacturer stated limit of detection were excluded from further analysis but do not count against data recovery

SGS SmartSense; Intra-model variability

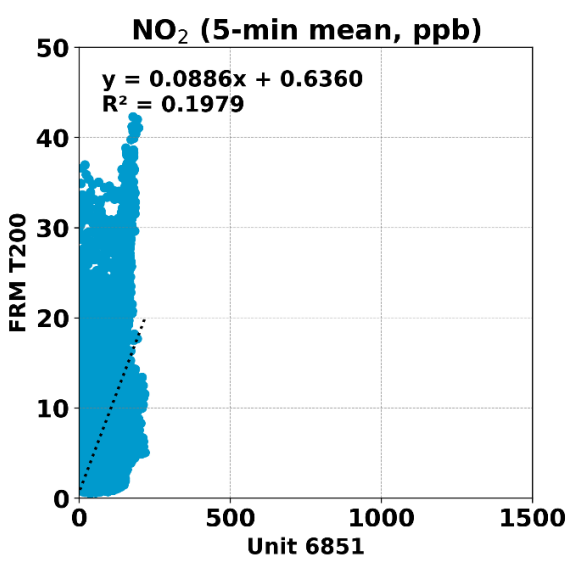
- Absolute intra-model variability was ~188.8 ppb for the NO_2 measurements (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~79.6% for the NO_2 measurements (calculated as the absolute intra-model variability relative to the mean of the three sensor means)

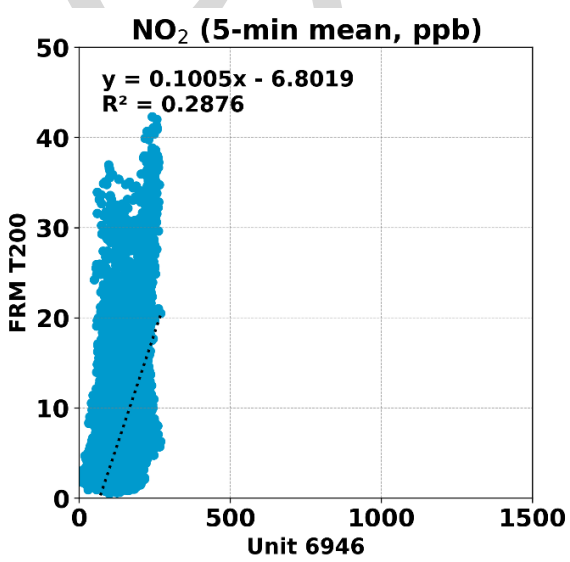


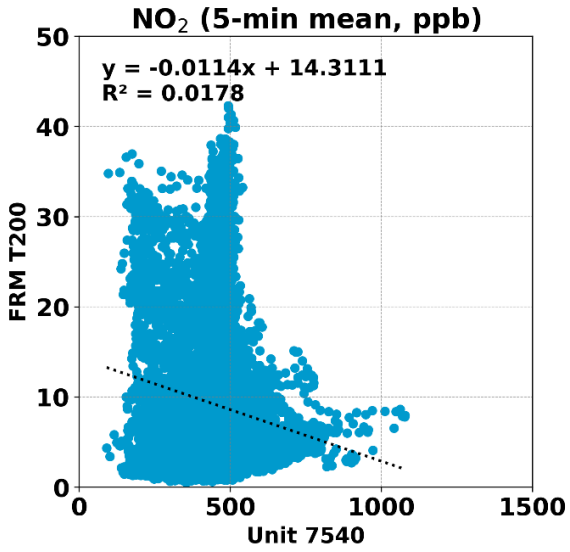
SGS SmartSense vs FRM T200 (NO_2; 5-min mean)



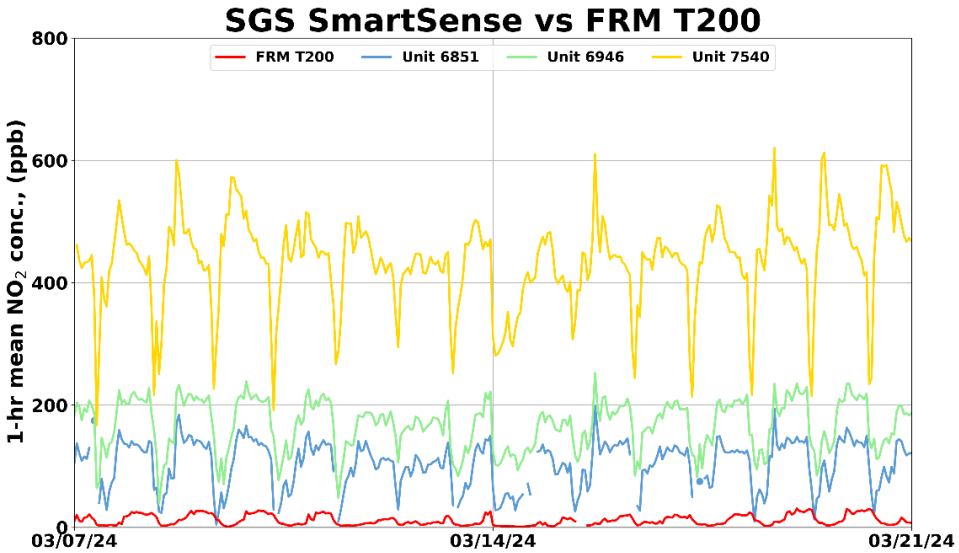
- The SGS SmartSense sensors showed no to very weak correlations with the corresponding FRM T200 NO_2 data ($0.02 < R^2 < 0.29$)
- Overall, the SGS SmartSense sensors overestimated the NO_2 concentration as measured by the FRM T200 instrument
- The SGS SmartSense sensors did not seem to track the diurnal NO_2 variations as recorded by the FRM T200 instrument



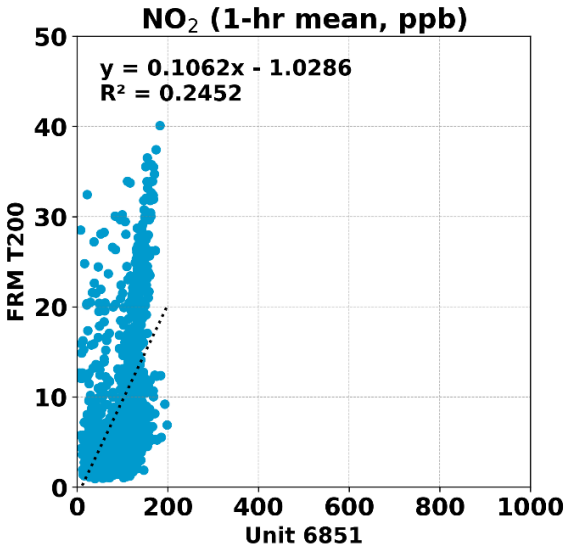


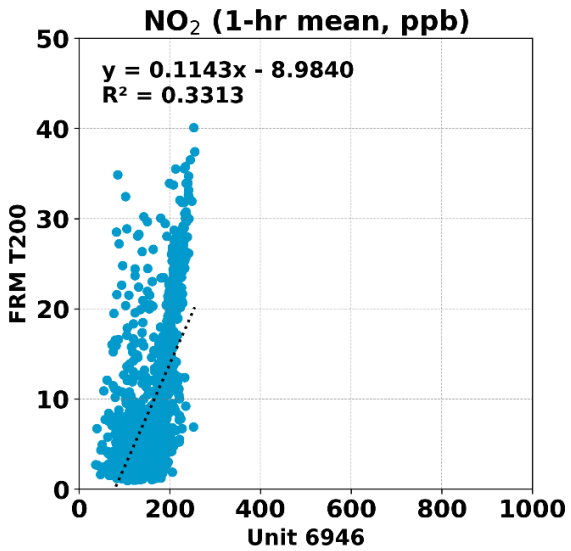


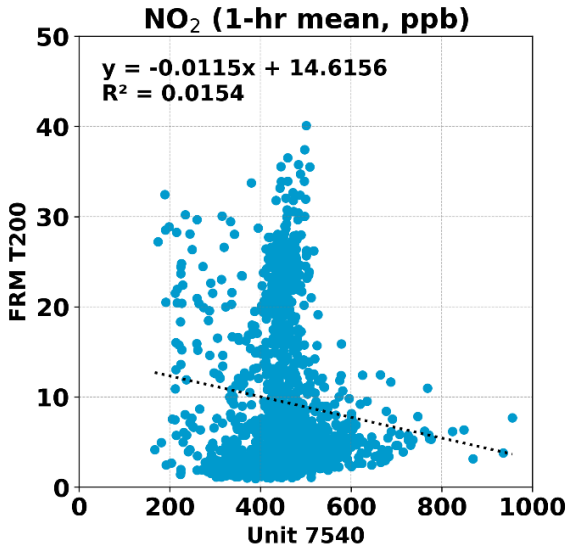
SGS SmartSense vs FRM T200 (NO_2; 1-hr mean)



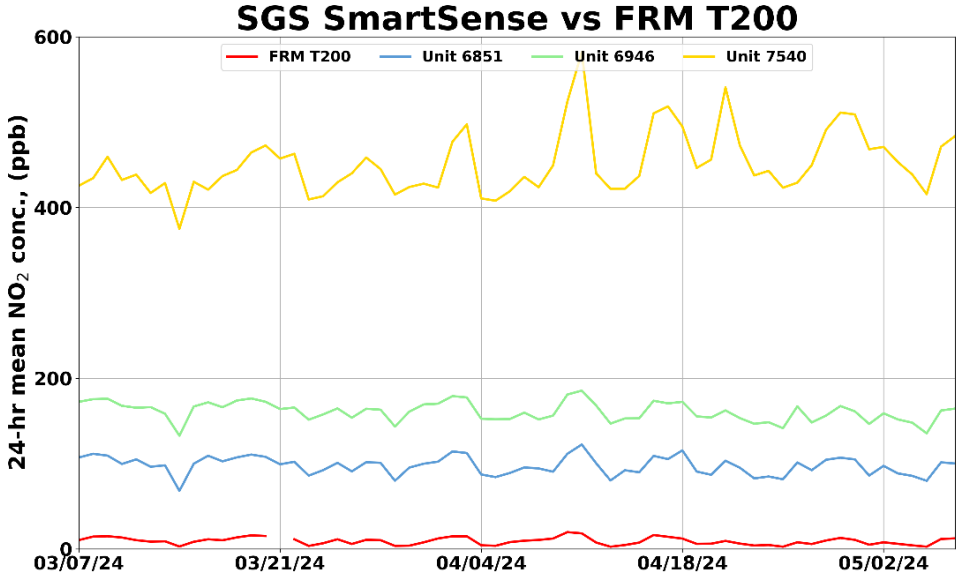
- The SGS SmartSense sensors showed no to weak correlations with the corresponding FRM T200 NO_2 data ($0.01 < R^2 < 0.34$)
- Overall, the SGS SmartSense sensors overestimated the NO_2 concentration as measured by the FRM T200 instrument
- The SGS SmartSense sensors did not seem to track the diurnal NO_2 variations as recorded by the FRM T200 instrument



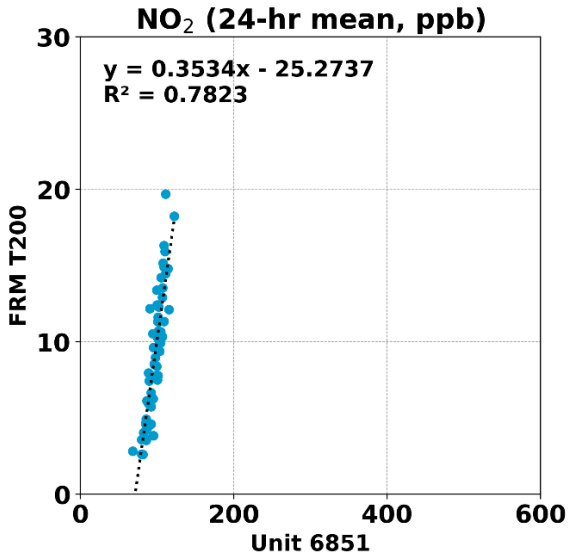


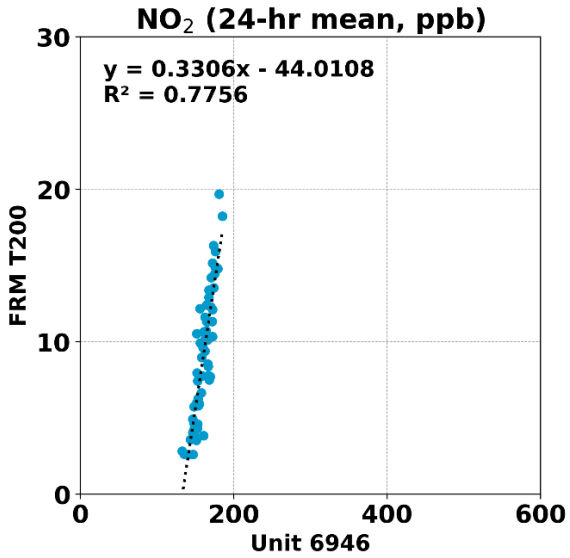


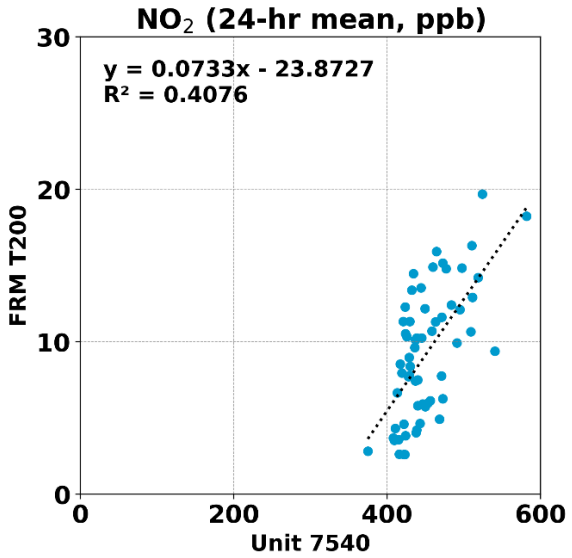
SGS SmartSense vs FRM T200 (NO_2; 24-hr mean)



- The SGS SmartSense sensors showed weak to strong correlations with the corresponding FRM T200 NO_2 data ($0.40 < R^2 < 0.79$)
- Overall, the SGS SmartSense sensors overestimated the NO_2 concentration as measured by the FRM T200 instrument
- The SGS SmartSense sensors seemed to track the daily NO_2 variations as recorded by the FRM T200 instrument, except for Unit 7540







Summary: NO_2

	Average of 3 Sensors, NO_2		SGS SmartSense 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	236.6	58.3	0.02 to 0.29	-0.01 to 0.10	-6.8 to 14.3	86.7 to 441.6	86.9 to 441.6	94.7 to 451.9	9.1	8.1	0.5 to 42.3
1-hr	236.8	55.9	0.02 to 0.33	-0.01 to 0.11	-9.0 to 14.6	89.0 to 441.5	89.1 to 441.5	95.5 to 450.4	9.4	8.2	1.0 to 40.1
24-hr	236.6	19.7	0.41 to 0.78	0.07 to 0.35	-44.0 to -23.9	88.3 to 441.8	88.3 to 441.8	88.6 to 443.1	9.2	4.3	2.6 to 19.7

[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.

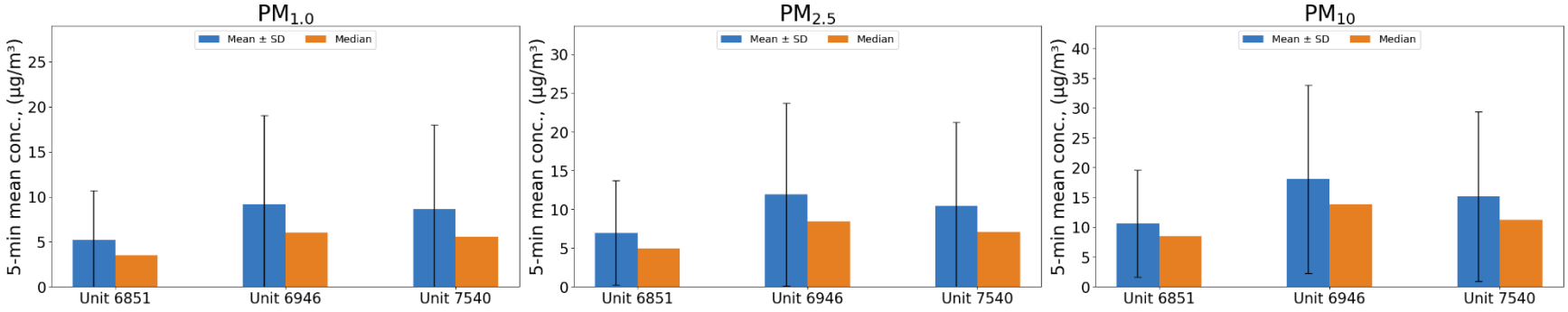
Particulate Matter (PM) in SGS SmartSense

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 6851, Unit 6946 and Unit 7540 was ~97.4% for all PM measurements
- Values below manufacturer stated limit of detection were excluded from further analysis but do not count against data recovery

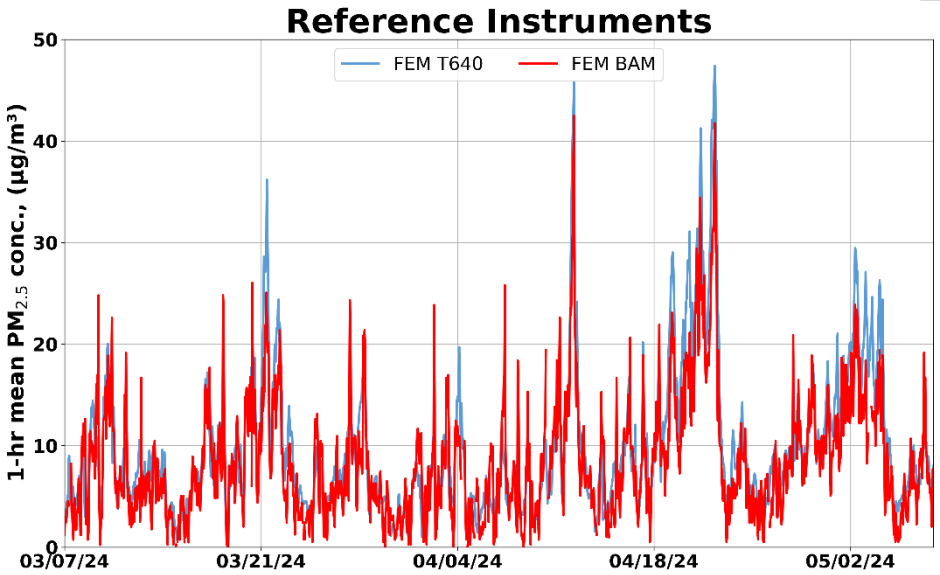
SGS SmartSense; intra-model variability

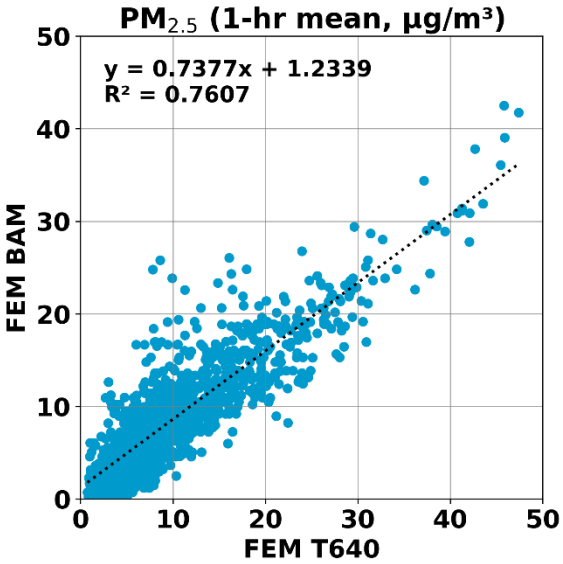
- Absolute intra-model variability was ~2.14, ~2.55 and ~3.73 µg/m^3 for $PM_{1.0}$, $PM_{2.5}$ and PM_{10}, respectively (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~28.0%, ~26.1% and ~25.5% for $PM_{1.0}$, $PM_{2.5}$ and PM_{10}, respectively (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

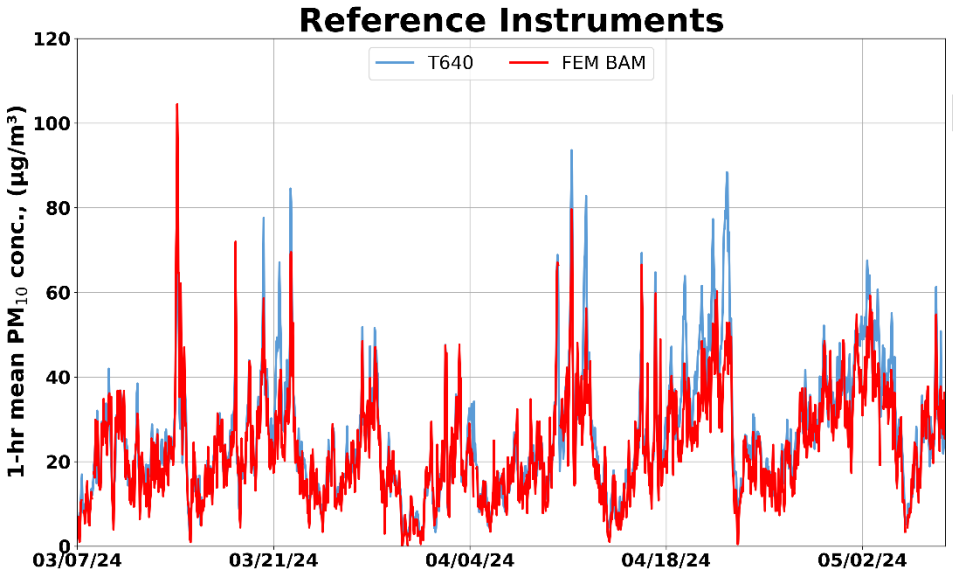
- Data recovery for $PM_{2.5}$ from FEM BAM and FEM T640 was ~97.4% and 99.9%, respectively.
- Strong correlations between the reference instruments for $PM_{2.5}$ measurements (R^2 ~ 0.76) were observed.

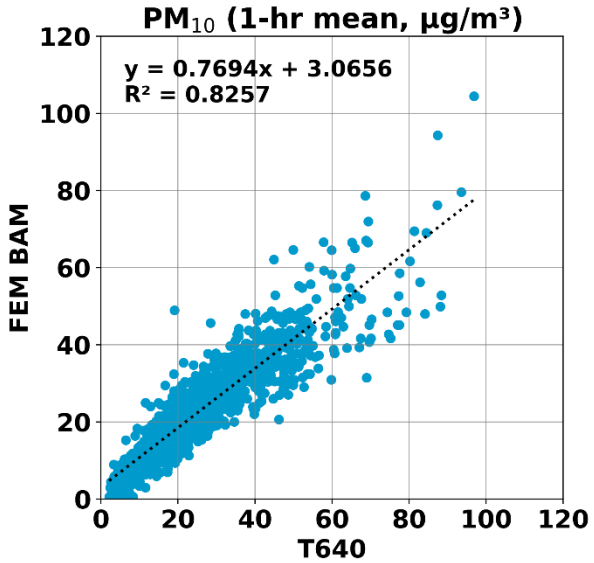




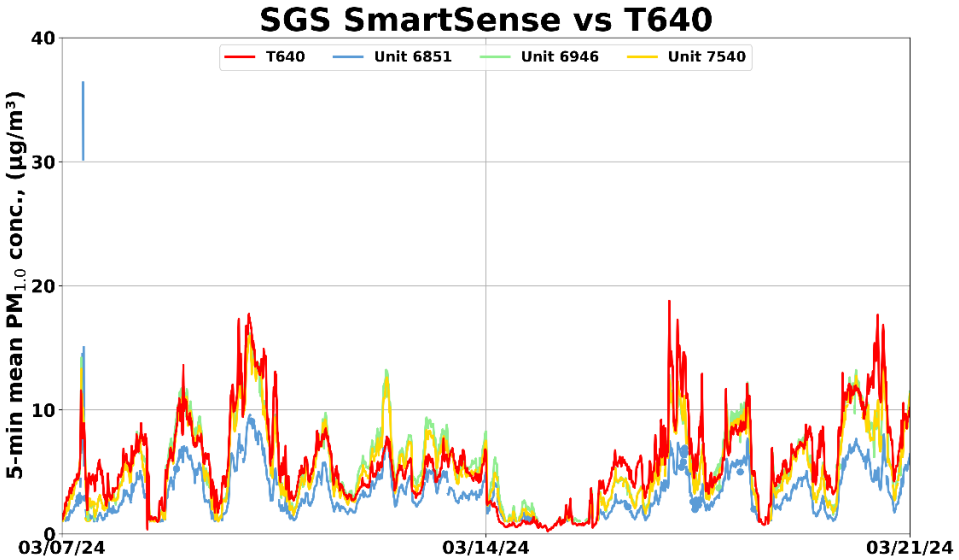
Reference Instruments: PM_{10} FEM BAM and T640

- Data recovery for PM_{10} from FEM BAM and T640 was ~97.4% and 99.9%, respectively.
- Strong correlations between the reference instruments for PM_{10} measurements (R^2 ~ 0.83) were observed.

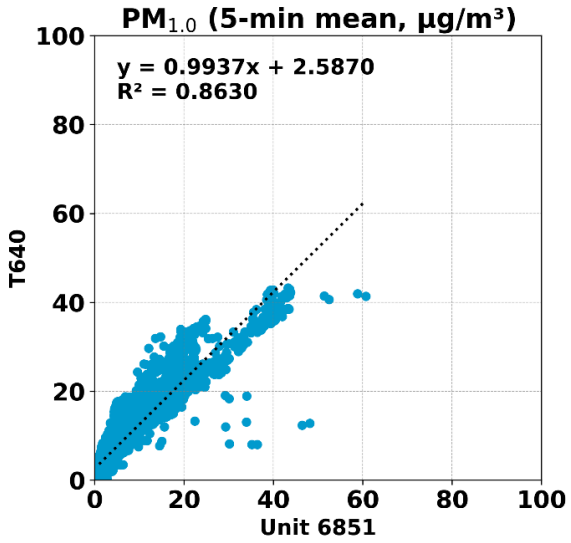


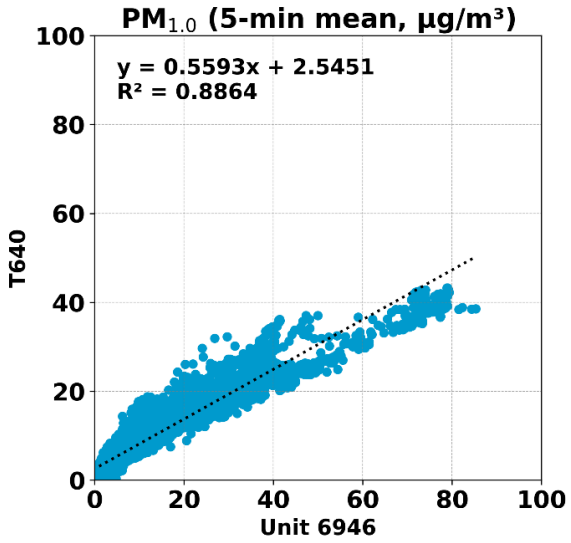


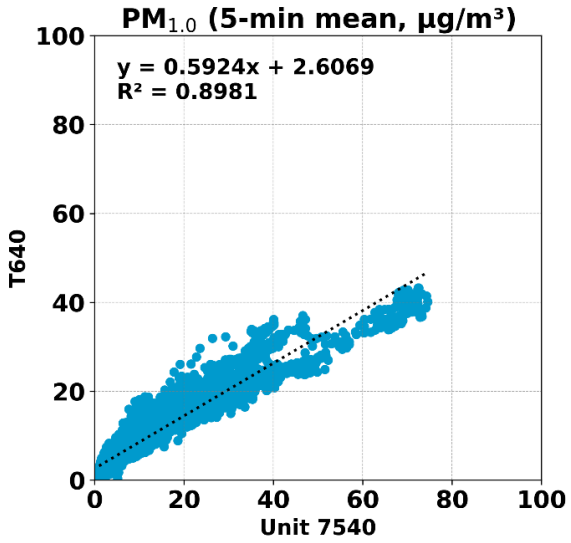
SGS SmartSense vs T640 ($PM_{1.0}$; 5-min mean)



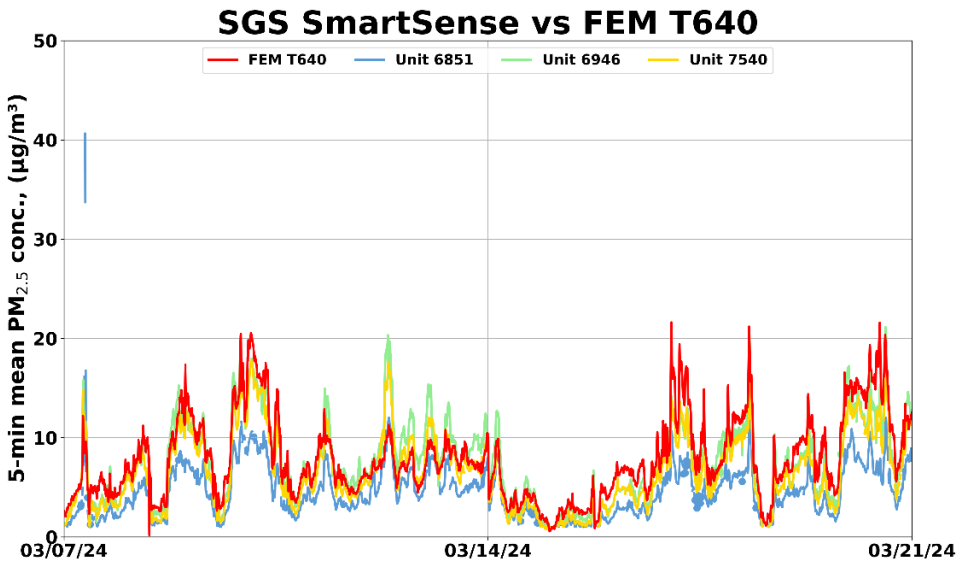
- The SGS SmartSense sensors showed strong correlations with the corresponding T640 data ($0.86 < R^2 < 0.90$)
- Overall, the SGS SmartSense sensors underestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The SGS SmartSense sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640



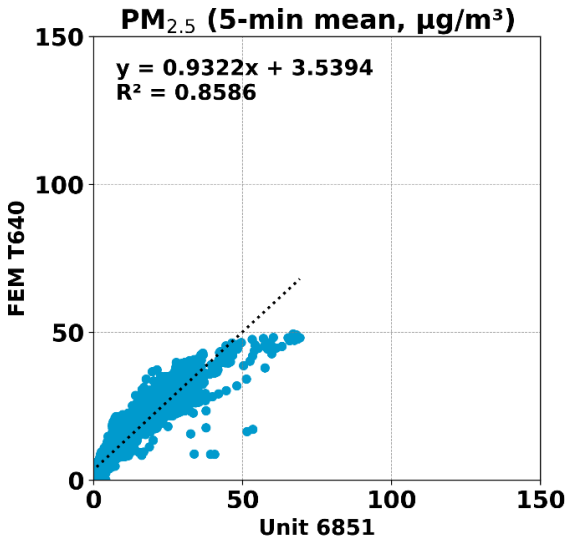


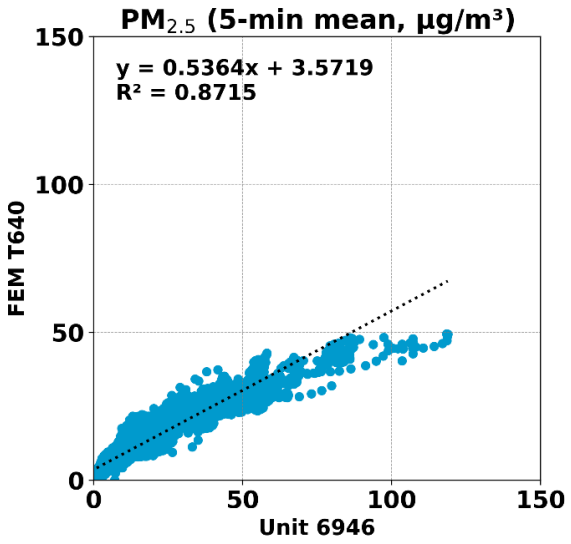


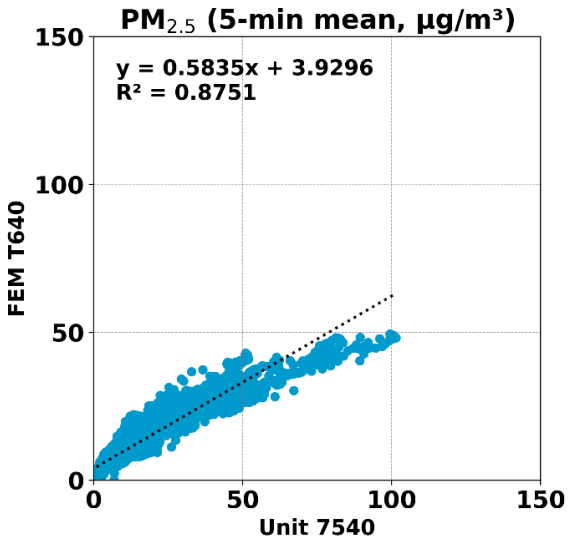
SGS SmartSense vs FEM T640 ($PM_{2.5}$; 5-min mean)



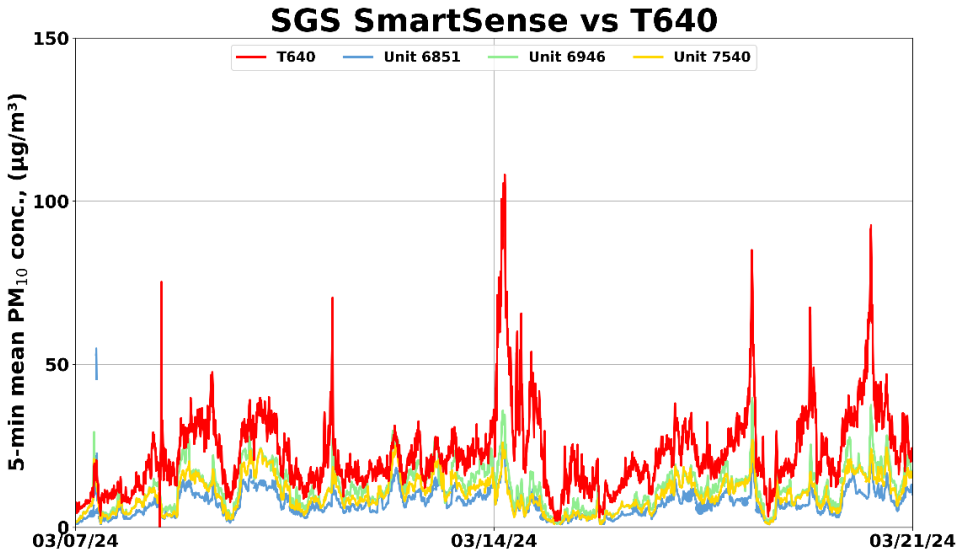
- The SGS SmartSense sensors showed strong correlations with the corresponding FEM T640 data ($0.85 < R^2 < 0.88$)
- Overall, the SGS SmartSense sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The SGS SmartSense sensors seemed to track the $PM_{2.5}$ diurnal variations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



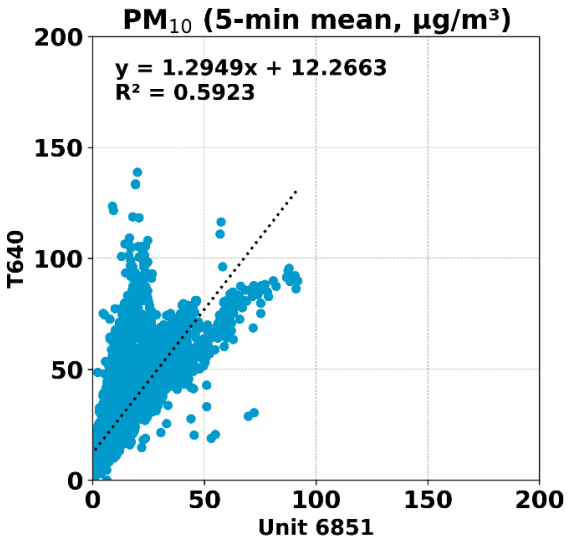


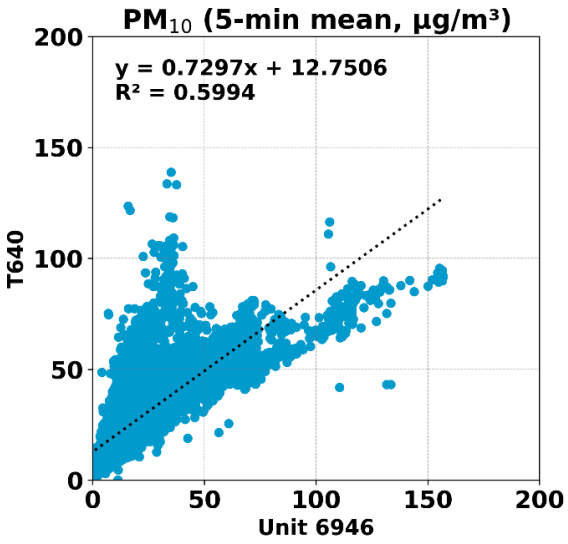


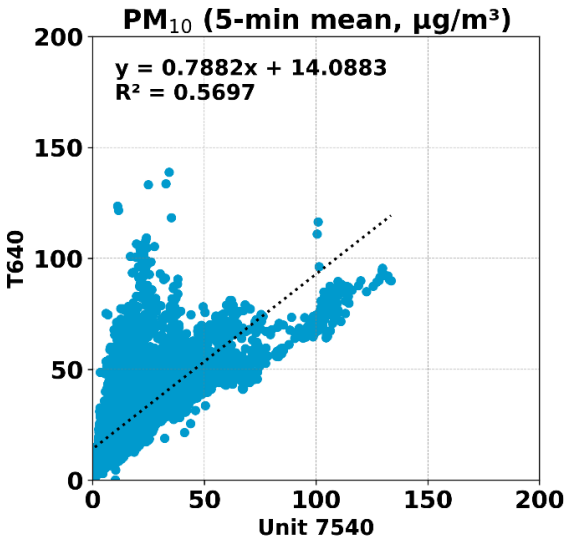
SGS SmartSense vs T640 (PM_{10}; 5-min mean)



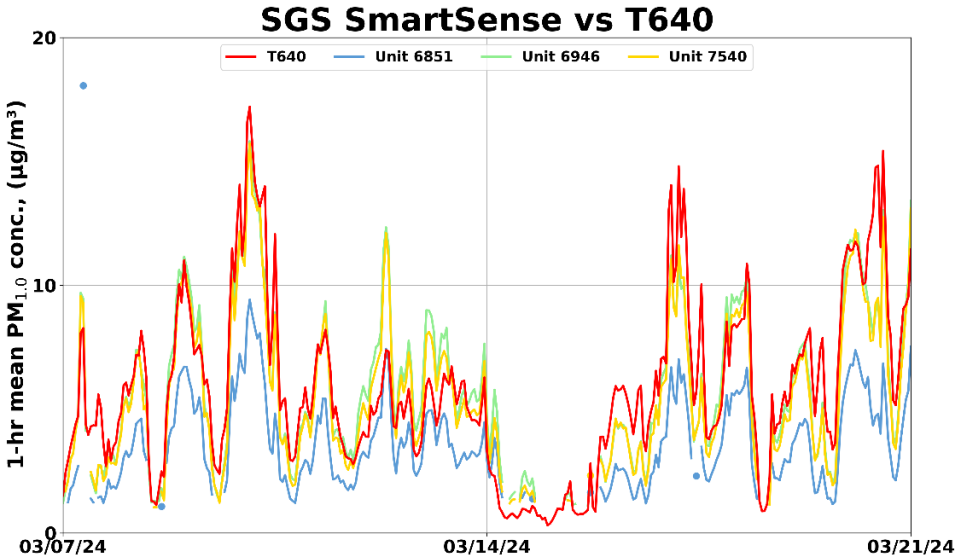
- The SGS SmartSense sensors showed moderate correlations with the corresponding T640 data ($0.56 < R^2 < 0.60$)
- Overall, the SGS SmartSense sensors underestimated the PM_{10} mass concentrations as measured by T640
- The SGS SmartSense sensors seemed to track the PM_{10} diurnal variations as recorded by T640



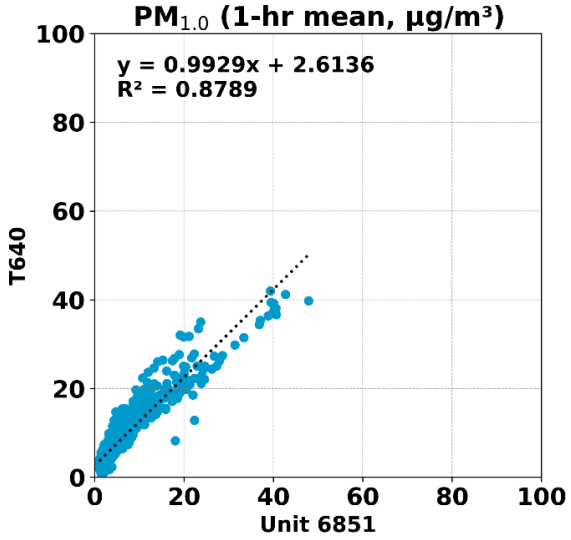


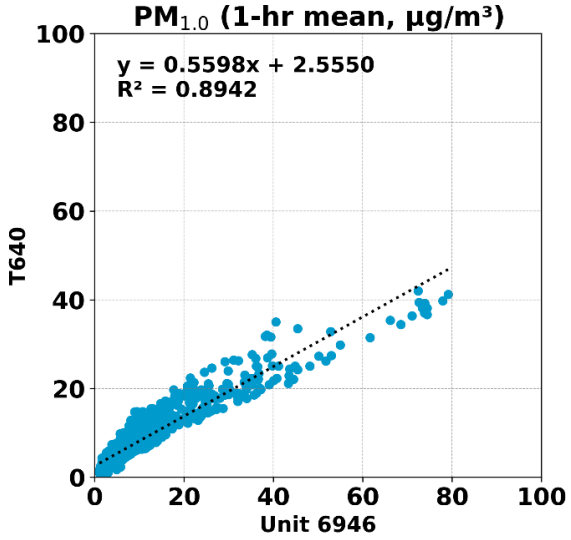


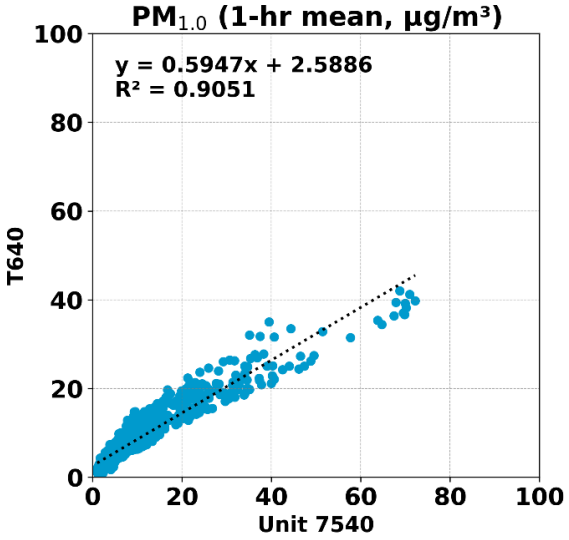
SGS SmartSense vs T640 ($PM_{1.0}$; 1-hr mean)



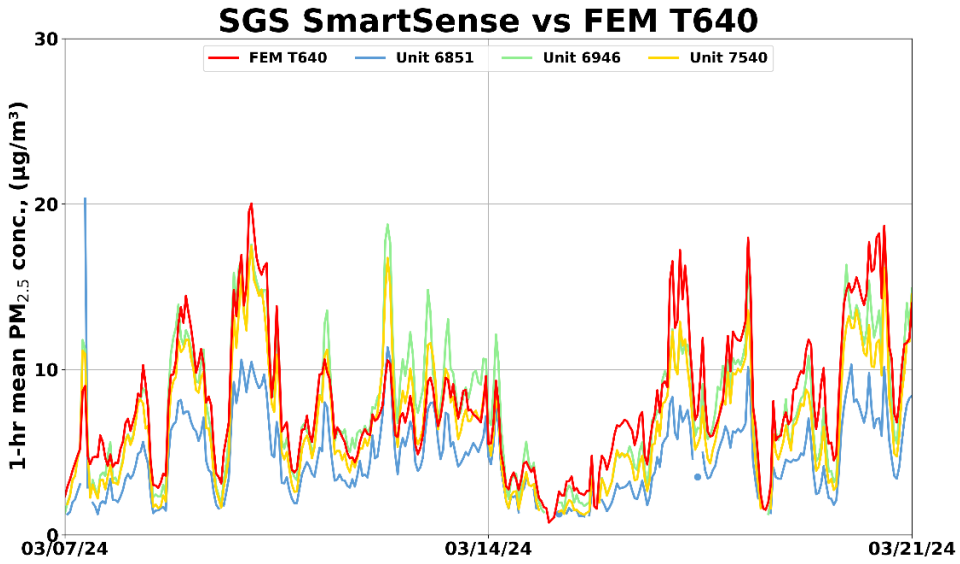
- The SGS SmartSense sensors showed strong to very strong correlations with the corresponding T640 data ($0.87 < R^2 < 0.91$)
- Overall, the SGS SmartSense sensors underestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The SGS SmartSense sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by T640



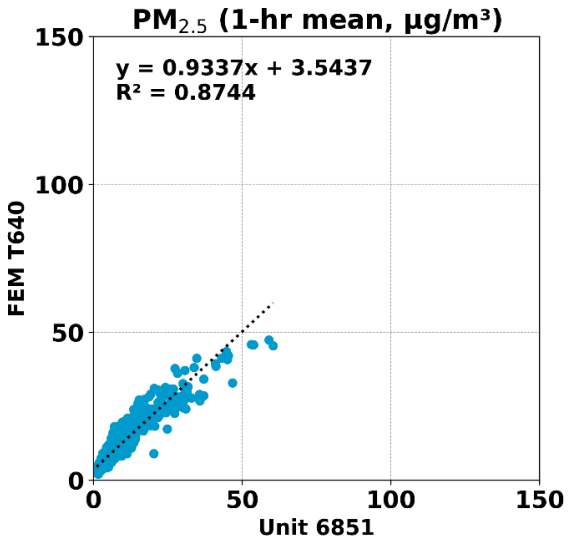


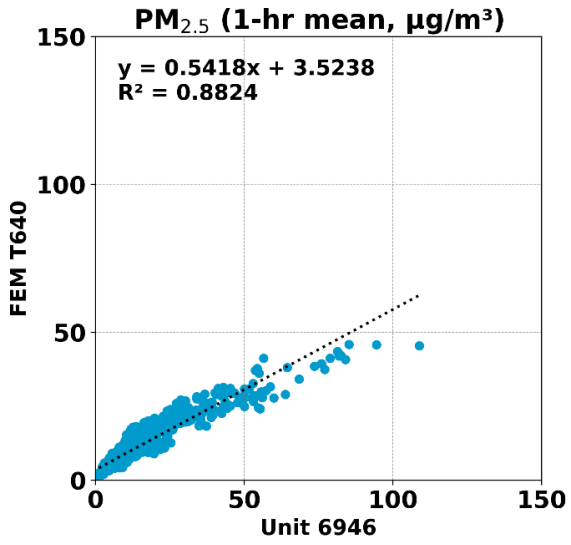


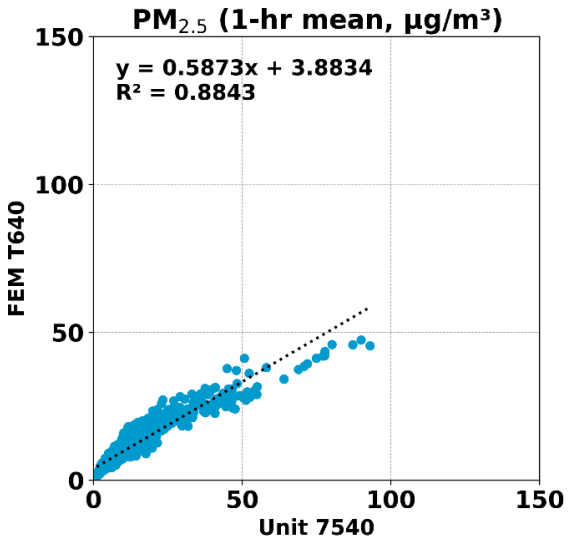
SGS SmartSense vs FEM T640 ($PM_{2.5}$; 1-hr mean)



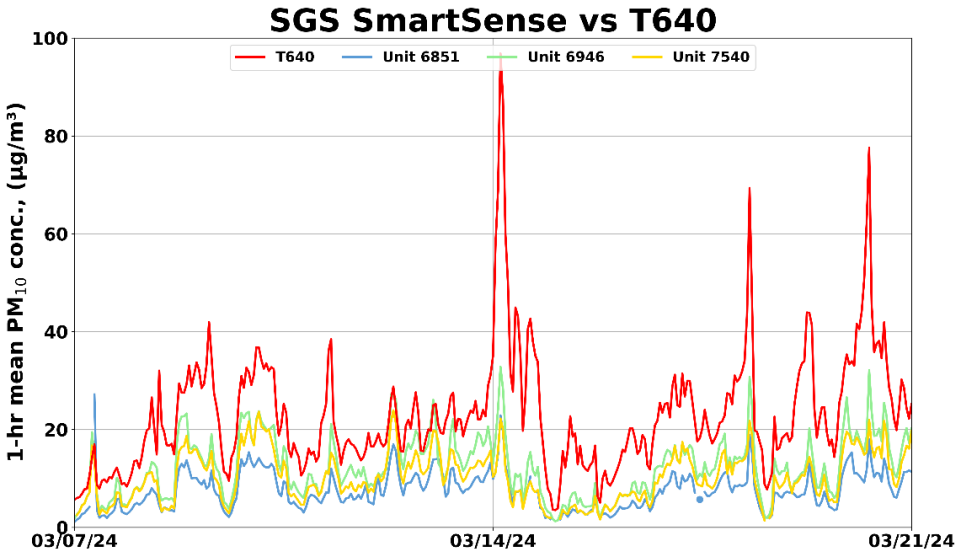
- The SGS SmartSense sensors showed strong correlations with the corresponding FEM T640 data ($0.87 < R^2 < 0.89$)
- Overall, the SGS SmartSense sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The SGS SmartSense sensors seemed to track the $PM_{2.5}$ diurnal variations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



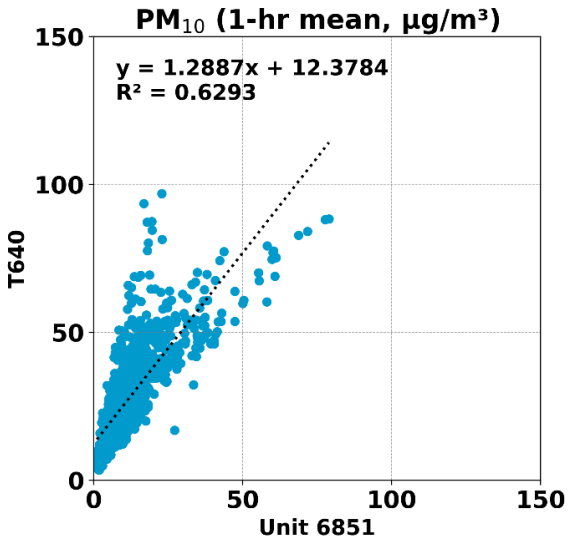


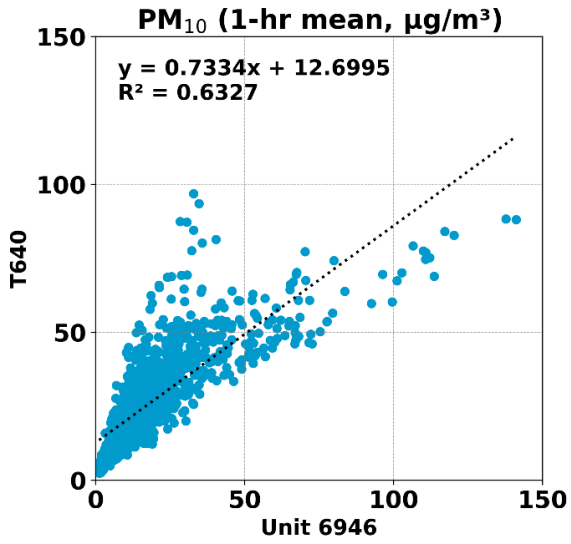


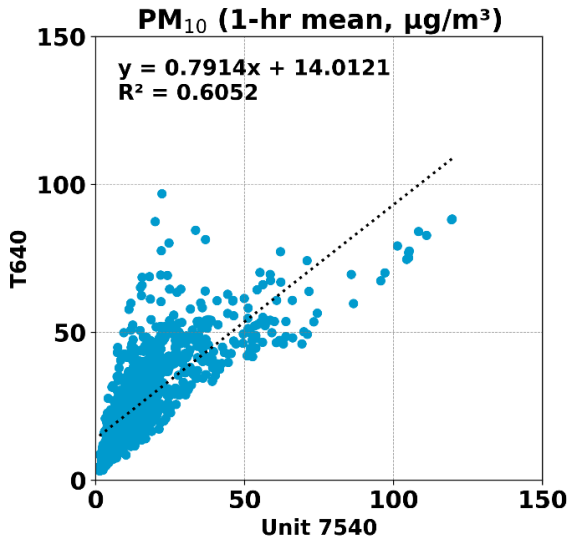
SGS SmartSense vs T640 (PM_{10}; 1-hr mean)



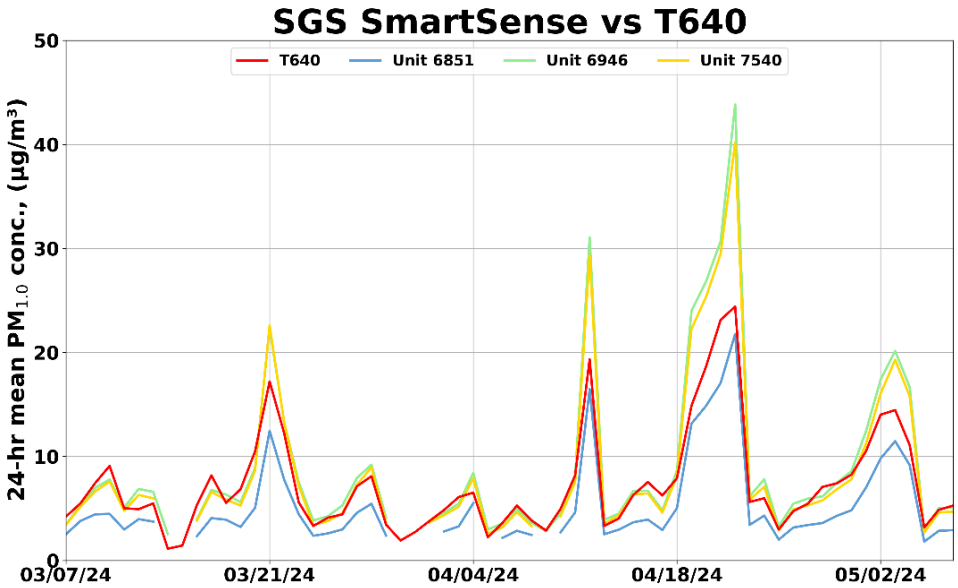
- The SGS SmartSense sensors showed moderate correlations with the corresponding T640 data ($0.60 < R^2 < 0.64$)
- Overall, the SGS SmartSense sensors underestimated the PM_{10} mass concentrations as measured by T640
- The SGS SmartSense sensors seemed to track the PM_{10} diurnal variations as recorded by T640



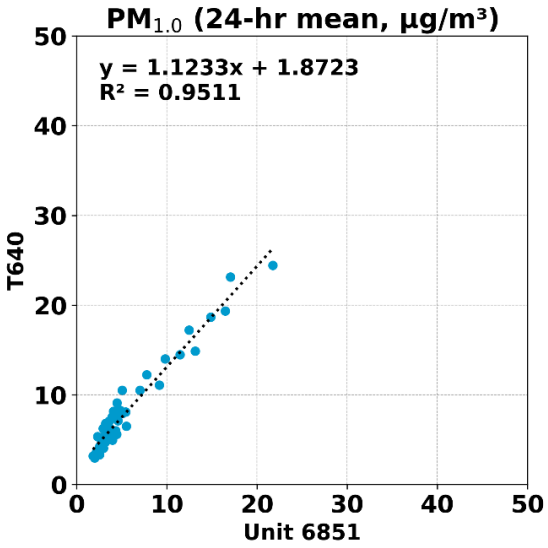


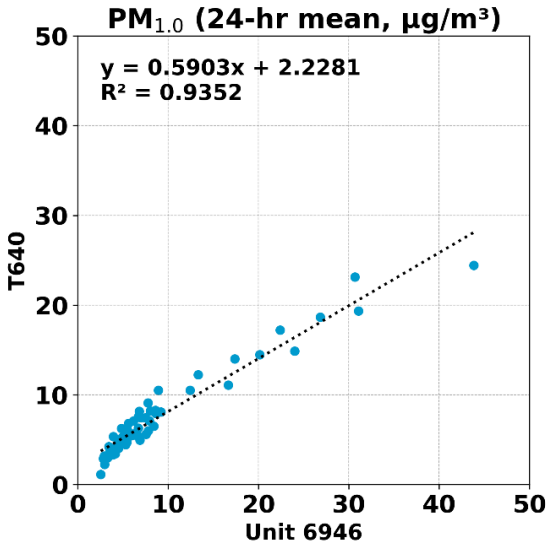


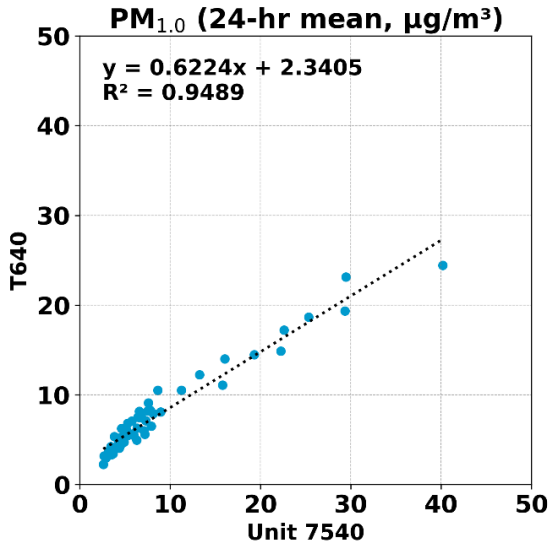
SGS SmartSense vs T640 ($PM_{1.0}$; 24-hr mean)



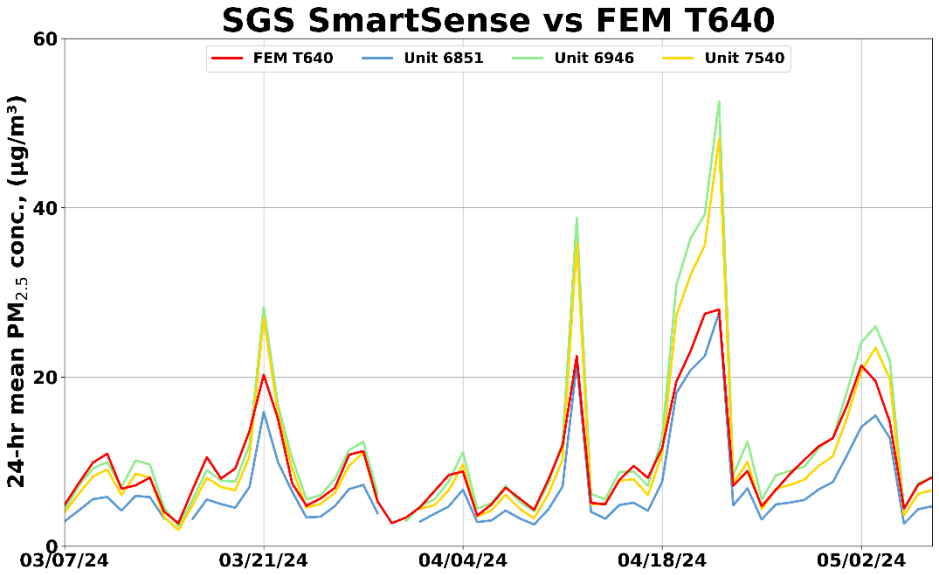
- The SGS SmartSense sensors showed very strong correlations with the corresponding T640 data ($0.93 < R^2 < 0.96$)
- Overall, the SGS SmartSense sensors underestimated the $PM_{1.0}$ mass concentrations as measured by T640
- The SGS SmartSense sensors seemed to track the $PM_{1.0}$ daily variations as recorded by T640



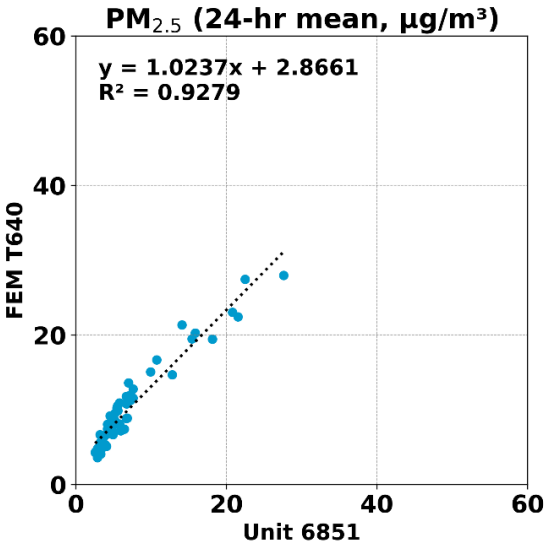


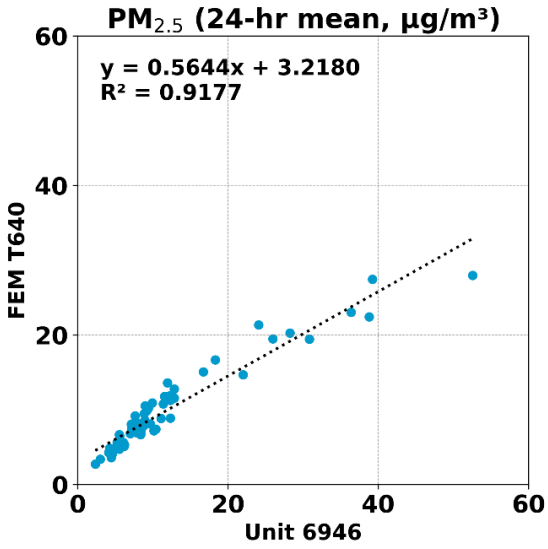


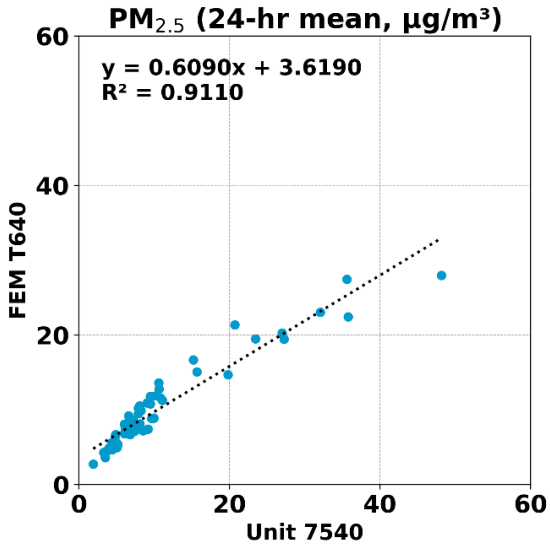
SGS SmartSense vs FEM T640 ($PM_{2.5}$; 24-hr mean)



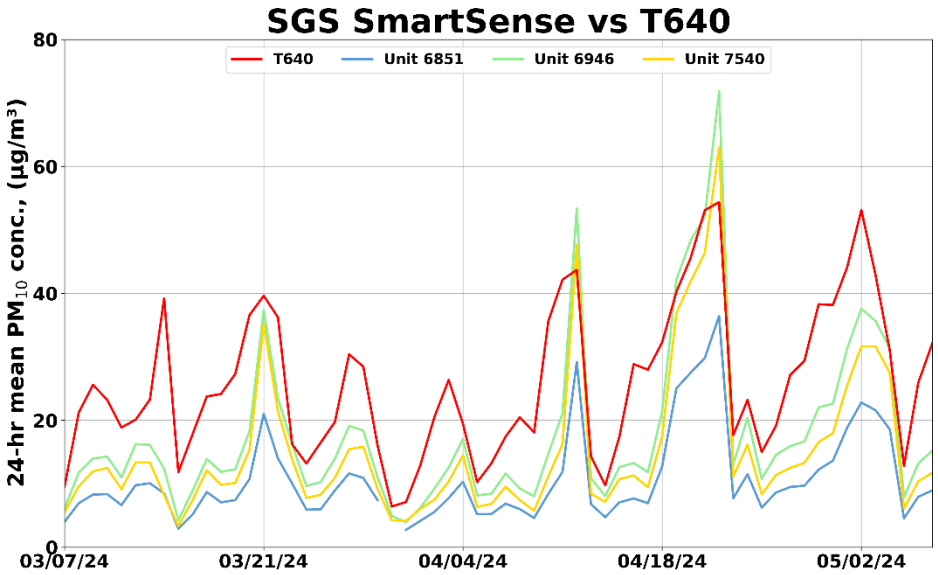
- The SGS SmartSense sensors showed very strong correlations with the corresponding FEM T640 data ($0.91 < R^2 < 0.93$)
- Overall, the SGS SmartSense sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM T640
- The SGS SmartSense sensors seemed to track the $PM_{2.5}$ daily variations as recorded by FEM T640



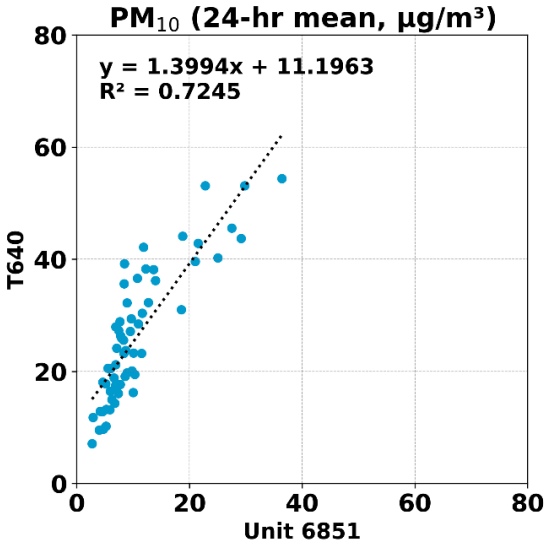


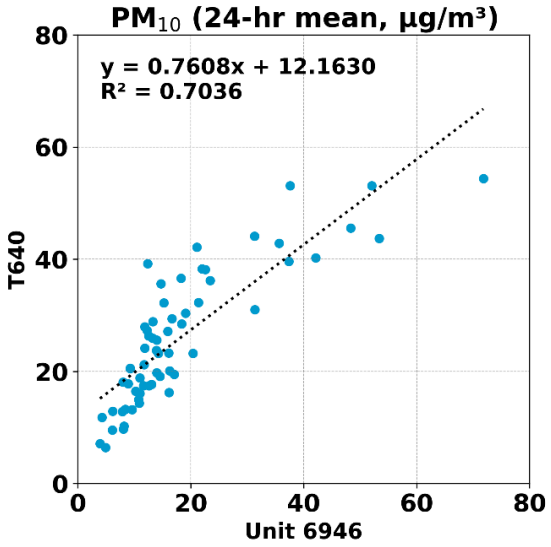


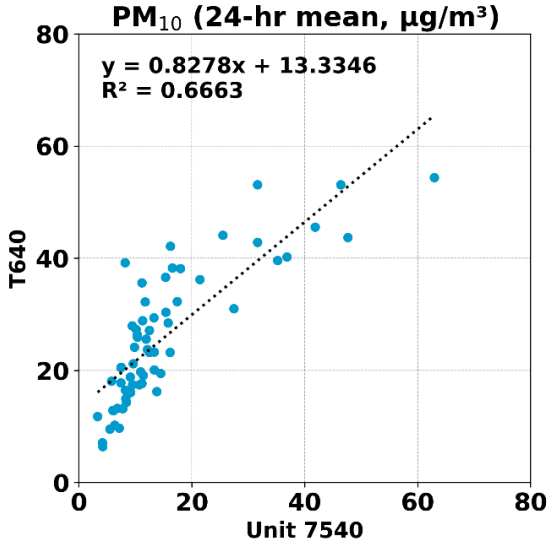
SGS SmartSense vs T640 (PM_{10}; 24-hr mean)



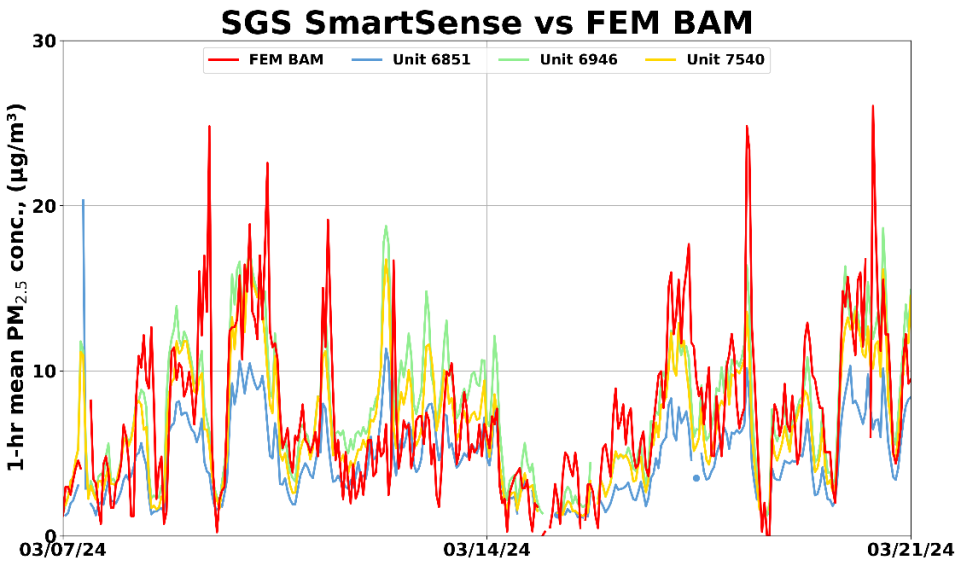
- The SGS SmartSense sensors showed moderate to strong correlations with the corresponding T640 data ($0.66 < R^2 < 0.73$)
- Overall, the SGS SmartSense sensors underestimated the PM_{10} mass concentrations as measured by T640
- The SGS SmartSense sensors seemed to track the PM_{10} daily variations as recorded by T640



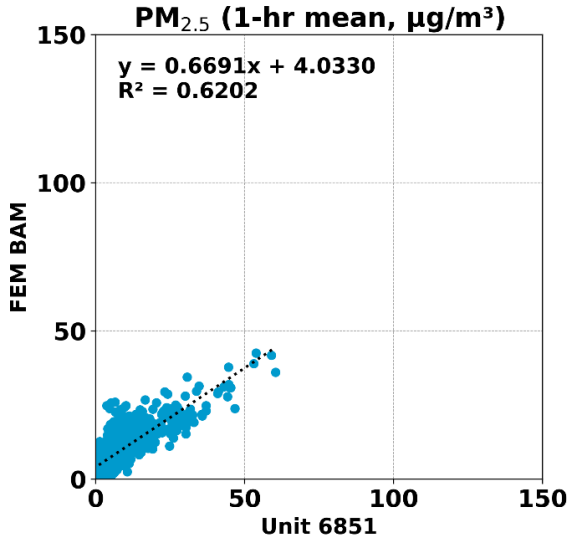


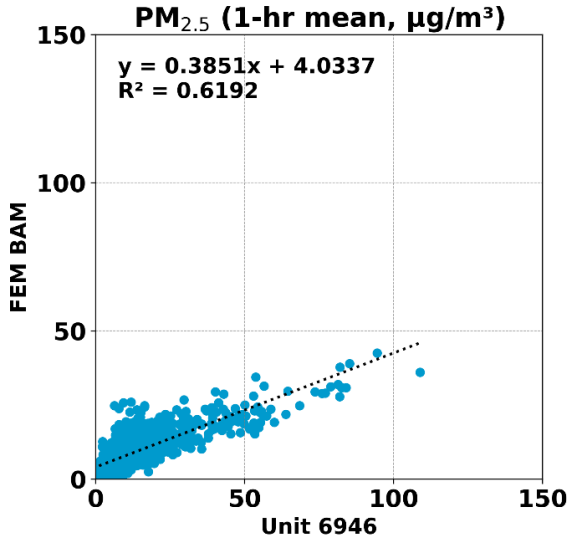


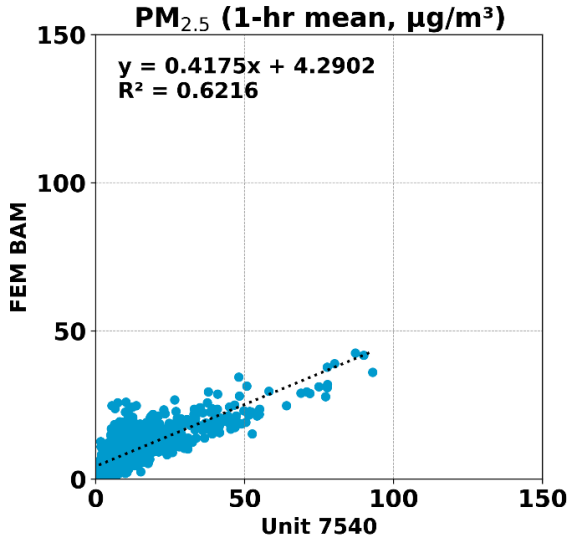
SGS SmartSense vs FEM BAM ($PM_{2.5}$; 1-hr mean)



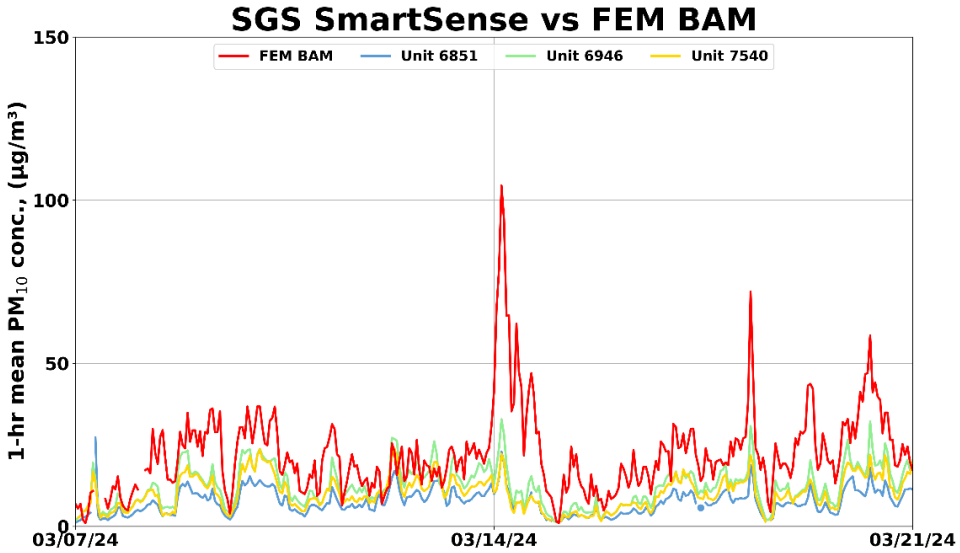
- The SGS SmartSense sensors showed moderate correlations with the corresponding FEM BAM data ($0.61 < R^2 < 0.63$)
- Overall, the SGS SmartSense sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM BAM
- The SGS SmartSense sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM BAM



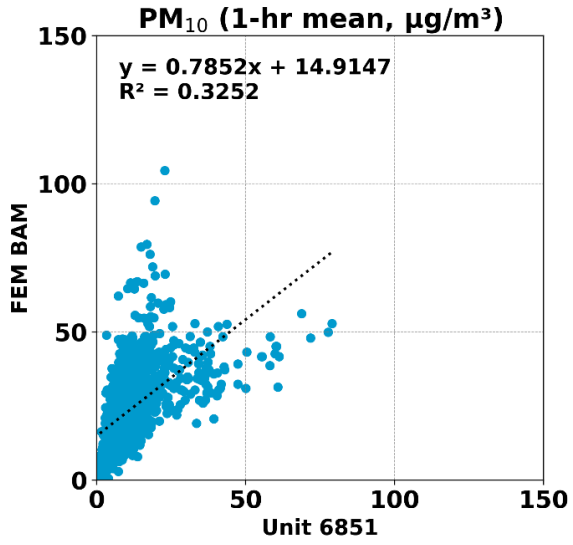


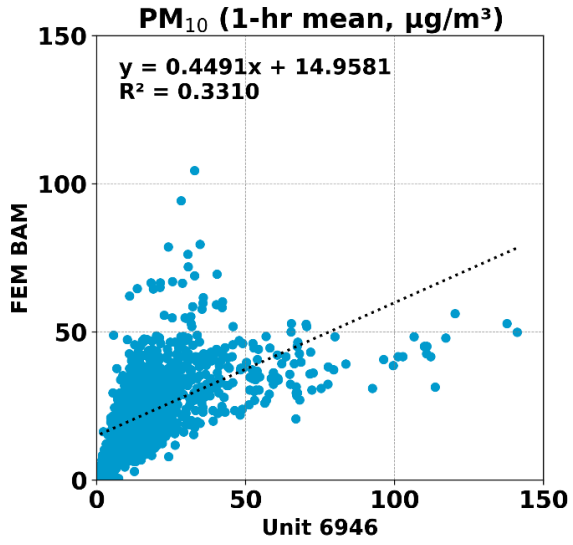


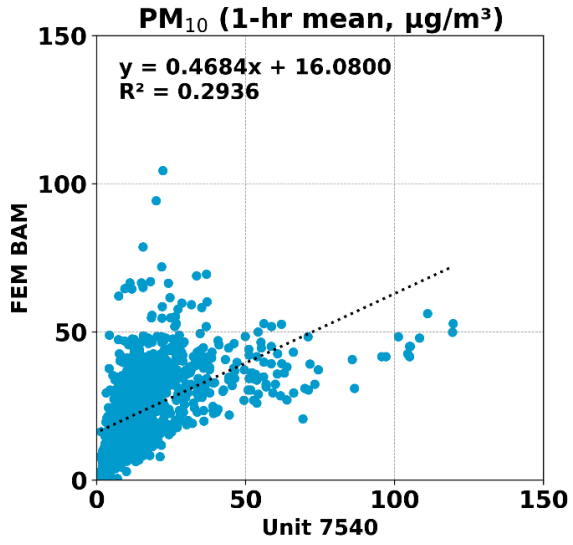
SGS SmartSense vs FEM BAM (PM_{10}; 1-hr mean)



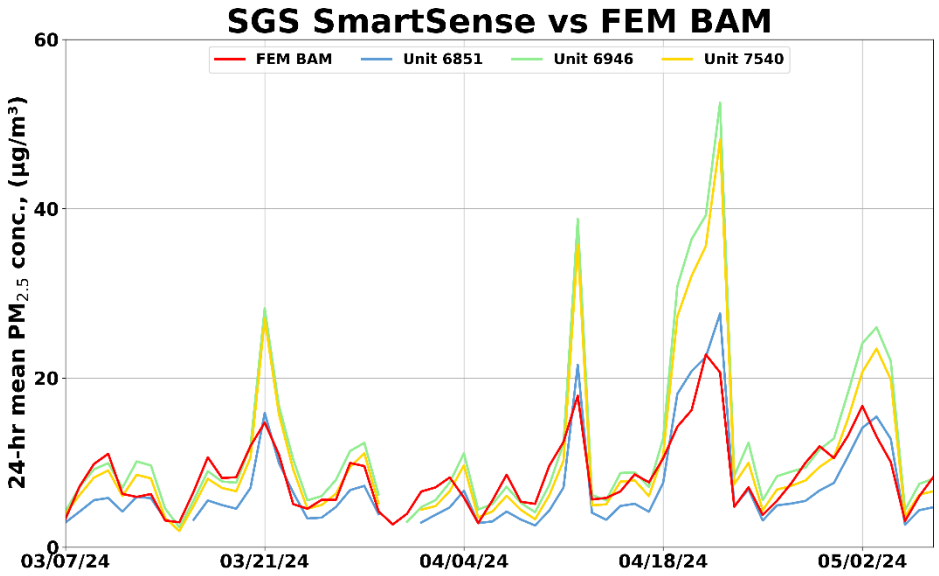
- The SGS SmartSense sensors showed very weak to weak correlations with the corresponding FEM BAM data ($0.29 < R^2 < 0.34$)
- Overall, the SGS SmartSense sensors underestimated the PM_{10} mass concentrations as measured by FEM BAM
- The SGS SmartSense sensors did not seem to track the PM_{10} diurnal variations as recorded by FEM BAM



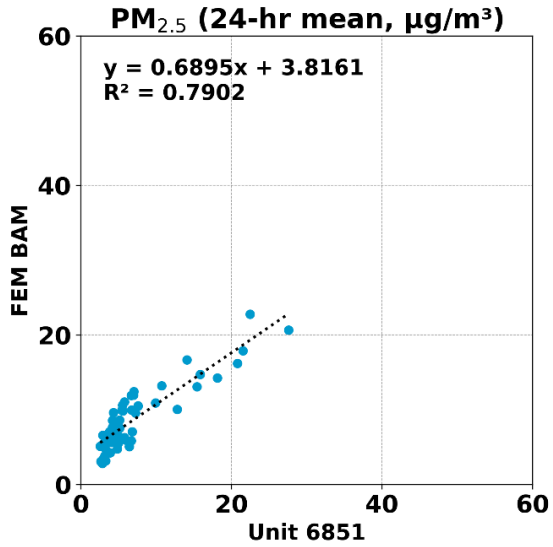


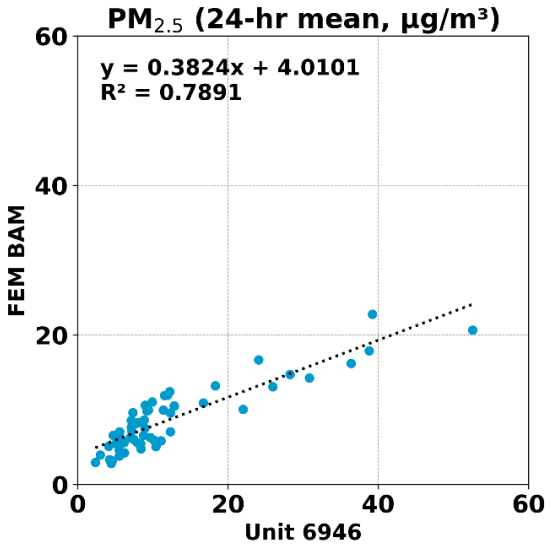


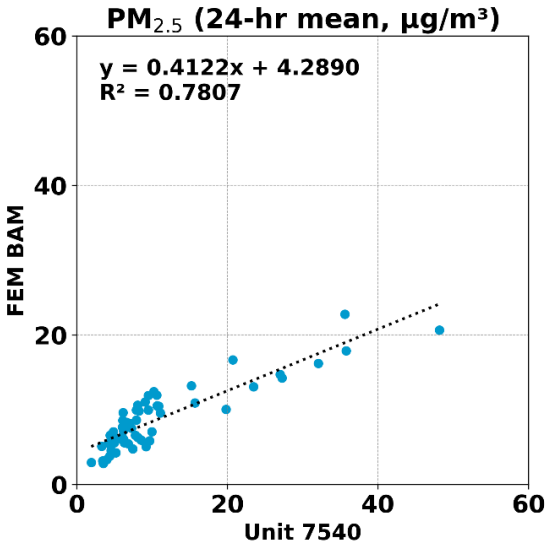
SGS SmartSense vs FEM BAM ($PM_{2.5}$; 24-hr mean)



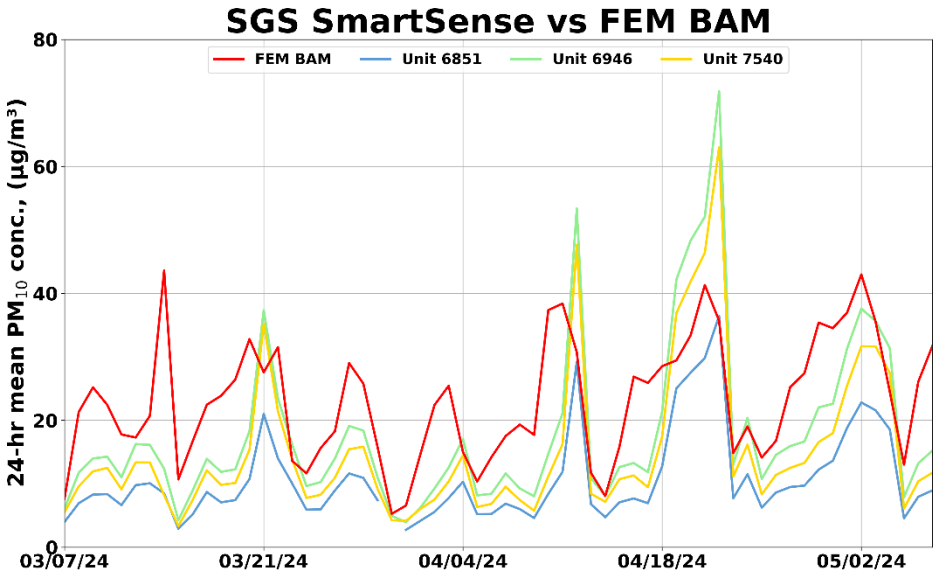
- The SGS SmartSense sensors showed strong correlations with the corresponding FEM BAM data ($0.78 < R^2 < 0.80$)
- Overall, the SGS SmartSense sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM BAM
- The SGS SmartSense sensors seemed to track the $PM_{2.5}$ daily variations as recorded by FEM BAM



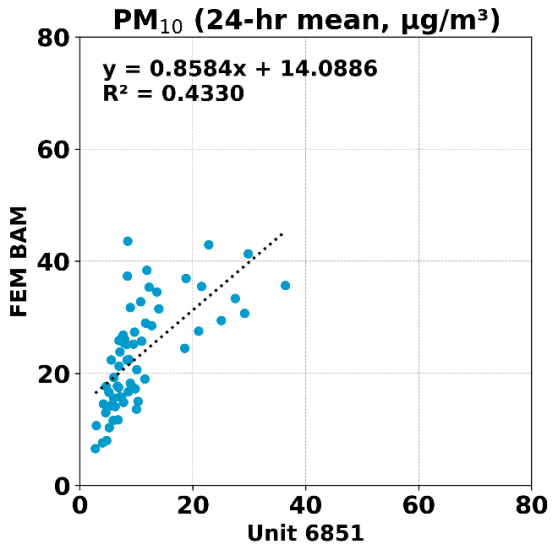


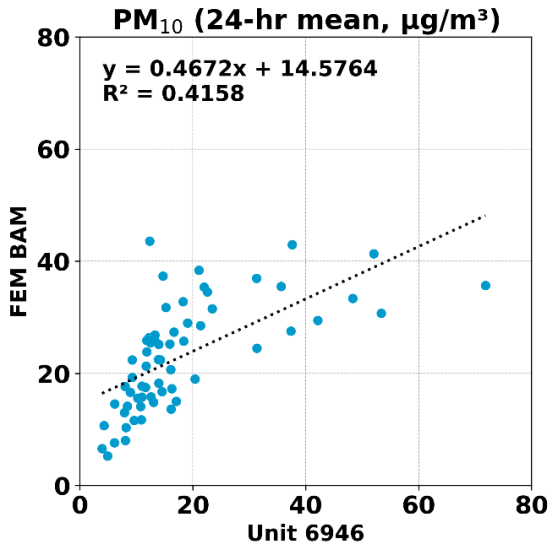


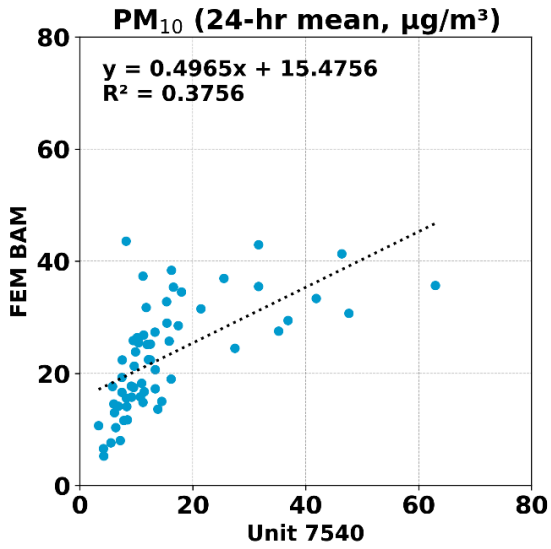
SGS SmartSense vs FEM BAM (PM_{10}; 24-hr mean)



- The SGS SmartSense sensors showed weak correlations with the corresponding FEM BAM data ($0.37 < R^2 < 0.44$)
- Overall, the SGS SmartSense sensors underestimated the PM_{10} mass concentrations as measured by FEM BAM
- The SGS SmartSense sensors seemed to track the PM_{10} daily variations as recorded by FEM BAM







Summary: PM

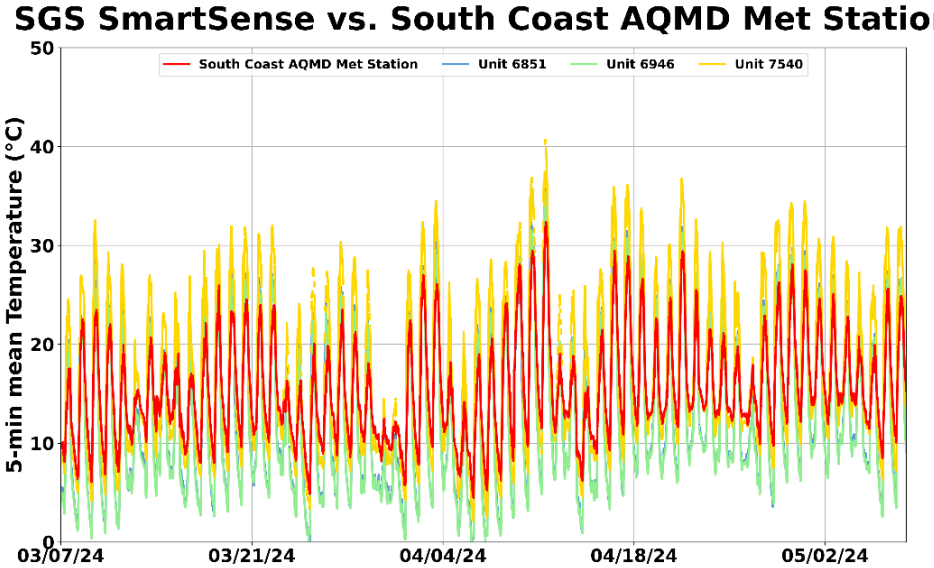
	Average of 3 Sensors, $PM_{1.0}$		SGS SmartSense vs T640, $PM_{1.0}$						T640 ($PM_{1.0}$, $\mu g/m^3$)		
	Average ($\mu g/m^3$)	SD ($\mu g/m^3$)	R^2	Slope	Intercept	MBE[1] ($\mu g/m^3$)	MAE[2] ($\mu g/m^3$)	RMSE[3] ($\mu g/m^3$)	Ref. Average	Ref. SD	Range during the field evaluation
5-min	7.5	8.4	0.86 to 0.90	0.56 to 0.99	2.5 to 2.6	-2.6 to 1.3	2.0 to 2.7	3.4 to 5.1	7.3	6.0	0.2 to 43.2
1-hr	7.5	8.4	0.88 to 0.91	0.56 to 0.99	2.6	-2.6 to 1.4	2.0 to 2.7	3.3 to 5.0	7.3	6.0	0.3 to 42.0
24-hr	7.6	6.8	0.94 to 0.95	0.59 to 1.12	1.9 to 2.3	-2.5 to 1.4	1.7 to 2.5	2.8 to 3.8	7.3	5.0	1.1 to 24.4
	Average of 3 Sensors, $PM_{2.5}$		SGS SmartSense 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	9.7	10.1	0.86 to 0.88	0.54 to 0.93	3.5 to 3.9	-3.1 to 1.9	2.6 to 3.3	4.1 to 6.5	9.8	7.1	0.1 to 49.5
1-hr	9.7	10.1	0.62 to 0.88	0.39 to 0.93	3.5 to 4.3	-3.1 to 3.2	2.5 to 4.9	4.0 to 8.9	8.5 to 9.8	6.0 to 7.1	0 to 47.4
24-hr	9.8	8.3	0.78 to 0.93	0.38 to 1.02	2.9 to 4.3	-3.0 to 3.3	2.2 to 3.9	3.0 to 7.3	8.4 to 9.8	4.4 to 5.9	2.7 to 28.0
	Average of 3 Sensors, PM_{10}		SGS SmartSense 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	14.6	13.4	0.57 to 0.60	0.73 to 1.29	12.3 to 14.1	-15.4 to -7.9	9.9 to 15.4	13.3 to 18.4	25.9	15.5	0.2 to 138.8
1-hr	14.7	13.3	0.29 to 0.63	0.45 to 1.29	12.4 to 16.1	-15.5 to -5.0	9.8 to 15.5	12.8 to 18.1	23.0 to 25.9	12.7 to 15.0	0 to 104.5
24-hr	14.7	10.8	0.38 to 0.72	0.47 to 1.40	11.2 to 15.5	-15.5 to -5.0	8.8 to 15.5	10.6 to 16.9	23.0 to 25.9	9.6 to 12.0	5.3 to 54.4

[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).

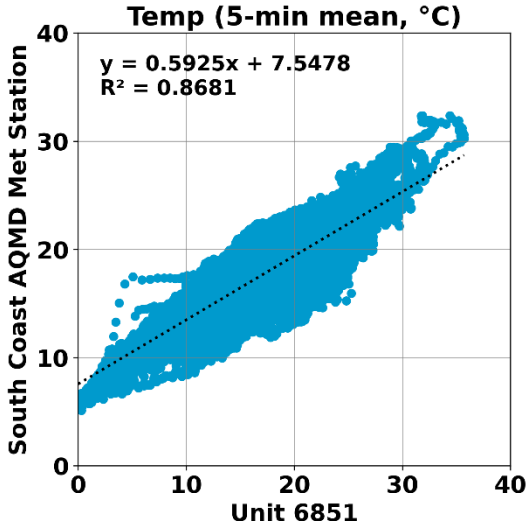
[2] Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.

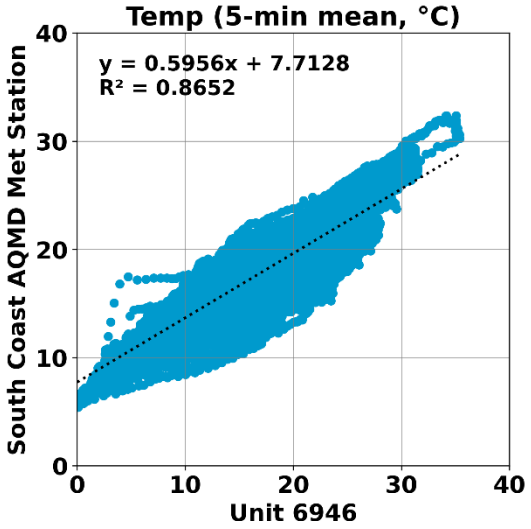
[3] Root Mean Square Error (RMSE): another metric to calculate measurement errors.

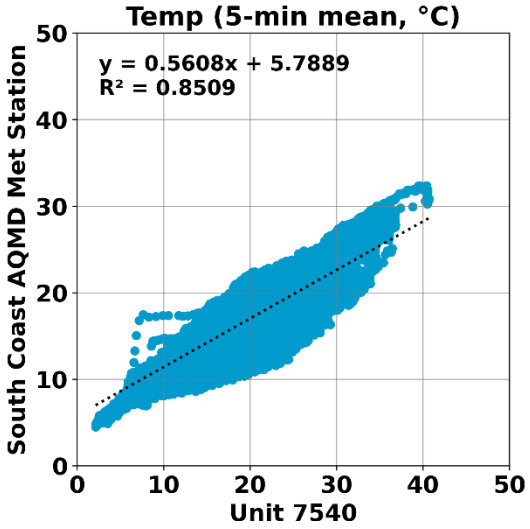
SGS SmartSense vs South Coast AQMD Met Station (Temp; 5-min mean)



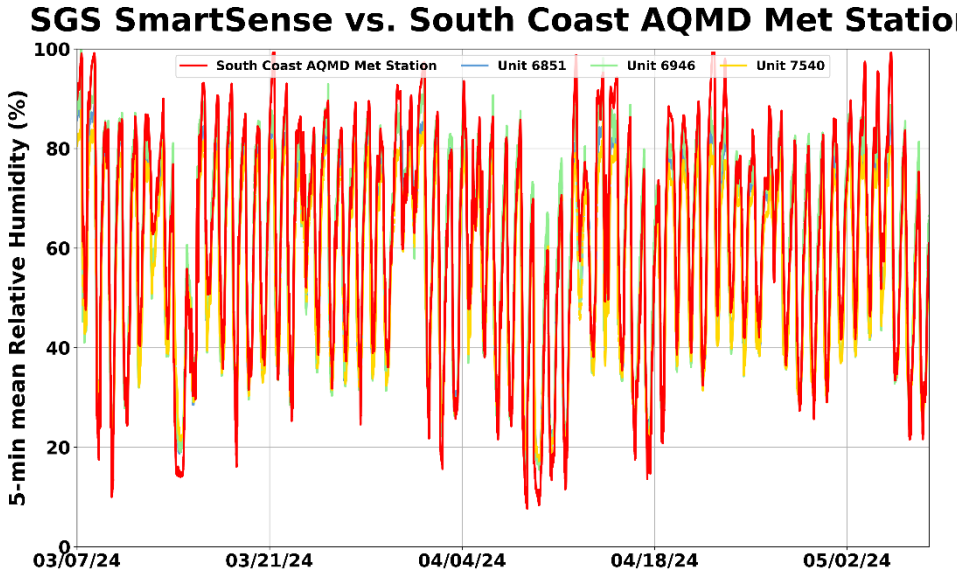
- The SGS SmartSense sensors showed strong correlations with the corresponding South Coast AQMD Met Station data ($0.85 < R^2 < 0.87$)
- Overall, the SGS SmartSense sensors underestimated the temperature measurement as recorded by South Coast AQMD Met Station
- The SGS SmartSense sensors seemed to track the diurnal temperature variations as recorded by South Coast AQMD Met Station



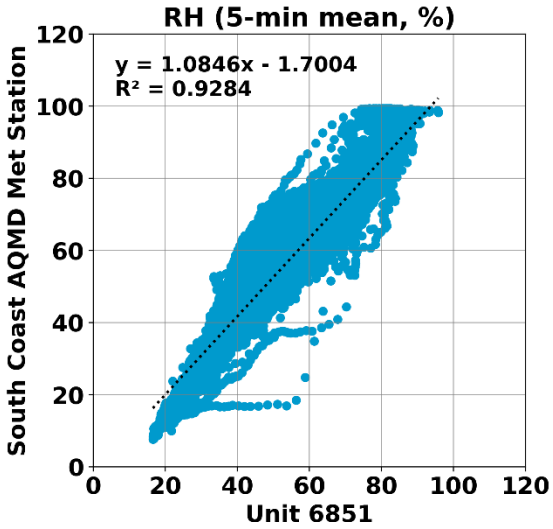


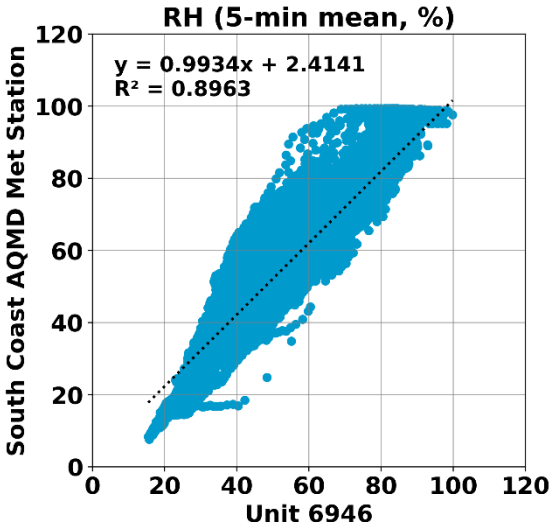


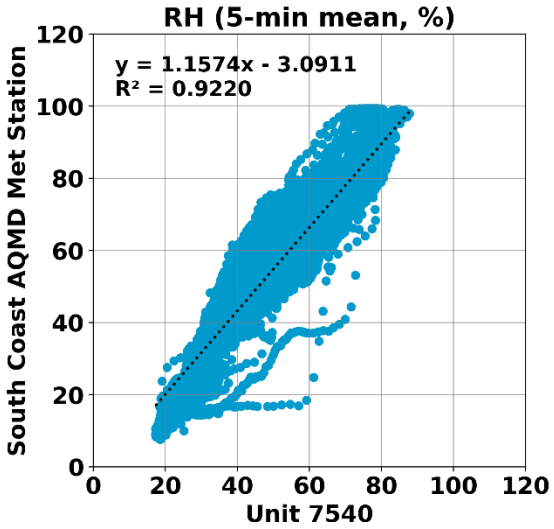
SGS SmartSense vs South Coast AQMD Met Station (RH; 5-min mean)



- SGS SmartSense sensors showed strong to very strong correlations with the corresponding South Coast AQMD Met Station data ($0.89 < R^2 < 0.93$)
- Overall, the SGS SmartSense sensors underestimated the RH measurement as recorded by South Coast AQMD Met Station
- The SGS SmartSense sensors seemed to track the diurnal RH variations as recorded by South Coast AQMD Met Station







Discussion

- The three **SGS SmartSense** sensors' data recovery for CO, O_3, NO_2, and all PM fractions was ~97.5%, ~97.5%, ~97.5%, and 97.4%, respectively.
- The absolute intra-model variability for CO, O_3, NO_2 was ~164.7 ppb, ~3.8 ppb, ~188.8 ppb respectively. Absolute intra-model variability was ~2.1, ~2.5, and ~3.7 µg/m^3 for $PM_{1.0}$, $PM_{2.5}$ and PM_{10}, respectively
- Reference instruments: strong correlations between FEM BAM and FEM T640 for $PM_{2.5}$ (R^2 ~0.76, 1-hr mean) and strong correlations between FEM BAM and T640 for PM_{10} (R^2 ~0.83, 1-hr mean) mass concentration measurements
- During the entire field deployment testing period:
  - CO sensors showed very weak to strong correlation with the FRM Horiba instrument ($0.28 < R^2 < 0.73$, 5-min mean) and generally underestimated the corresponding FRM Horiba data
  - Ozone sensors showed moderate to strong correlation with the FEM T400 instrument ($0.58 < R^2 < 0.71$, 5-min mean) and generally underestimated the corresponding FEM T400 data
  - NO_2 sensors showed no to very weak correlations with the FRM T200 instrument ($0.02 < R^2 < 0.29$, 5-min mean) and overestimated the corresponding FRM T200 data
  - The SGS SmartSense sensors showed strong to very strong correlations with the corresponding T640 $PM_{1.0}$ data ($0.88 < R^2 < 0.91$, 1-hr mean), moderate to strong correlations with the corresponding FEM BAM and FEM T640 $PM_{2.5}$ data ($0.61 < R^2 < 0.89$, 1-hr mean) and very weak to moderate correlations with the corresponding FEM BAM and T640 reference PM_{10} data ($0.29 < R^2 < 0.64$; 1-hr mean). The sensors generally underestimated $PM_{1.0}$, $PM_{2.5}$ and PM_{10} mass concentrations as measured by the reference instruments; except that the sensors overestimated $PM_{2.5}$ mass concentrations as measured by FEM BAM
  - Temperature and relative humidity sensors showed strong correlations for T and strong to very strong correlation for RH with the South Coast AQMD Met Station T and RH data, respectively (R^2 ~ 0.86 for T and R^2 ~ 0.91 for RH) and underestimated T and 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