Field Evaluation
Igienair Zaack AQI

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 11/13/2020 to 01/08/2021, three **Igienair Zaack AQI (hereinafter Zaack AQI)** 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

- Zaack AQI (*3 units tested*):
  - Gas Sensors: Electrochemical; non-FEM (Alphasense)
  - Particle Sensor – Optical; non-FEM (Alphasense OPC R1)
  - Each unit measures: O_3 (ppb), NO_2 (ppb), CO (ppb), $PM_{1.0}$, $PM_{2.5}$ and PM_{10} ($\mu g/m^3$), T (°C), RH (%)
  - Units also measure VOC (ppb) and CO_2 (ppm)
  - Unit cost: $3000 + $1199 Yearly calibration and maintenance contract
  - Time resolution: 30-sec
  - Units IDs: 1264, 1271, 1332

- South Coast AQMD Reference instruments:
  - O_3 instrument (FEM); cost: ~$7,000
    - Time resolution; 1-min
  - CO instrument (FRM); cost: ~$10,000
    - Time resolution; 1-min
  - NO_2 instrument (FRM); cost: ~$11,000
    - Time resolution: 1-min
  - MetOne BAM (FEM $PM_{2.5}$ & FEM PM_{10}); cost: ~$20,000
    - Time resolution: 1-hr
  - Teledyne API T640 (FEM $PM_{2.5}$); cost: $21,000
    - Time resolution: 1-min
  - Met station (T, RH, P, WS, WD); cost: ~$5,000
    - Time resolution: 1-min

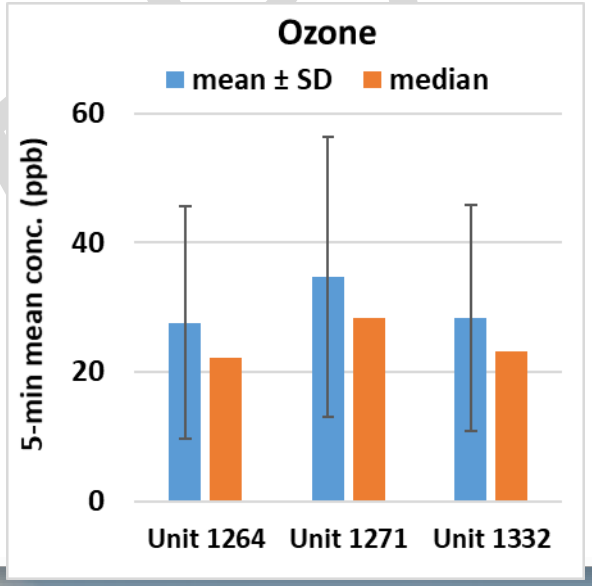
Ozone (O_3) in Zaack AQI

Data validation & recovery

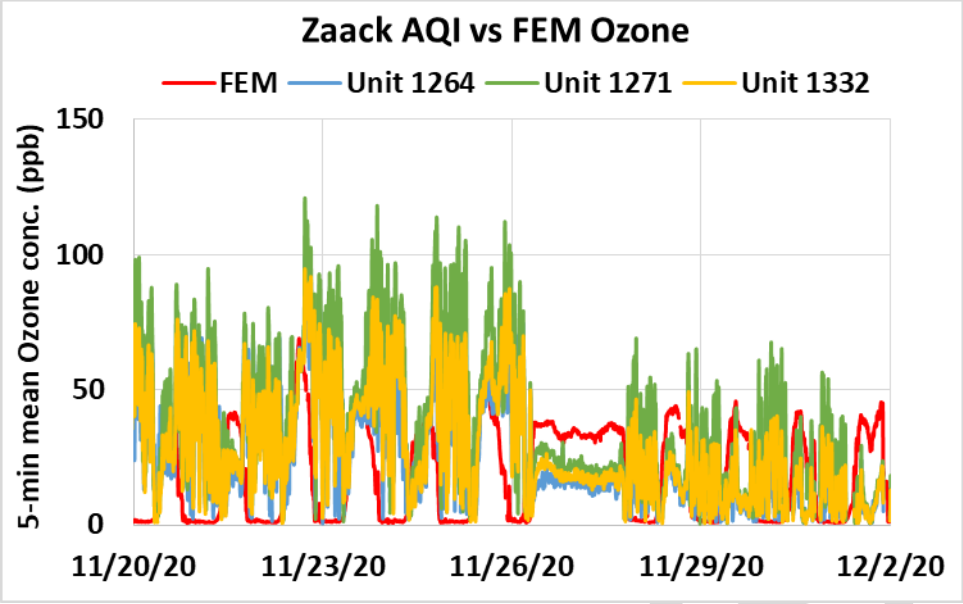
- Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
- Data recovery for ozone from all units was ~ 90%

Zaack AQI; Intra-model variability

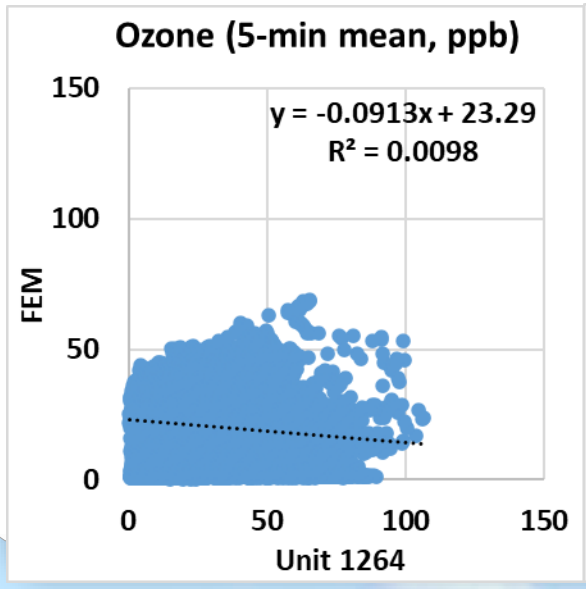
- Absolute intra-model variability was ~ 3.9 ppb for the ozone measurements (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 12.9% for the ozone measurements (calculated as the absolute intra-model variability relative to the mean of the three sensor means)

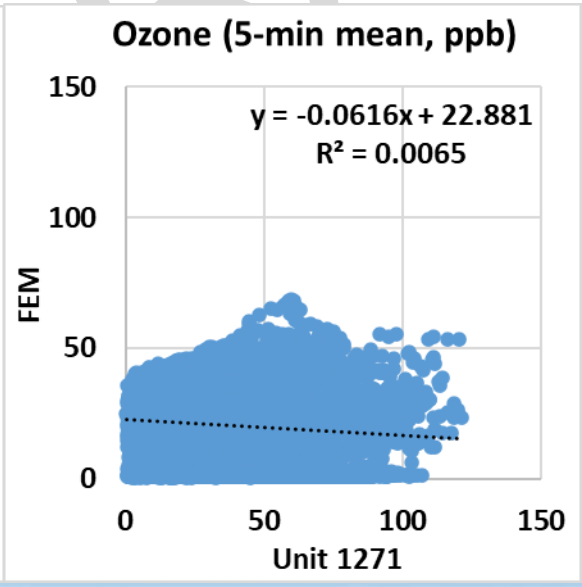


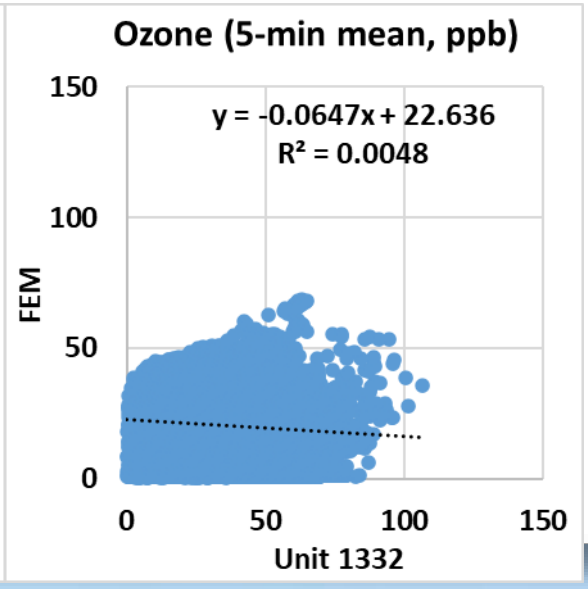
Zaack AQI vs FEM (Ozone; 5-min mean)



- Zaack AQI sensors did not correlate with the corresponding FEM ozone data ($R^2 < 0.01$)
- Overall, the Zaack AQI sensors overestimated the ozone concentration as measured by the FEM ozone instrument
- The Zaack AQI sensors did not seem to track the diurnal ozone variations as recorded by the FEM instrument







Summary: Ozone

	Average of 3 Sensors, Ozone		Zaack AQI vs FEM, Ozone						FEM Ozone (ppb)		
	Average (ppb)	SD (ppb)	R^2	Slope	Intercept	MBE[1] (ppb)	MAE[2] (ppb)	RMSE[3] (ppb)	FEM Average	FEM SD	Range during the field evaluation
5-min	29.2	19.2	0.005 to 0.01	-0.06 to -0.09	22.6 to 23.3	5.3 to 12.2	20.7 to 23.9	41.2 to 49.4	19.4	16.3	0.4 to 68.9

[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 Zaack AQI

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 1264, Unit 1271 and Unit 1332 was ~ 99%, 94% and 99% respectively.

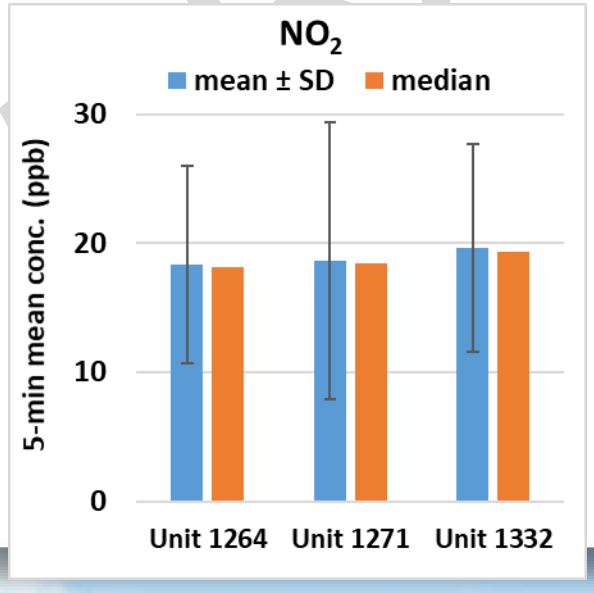
Zaack AQI; Intra-model variability

- Absolute intra-model variability was ~ 0.67 ppb for the NO_2 measurements

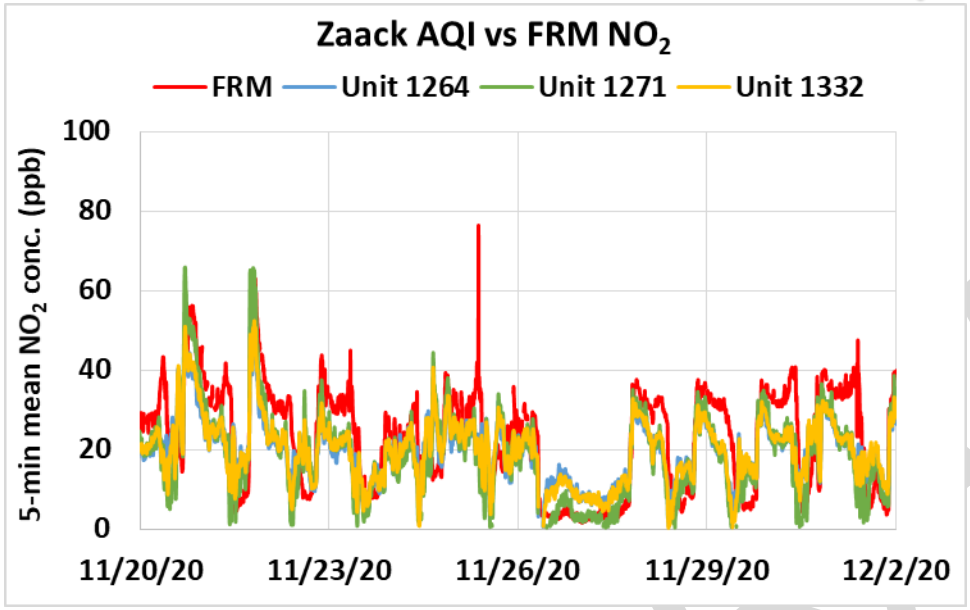
(calculated as the standard deviation of the three sensor means)

- Relative intra-model variability was ~ 3.5% for the NO_2 measurements

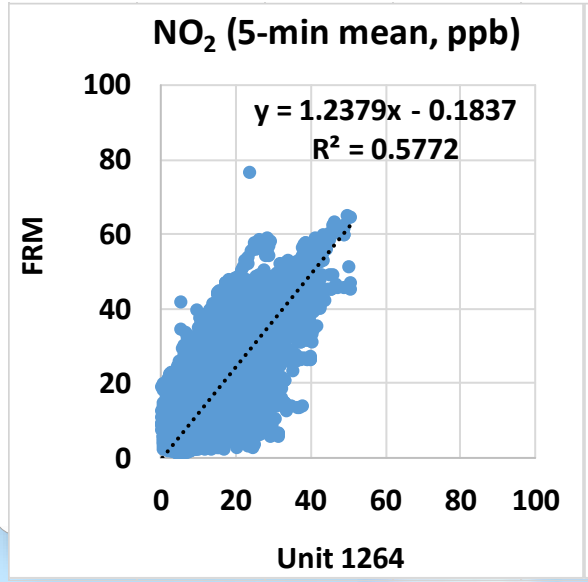
(calculated as the absolute intra-model variability relative to the mean of the three sensor means)

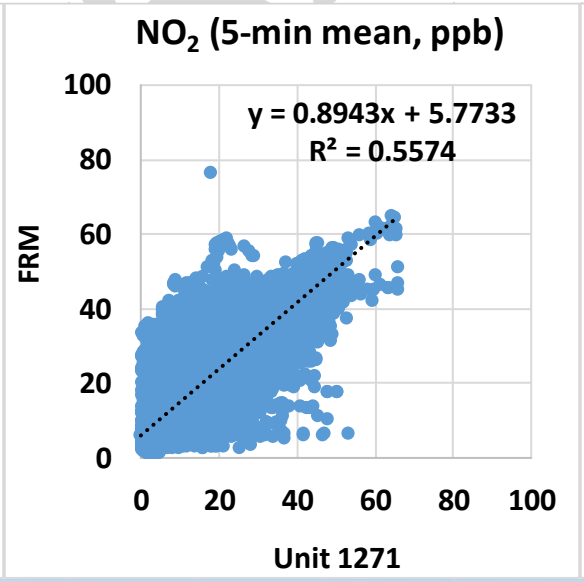


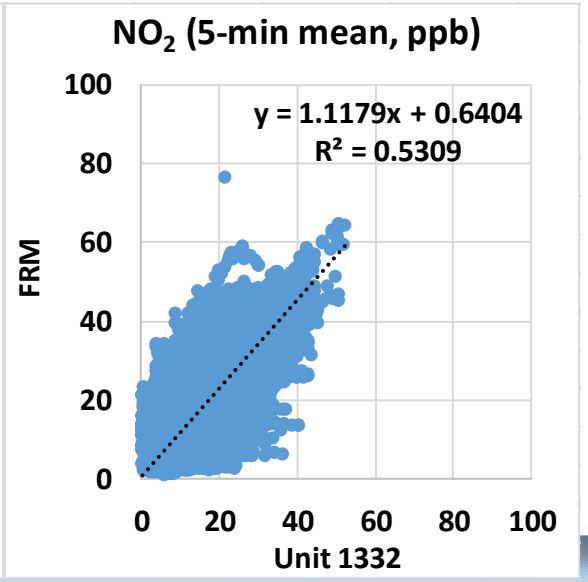
Zaack AQI vs FRM (NO_2; 5-min mean)



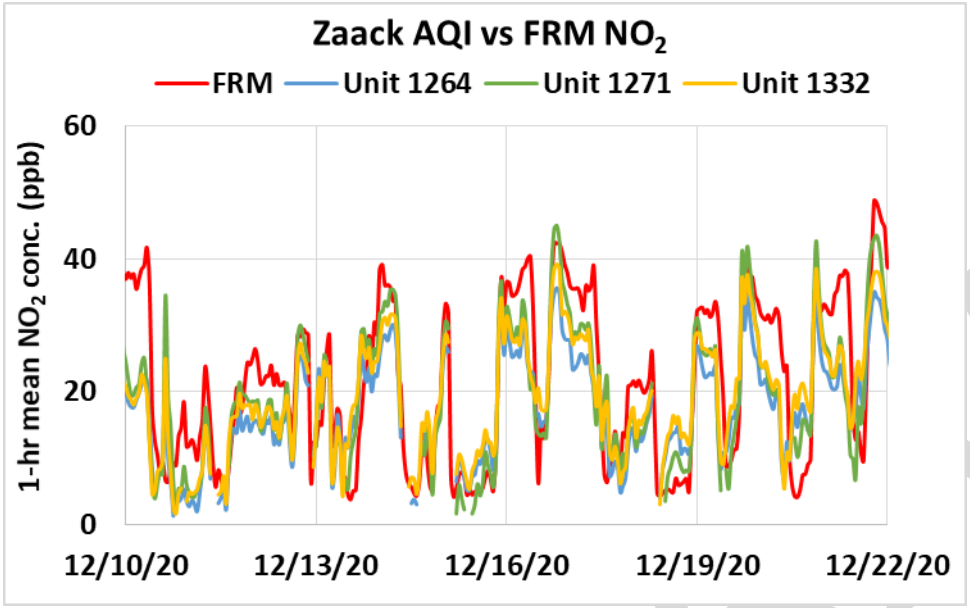
- Zaack AQI sensors showed moderate correlations with the corresponding FRM NO_2 data ($0.53 < R^2 < 0.58$)
- Overall, the Zaack AQI sensors underestimated the NO_2 concentration as measured by the FRM instrument
- The Zaack AQI sensors seemed to track the diurnal NO_2 variations as recorded by the FRM instrument



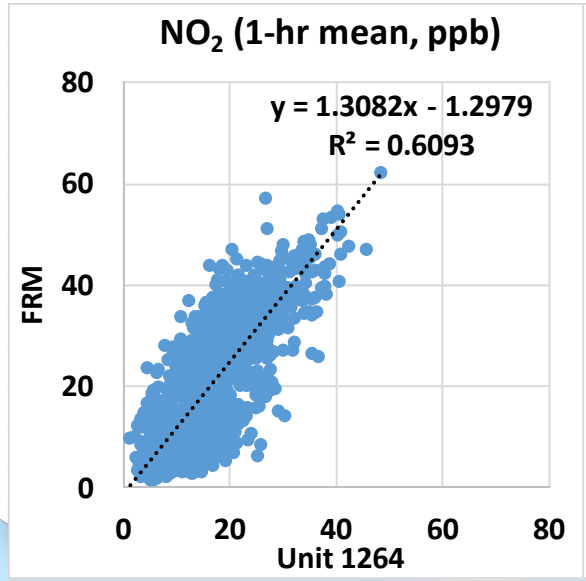


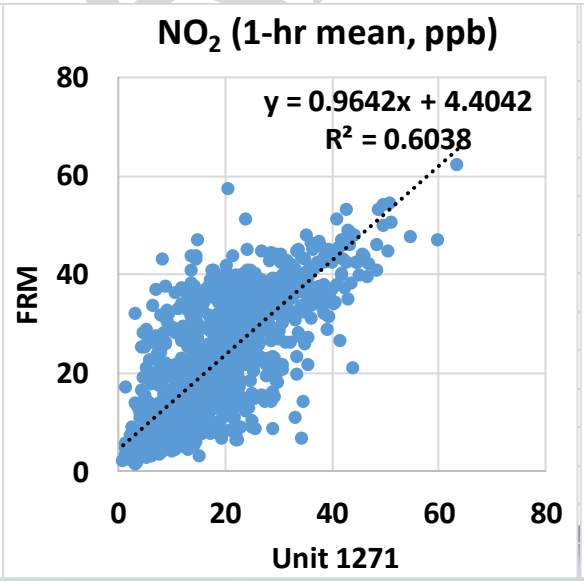


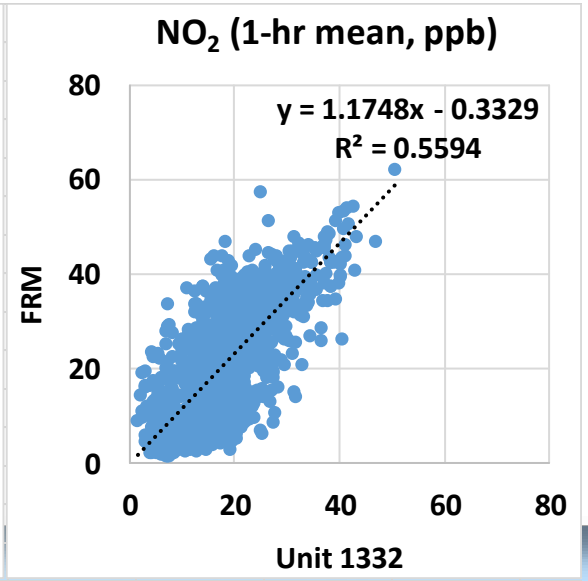
Zaack AQI vs FRM (NO_2; 1-hr mean)



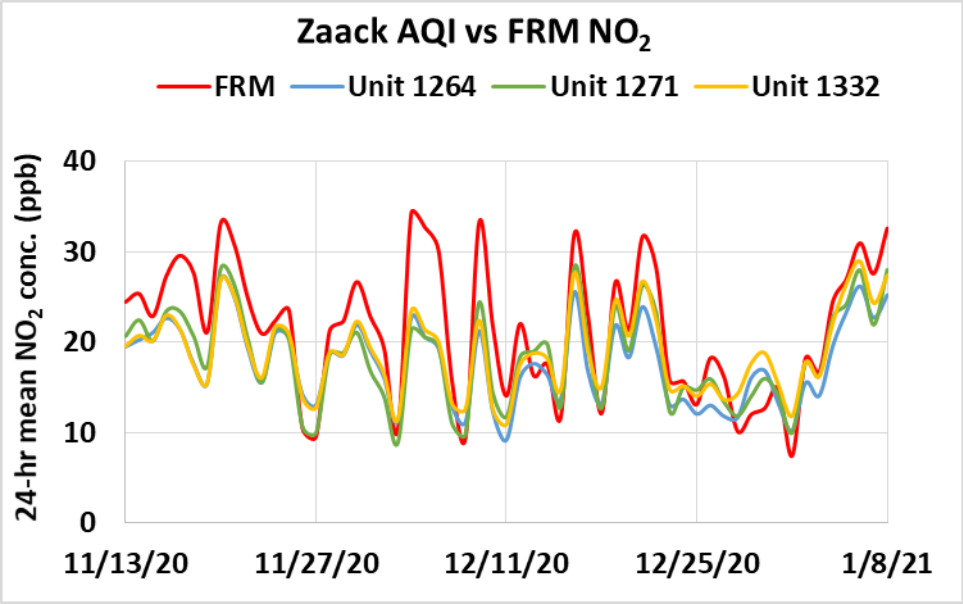
- Zaack AQI sensors showed moderate correlations with the corresponding FRM data ($0.55 < R^2 < 0.61$)
- Overall, the Zaack AQI sensors underestimated the NO_2 concentration as measured by the FRM instrument
- The Zaack AQI sensors seemed to track the diurnal NO_2 variations as recorded by the FRM instrument



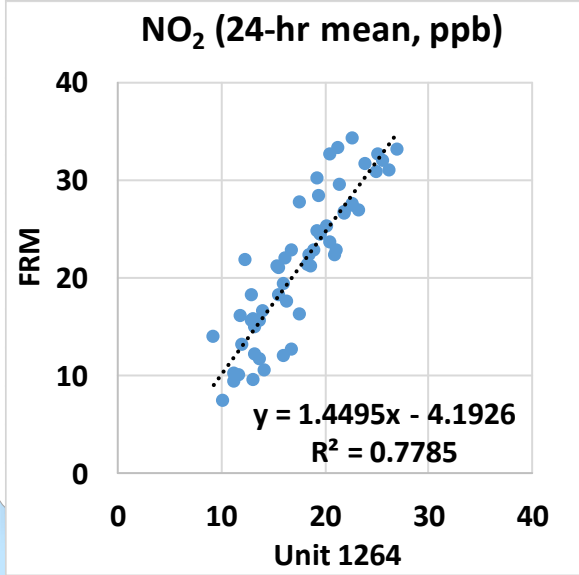


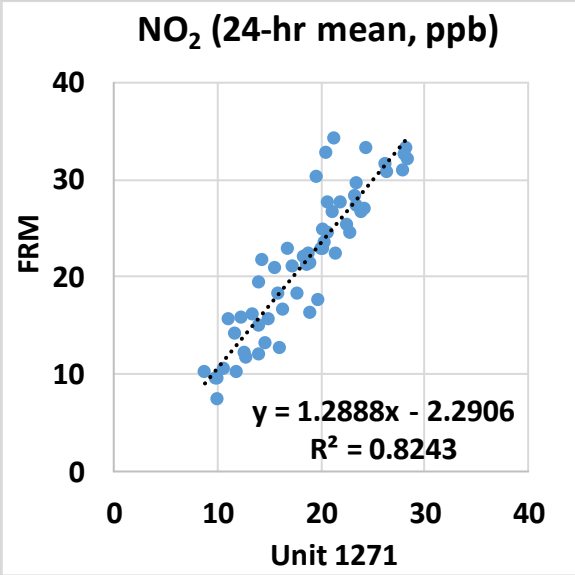


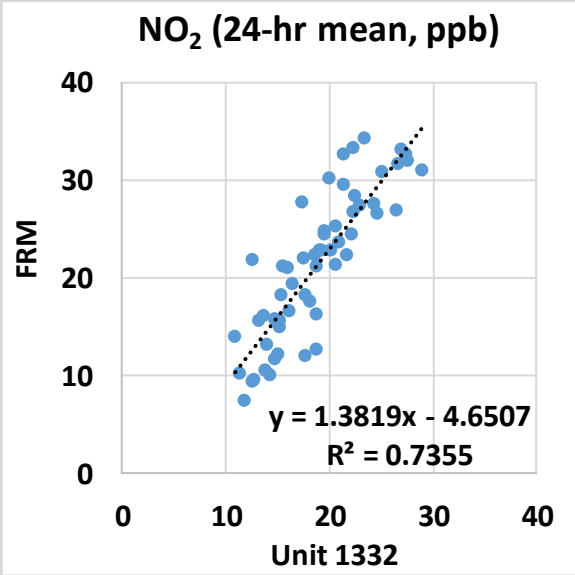
Zaack AQI vs FRM (NO_2; 24-hr mean)



- Zaack AQI sensors showed strong correlations with the corresponding FRM data ($0.74 < R^2 < 0.83$)
- Overall, the Zaack AQI sensors underestimated the NO_2 concentration as measured by the FRM instrument
- The Zaack AQI sensors seemed to track the diurnal NO_2 variations as recorded by the FRM instrument







Summary: NO_2

	Average of 3 Sensors, NO_2		Zaack AQI vs FRM, NO_2						FRM NO_2 (ppb)		
	Average (ppb)	SD (ppb)	R^2	Slope	Intercept	MBE[1] (ppb)	MAE[2] (ppb)	RMSE[3] (ppb)	FRM Average	FRM SD	Range during the field evaluation
5-min	18.5	9.0	0.53 to 0.58	0.89 to 1.24	-0.2 to 5.8	-2.8 to -4.0	7.2 to 8.0	15.0 to 15.2	21.3	13.1	1.0 to 76.3
1-hr	18.6	8.6	0.56 to 0.61	0.96 to 1.31	-1.3 to 4.4	-3.0 to -4.2	6.7 to 7.9	8.8 to 9.3	21.8	12.7	1.3 to 62.1
24-hr	18.4	4.8	0.74 to 0.82	1.29 to 1.45	-4.7 to -2.3	-2.6 to -3.8	3.7 to 4.7	4.6 to 5.5	21.5	7.4	7.4 to 34.3

[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.

Carbon Monoxide (CO) in Zaack AQI

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 1264, Unit 1271 and Unit 1332 was ~ 87%, 64% and 83% respectively.

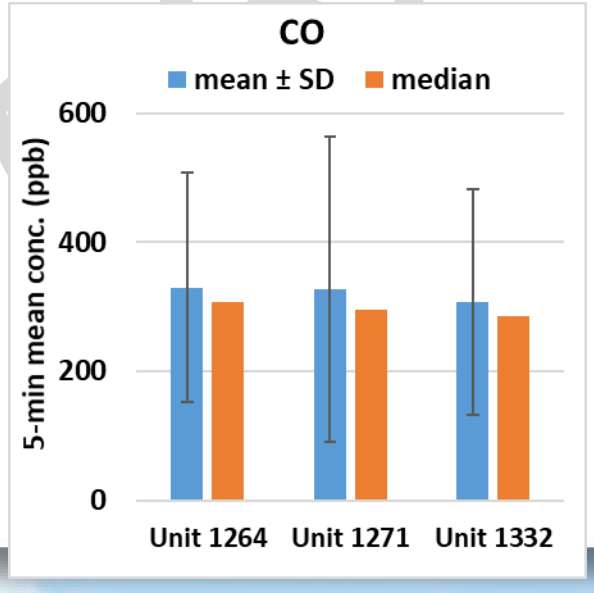
Zaack AQI; Intra-model variability

- Absolute intra-model variability was ~ 12.1 ppb for the CO measurements

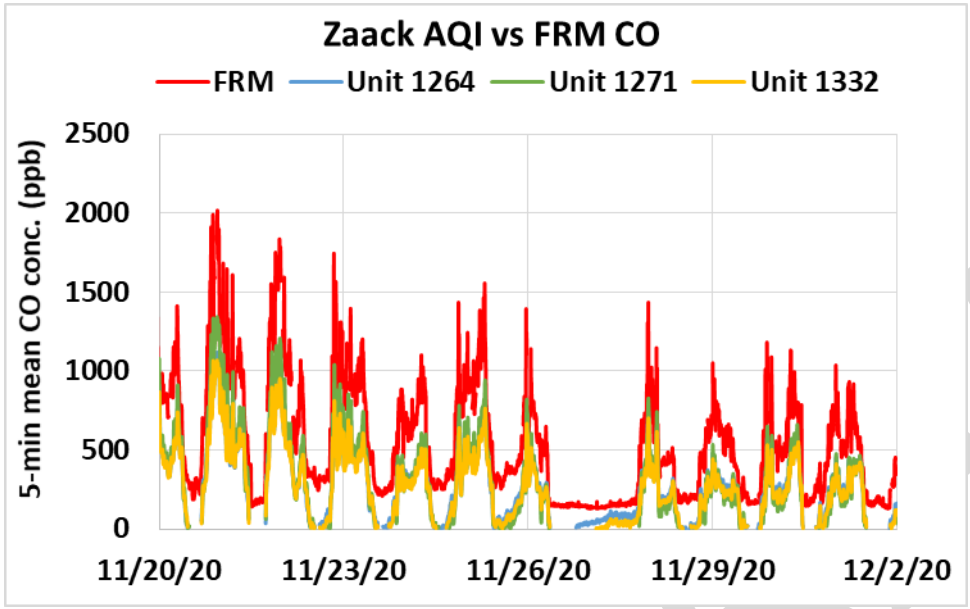
(calculated as the standard deviation of the three sensor means)

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

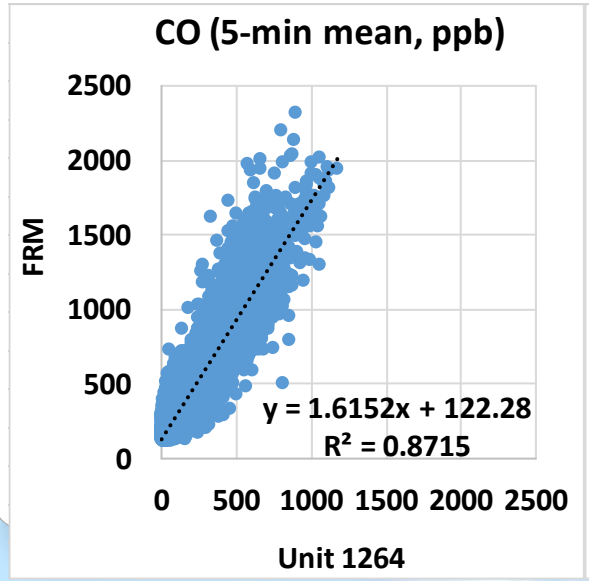
(calculated as the absolute intra-model variability relative to the mean of the three sensor means)

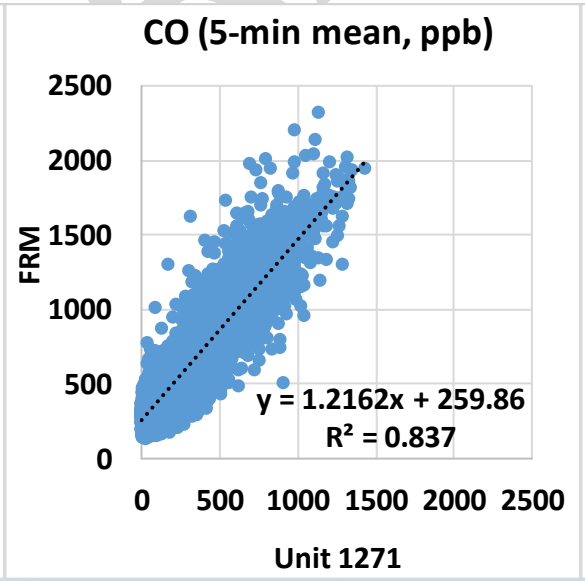


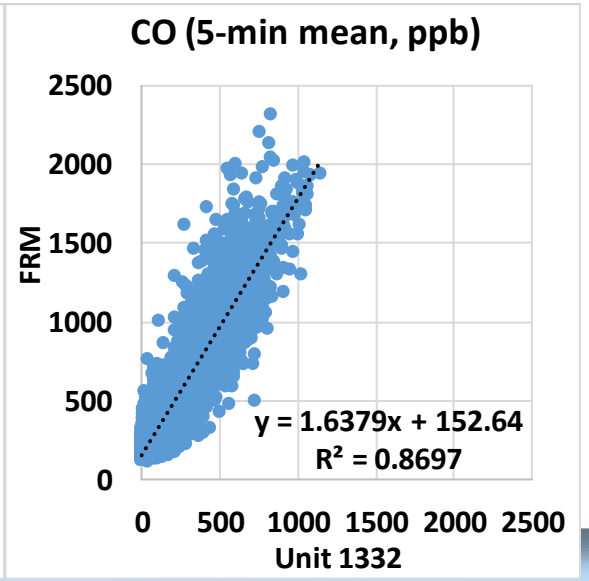
Zaack AQI vs FRM (CO; 5-min mean)



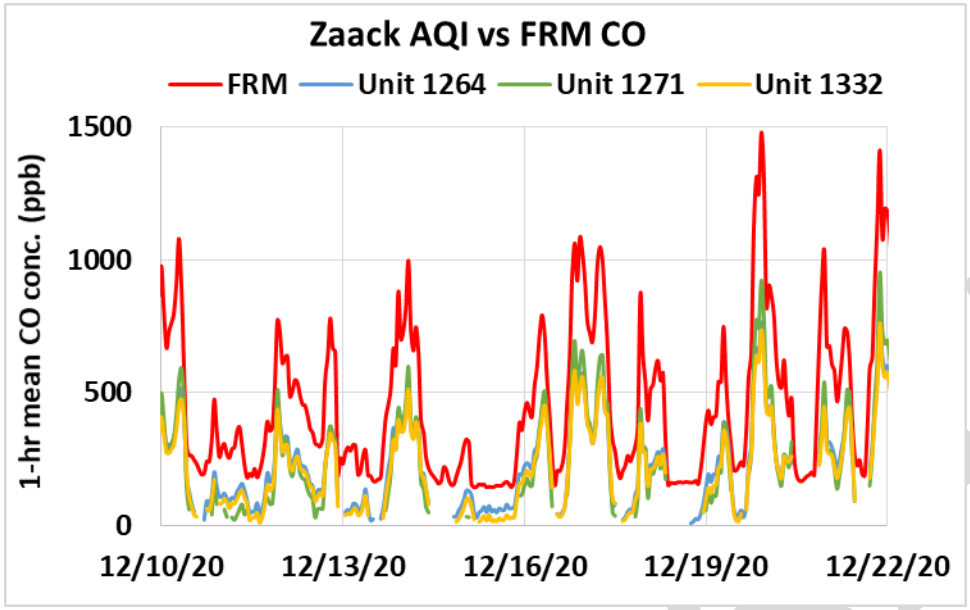
- Zaack AQI sensors showed strong correlations with the corresponding FRM CO data ($0.84 < R^2 < 0.88$)
- Overall, the Zaack AQI sensors underestimated the CO concentration as measured by the FRM instrument
- The Zaack AQI sensors seemed to track the diurnal CO variations as recorded by the FRM instrument



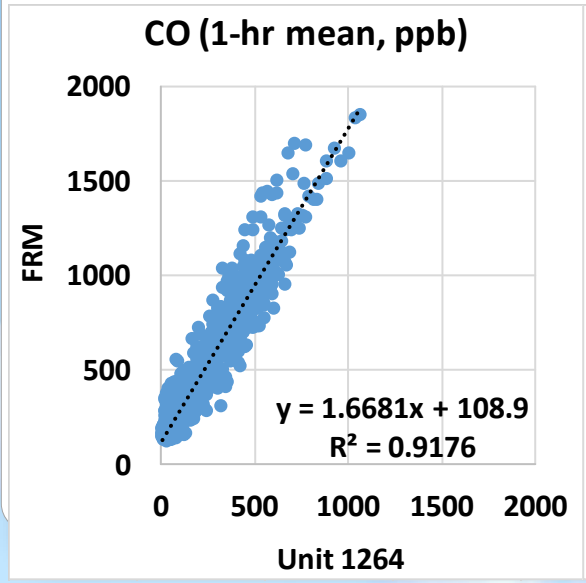


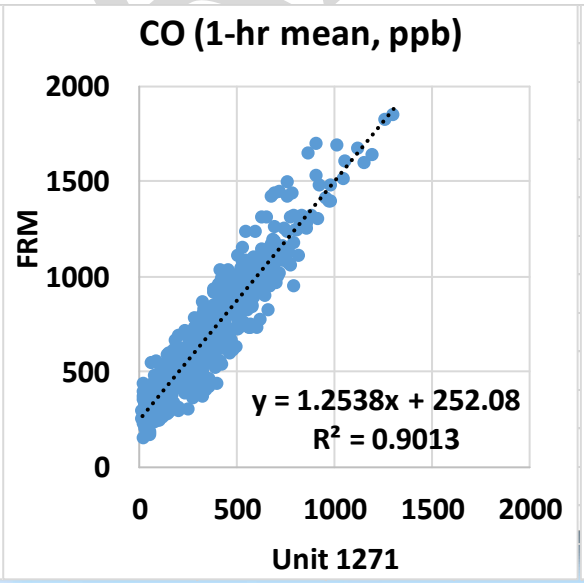


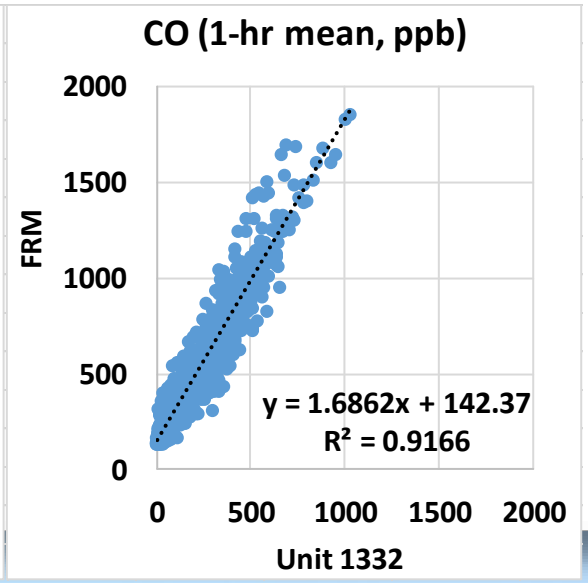
Zaack AQI vs FRM (CO; 1-hr mean)



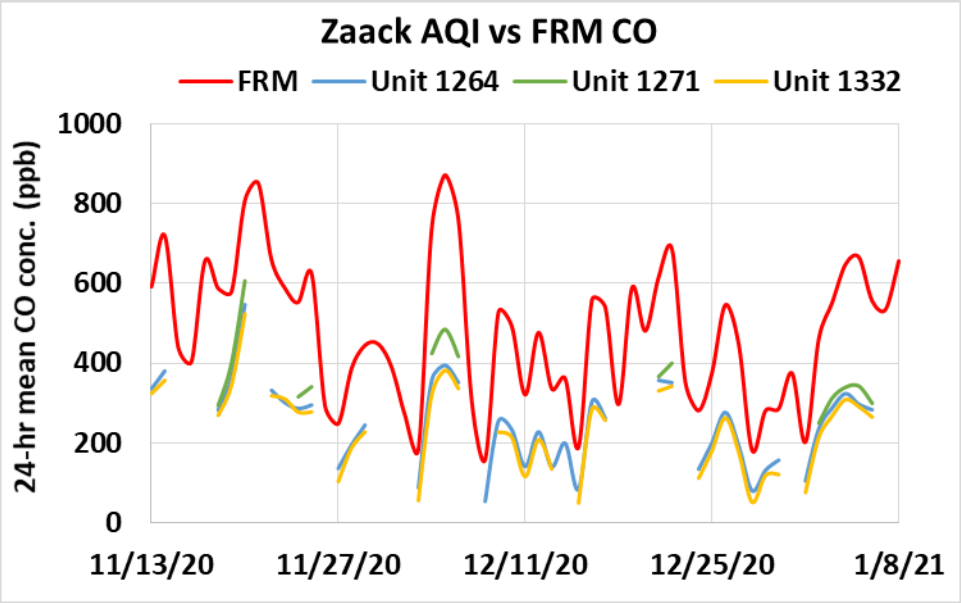
- Zaack AQI sensors showed very strong correlations with the corresponding FRM CO data ($0.90 < R^2 < 0.92$)
- Overall, the Zaack AQI sensors underestimated the CO concentration as measured by the FRM instrument
- The Zaack AQI sensors seemed to track the diurnal CO variations as recorded by the FRM instrument



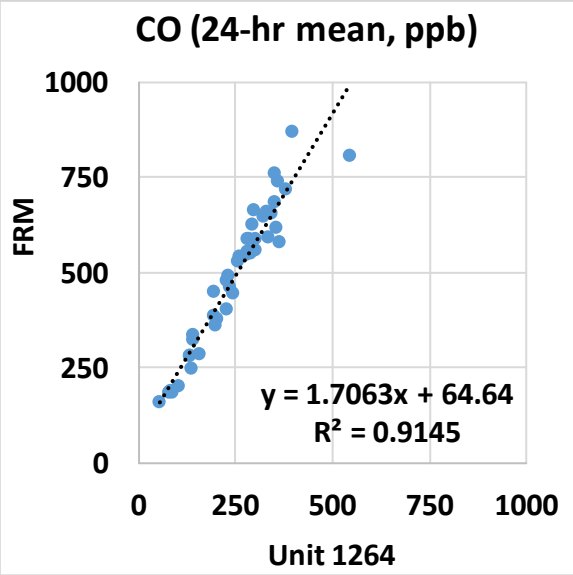


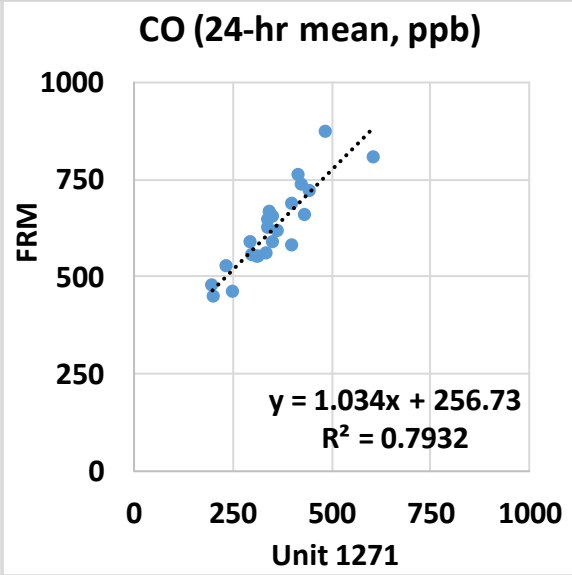


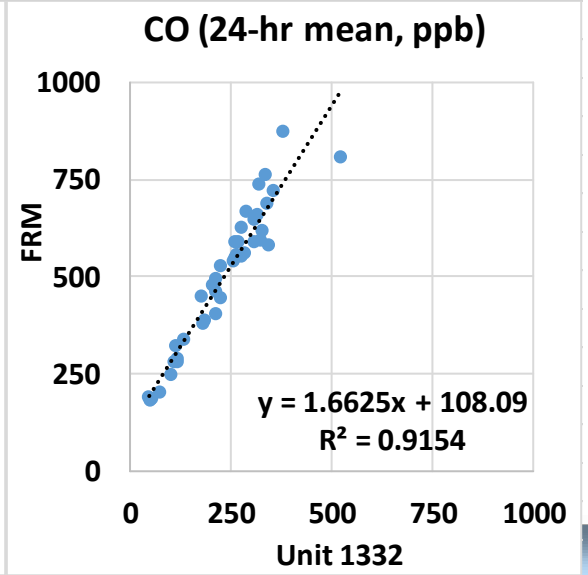
Zaack AQI vs FRM (CO; 24-hr mean)



- Zaack AQI sensors showed strong to very strong correlations with the corresponding FRM CO data ($0.79 < R^2 < 0.92$)
- Overall, the Zaack AQI sensors underestimated the CO concentration as measured by the FRM instrument
- The Zaack AQI sensors seemed to track the diurnal CO variations as recorded by the FRM instrument







Summary: CO

	Average of 3 Sensors CO		Zaack AQI vs FRM, CO						FRM CO (ppb)		
	Average (ppb)	SD (ppb)	R^2	Slope	Intercept	MBE[1] (ppb)	MAE[2] (ppb)	RMSE[3] (ppb)	FRM Average	FRM SD	Range during the field evaluation
5-min	275.3	207.7	0.84 to 0.87	1.22 to 1.64	122.3 to 259.9	-275.7 to -329.1	276.0 to 329.6	525.6 to 568.5	476.3	331.8	115.5 to 2312.9
1-hr	285.9	198.7	0.90 to 0.92	1.25 to 1.69	108.9 to 252.1	-283.2 to -339.6	283.3 to 339.6	324.5 to 356.2	490.4	328.4	120.3 to 1846.7
24-hr	281.5	98.1	0.79 to 0.92	1.03 to 1.71	64.6 to 256.7	-242.3 to -268.8	242.3 to 262.8	258.2 to 279.4	481.1	178.1	158.5 to 870.9

[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.

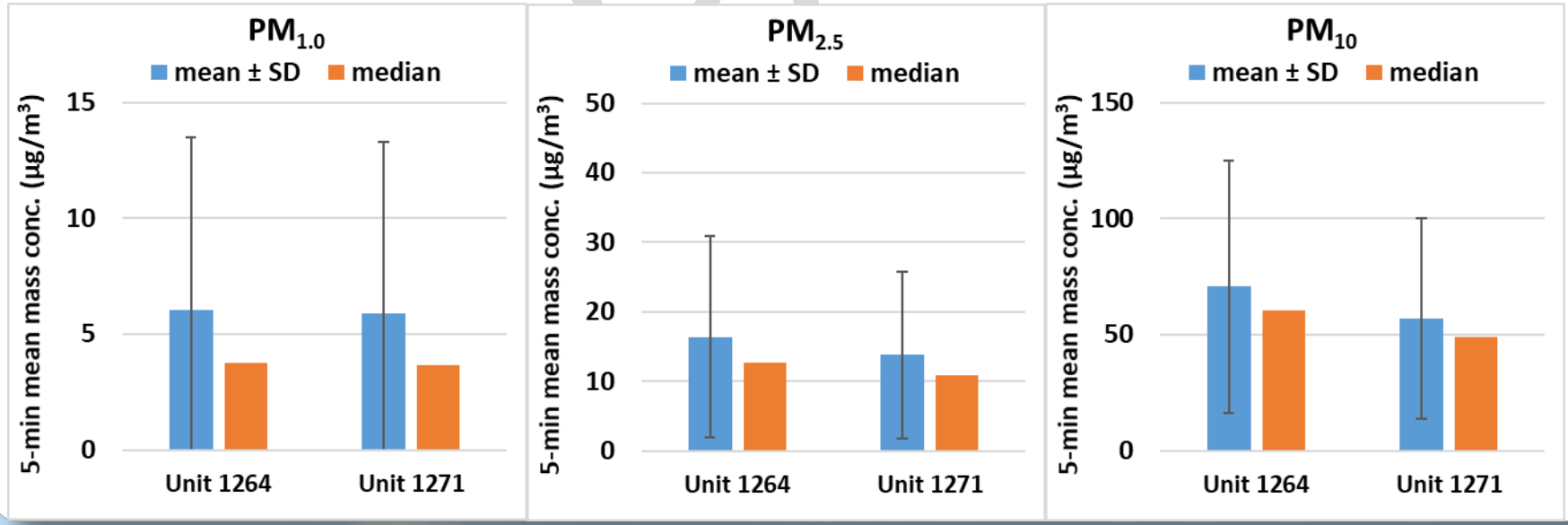
PM in Zaack AQI

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 1264 and Unit 1271 was ~ 100% for all PM fractions. Unit 1332 data was not included for further analysis due to the malfunction of the PM sensor.

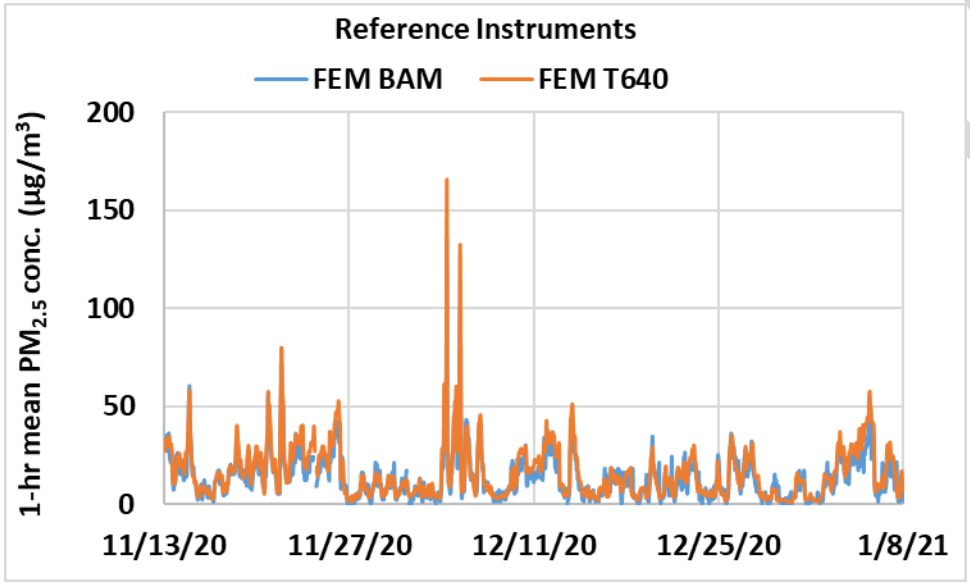
Zaack AQI; Intra-model variability

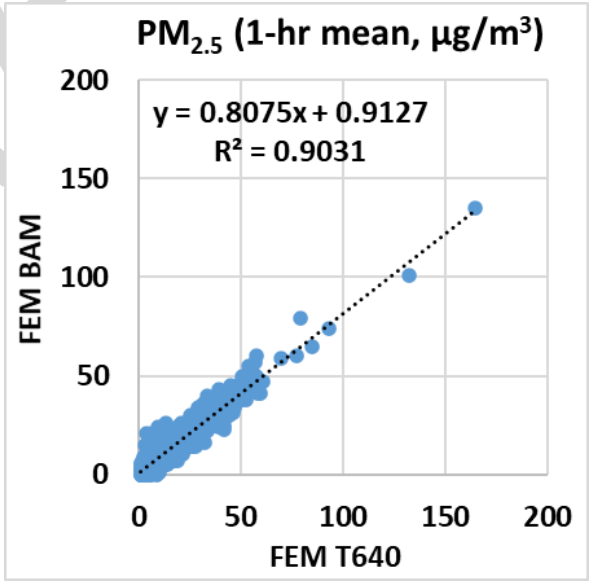
- Absolute intra-model variability was ~ 0.08, 1.3 and 6.9 µg/m^3 for the $PM_{1.0,}$ $PM_{2.5}$ and PM_{10}, respectively. (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 1.4%, 8.5% and 10.8% for the $PM_{1.0,}$ $PM_{2.5}$ and $PM_{10,}$ respectively. (calculated as the absolute intra-model variability relative to the mean of the three sensor means)



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

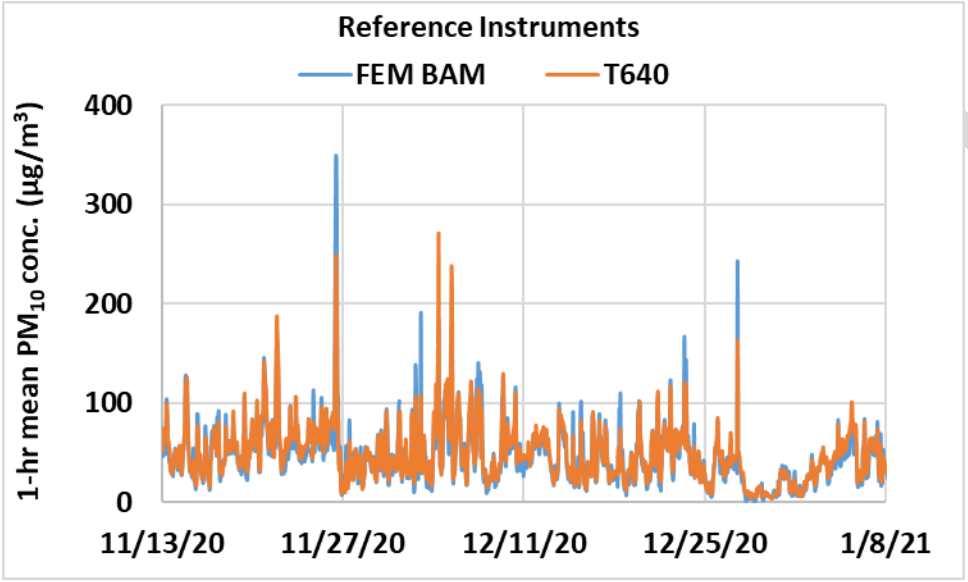
- Basic QA/QC procedures were used to validate the collected data (i.e. obvious outliers, negative values and invalid data-points were eliminated from the data-set)
- Data recovery for $PM_{2.5}$ from FEM BAM and FEM T640 is ~97% and 100%, respectively.
- Very strong correlations between FEM BAM and FEM T640 for $PM_{2.5}$ measurements (R^2 ~ 0.90)

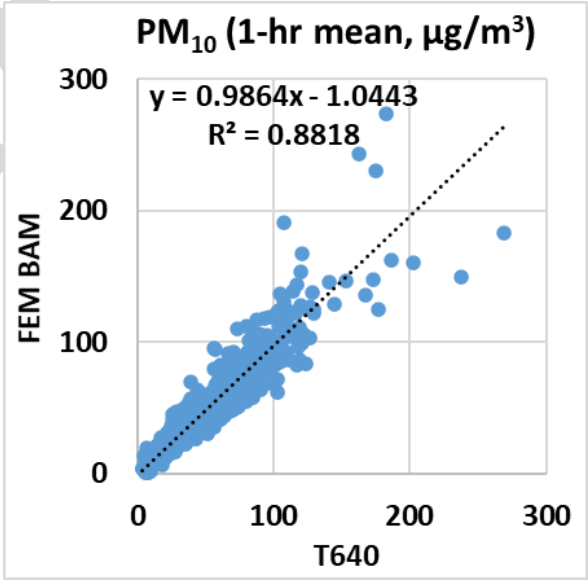




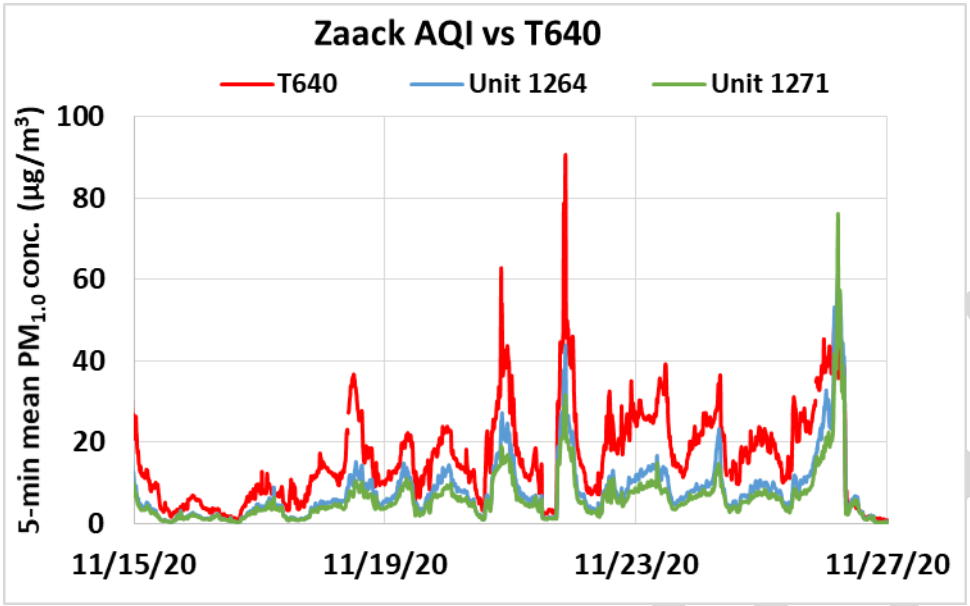
Reference Instruments: PM_{10} FEM BAM & T640

- 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 PM_{10} from FEM BAM and T640 is ~99% and 100%, respectively.
- Strong correlations between FEM BAM and T640 for PM_{10} measurements (R^2 ~ 0.88)



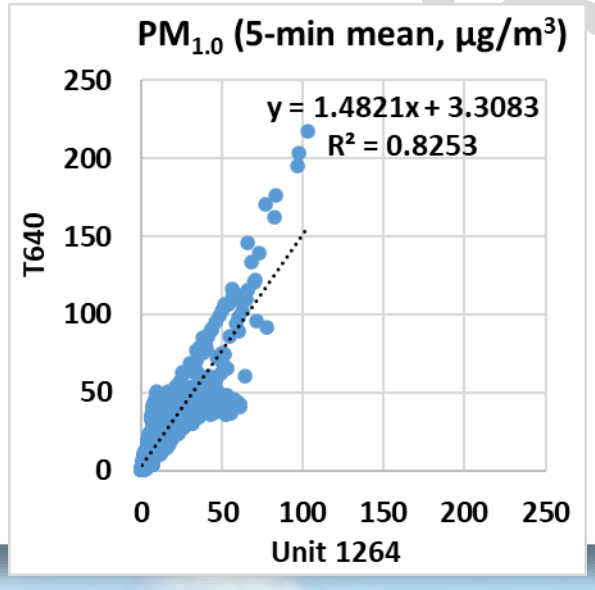


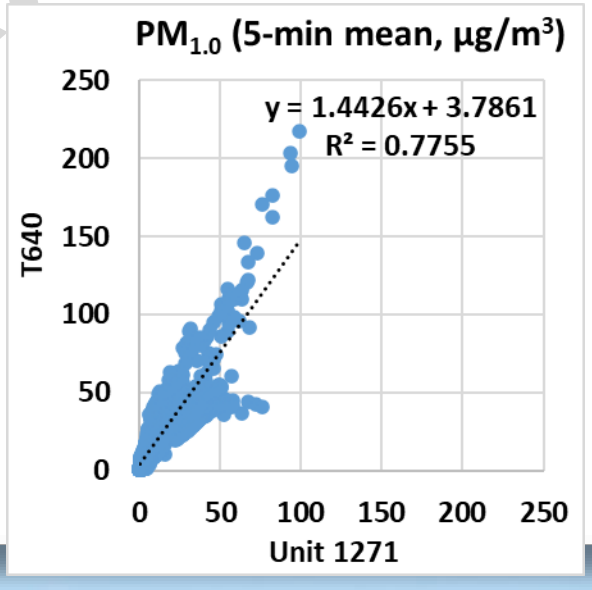
Zaack AQI vs T640 ($PM_{1.0}$; 5-min mean)



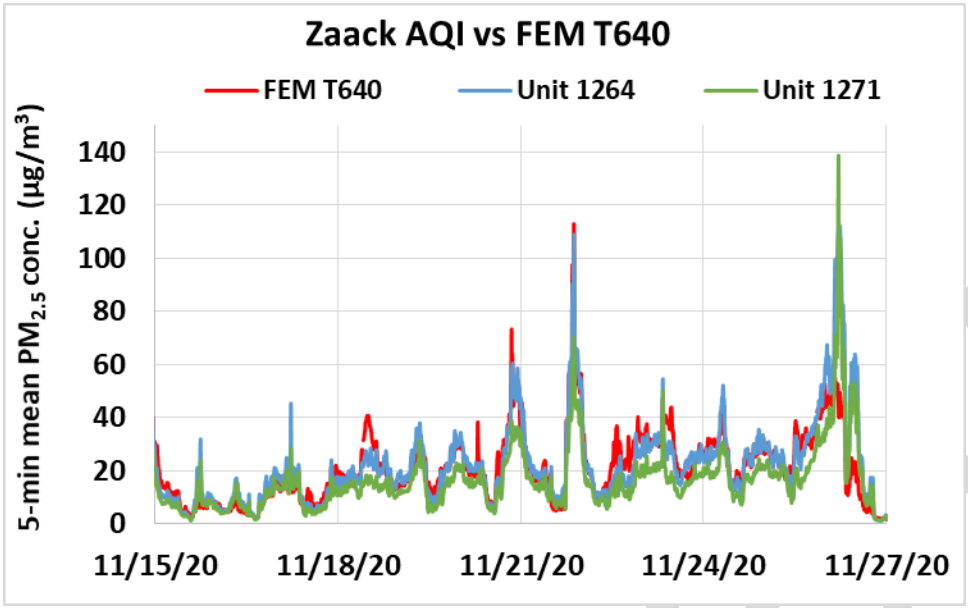
- Zaack AQI sensors showed strong correlations with the corresponding T640 data ($0.77 < R^2 < 0.83$)
- Overall, the Zaack AQI sensors underestimated the $PM_{1.0}$ mass concentration as measured by the T640
- The Zaack AQI sensors seemed to track the diurnal $PM_{1.0}$ variations as recorded by the T640

Note: Unit 1332 was excluded from data analysis due to a malfunctioning PM sensor.



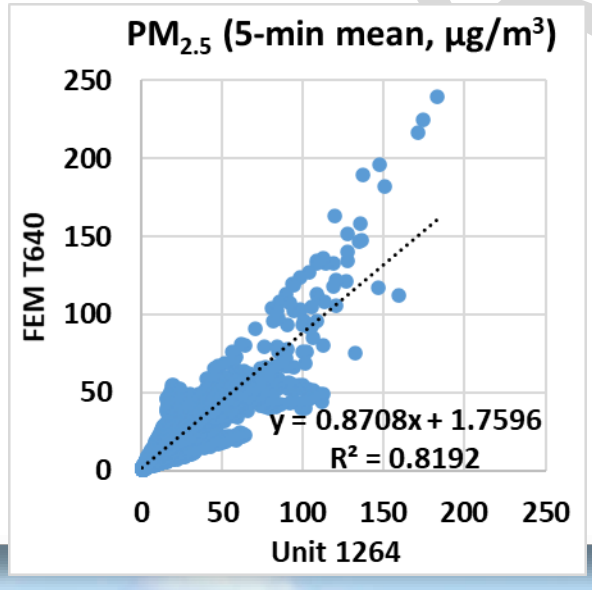


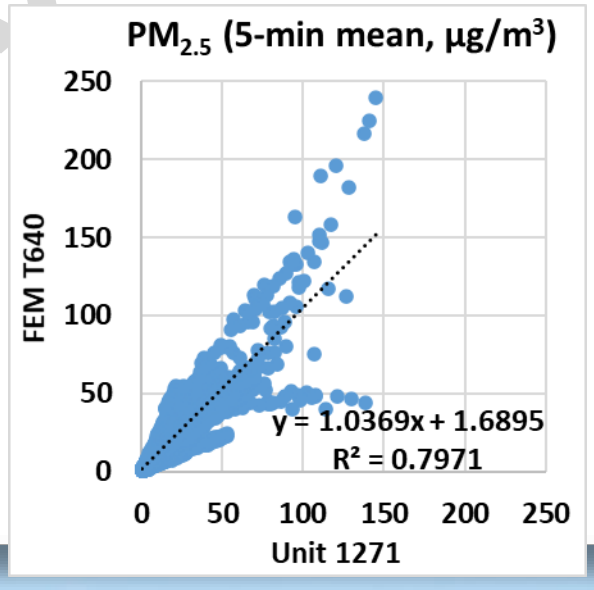
Zaack AQI vs FEM T640 ($PM_{2.5}$; 5-min mean)



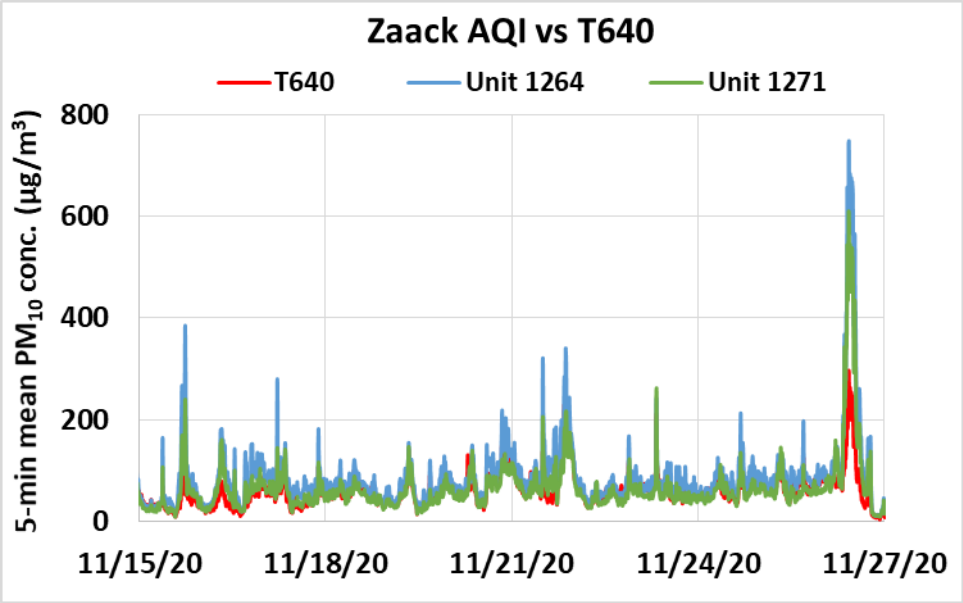
- Zaack AQI sensors showed strong correlations with the corresponding FEM T640 data ($0.79 < R^2 < 0.82$)
- Overall, the Zaack AQI sensors underestimated the $PM_{2.5}$ mass concentration as measured by the FEM T640
- The Zaack AQI sensors seemed to track the diurnal $PM_{2.5}$ variations as recorded by the FEM T640

Note: Unit 1332 was excluded from data analysis due to a malfunctioning PM sensor.



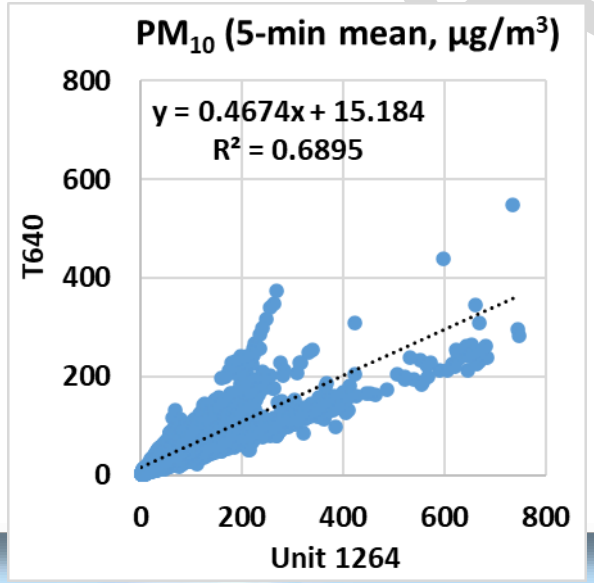


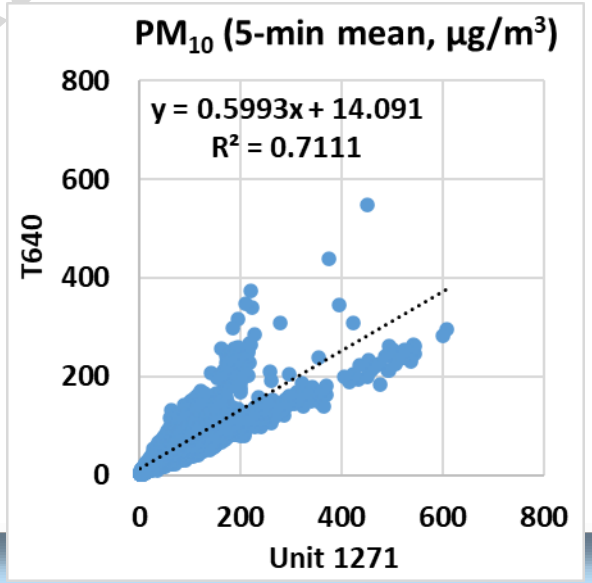
Zaack AQI vs T640 (PM_{10}; 5-min mean)



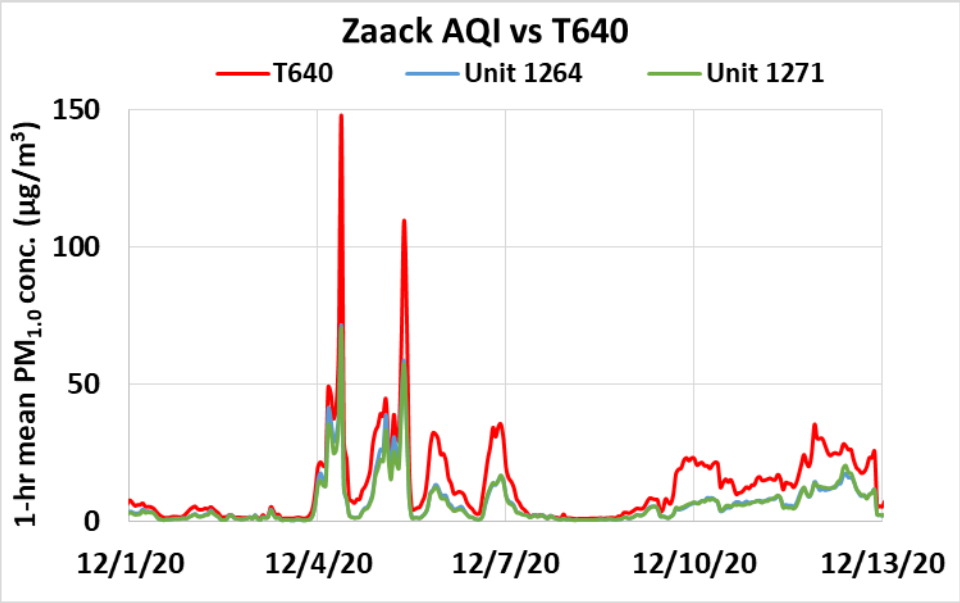
- Zaack AQI sensors showed moderate to strong correlations with the corresponding T640 data ($0.68 < R^2 < 0.72$)
- Overall, the Zaack AQI sensors overestimated the PM_{10} mass concentration as measured by the T640
- The Zaack AQI sensors seemed to track the diurnal PM_{10} variations as recorded by the T640

Note: Unit 1332 was excluded from data analysis due to a malfunctioning PM sensor.



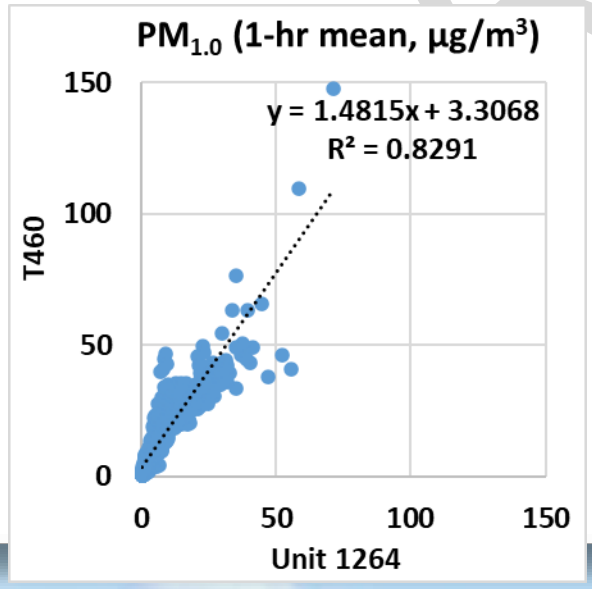


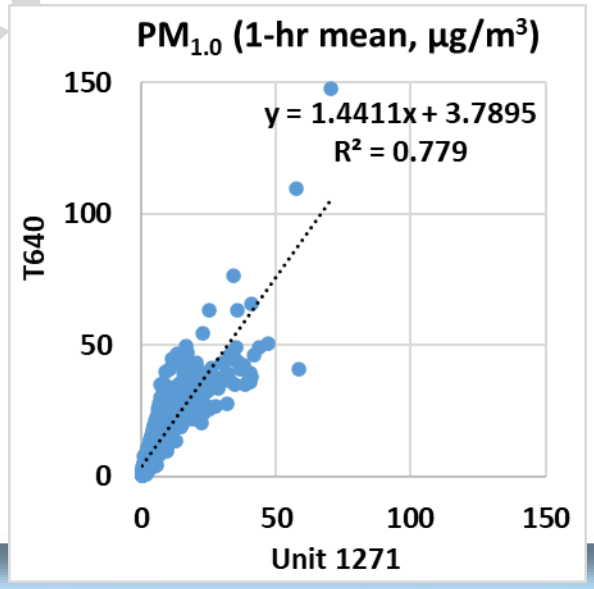
Zaack AQI vs T640 ($PM_{1.0}$; 1-hr mean)



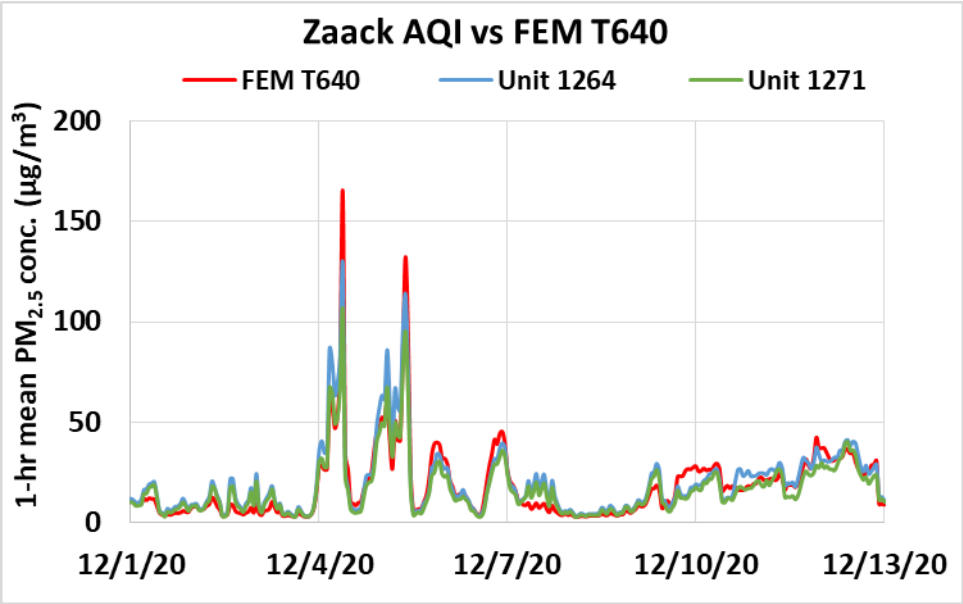
- Zaack AQI sensors showed strong correlations with the corresponding T640 data ($0.77 < R^2 < 0.83$)
- Overall, the Zaack AQI sensors underestimated the $PM_{1.0}$ mass concentration as measured by the T640
- The Zaack AQI sensors seemed to track the diurnal $PM_{1.0}$ variations as recorded by the T640

Note: Unit 1332 was excluded from data analysis due to a malfunctioning PM sensor.



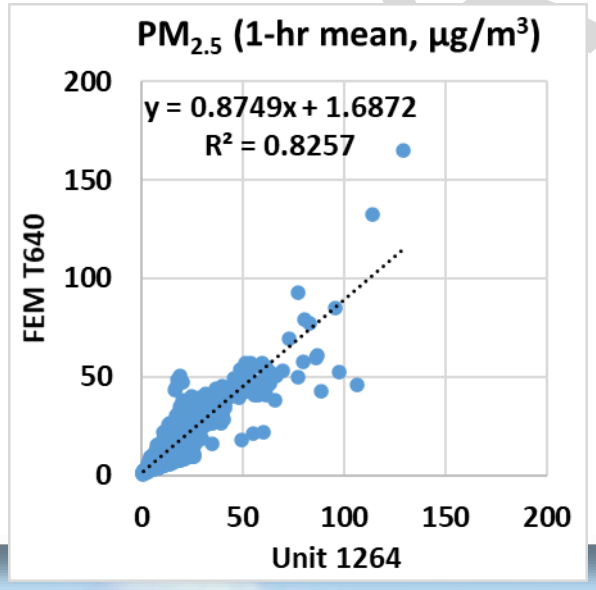


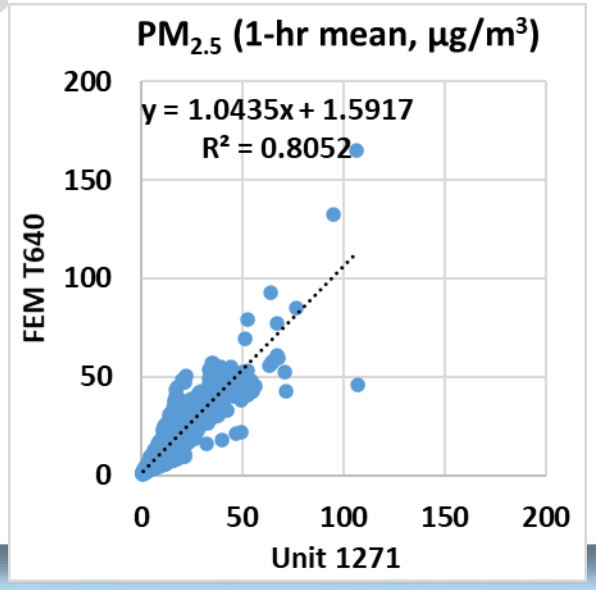
Zaack AQI vs FEM T640 ($PM_{2.5}$; 1-hr mean)



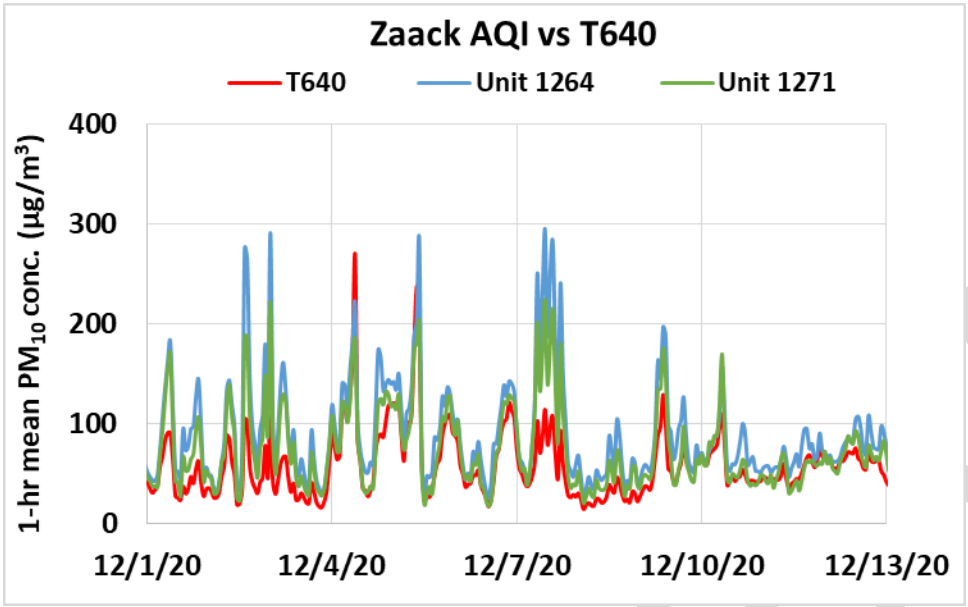
- Zaack AQI sensors showed strong correlations with the corresponding FEM T640 data ($0.80 < R^2 < 0.83$)
- Overall, the Zaack AQI sensors underestimated the $PM_{2.5}$ mass concentration as measured by the FEM T640
- The Zaack AQI sensors seemed to track the diurnal $PM_{2.5}$ variations as recorded by the FEM T640

Note: Unit 1332 was excluded from data analysis due to a malfunctioning PM sensor.



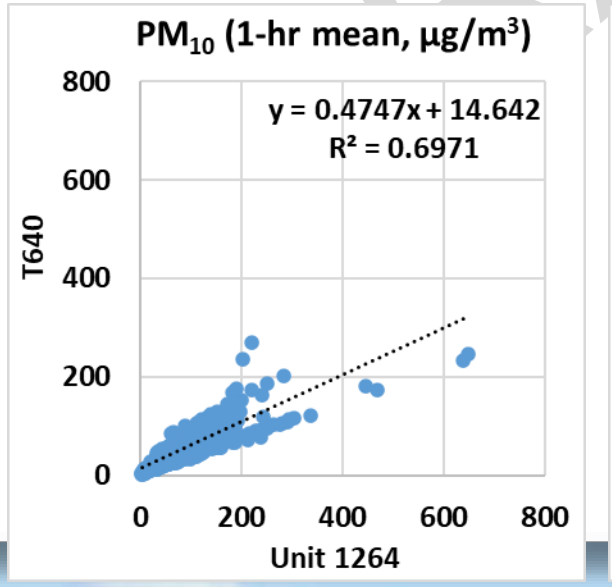


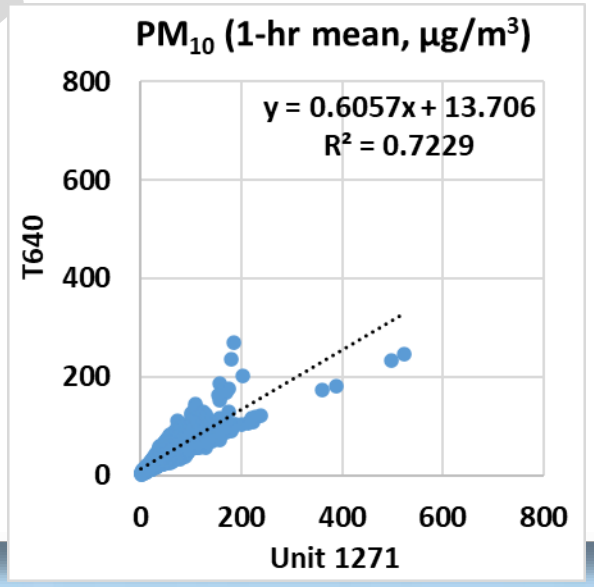
Zaack AQI vs T640 (PM_{10}; 1-hr mean)



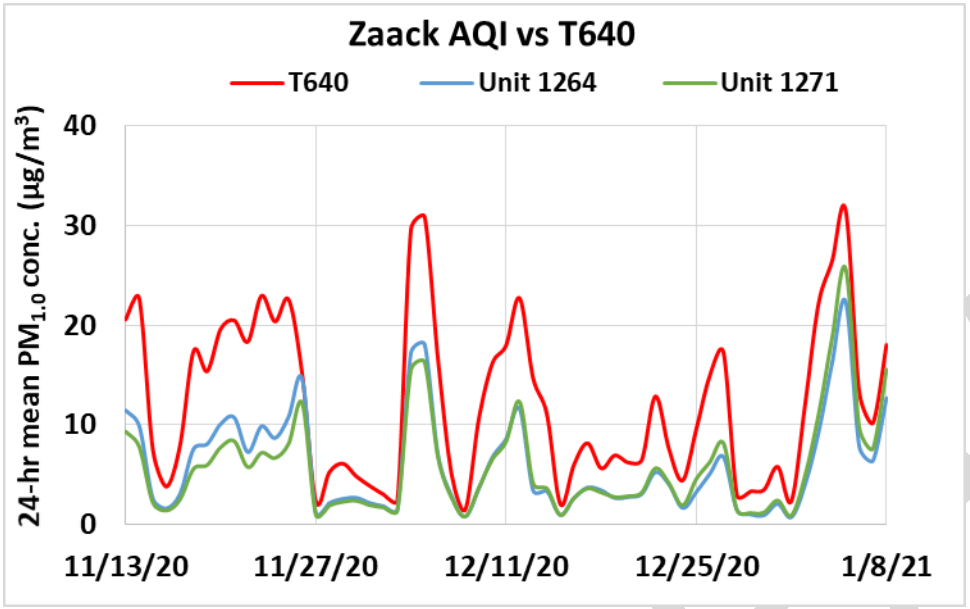
- Zaack AQI sensors showed moderate to strong correlations with the corresponding T640 data ($0.69 < R^2 < 0.73$)
- Overall, the Zaack AQI sensors overestimated the PM_{10} mass concentration as measured by the T640
- The Zaack AQI sensors seemed to track the diurnal PM_{10} variations as recorded by the T640

Note: Unit 1332 was excluded from data analysis due to a malfunctioning PM sensor.



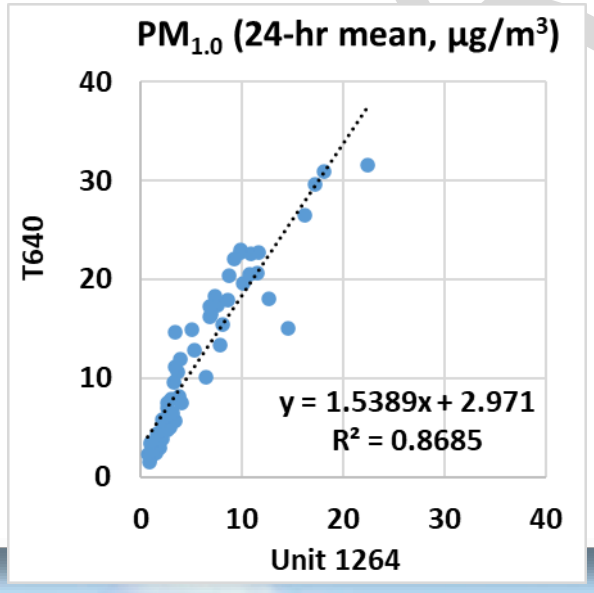


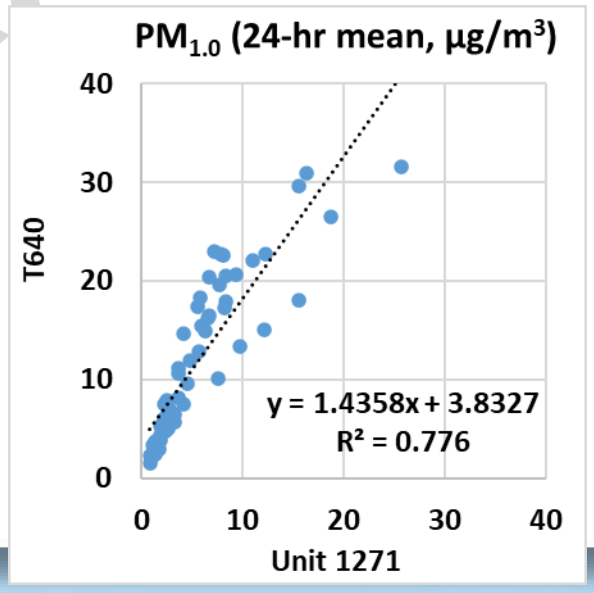
Zaack AQI vs T640 ($PM_{1.0}$; 24-hr mean)



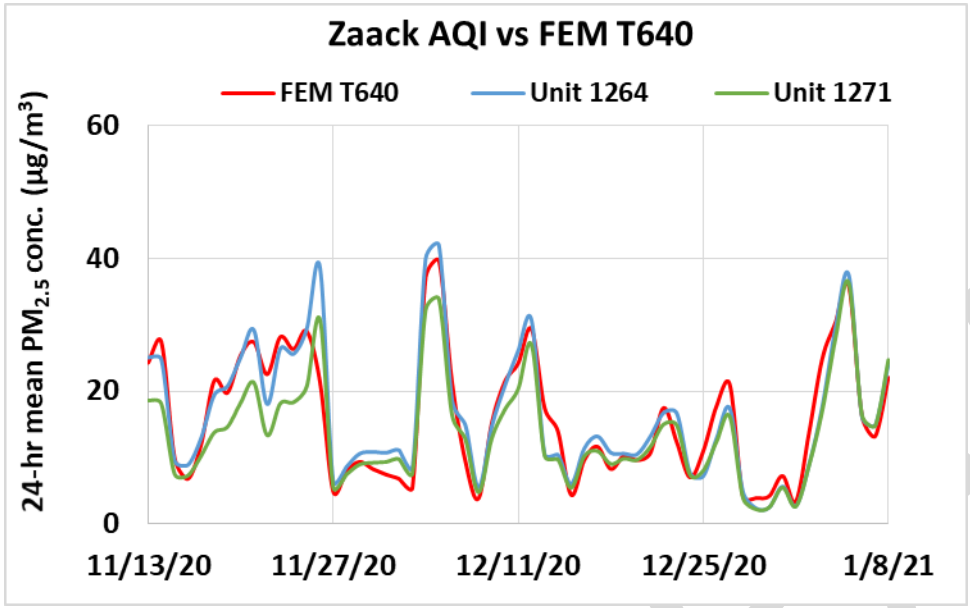
- Zaack AQI sensors showed strong correlations with the corresponding T640 data ($0.77 < R^2 < 0.87$)
- Overall, the Zaack AQI sensors underestimated the $PM_{1.0}$ mass concentration as measured by the T640
- The Zaack AQI sensors seemed to track the diurnal $PM_{1.0}$ variations as recorded by the T640

Note: Unit 1332 was excluded from data analysis due to a malfunctioning PM sensor.



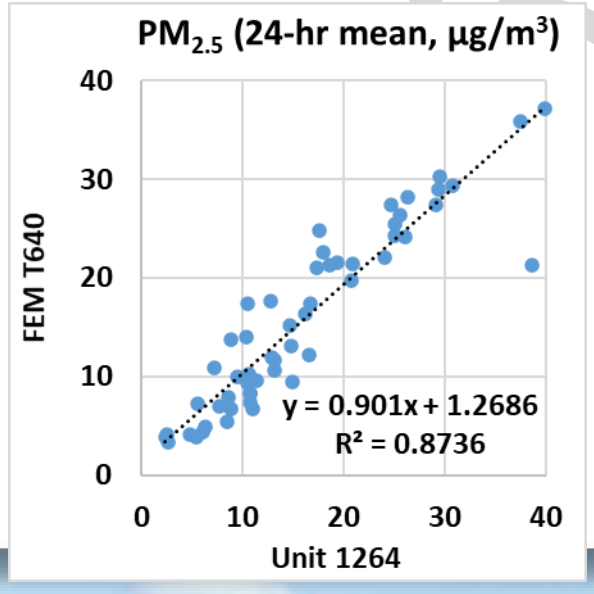


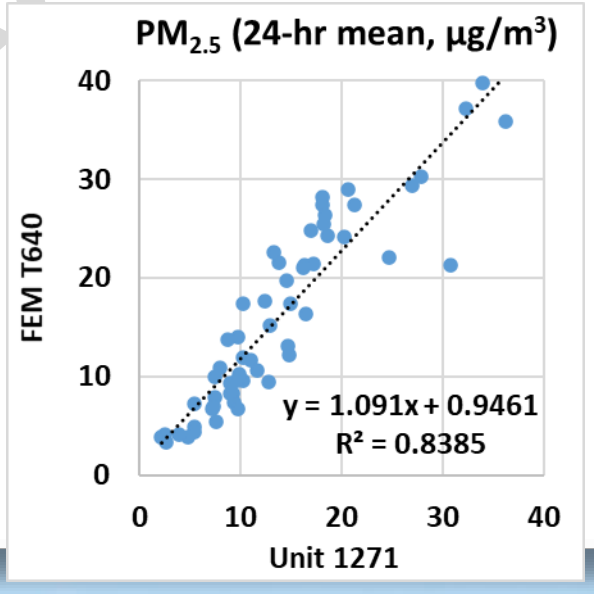
Zaack AQI vs FEM T640 ($PM_{2.5}$; 24-hr mean)



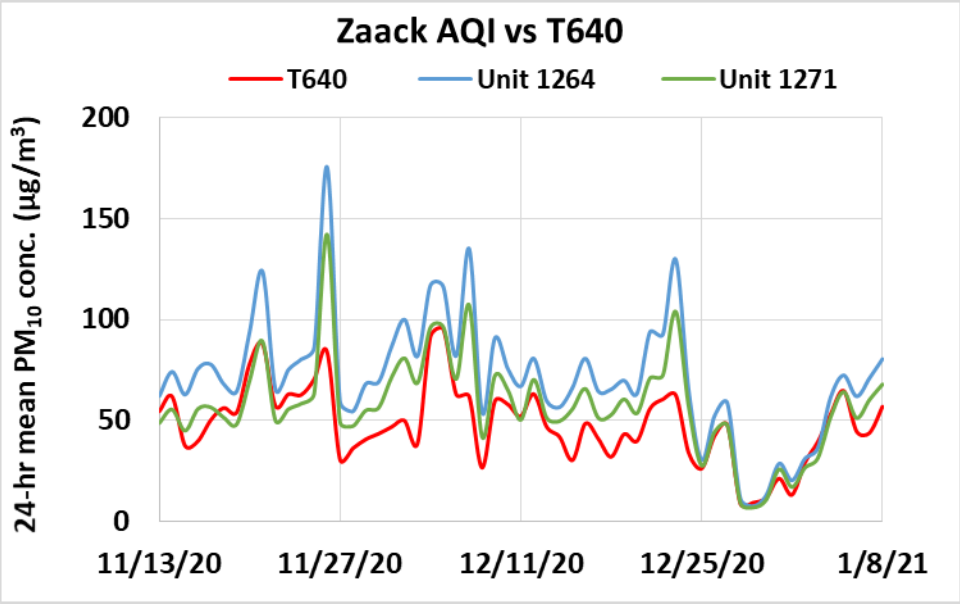
- Zaack AQI sensors showed strong correlations with the corresponding FEM T640 data ($0.83 < R^2 < 0.88$)
- Overall, the Zaack AQI sensors underestimated the $PM_{2.5}$ mass concentration as measured by the FEM T640
- The Zaack AQI sensors seemed to track the diurnal $PM_{2.5}$ variations as recorded by the FEM T640

Note: Unit 1332 was excluded from data analysis due to a malfunctioning PM sensor.



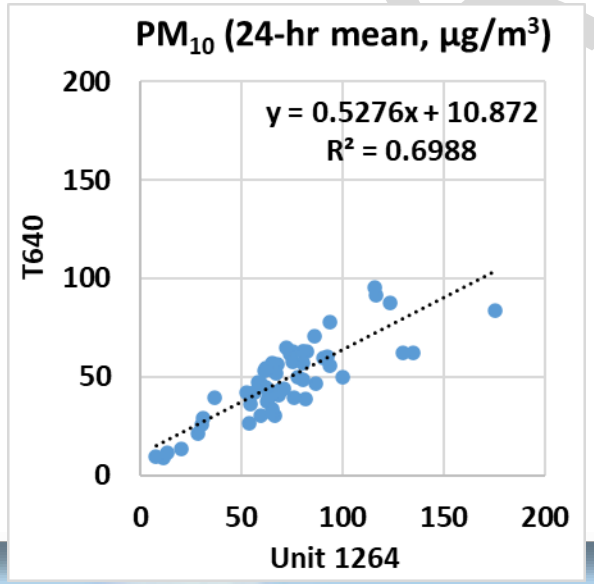


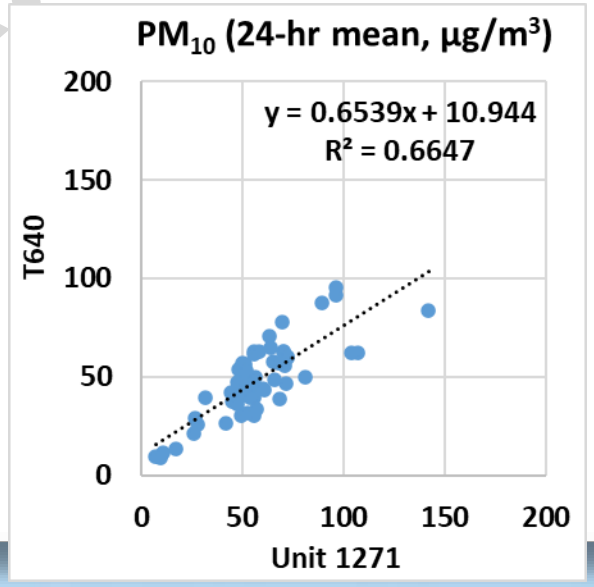
Zaack AQI vs T640 (PM_{10}; 24-hr mean)



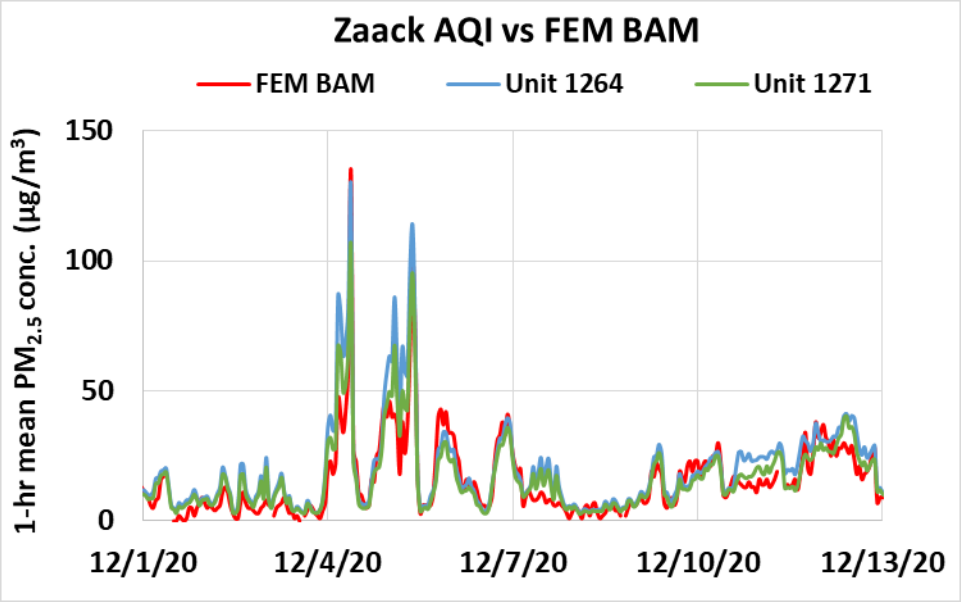
- Zaack AQI sensors showed moderate correlations with the corresponding T640 data ($0.66 < R^2 < 0.70$)
- Overall, the Zaack AQI sensors overestimated the PM_{10} mass concentration as measured by the T640
- The Zaack AQI sensors seemed to track the diurnal PM_{10} variations as recorded by the T640

Note: Unit 1332 is excluded from data analysis due to a malfunctioning PM sensor.



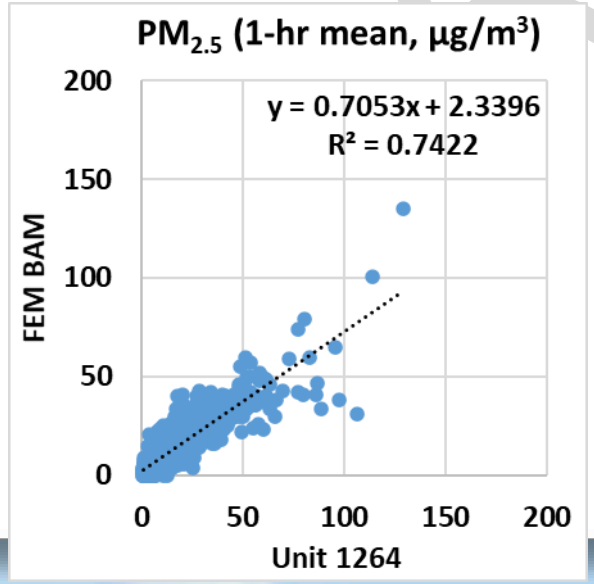


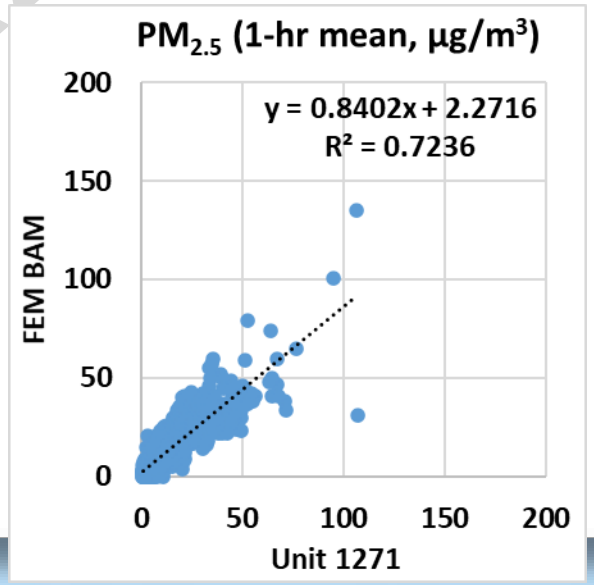
Zaack AQI vs FEM BAM ($PM_{2.5}$; 1-hr mean)



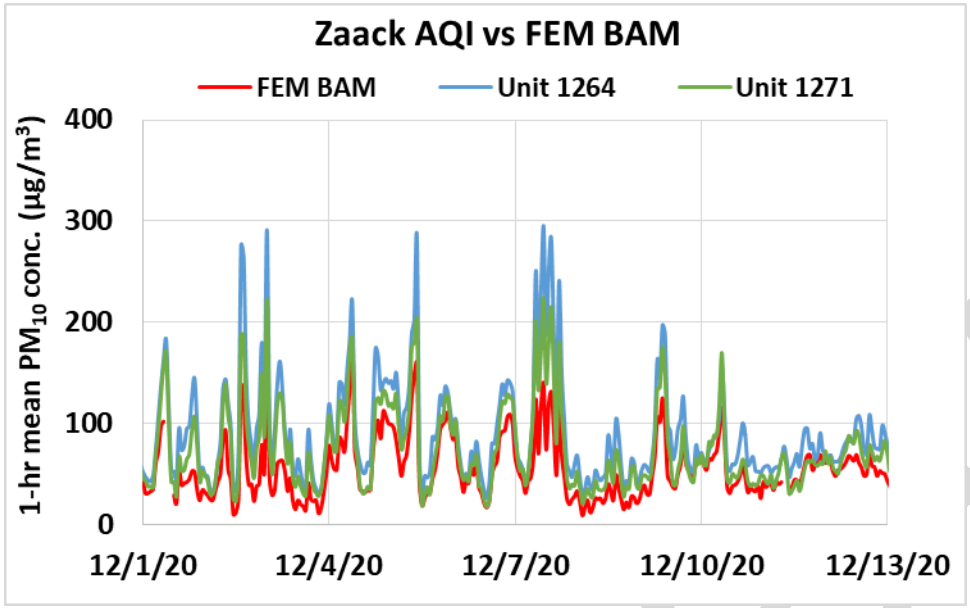
- Zaack AQI sensors showed strong correlations with the corresponding FEM BAM data ($0.72 < R^2 < 0.74$)
- Overall, the Zaack AQI sensors overestimated the $PM_{2.5}$ mass concentration as measured by the FEM BAM
- The Zaack AQI sensors seemed to track the diurnal $PM_{2.5}$ variations as recorded by the FEM BAM

Note: Unit 1332 was excluded from data analysis due to a malfunctioning PM sensor.



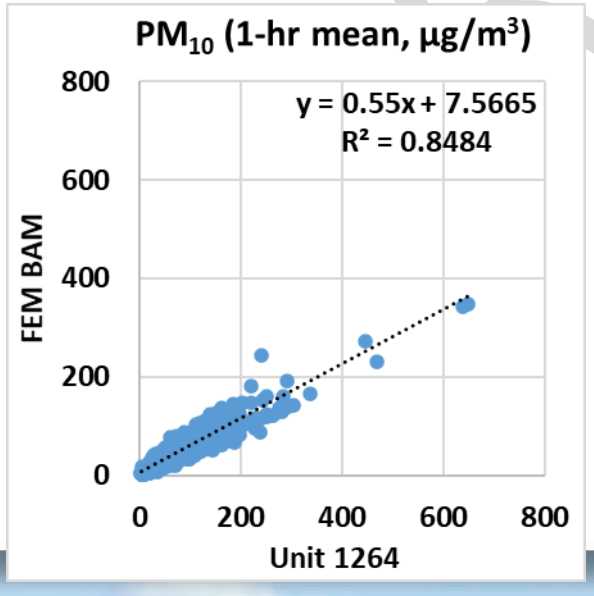


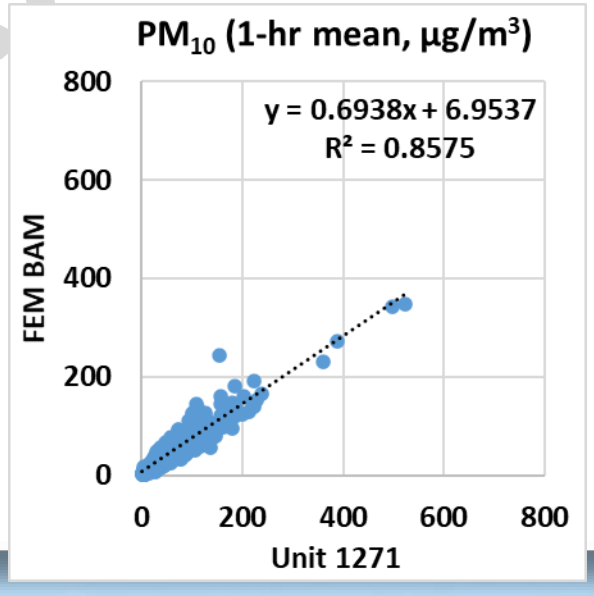
Zaack AQI vs FEM BAM (PM_{10}; 1-hr mean)



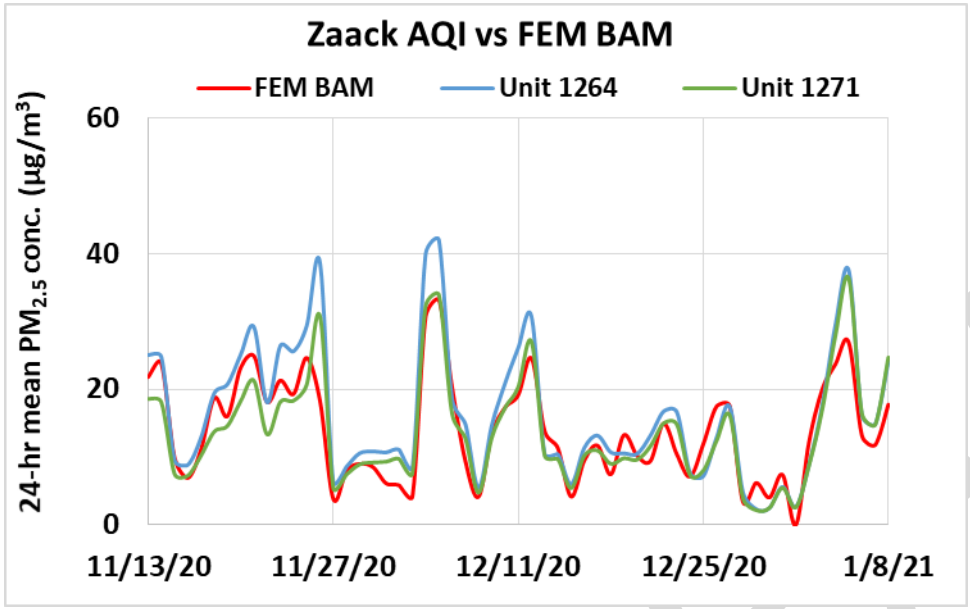
- Zaack AQI sensors showed strong correlations with the corresponding FEM BAM data ($0.84 < R^2 < 0.86$)
- Overall, the Zaack AQI sensors overestimated the PM_{10} mass concentration as measured by the FEM BAM
- The Zaack AQI sensors seemed to track the diurnal PM_{10} variations as recorded by the FEM BAM

Note: Unit 1332 was excluded from data analysis due to a malfunctioning PM sensor.



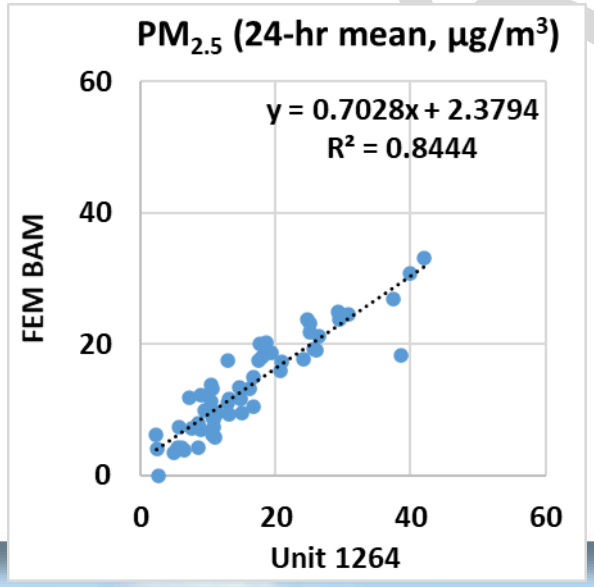


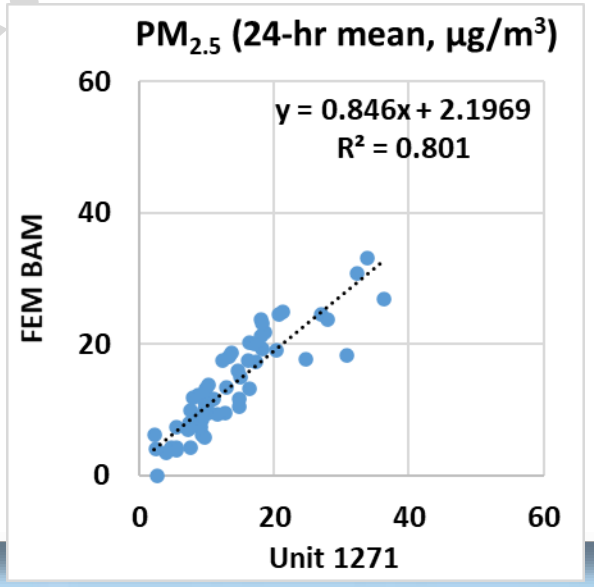
Zaack AQI vs FEM BAM ($PM_{2.5}$; 24-hr mean)



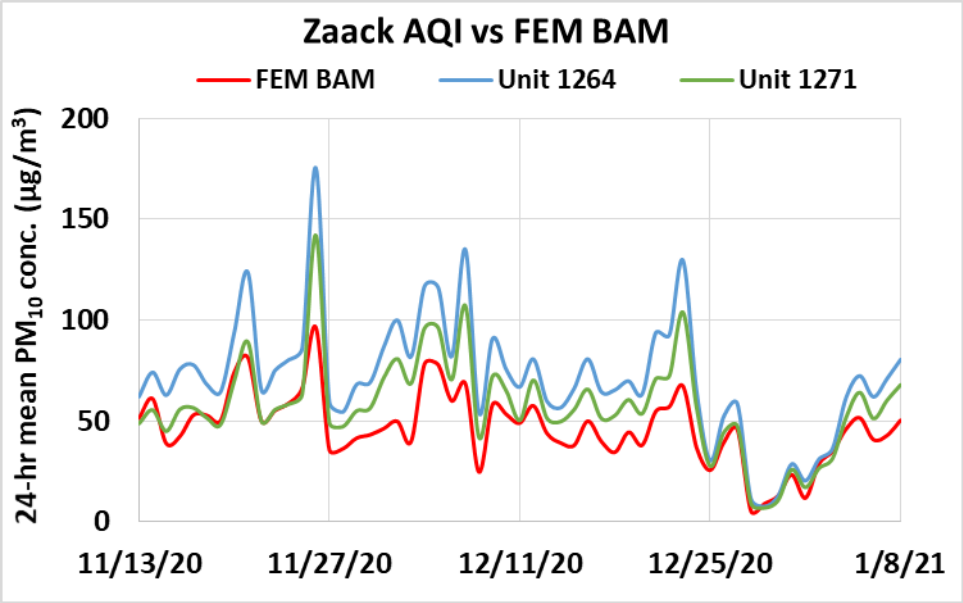
- Zaack AQI sensors showed strong correlations with the corresponding FEM BAM data ($0.80 < R^2 < 0.85$)
- Overall, the Zaack AQI sensors overestimated the $PM_{2.5}$ mass concentration as measured by the FEM BAM
- The Zaack AQI sensors seemed to track the diurnal $PM_{2.5}$ variations as recorded by the FEM BAM

Note: Unit 1332 was excluded from data analysis due to a malfunctioning PM sensor.



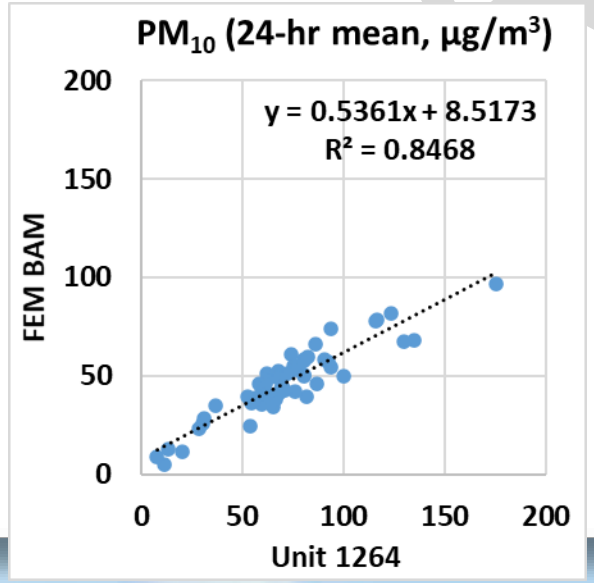


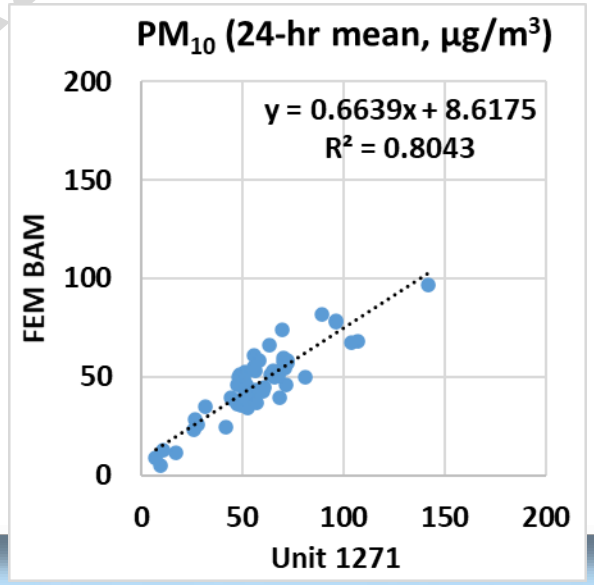
Zaack AQI vs FEM BAM (PM_{10}; 24-hr mean)



- Zaack AQI sensors showed strong correlations with the corresponding FEM BAM data ($0.80 < R^2 < 0.85$)
- Overall, the Zaack AQI sensors overestimated the PM_{10} mass concentration as measured by the FEM BAM
- The Zaack AQI sensors seemed to track the diurnal PM_{10} variations as recorded by the FEM BAM

Note: Unit 1332 was excluded from data analysis due to a malfunctioning PM sensor.





Summary: PM

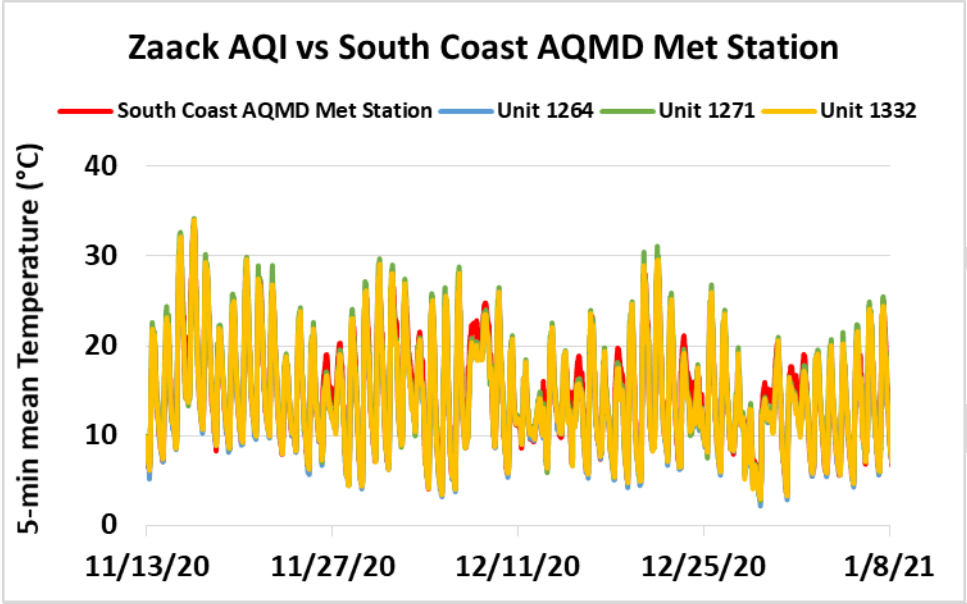
	Average of 3 Sensors, $PM_{1.0}$		Zaack AQI vs T640, $PM_{1.0}$						T640 ($PM_{1.0}$, µg/m^3)		
	Average (µg/m^3)	SD (µg/m^3)	R^2	Slope	Intercept	MBE[1] (µg/m^3)	MAE[2] (µg/m^3)	RMSE[3] (µg/m^3)	Ref. Average	Ref. SD	Range during the field evaluation
5-min	5.9	7.4	0.78 to 0.83	1.44 to 1.48	3.3 to 3.8	-6.2 to -6.4	6.3 to 6.5	14.1 to 14.7	12.3	12.1	0.4 to 217.0
1-hr	5.9	7.3	0.78 to 0.83	1.44 to 1.48	3.3 to 3.8	-6.2 to -6.4	6.3 to 6.4	8.7 to 9.1	12.3	11.9	0.4 to 63.2
24-hr	6.0	5.0	0.78 to 0.87	1.44 to 1.54	3.0 to 3.8	-5.9 to -6.0	6.2 to 6.4	4.6 to 5.5	12.3	8.1	1.5 to 31.2
	Average of 3 Sensors, $PM_{2.5}$		Zaack AQI vs BAM & T640, $PM_{2.5}$						FEM BAM and FEM T640 ($PM_{2.5}$, µg/m^3)		
	Average (µg/m^3)	SD (µg/m^3)	R^2	Slope	Intercept	MBE[1] (µg/m^3)	MAE[2] (µg/m^3)	RMSE[3] (µg/m^3)	Ref. Average	Ref. SD	Range during the field evaluation
5-min	15.1	13.2	0.80 to 0.82	0.87 to 1.04	1.7 to 1.8	-2.2 to 0.4	3.8 to 4.2	9.9 to 10.6	16.1	13.9	0.8 to 239.7
1-hr	15.1	12.9	0.73 to 0.83	0.71 to 1.04	1.6 to 2.3	-2.2 to 2.6	3.7 to 5.0	6.0 to 7.7	14.1 to 16.0	11.6 to 13.6	0 to 165.1
24-hr	15.1	8.9	0.80 to 0.87	0.71 to 1.09	0.9 to 2.4	-2.0 to 2.5	2.4 to 3.6	3.5 to 4.9	14.1 to 16.0	7.3 to 9.4	3.4 to 39.7
	Average of 3 Sensors, PM_{10}		Zaack AQI vs BAM & T640, PM_{10}						FEM BAM and T640 (PM_{10}, µg/m^3)		
	Average (µg/m^3)	SD (µg/m^3)	R^2	Slope	Intercept	MBE[1] (µg/m^3)	MAE[2] (µg/m^3)	RMSE[3] (µg/m^3)	Ref. Average	Ref. SD	Range during the field evaluation
5-min	64.4	48.7	0.69 to 0.71	0.47 to 0.60	14.1 to 15.2	8.8 to 22.8	14.4 to 23.9	40.7 to 65.0	48.5	30.6	1.3 to 547.2
1-hr	64.4	46.0	0.70 to 0.86	0.47 to 0.69	7.0 to 14.6	9.0 to 24.5	13.2 to 25.0	20.1 to 38.7	46.8 to 48.5	29.1 to 30.6	1 to 349
24-hr	64.4	26.8	0.66 to 0.85	0.53 to 0.66	8.5 to 10.9	9.2 to 24.6	11.6 to 24.6	15.4 to 29.1	46.8 to 48.5	18.9 to 30.6	5.4 to 96.5

[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).

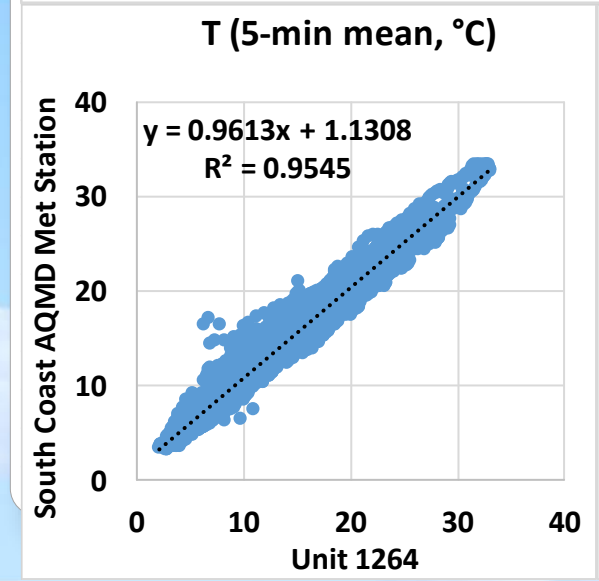
[2] Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.

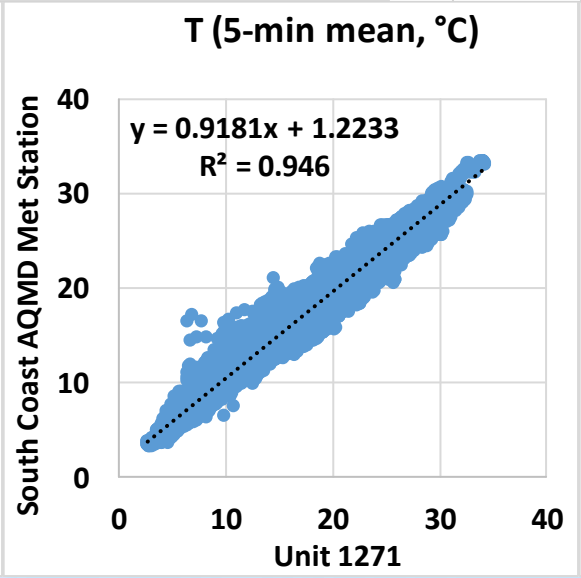
[3] Root Mean Square Error (RMSE): another metric to calculate measurement errors.

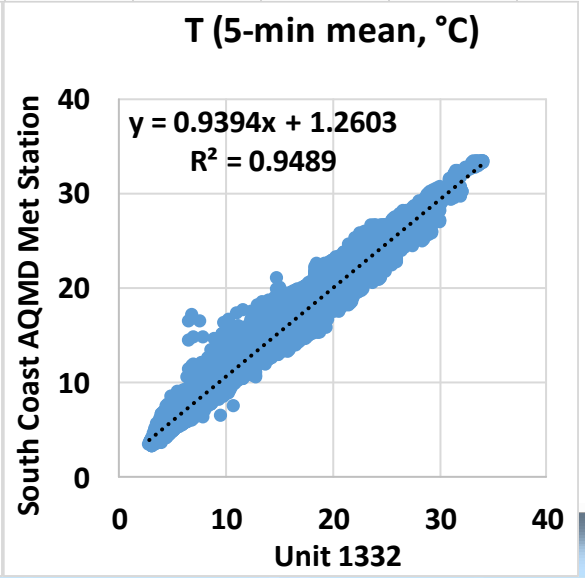
Zaack AQI vs South Coast AQMD Met Station (Temp; 5-min mean)



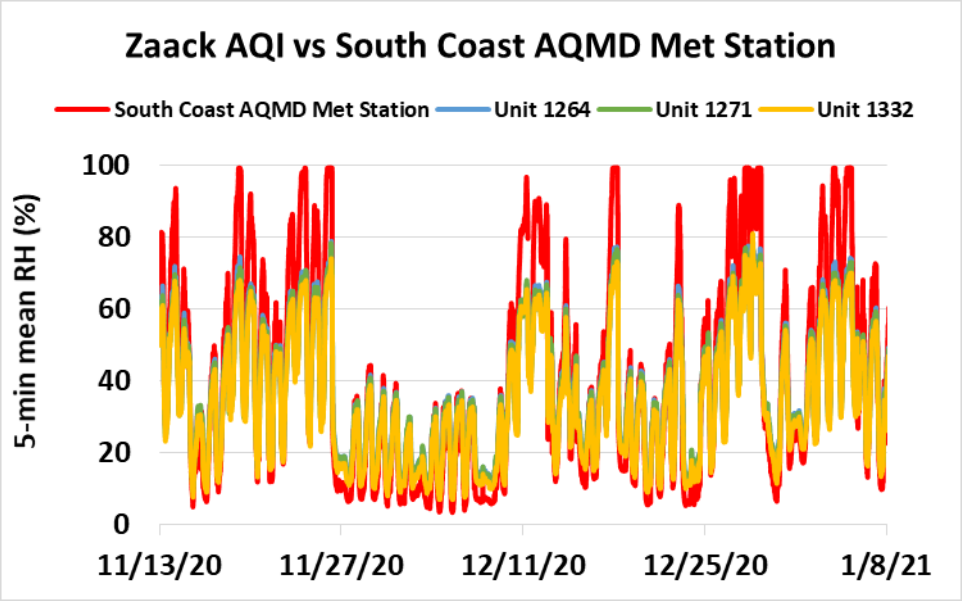
- Zaack AQI sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($0.94 < R^2 < 0.96$)
- Overall, the Zaack AQI sensors overestimated the temperature measurement as recorded by South Coast AQMD Met Station
- The Zaack AQI sensors seemed to track the diurnal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



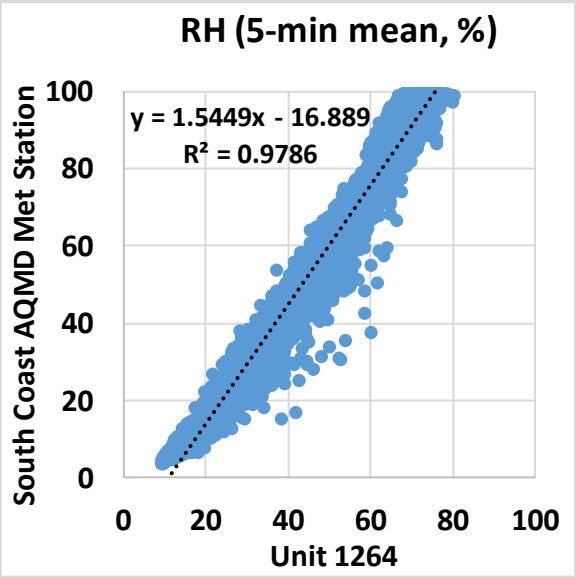


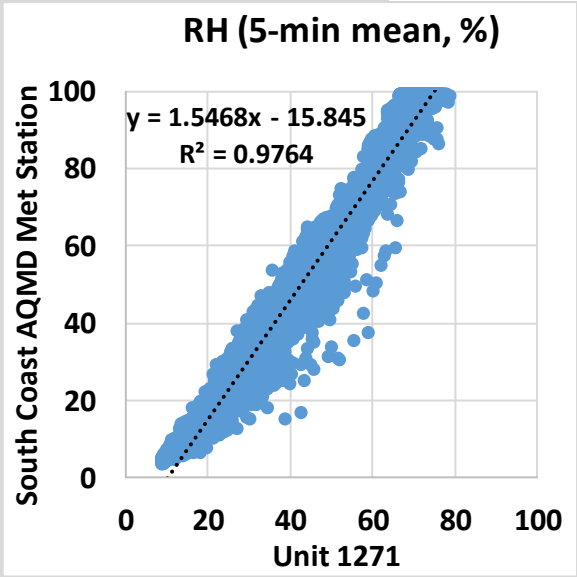


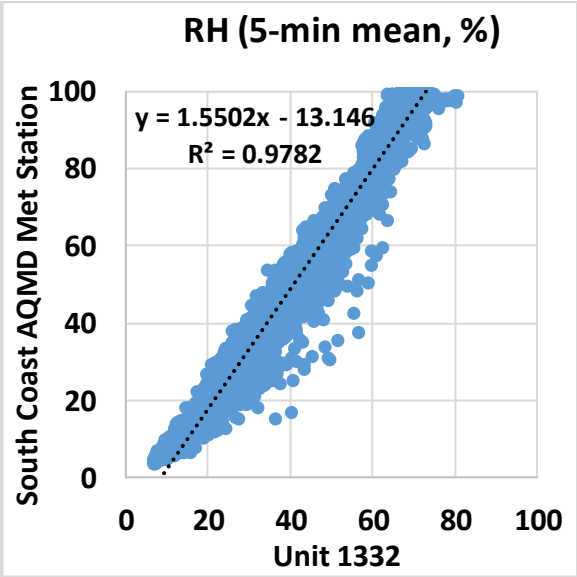
Zaack AQI vs South Coast AQMD Met Station (RH; 5-min mean)



- Zaack AQI sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data (R^2 ~ 0.98)
- Overall, the Zaack AQI sensors underestimated the RH measurement as recorded by South Coast AQMD Met Station
- The Zaack AQI sensors seemed to track the diurnal RH variations as recorded by South Coast AQMD Met Station







Discussion

- The three **Zaack AQI** sensors' average data recovery for ozone, NO_2 and CO was ~ 90%, 97% and 78%; respectively. Data recovery from Unit 1264 and Unit 1271 was ~ 100% for all PM fractions.
- The absolute intra-model variability was 3.9 ppb, 0.67 ppb and 12.1 ppb for ozone, NO_2 and CO, respectively. Absolute intra-model variability for Unit 1264 and Unit 1271 was ~ 0.08, 1.3 and 6.9 $\mu g/m^3$ for the $PM_{1.0,}$ $PM_{2.5}$ and PM_{10}, respectively.
- The reference instruments (FEM BAM and FEM T640) showed very strong and strong correlations with each other for $PM_{2.5}$ and PM_{10} mass concentration measurements (R^2 ~ 0.90 and R^2 ~ 0.88, 1-hr mean), respectively.
- During the <u>entire</u> field deployment testing period:
  - Ozone sensors did not correlate with the FEM instrument ($R^2 < 0.01$, 5-min mean) and overestimated the corresponding FEM data
  - NO_2 sensors showed moderate correlations with the FRM instrument ($0.53 < R^2 < 0.58$, 5-min mean) and underestimated the corresponding FRM data
  - CO sensors showed strong correlations with the FRM instrument ($0.84 < R^2 < 0.88$, 5-min mean) and underestimated the corresponding FRM data
  - The sensors (Unit 1264 and Unit 1271) showed strong correlations with the corresponding $PM_{1.0}$ data ($0.77 < R^2 < 0.83$, 1-hr mean); strong correlations with the corresponding $PM_{2.5}$ data ($0.72 < R^2 < 0.83$, 1-hr mean) and moderate to strong correlations with the corresponding PM_{10} data ($0.69 < R^2 < 0.86$, 1-hr mean). Overall, the sensors underestimated the corresponding $PM_{1.0}$ and $PM_{2.5}$ data and overestimated the corresponding PM_{10} data.
  - Temperature and relative humidity sensors showed very strong correlations with the South Coast AQMD Met Station data (T: R^2 ~ 0.95 and RH: R^2 ~ 0.98) and overestimated the T data and underestimated the RH data as recorded by the South Coast AQMD Met Station
- No sensor calibration was performed by AQ-SPEC prior to the beginning of this field testing
- 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.
- <u>These results are still preliminary</u>