

Field Evaluation Wicked Device – Air Quality Egg 2022 Model O_3 and NO_2



Background

- From 03/18/2022 to 05/18/2022, three **Wicked Device – Air Quality Egg 2022 Model_O₃ and NO₂ (hereinafter Air Quality Egg 2022 Model)** sensors were deployed at the South Coast AQMD stationary ambient monitoring site in Rubidoux and were run side-by-side with Federal Equivalent Method (FEM) and Federal Reference Method (FRM) instruments measuring the same pollutants
- Air Quality Egg 2022 Model (3 units tested):
 - Gas sensor: **Electrochemical; non-FEM (Winsen ZE12A)**
 - Each unit reports: O₃ (ppb), NO₂ (ppb), T (°C), RH (%)
 - **Unit cost: \$971 (included data logging package)**
 - Time resolution: 1-min
 - Units IDs: 233d, 1f4e, 8a60
- South Coast AQMD Reference Instruments:
 - O₃ instrument (**Teledyne T400, hereinafter FEM T400**); **cost: ~\$7,000**
 - Time resolution; 1-min
 - NO/NO₂ instrument (**Teledyne T200, hereinafter FRM T200**); **cost: ~\$11,000**
 - Time resolution: 1-min
 - Met station (T, RH, P, WS, WD); **cost: ~\$5,000**
 - Time resolution: 1-min



FEM T400



FRM T200

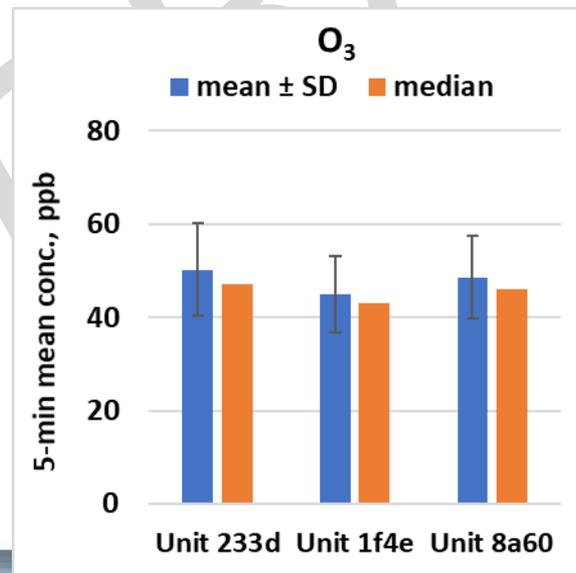
Ozone (O_3)
in Air Quality Egg 2022 Model

Data validation & recovery

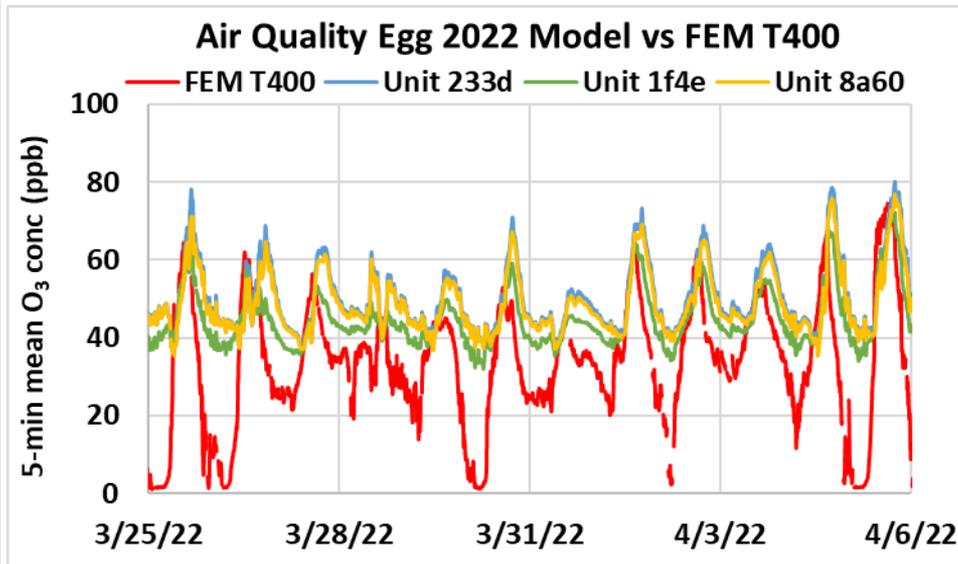
- Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
- Data recovery for O₃ from all units was ~ 100%

Air Quality Egg 2022 Model; Intra-model variability

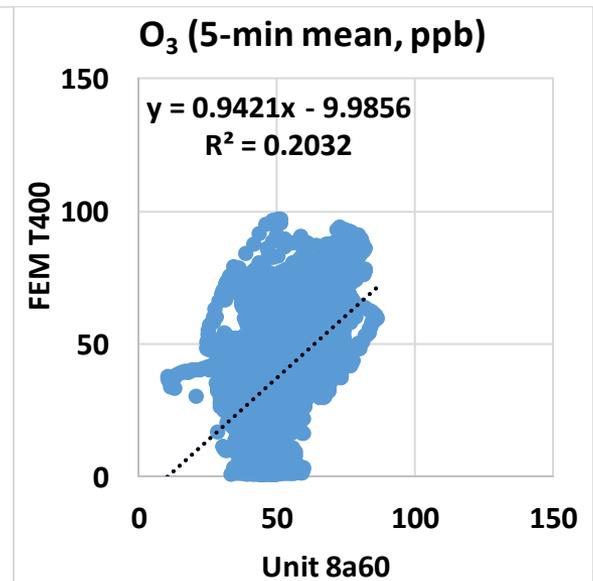
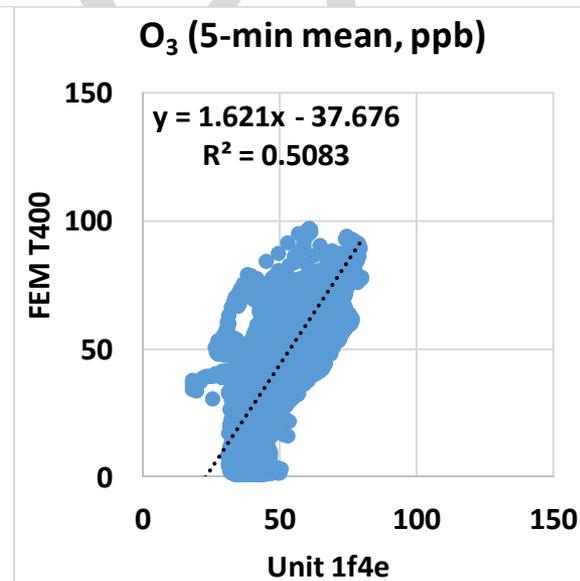
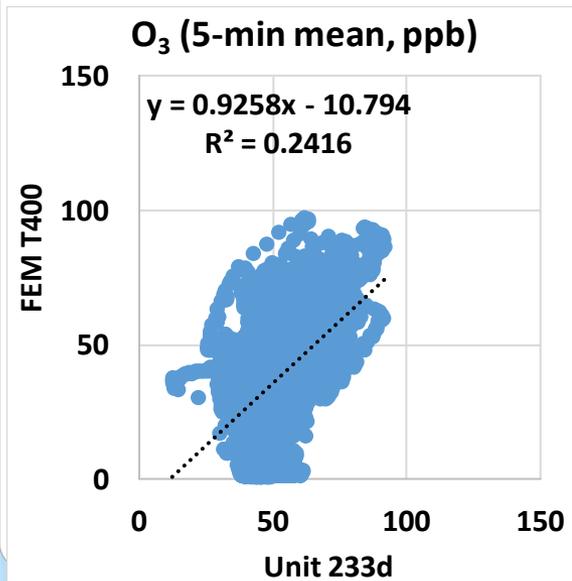
- Absolute intra-model variability was ~ 2.2 ppb for the O₃ measurements (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 4.5% for the O₃ measurements (calculated as the absolute intra-model variability relative to the mean of the three sensor means)



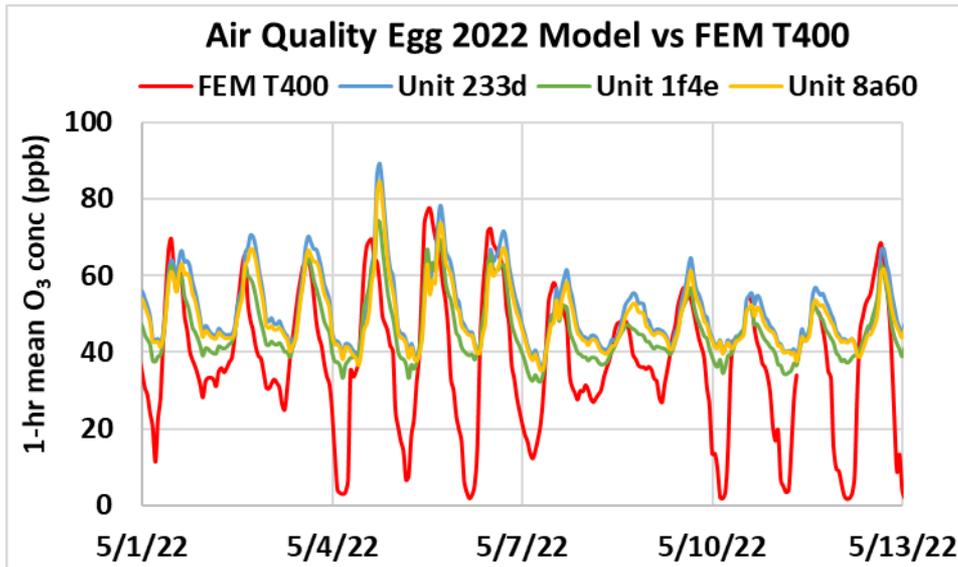
Air Quality Egg 2022 Model vs FEM T400 (O₃; 5-min mean)



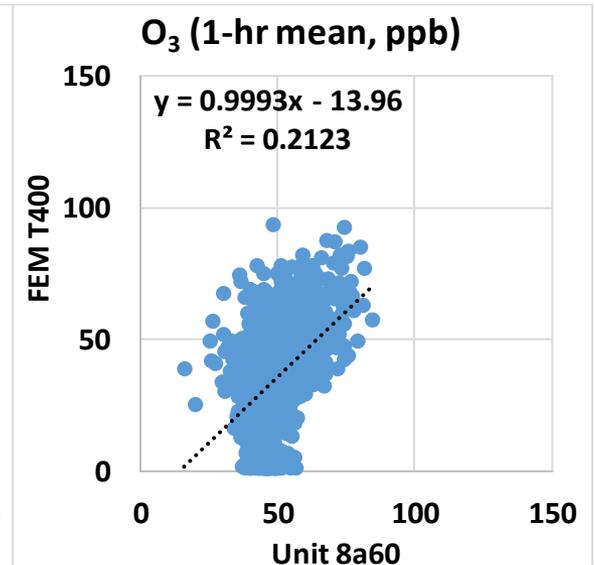
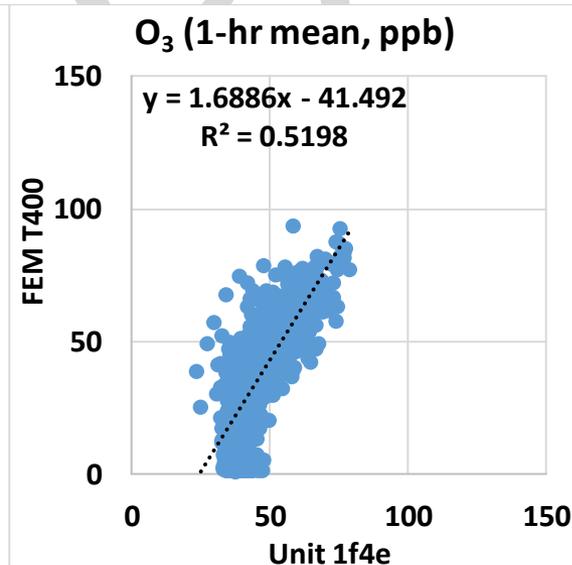
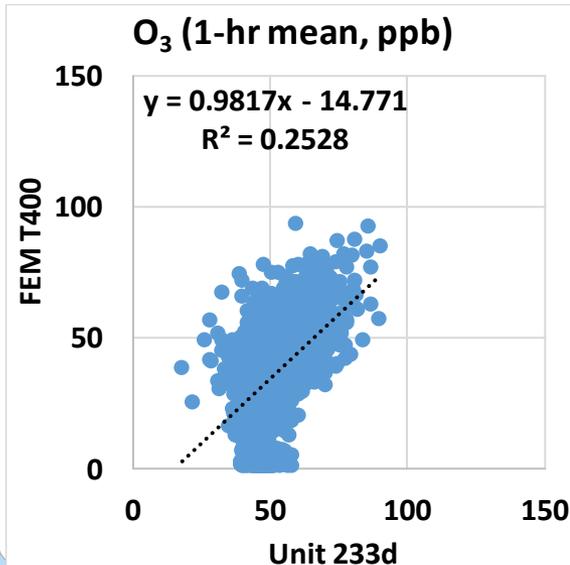
- The Air Quality Egg 2022 Model sensors showed very weak to moderate correlations with the corresponding FEM T400 data ($0.20 < R^2 < 0.51$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the O₃ concentration as measured by the FEM T400 instrument
- The Air Quality Egg 2022 Model sensors sometimes seemed to track the diurnal O₃ variations as recorded by the FEM T400 instrument



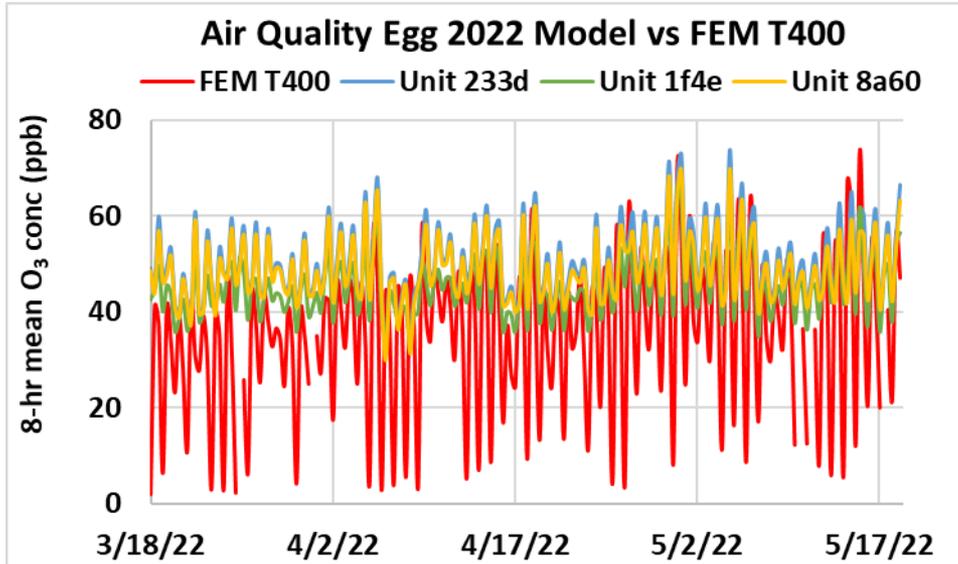
Air Quality Egg 2022 Model vs FEM T400 (O₃; 1-hr mean)



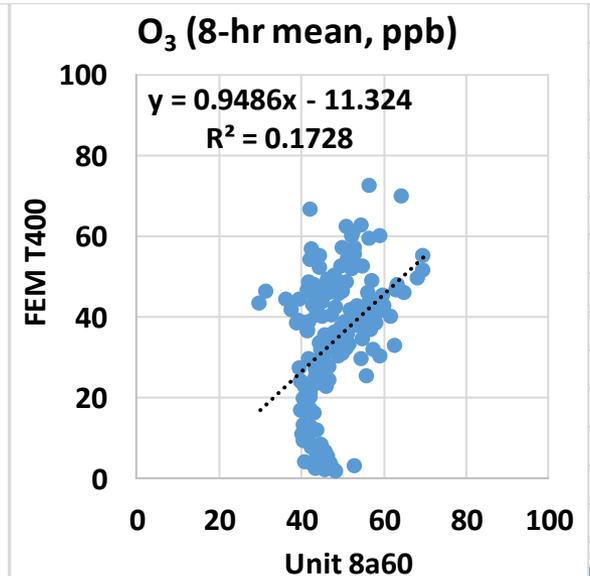
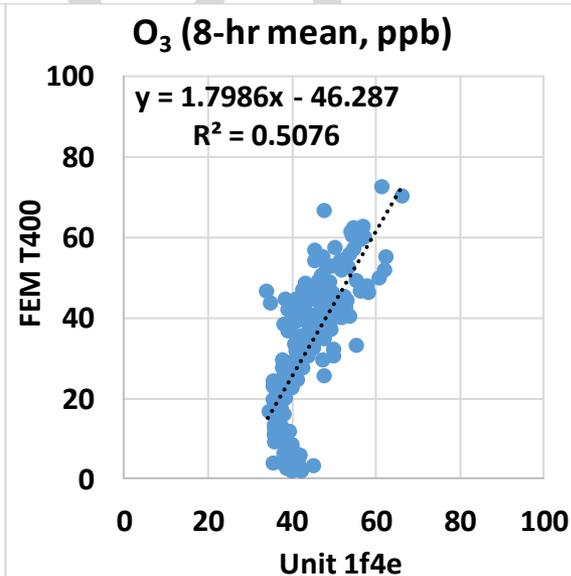
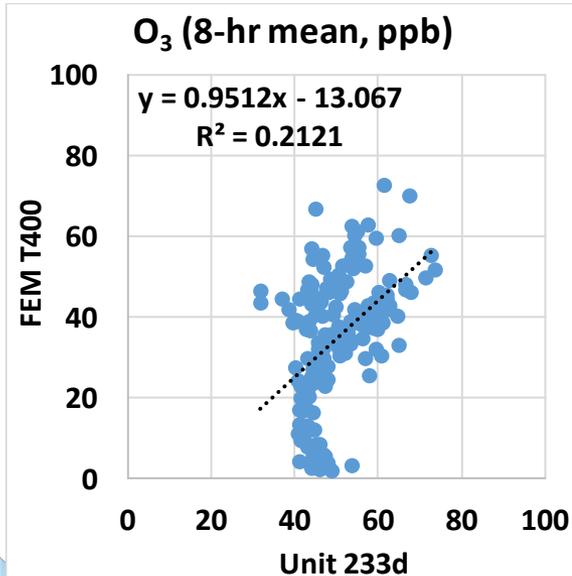
- The Air Quality Egg 2022 Model sensors showed very weak to moderate correlations with the corresponding FEM T400 data ($0.21 < R^2 < 0.52$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the O₃ concentration as measured by the FEM T400 instrument
- The Air Quality Egg 2022 Model sensors sometimes seemed to track the diurnal O₃ variations as recorded by the FEM T400 instrument



Air Quality Egg 2022 Model vs FEM T400 (O₃; 8-hr mean)



- The Air Quality Egg 2022 Model sensors showed very weak to moderate correlations with the corresponding FEM T400 data ($0.17 < R^2 < 0.51$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the O₃ concentration as measured by the FEM T400 instrument
- The Air Quality Egg 2022 Model sensors sometimes seemed to track the diurnal O₃ variations as recorded by the FEM T400 instrument



Summary: O₃

	Average of 3 Sensors O ₃		Air Quality Egg 2022 Model vs FEM, O ₃						FEM O ₃ (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	48.0	9.1	0.20 to 0.51	0.93 to 1.62	-37.7 to -10.0	9.5 to 14.5	13.2 to 18.0	17.2 to 22.0	35.9	19.3	1.1 to 97.5
1-hr	48.0	9.0	0.21 to 0.52	0.98 to 1.69	-41.5 to -14.0	10.5 to 15.7	13.8 to 18.7	17.7 to 22.7	34.6	19.3	1.3 to 94.0
8-hr	48.0	7.1	0.17 to 0.51	0.95 to 1.80	-46.3 to -11.3	10.3 to 15.5	12.4 to 17.4	14.5 to 19.8	34.8	16.3	2.0 to 72.9

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.

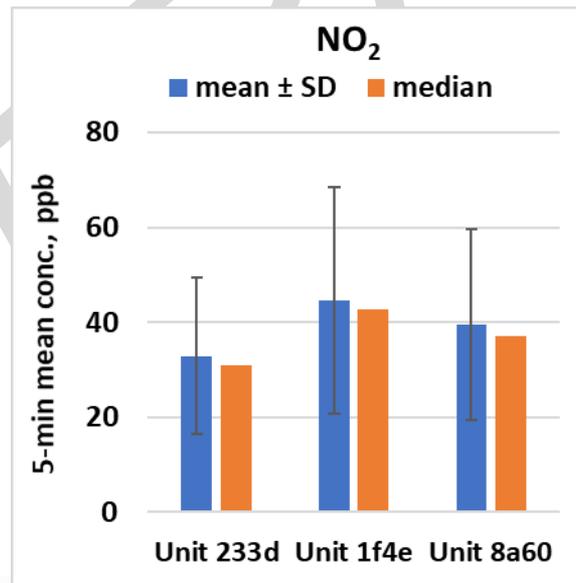
**Nitrogen Dioxide (NO₂)
in Air Quality Egg 2022 Model**

Data validation & recovery

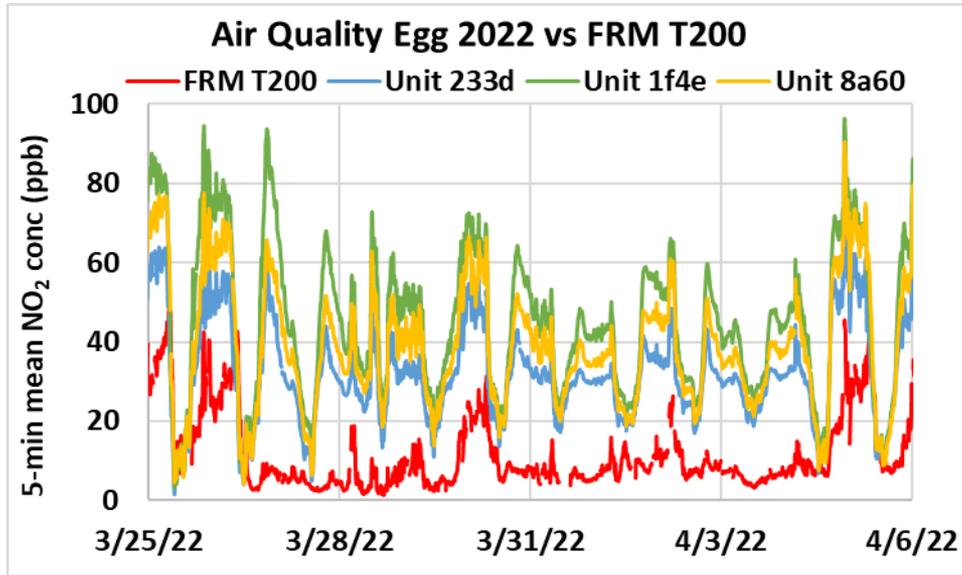
- Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
- Data recovery for NO₂ from all units was ~ 100%

Air Quality Egg 2022 Model; Intra-model variability

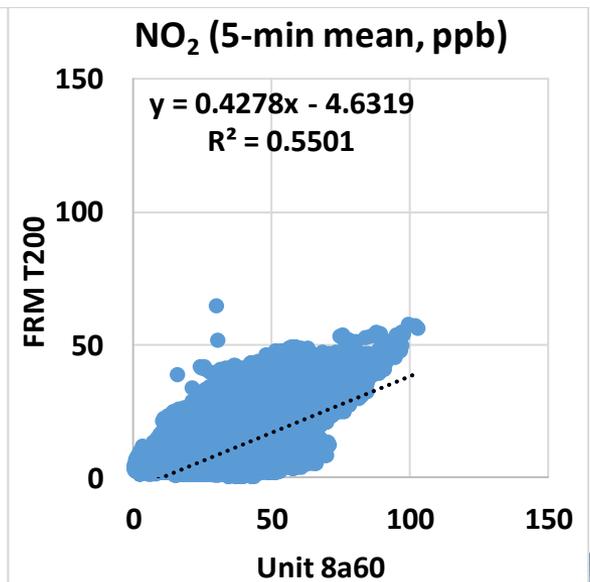
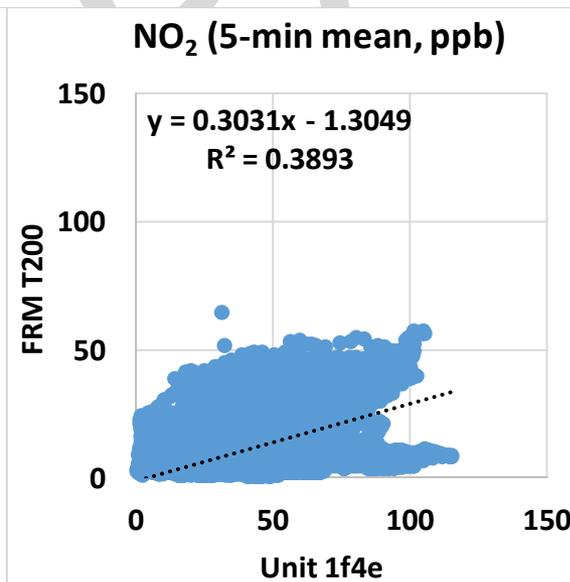
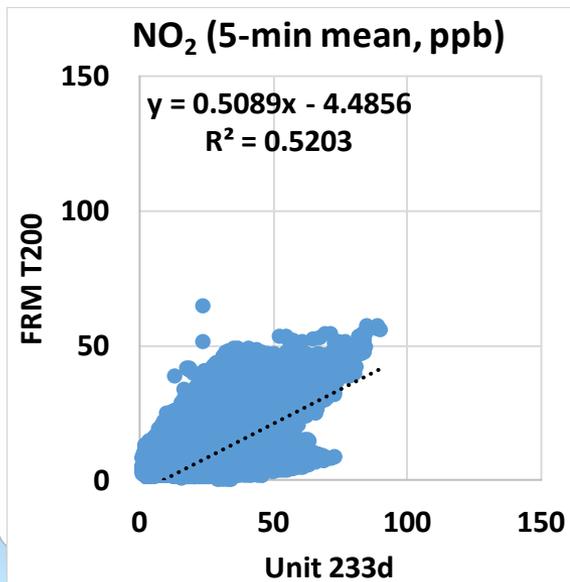
- Absolute intra-model variability was ~ 4.8 ppb for the NO₂ measurements (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 12.2% for the NO₂ measurements (calculated as the absolute intra-model variability relative to the mean of the three sensor means)



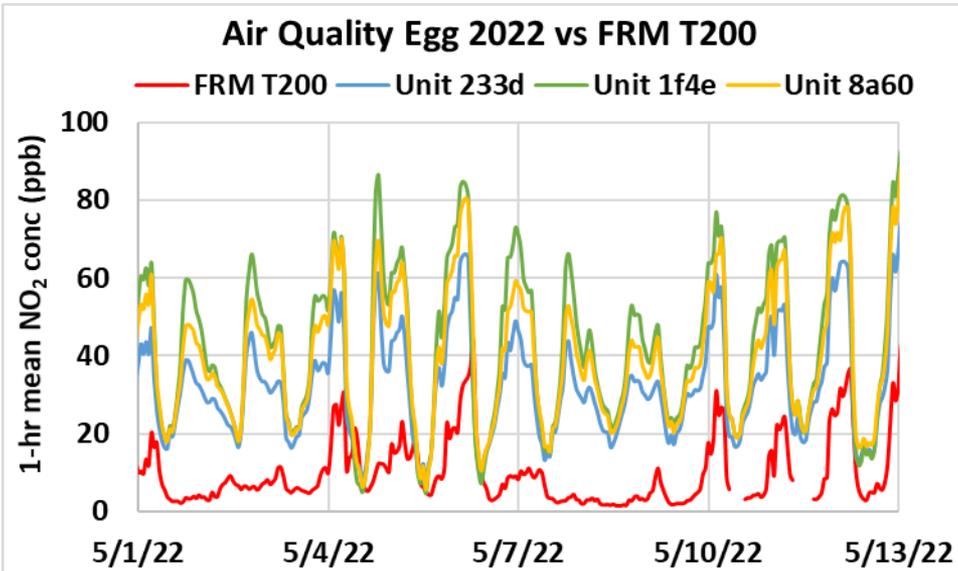
Air Quality Egg 2022 Model vs FRM T200 (NO₂; 5-min mean)



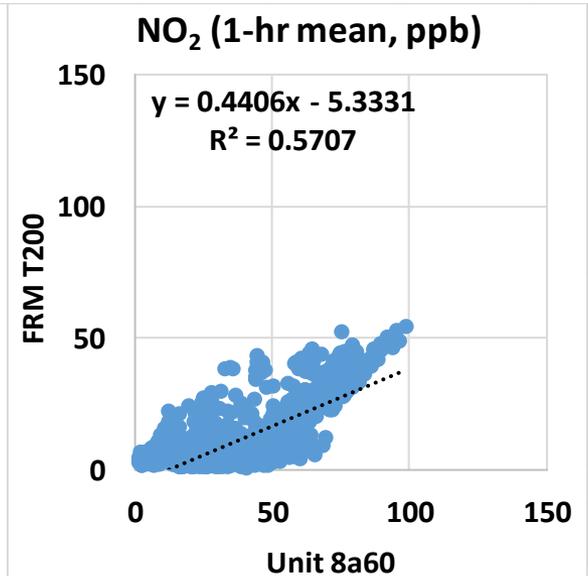
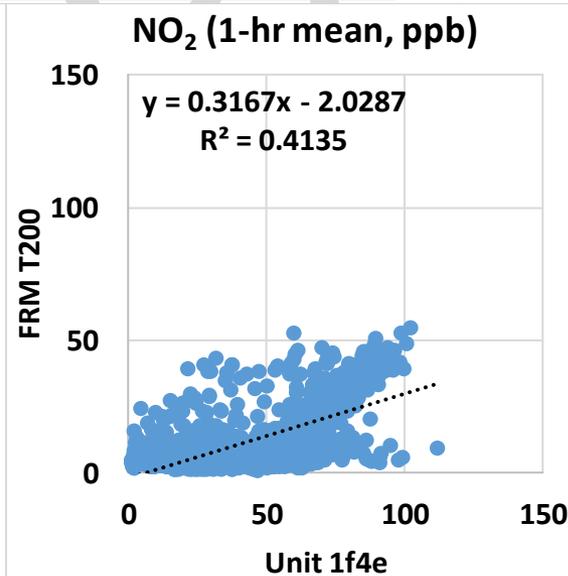
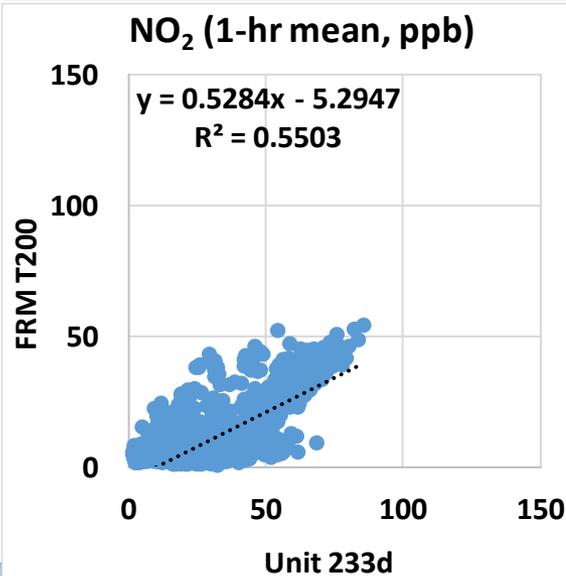
- The Air Quality Egg 2022 Model sensors showed weak to moderate correlations with the corresponding FRM T200 data ($0.38 < R^2 < 0.56$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the NO₂ concentration as measured by the FRM T200 instrument
- The Air Quality Egg 2022 Model sensors sometimes seemed to track the diurnal NO₂ variations as recorded by the FRM T200 instrument



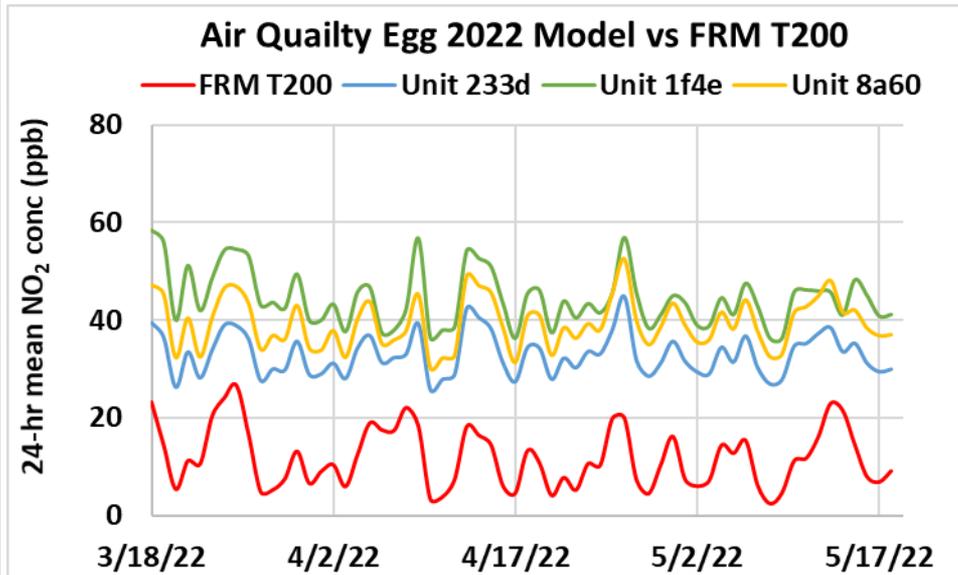
Air Quality Egg 2022 Model vs FRM T200 (NO₂; 1-hr mean)



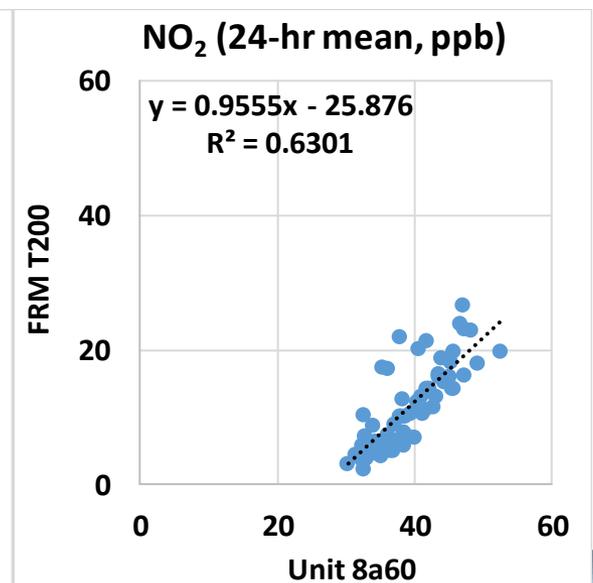
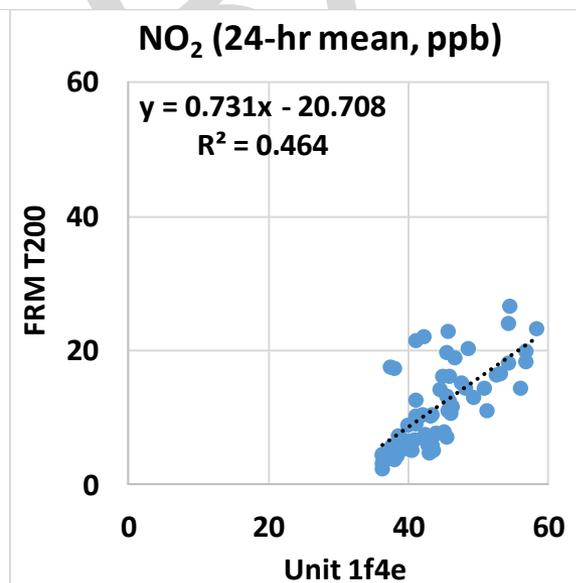
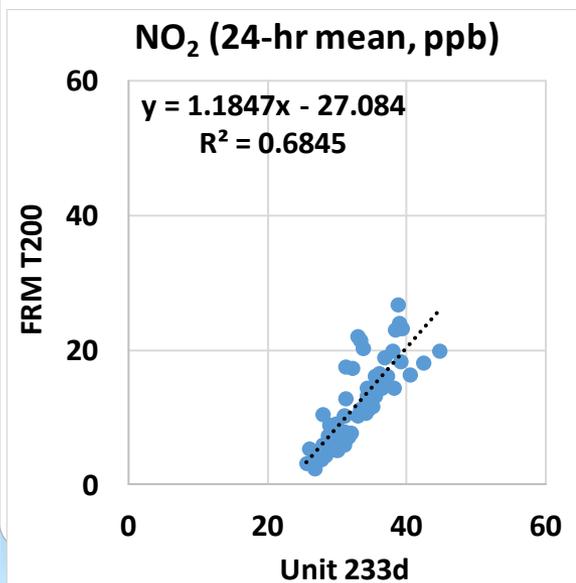
- The Air Quality Egg 2022 Model sensors showed weak to moderate correlations with the corresponding FRM T200 data ($0.41 < R^2 < 0.58$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the NO₂ concentration as measured by the FRM T200 instrument
- The Air Quality Egg 2022 Model sensors sometimes seemed to track the diurnal NO₂ variations as recorded by the FRM T200 instrument



Air Quality Egg 2022 Model vs FRM T200 (NO₂; 24-hr mean)



- The Air Quality Egg 2022 Model sensors showed weak to moderate correlations with the corresponding FRM T200 data ($0.46 < R^2 < 0.69$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the NO₂ concentration as measured by the FRM T200 instrument
- The Air Quality Egg 2022 Model sensors sometimes seemed to track the daily NO₂ variations as recorded by the FRM T200 instrument



Summary: NO₂

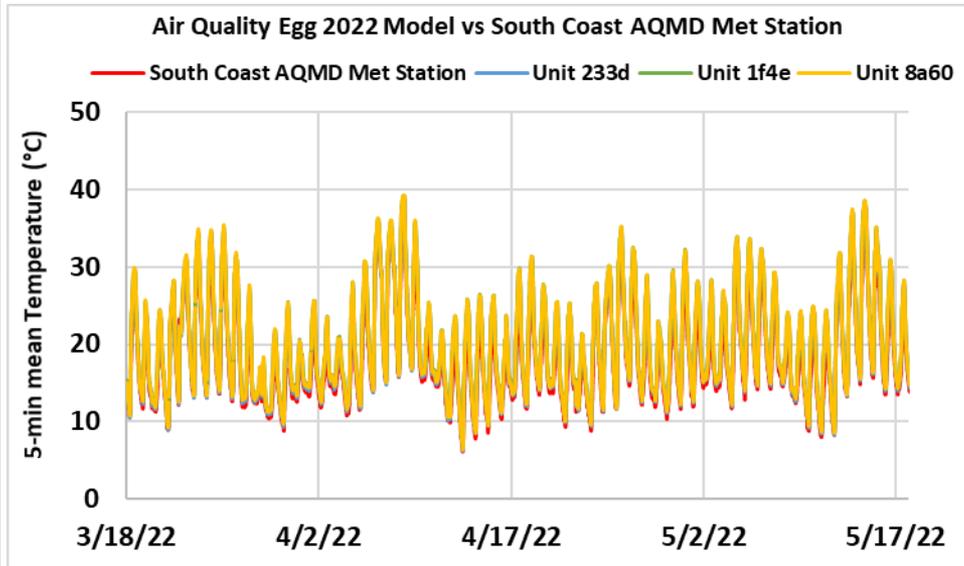
	Average of 3 Sensors NO ₂		Air Quality Egg 2022 Model vs FRM, NO ₂						FRM NO ₂ (ppb)		
	Average (ppb)	SD (ppb)	R ²	Slope	Intercept	MBE ¹ (ppb)	MAE ² (ppb)	RMSE ³ (ppb)	FRM Average	FRM SD	Range during the field evaluation
5-min	38.9	20.1	0.39 to 0.55	0.30 to 0.51	-4.6 to -1.3	20.2 to 31.4	20.8 to 32.0	23.2 to 36.6	11.8	11.5	0.6 to 65.0
1-hr	38.9	19.9	0.41 to 0.57	0.32 to 0.53	-5.3 to -2.0	20.9 to 32.7	21.4 to 33.2	23.7 to 37.5	12.2	11.6	0.8 to 54.7
24-hr	38.9	5.0	0.46 to 0.68	0.73 to 1.18	-27.1 to -20.7	21.0 to 32.7	21.0 to 32.7	21.3 to 33.0	11.8	6.1	2.4 to 26.7

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).

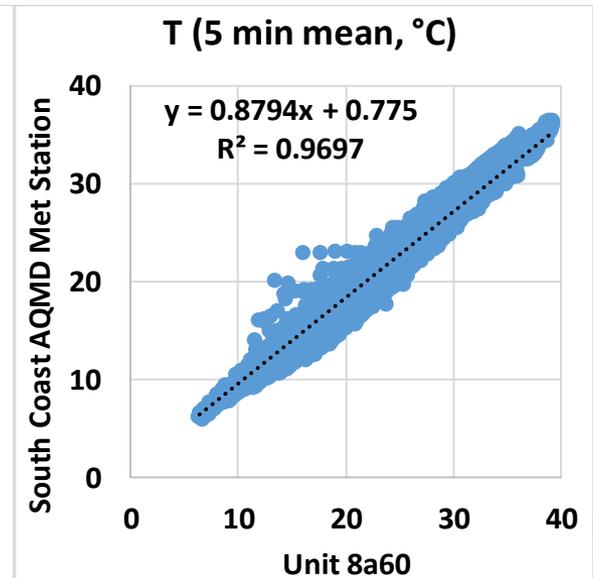
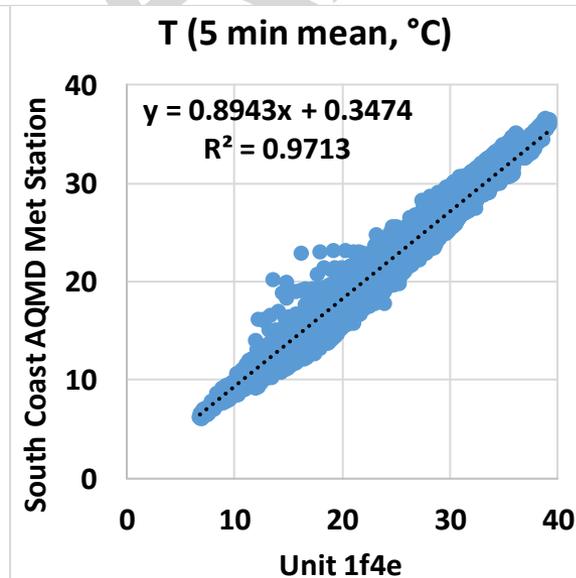
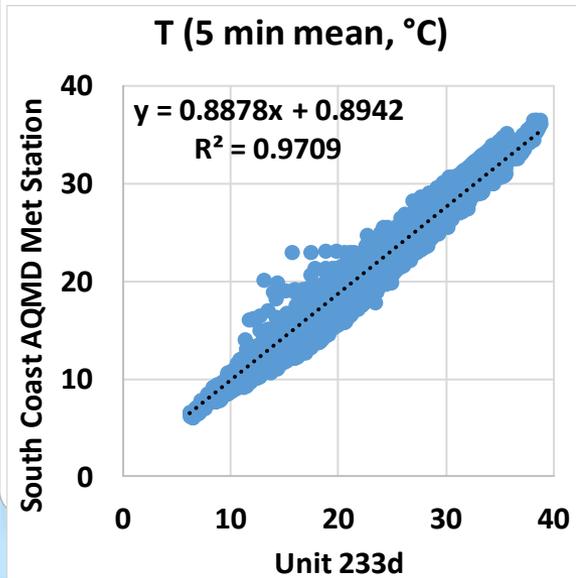
² Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.

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

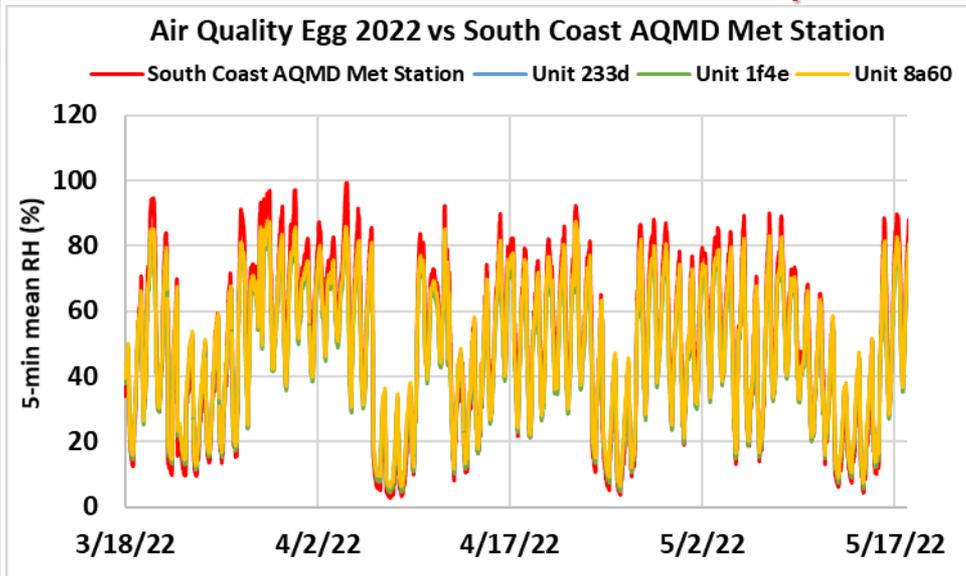
Air Quality Egg 2022 Model vs South Coast AQMD Met Station Met Station (Temp; 5-min mean)



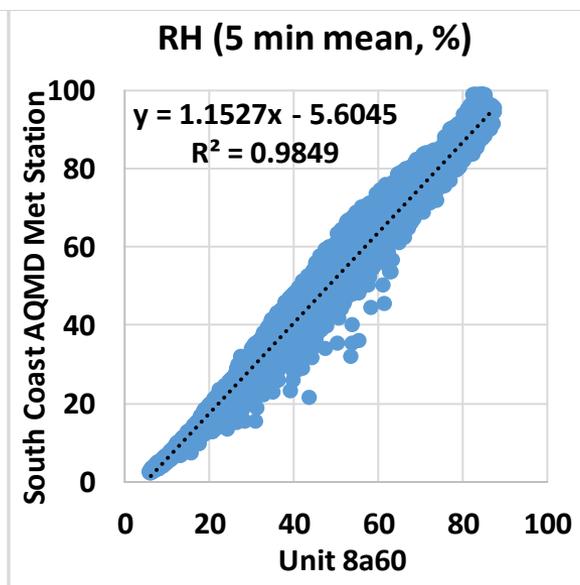
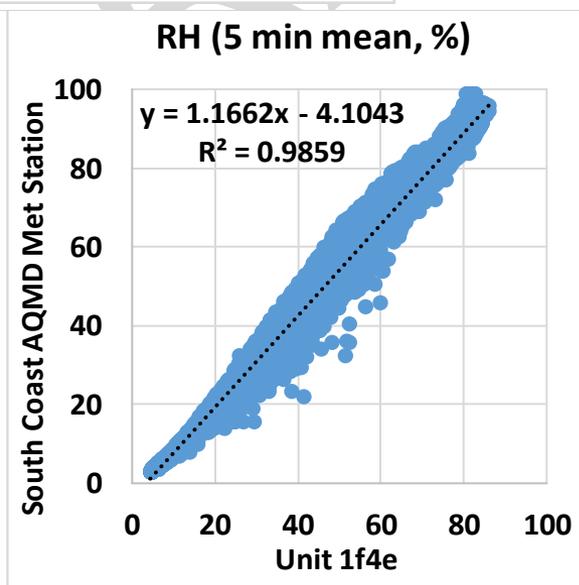
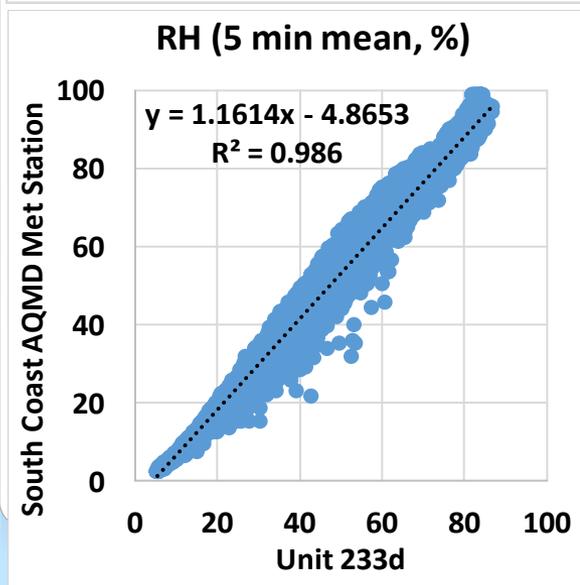
- The Air Quality Egg 2022 Model sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.97$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the temperature measurement as recorded by South Coast AQMD Met Station
- The Air Quality Egg 2022 Model sensors seemed to track the diurnal temperature variations as recorded by South Coast AQMD Met Station



Air Quality Egg 2022 Model vs South Coast AQMD Met Station Met Station (RH; 5-min mean)



- The Air Quality Egg 2022 Model sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.99$)
- Overall, the Air Quality Egg 2022 Model sensors underestimated the RH measurement as recorded by South Coast AQMD Met Station
- The Air Quality Egg 2022 Model sensors seemed to track the diurnal RH variations as recorded by South Coast AQMD Met Station



Discussion

- The three **Air Quality Egg 2022 Model** sensors' data recovery from all units was ~ 100% for O₃ and NO₂ measurements
- The absolute intra-model variability was ~ 2.2 ppb for O₃ and ~ 4.8 ppb for NO₂ measurements
- During the entire field deployment testing period:
 - Ozone sensors showed very weak to moderate correlation with the FEM T400 instrument ($0.20 < R^2 < 0.51$, 5-min mean) and generally overestimated the corresponding FEM T400 data
 - NO₂ sensors showed weak to moderate correlations with the FRM T200 instrument ($0.38 < R^2 < 0.56$, 5-min mean) and overestimated the corresponding FRM T200 data
- No sensor calibration was performed by South Coast AQMD Staff for this evaluation
- Laboratory chamber testing is necessary to fully evaluate the performance of these sensors under known aerosol concentrations and controlled temperature and relative humidity conditions
- All results are still preliminary