

Field Evaluation Aeroqual AQY (v1.0)



Background

- From 2/20/2020 to 04/22/2020, three **Aeroqual AQY v1.0** 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
- Aeroqual AQY v1.0 (3 units tested):
 - Sensors: Ozone – Gas Sensitive Semiconductor (GSS);
 - NO₂ – Gas Sensitive Electrochemical (GSE) (**non-FEM/non-FRM**);
 - PM_{2.5} – Laser Particle Counter (LPC) (**non-FEM**), (model SDS011 by Nova Fitness)
 - Each unit measures: O₃ (ppb), NO₂ (ppb), PM_{2.5} (µg/m³), T (°C), RH (%)
 - **Unit cost: ~\$3,000 w/ modem (\$4000 including 2-yr care package with cloud software and remote tech support)**
 - Time resolution: 1-min
 - Units IDs: 1085, 1094, 1104
 - Differences from AQY v0.5
 - Separate USB drive memory
 - New PCB board with sensor connector
 - Real time clock added
 - Mounting bracket for Ozone, NO₂ and PM_{2.5} sensors
- South Coast AQMD Reference instruments:
 - O₃ instrument (**FEM**); **cost: ~\$7,000**
 - Time resolution; 1-min
 - NO_x instrument (**FRM**); **cost: ~\$11,000**
 - Time resolution: 1-min
 - GRIMM (**FEM PM_{2.5}**); **cost: \$25,000 and up**
 - Time resolution: 1-min
 - 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 AQY v1.0

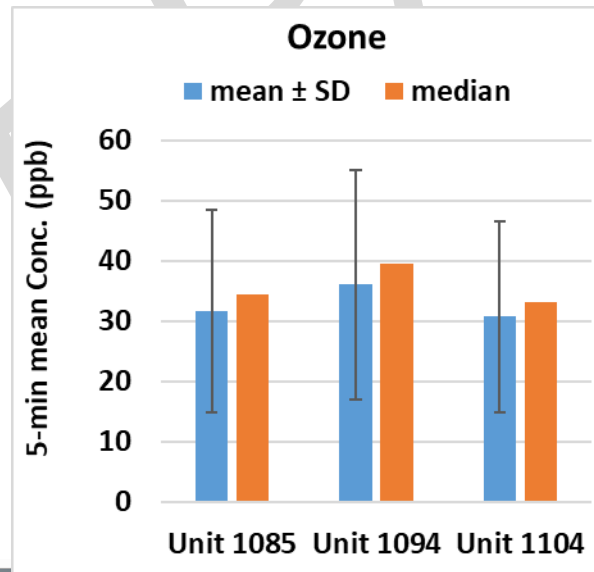
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Data validation & recovery

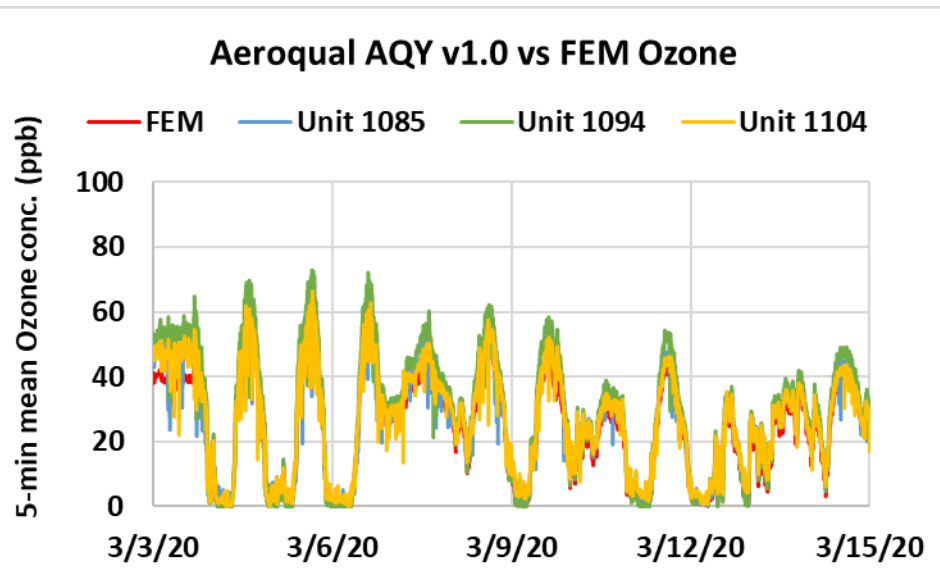
- Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
- Data recovery for ozone from all units was ~ 100%

Aeroqual AQY v1.0; Intra-model variability

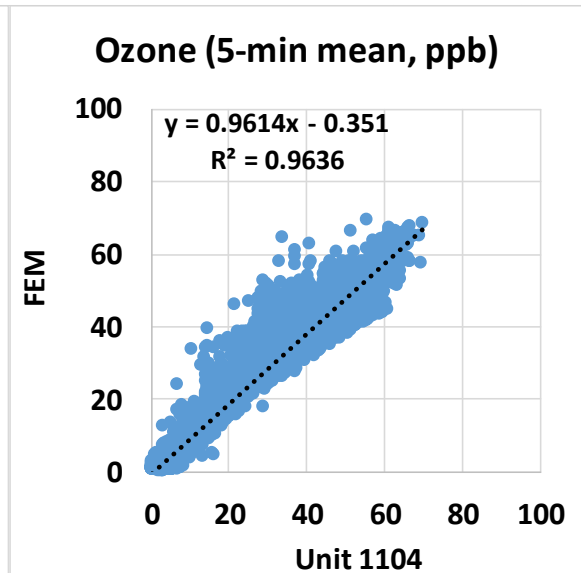
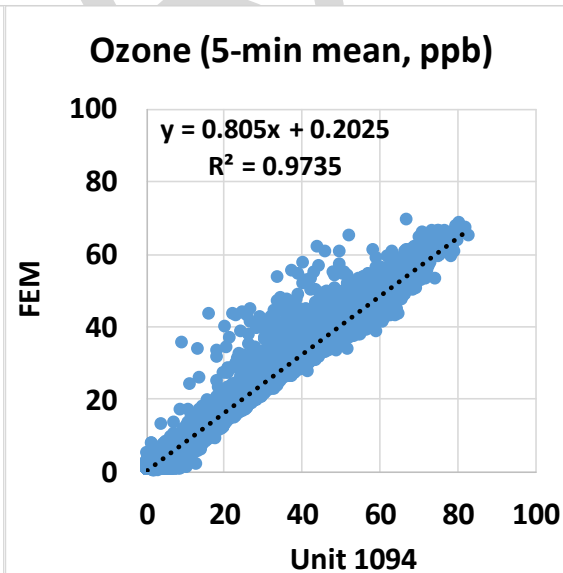
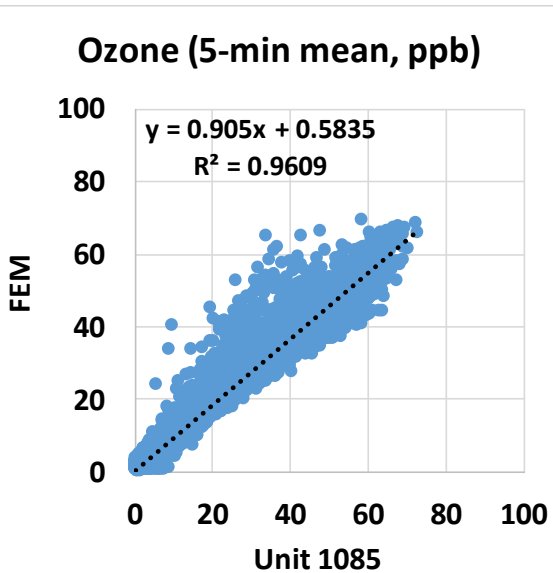
- Absolute intra-model variability was ~ 2.9 ppb for the ozone measurements (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 8.7% for the ozone measurements (calculated as the absolute intra-model variability relative to the mean of the three sensor means)



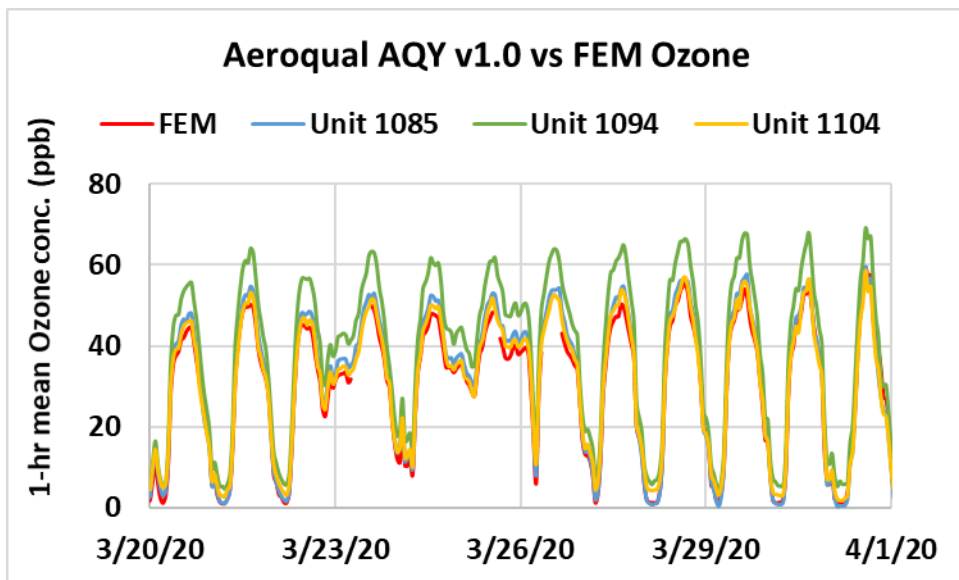
Aeroqual AQY v1.0 vs FEM (Ozone; 5-min mean)



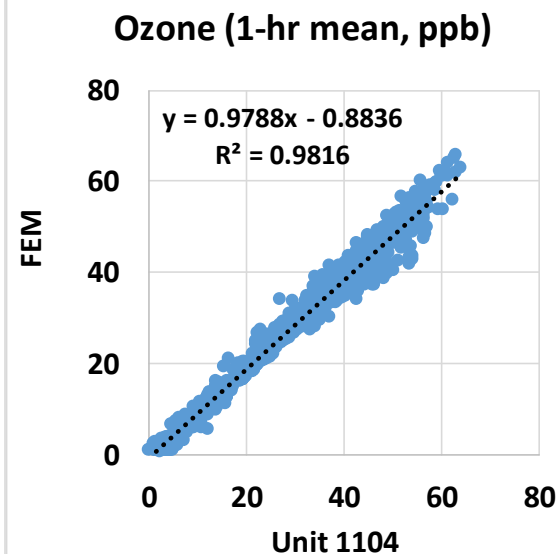
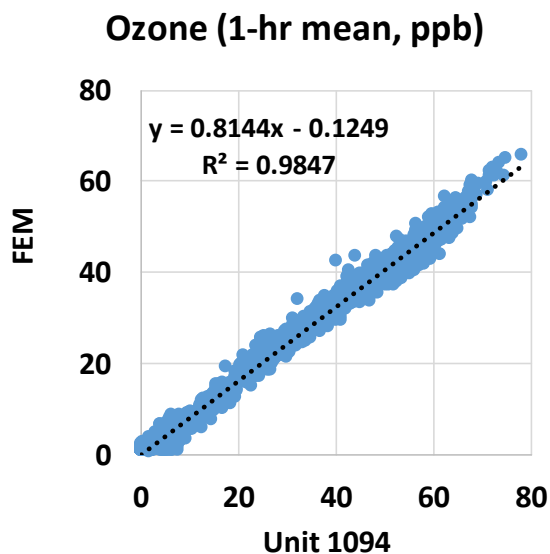
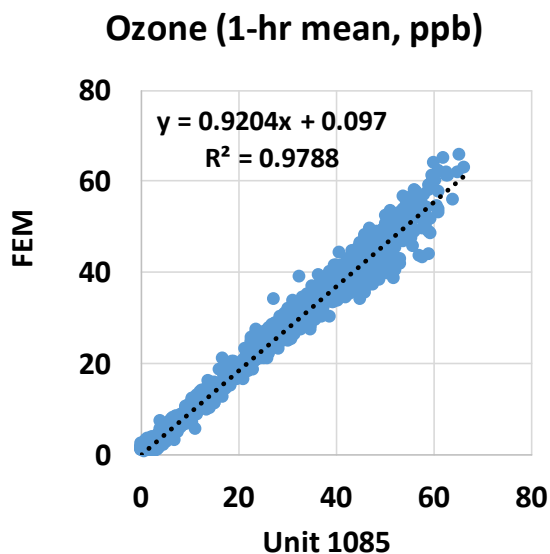
- Aeroqual AQY v1.0 sensors showed very strong correlations with the corresponding FEM ozone data ($R^2 \sim 0.96$)
- Overall, the Aeroqual AQY v1.0 sensors overestimated the ozone concentration as measured by the FEM ozone instrument
- The Aeroqual AQY v1.0 sensors seemed to track the diurnal ozone variations as recorded by the FEM instrument



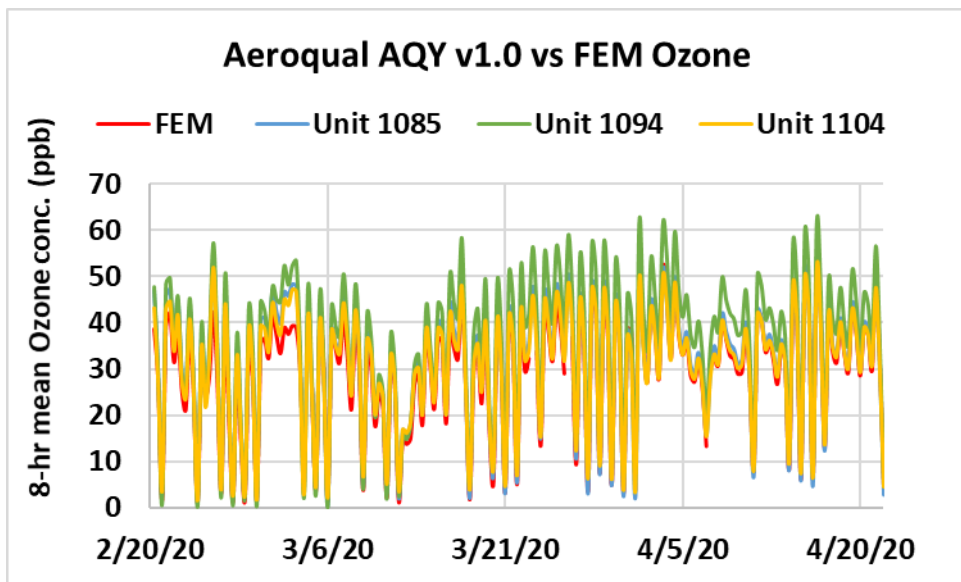
Aeroqual AQY v1.0 vs FEM (Ozone; 1-hr mean)



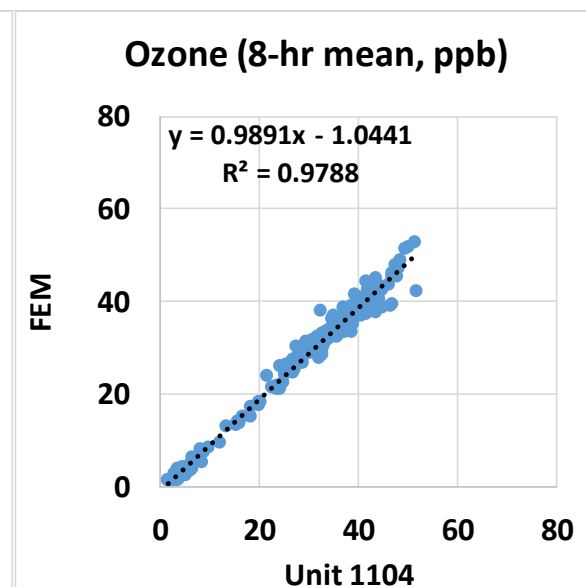
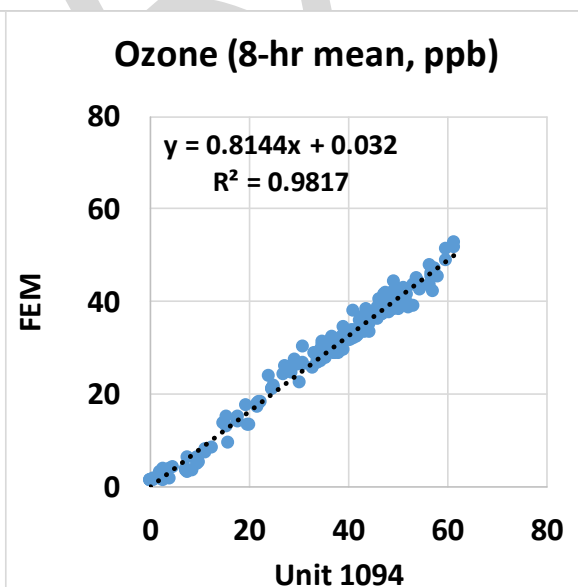
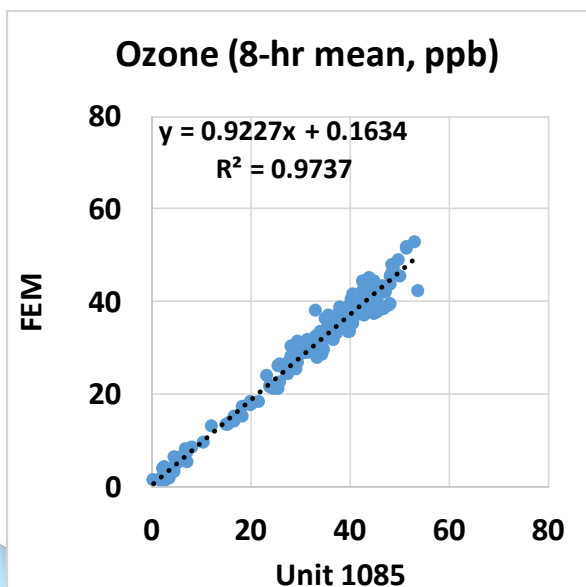
- Aeroqual AQY v1.0 sensors showed very strong correlations with the corresponding FEM ozone data ($R^2 \sim 0.98$)
- Overall, the Aeroqual AQY v1.0 sensors overestimated the ozone concentration as measured by the FEM instrument
- The Aeroqual AQY v1.0 sensors seemed to track the diurnal ozone variations as recorded by the FEM instrument



Aeroqual AQY v1.0 vs FEM (Ozone; 8-hr mean)



- Aeroqual AQY v1.0 sensors showed very strong correlations with the corresponding FEM ozone data ($R^2 \sim 0.98$)
- Overall, the Aeroqual AQY v1.0 sensors overestimated the ozone concentration as measured by the FEM instrument
- The Aeroqual AQY v1.0 sensors seemed to track the diurnal ozone variations as recorded by the FEM instrument



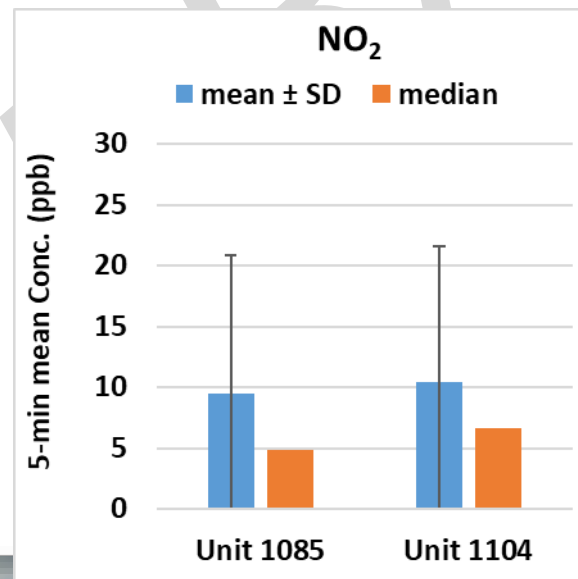
Nitrogen Dioxide (NO₂) in AQY v1.0

Data validation & recovery

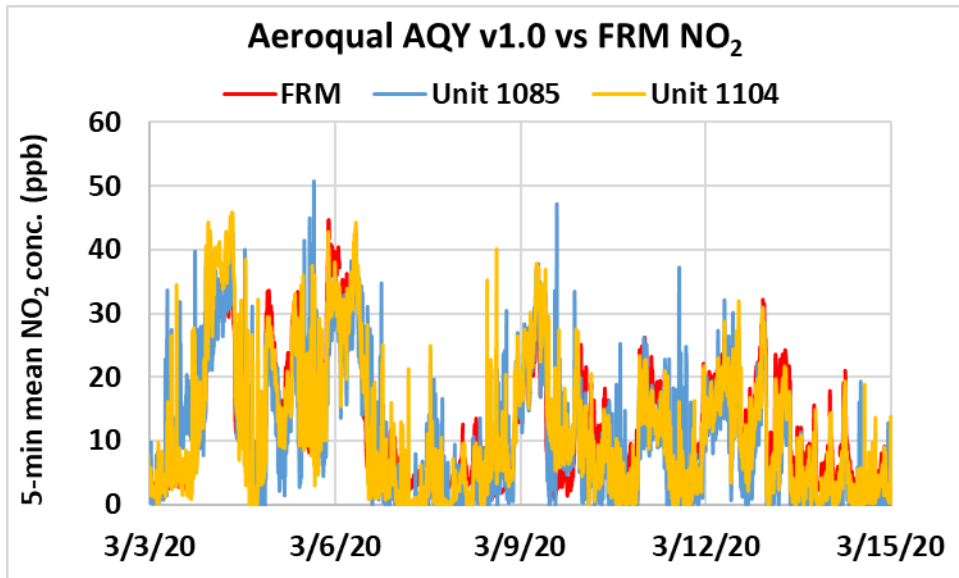
- Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
- Data recovery for NO₂ from Unit 1085 and Unit 1104 is ~ 100%. Due to a Factory calibration error in the Ox sensor in Unit 1094, the NO₂ data from Unit 1094 was **not included** in this evaluation

Aeroqual AQY v1.0; Intra-model variability

- Absolute intra-model variability was ~ 0.7 ppb for the NO₂ measurements (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 6.7% for the NO₂ measurements (calculated as the absolute intra-model variability relative to the mean of the three sensor means)

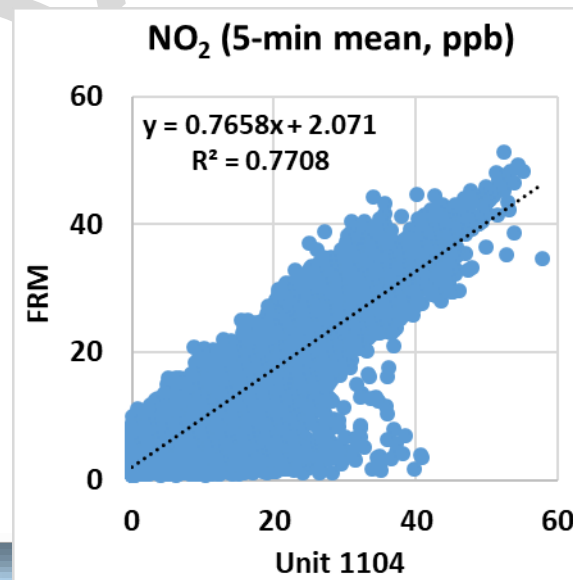
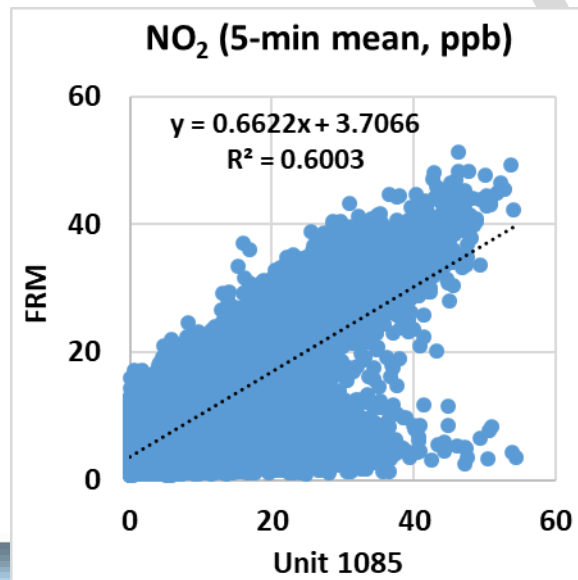


Aeroqual AQY v1.0 vs FRM (NO₂; 5-min mean)

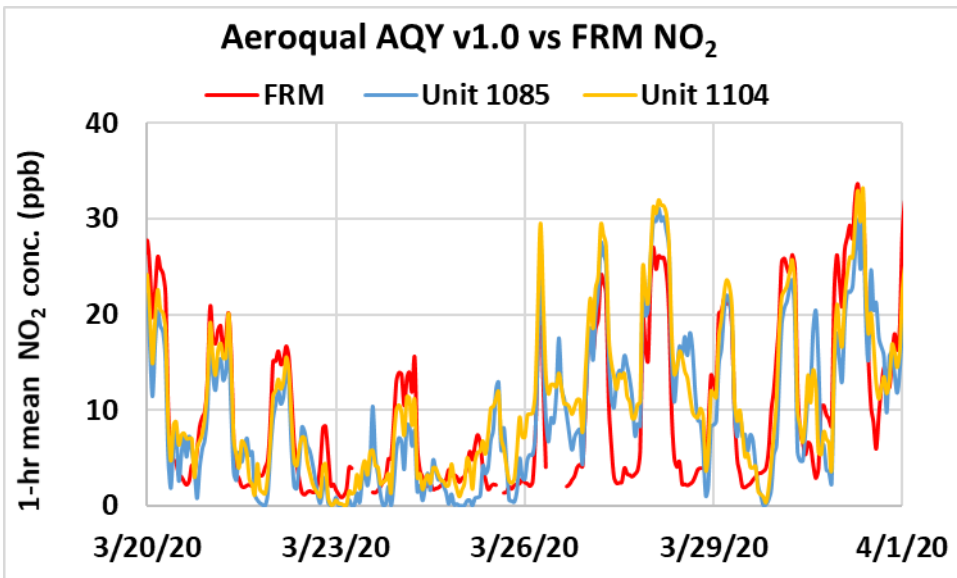


- Aeroqual AQY v1.0 sensors showed moderate to strong correlations with the corresponding FRM NO₂ data ($0.60 < R^2 < 0.78$)
- Overall, the Aeroqual AQY v1.0 sensors overestimated the NO₂ concentration as measured by the FRM instrument
- The Aeroqual AQY v1.0 sensors seemed to track the diurnal NO₂ variations as recorded by the FRM instrument

Note: Unit 1094 was excluded from the NO₂ evaluation due to an Ox sensor error

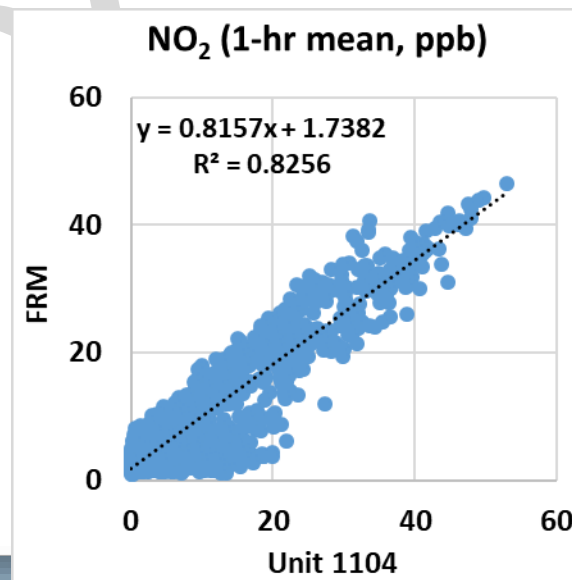
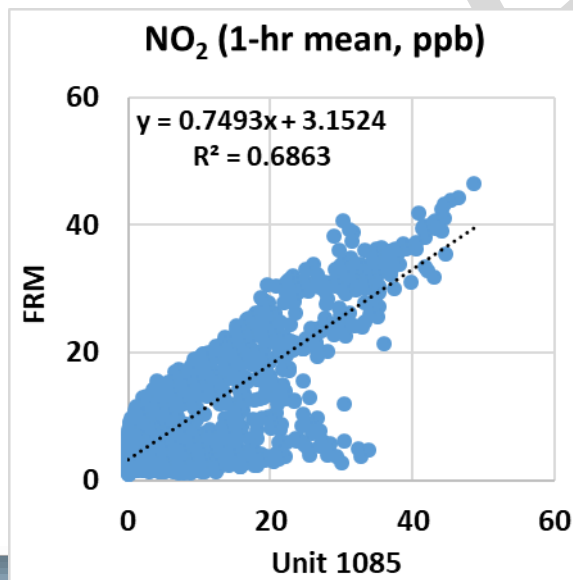


Aeroqual AQY v1.0 vs FRM (NO₂; 1-hr mean)

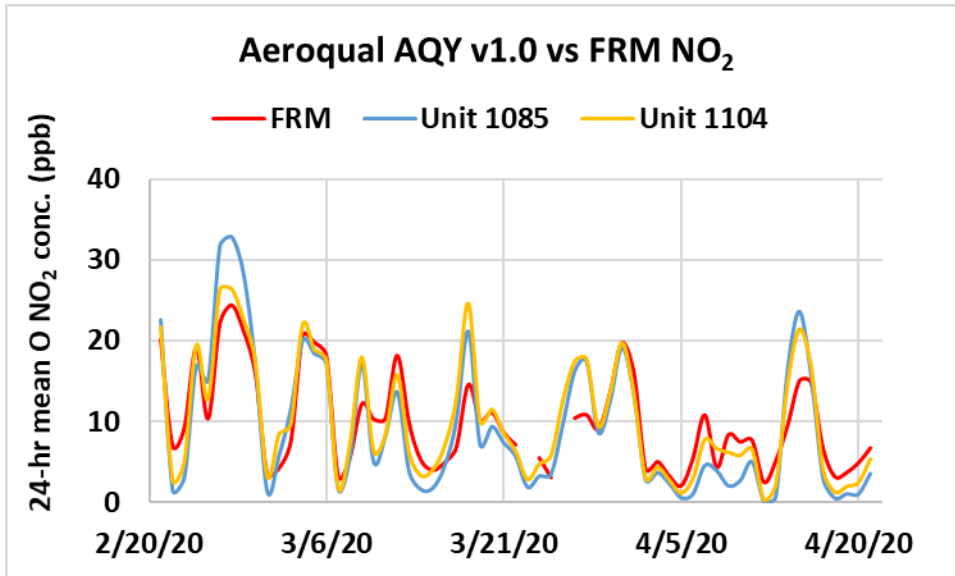


- Aeroqual AQY v1.0 sensors showed moderate to strong correlations with the corresponding FRM data ($0.68 < R^2 < 0.83$)
- Overall, the Aeroqual AQY v1.0 sensors overestimated the NO₂ concentration as measured by the FRM instrument
- The Aeroqual AQY v1.0 sensors seemed to track the diurnal NO₂ variations as recorded by the FRM instrument

Note: Unit 1094 was excluded from the NO₂ evaluation due to an Ox sensor error

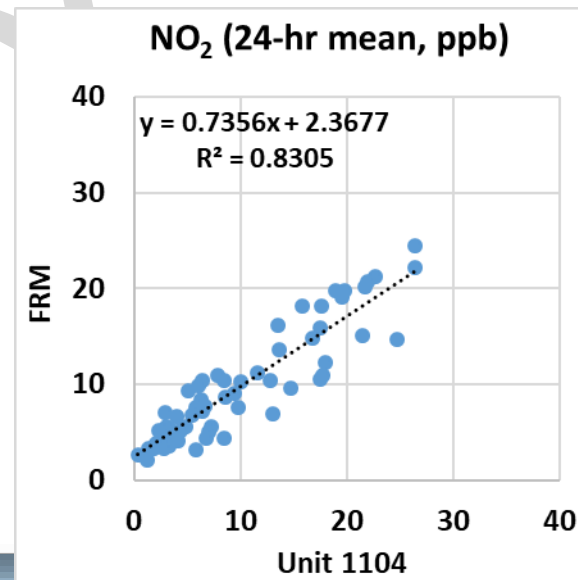
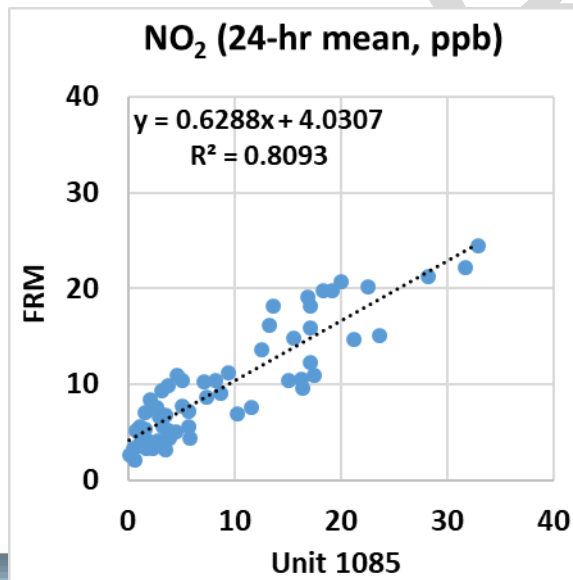


Aeroqual AQY V1.0 vs FRM (NO₂; 24-hr mean)



- Aeroqual AQY v1.0 sensors showed moderate to strong correlations with the corresponding FRM data ($0.80 < R^2 < 0.84$)
- Overall, the Aeroqual AQY v1.0 sensors overestimated the NO₂ concentration as measured by the FRM instrument
- The Aeroqual AQY v1.0 sensors seemed to track the diurnal NO₂ variations as recorded by the FRM instrument

Note: Unit 1094 was excluded from the NO₂ evaluation due to an Ox sensor error



PM_{2.5} in AQY v1.0

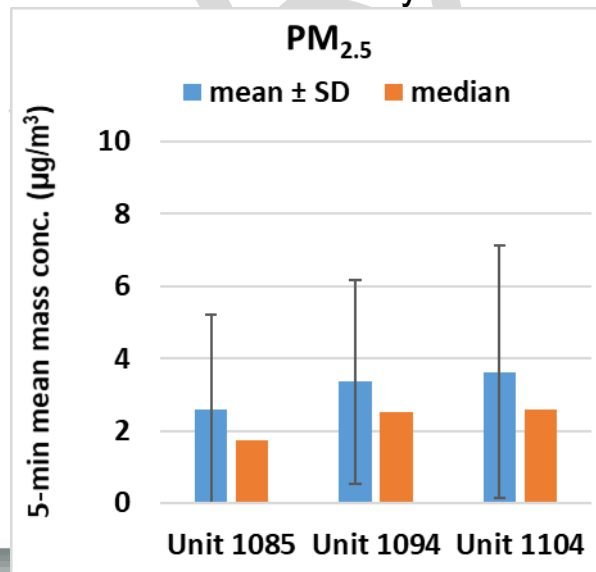
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Data validation & recovery

- 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)
- AQY PM_{2.5} was corrected based on AQY RH data in real-time
- Data recovery for PM_{2.5} from all units was ~ 100%

Aeroqual AQY v1.0; Intra-model variability

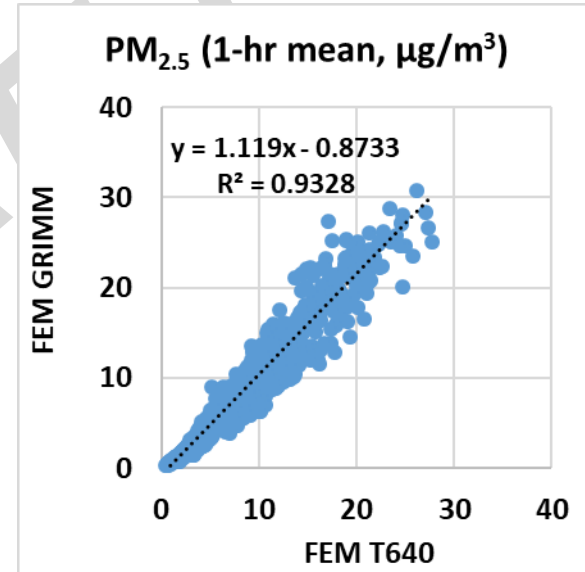
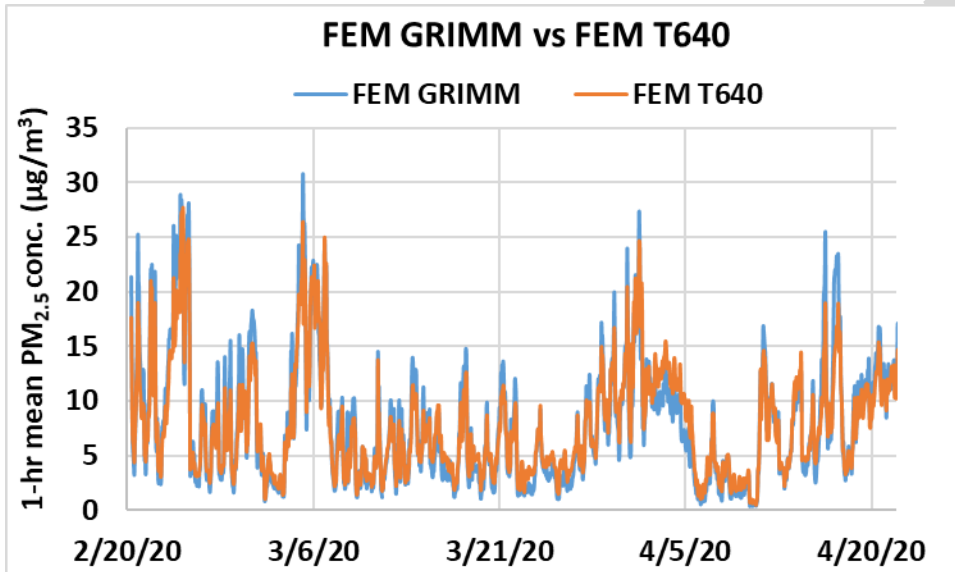
- Absolute intra-model variability was ~ 0.76 $\mu\text{g}/\text{m}^3$ for the PM_{2.5} measurements (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 17.1% for the PM_{2.5} measurements (calculated as the absolute intra-model variability relative to the mean of the three sensor means)



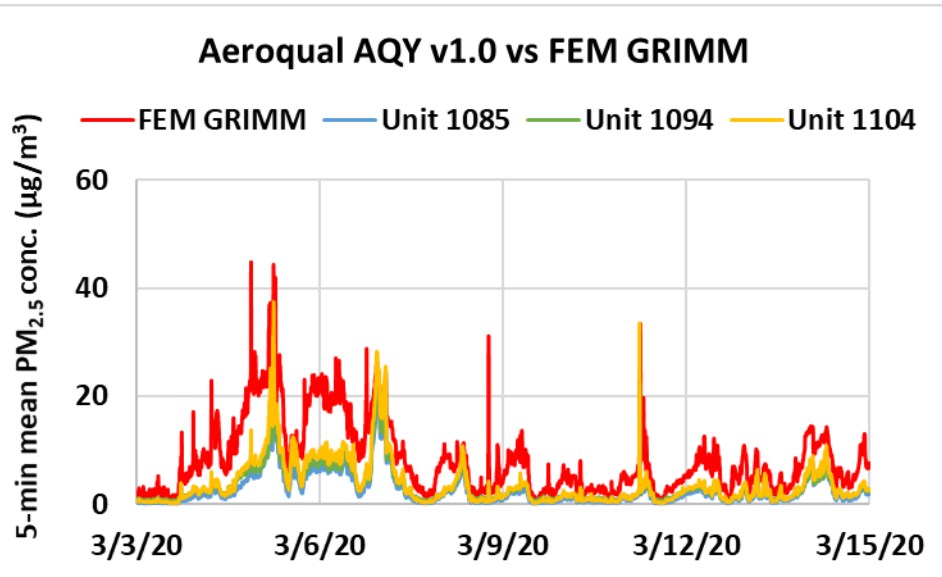
Reference Instruments: PM_{2.5}

FEM GRIMM & FEM T640

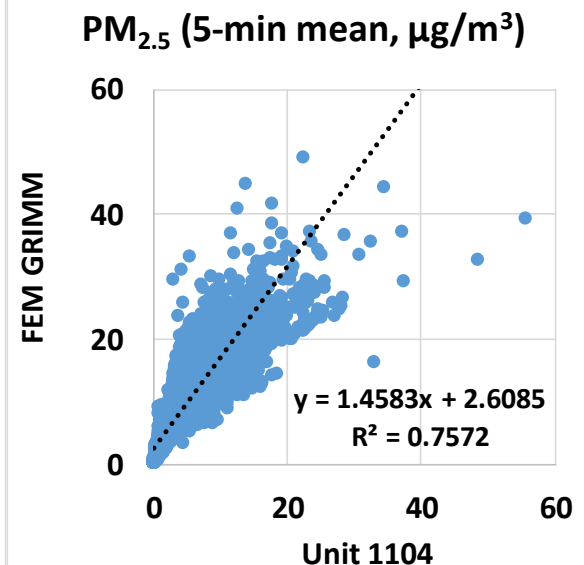
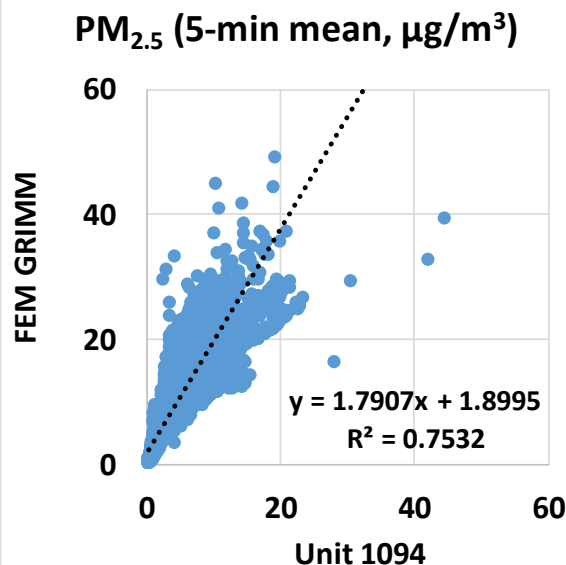
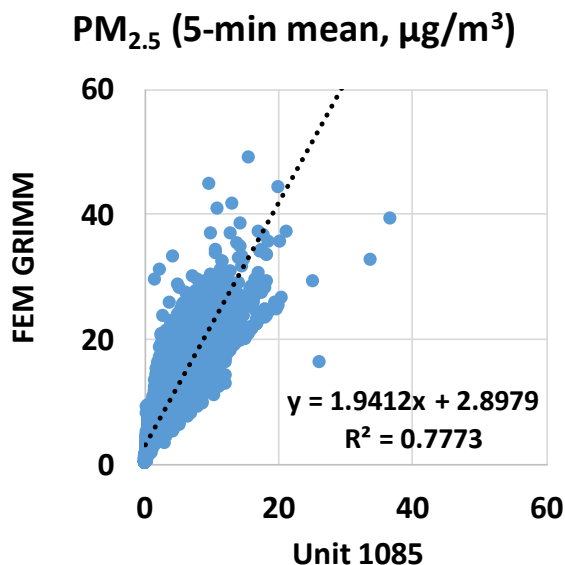
- Basic QA/QC procedures were used to validate the collected data (i.e. obvious outliers, negative values and invalid data-points were eliminated from the data-set)
- Data recovery for PM_{2.5} from FEM GRIMM and FEM T640 is ~100%
- Very strong correlations between FEM GRIMM and FEM T640 for PM_{2.5} measurements ($R^2 \sim 0.93$)



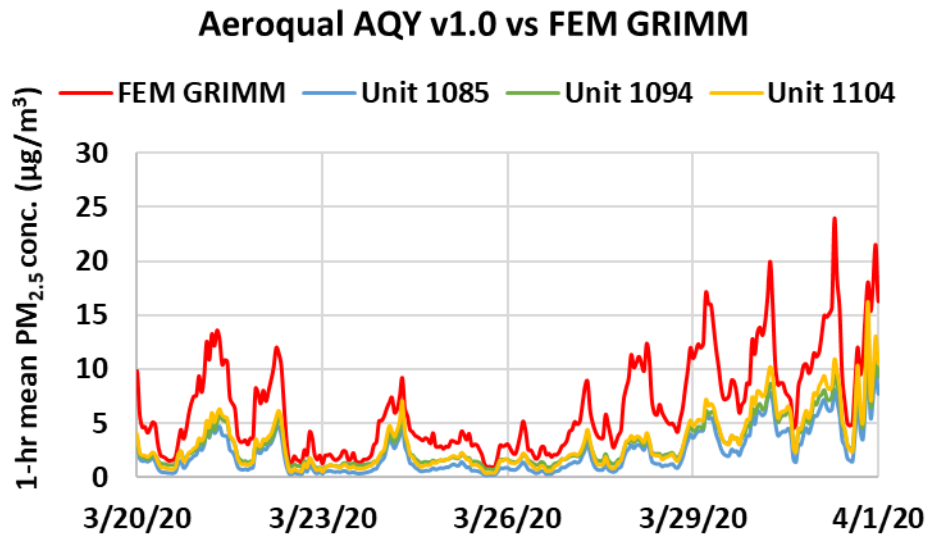
Aeroqual AQY v1.0 vs FEM GRIMM (PM_{2.5}; 5-min mean)



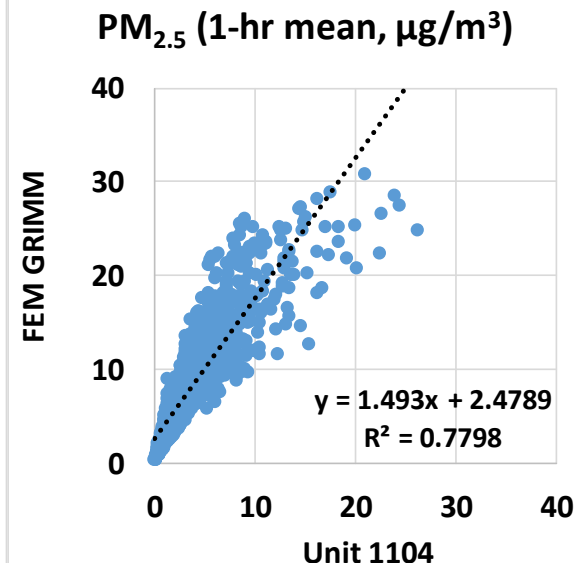
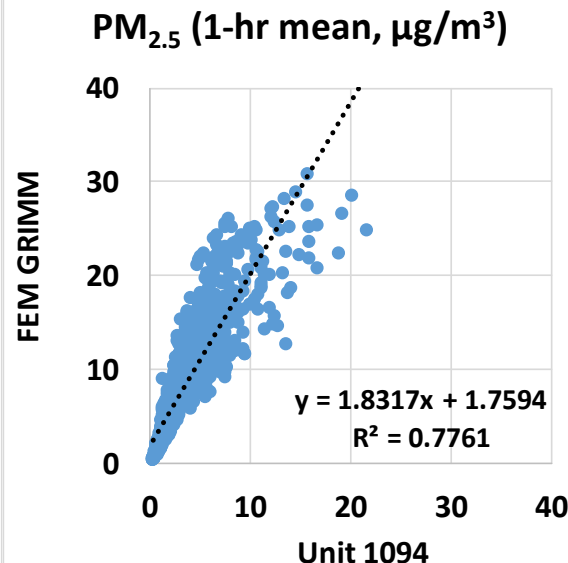
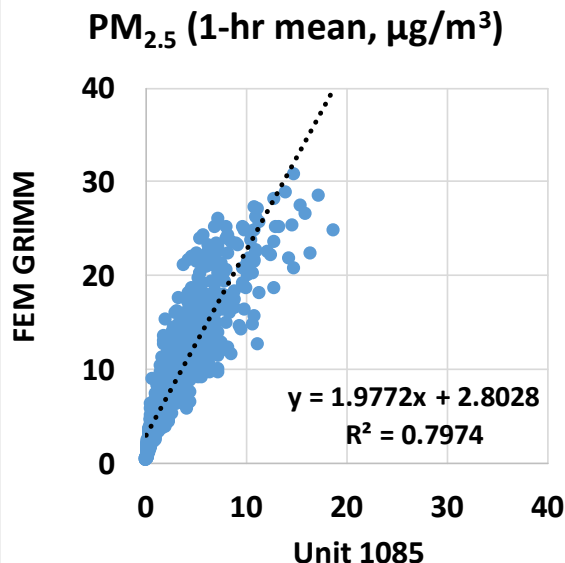
- Aeroqual AQY v1.0 sensors showed strong correlations with the corresponding FEM GRIMM data ($R^2 \sim 0.76$)
- Overall, the Aeroqual AQY v1.0 sensors underestimated the PM_{2.5} mass concentration as measured by the FEM GRIMM
- The Aeroqual AQY v1.0 sensors seemed to track the diurnal PM_{2.5} variations as recorded by the FEM GRIMM



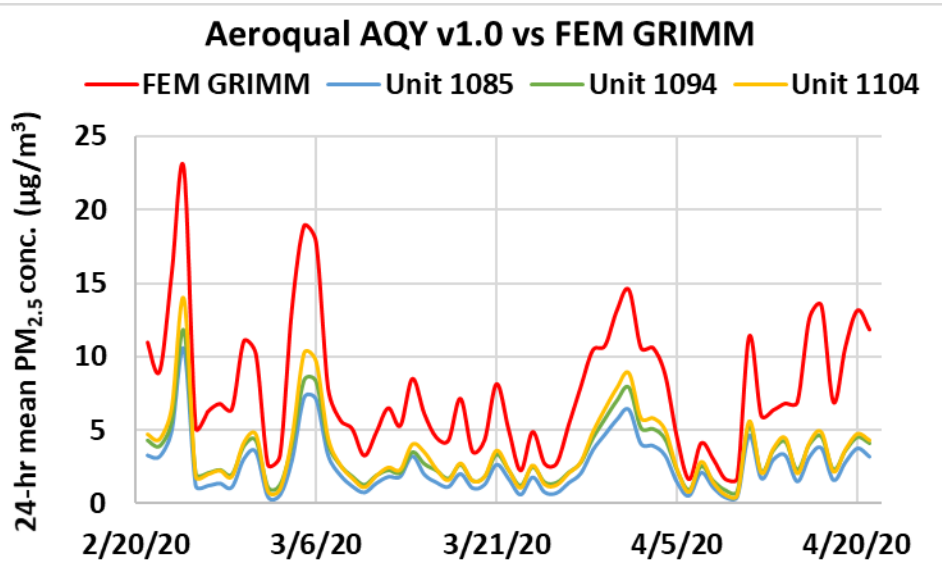
Aeroqual AQY v1.0 vs FEM GRIMM (PM_{2.5}; 1-hr mean)



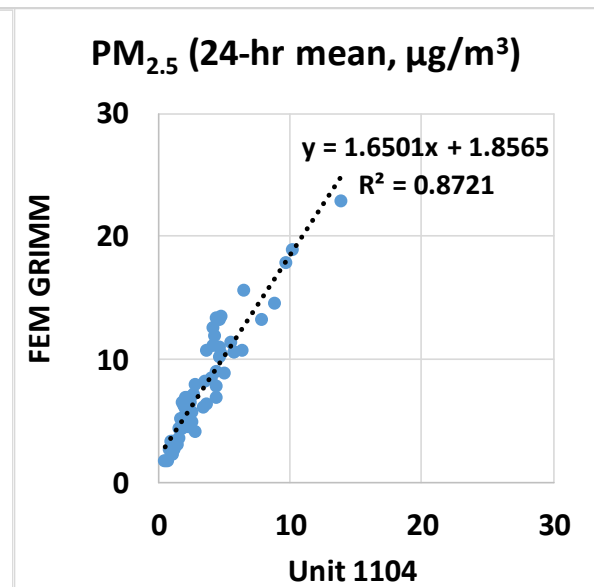
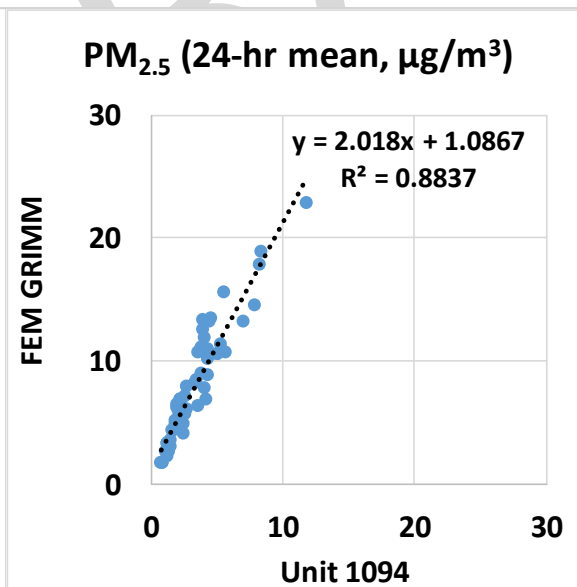
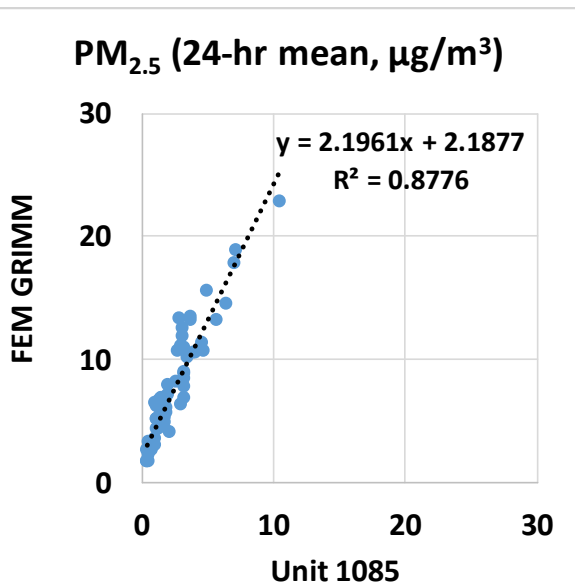
- Aeroqual AQY v1.0 sensors showed strong correlations with the corresponding FEM GRIMM data ($R^2 \sim 0.78$)
- Overall, the Aeroqual AQY v1.0 sensors underestimated the PM_{2.5} mass concentration as measured by the FEM GRIMM
- The Aeroqual AQY v1.0 sensors seemed to track the diurnal PM_{2.5} variations as recorded by the FEM GRIMM



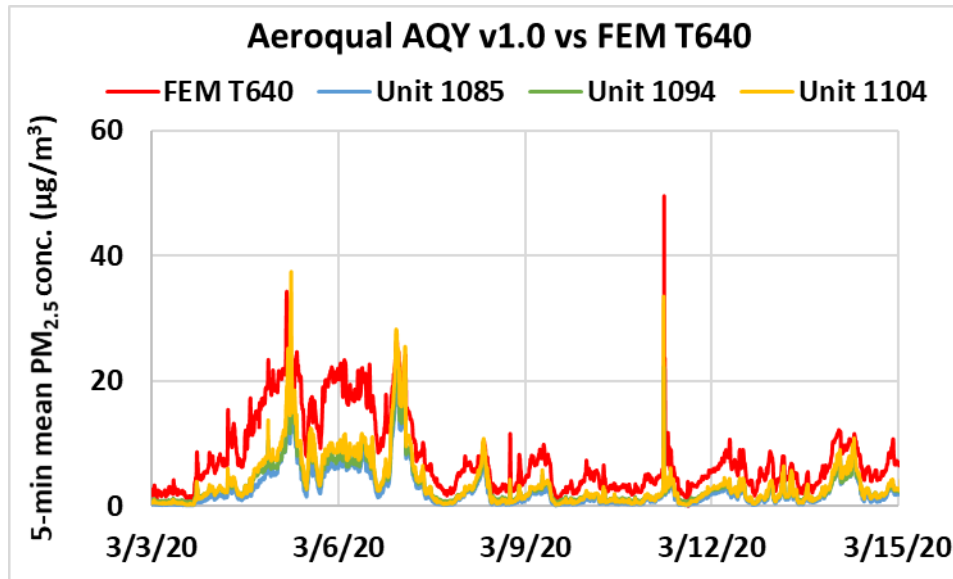
Aeroqual AQY v1.0 vs FEM GRIMM (PM_{2.5}; 24-hr mean)



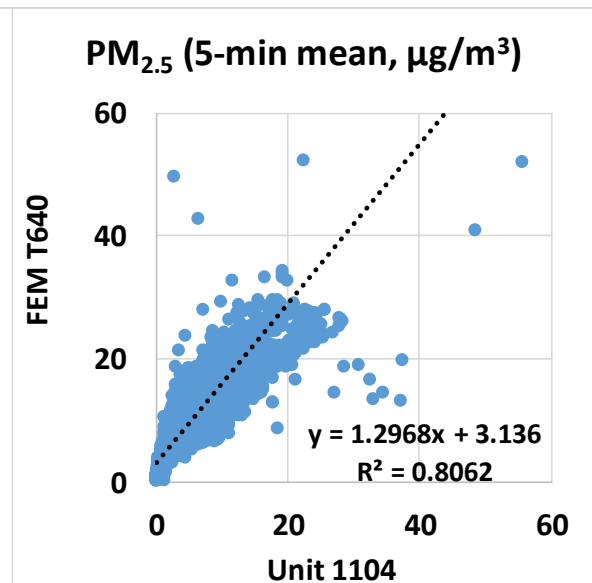
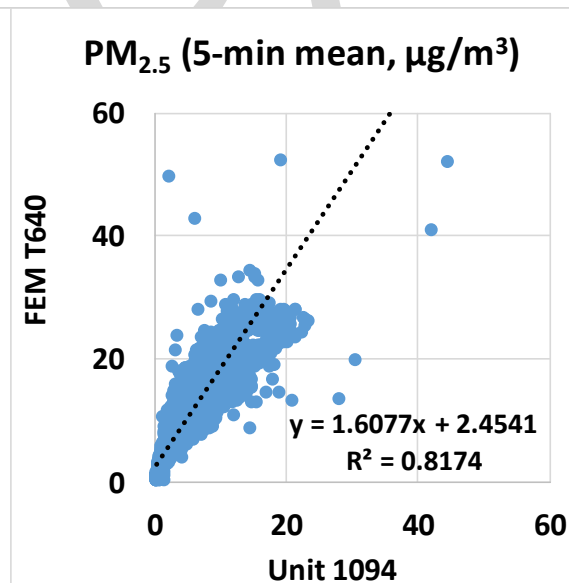
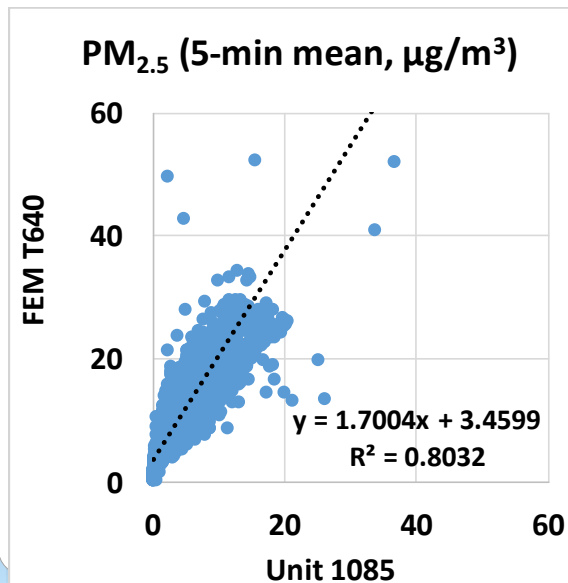
- Aeroqual AQY v1.0 sensors showed strong correlations with the corresponding FEM GRIMM data ($R^2 \sim 0.88$)
- Overall, the Aeroqual AQY v1.0 sensors underestimated the PM_{2.5} mass concentration as measured by the FEM GRIMM
- The Aeroqual AQY v1.0 sensors seemed to track the diurnal PM_{2.5} variations as recorded by the FEM GRIMM



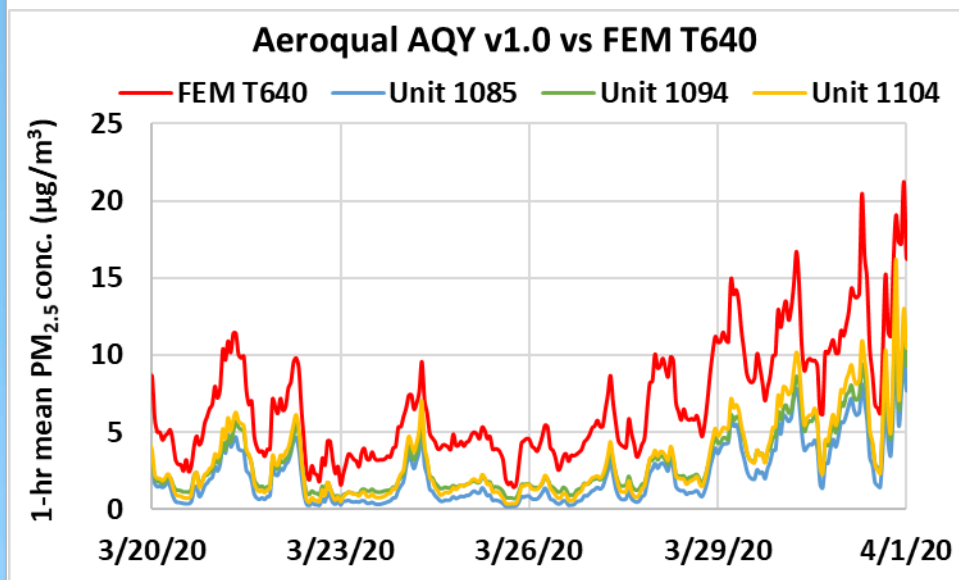
Aeroqual AQY v1.0 vs FEM T640 (PM_{2.5}; 5-min mean)



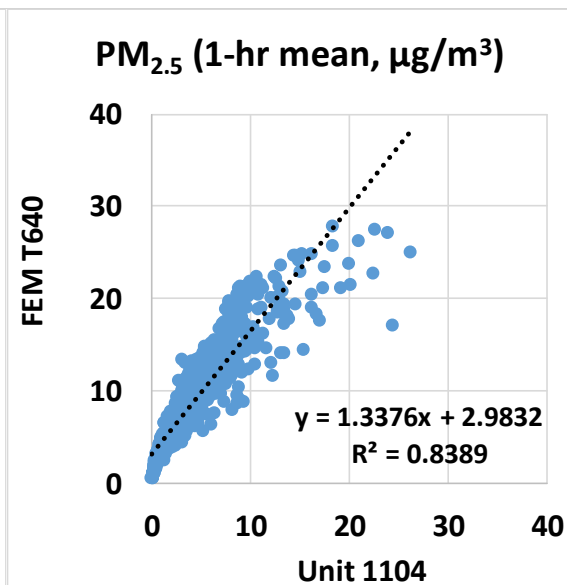
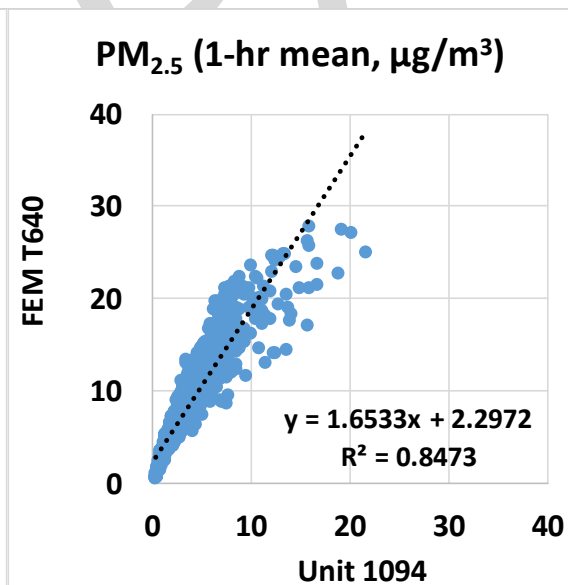
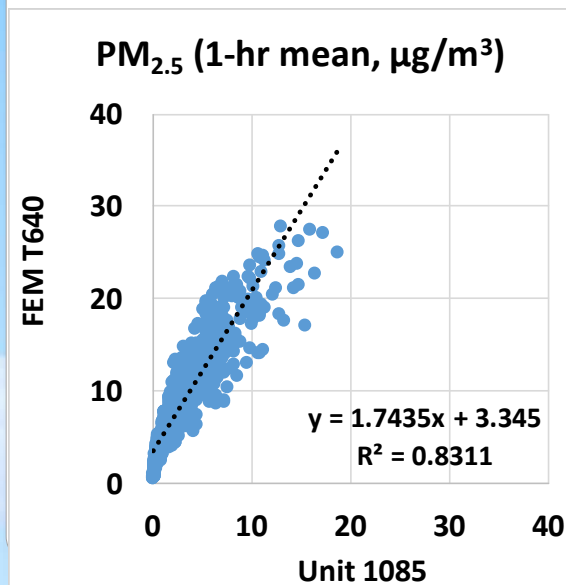
- Aeroqual AQY v1.0 sensors showed strong correlations with the corresponding FEM T640 data ($R^2 \sim 0.81$)
- Overall, the Aeroqual AQY v1.0 sensors underestimated the PM_{2.5} mass concentration as measured by the FEM T640
- The Aeroqual AQY v1.0 sensors seemed to track the diurnal PM_{2.5} variations as recorded by the FEM T640



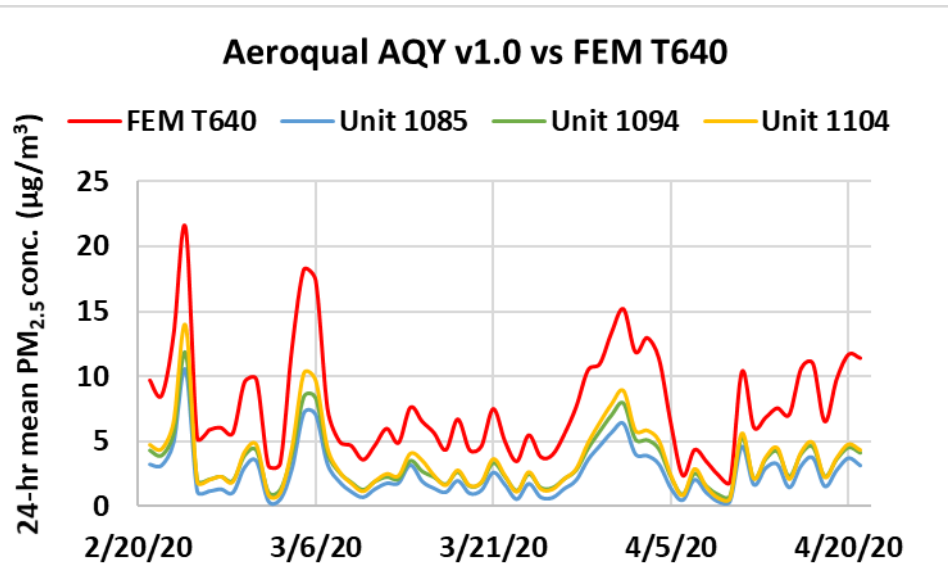
Aeroqual AQY v1.0 vs FEM T640 (PM_{2.5}; 1-hr mean)



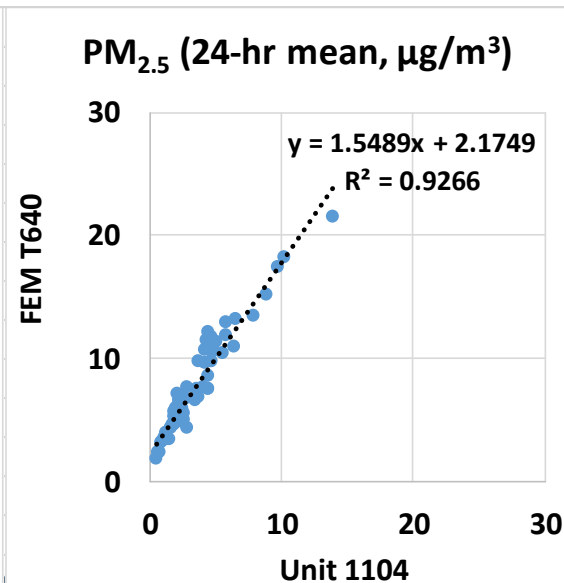
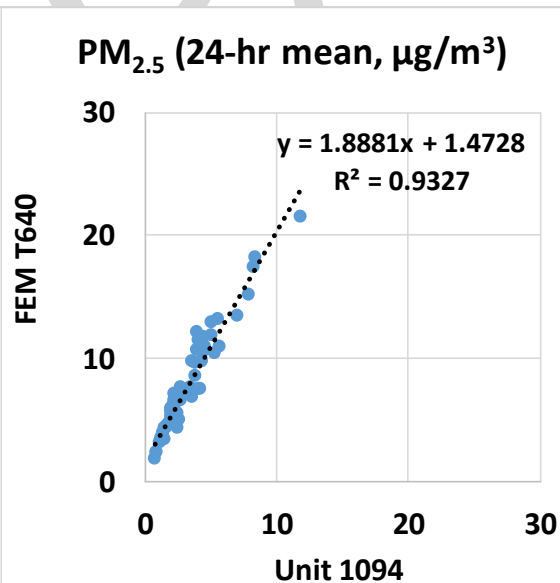
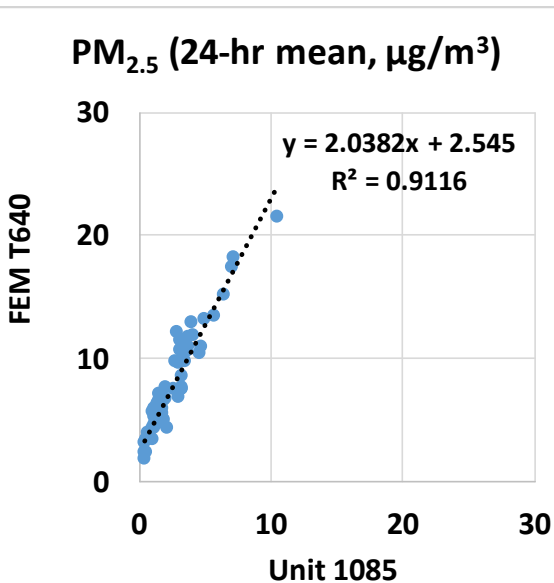
- Aeroqual AQY v1.0 sensors showed strong correlations with the corresponding FEM T640 data ($R^2 \sim 0.84$)
- Overall, the Aeroqual AQY v1.0 sensors underestimated the PM_{2.5} mass concentration as measured by the FEM T640
- The Aeroqual AQY v1.0 sensors seemed to track the diurnal PM_{2.5} variations as recorded by the FEM T640



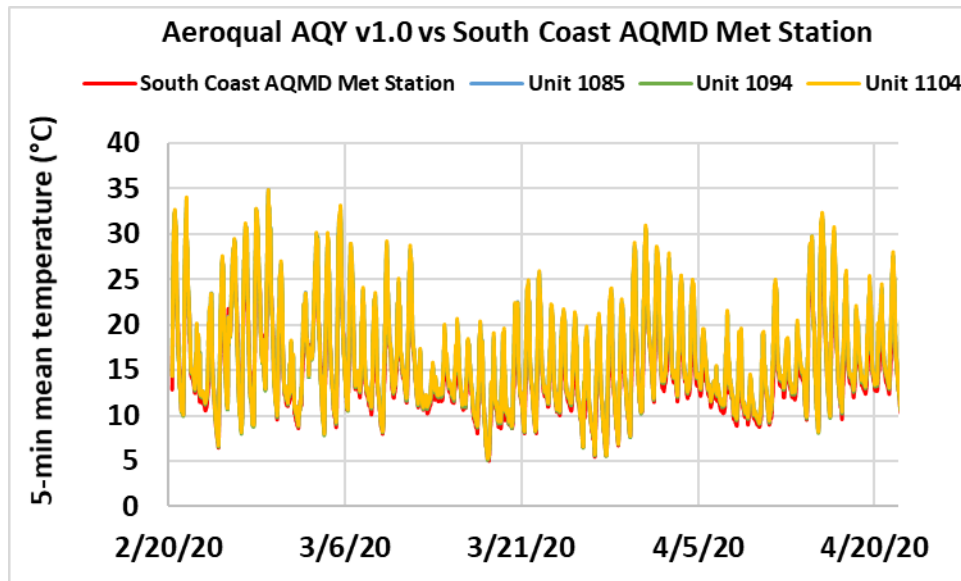
Aeroqual AQY v1.0 vs FEM T640 (PM_{2.5}; 24-hr mean)



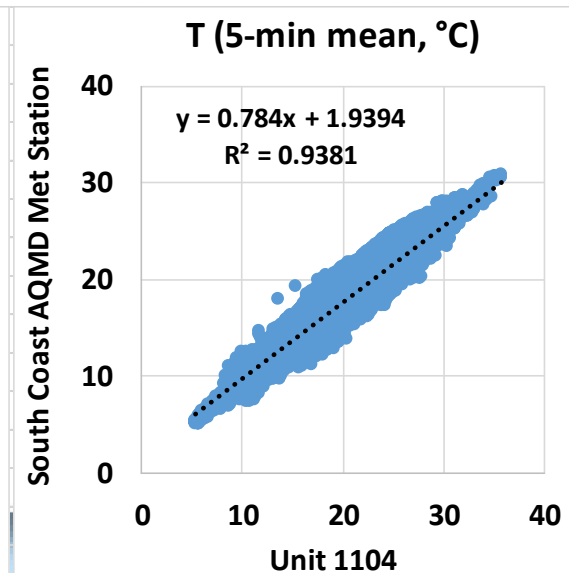
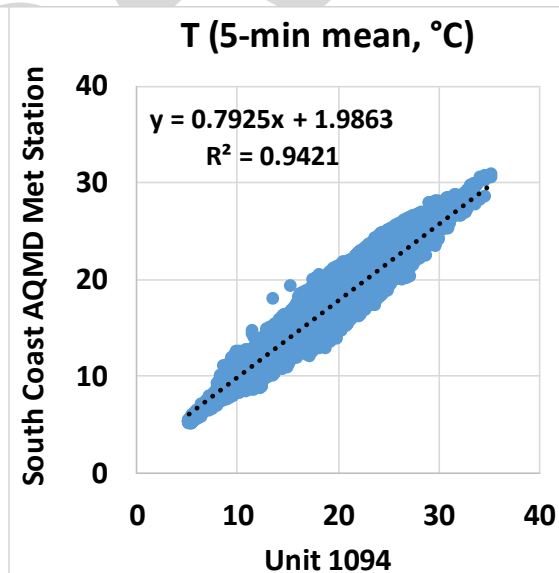
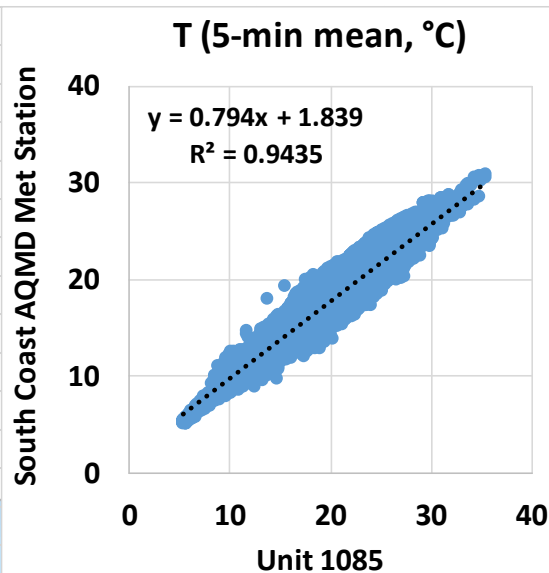
- Aeroqual AQY v1.0 sensors showed very strong correlations with the corresponding FEM T640 data ($R^2 \sim 0.92$)
- Overall, the Aeroqual AQY v1.0 sensors underestimated the PM_{2.5} mass concentration as measured by the FEM T640
- The Aeroqual AQY v1.0 sensors seemed to track the diurnal PM_{2.5} variations as recorded by the FEM T640



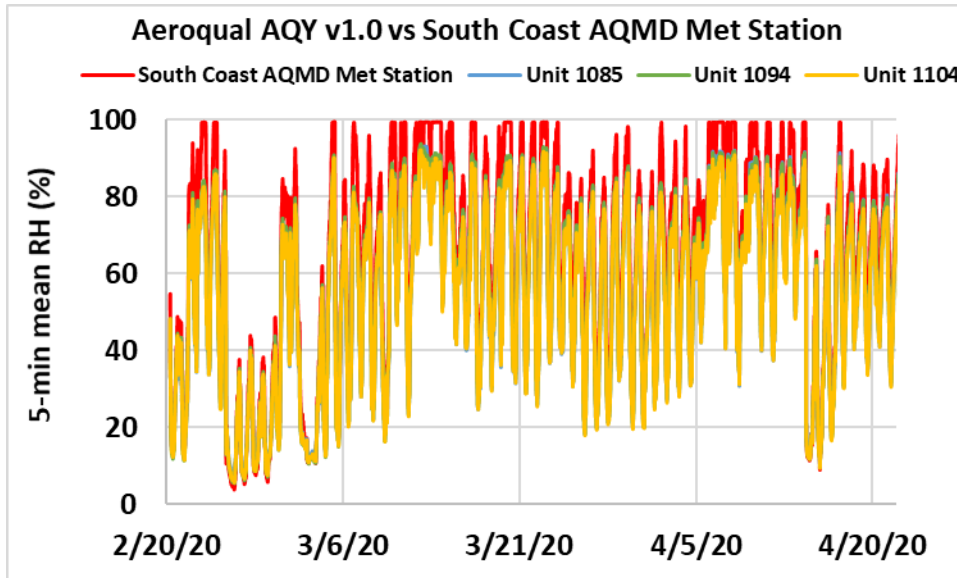
Aeroqual AQY v1.0 vs South Coast AQMD Met Station (Temp; 5-min mean)



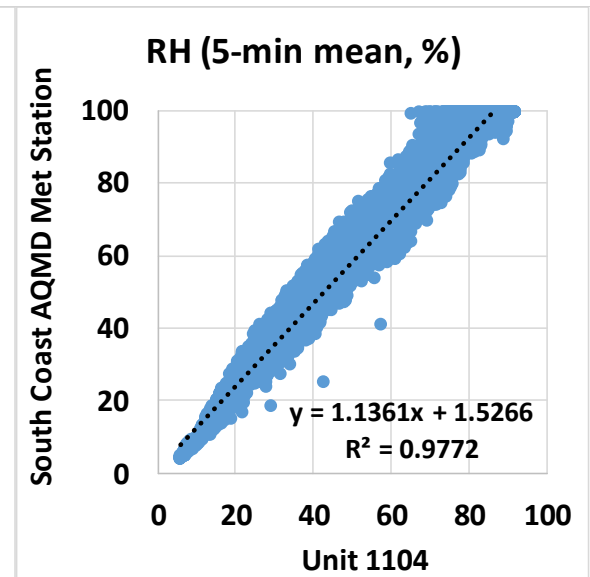
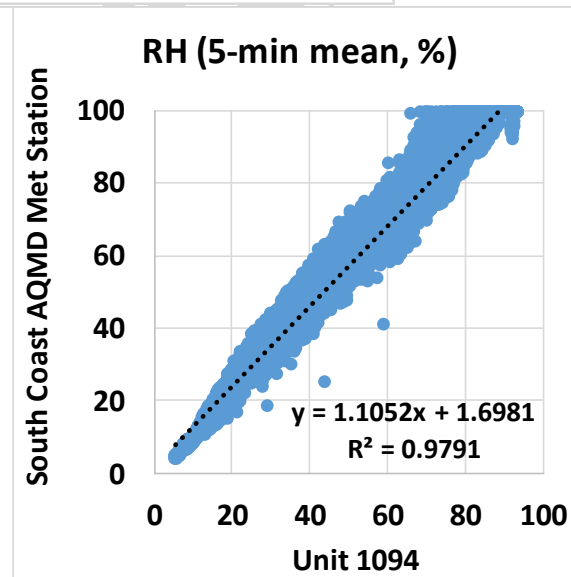
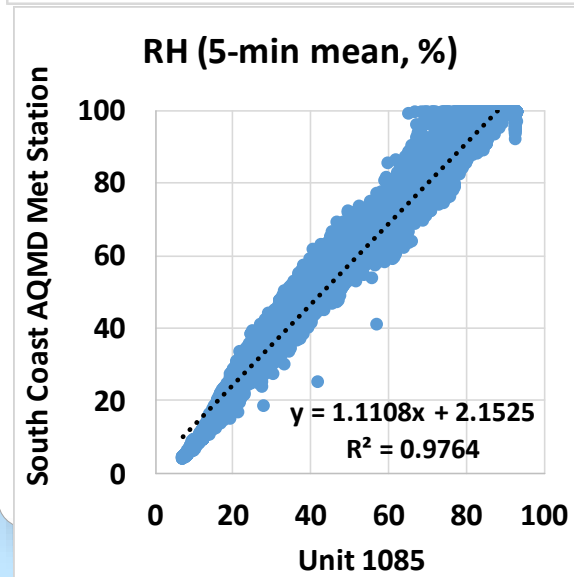
- Aeroqual AQY v1.0 sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.94$)
- Overall, the Aeroqual AQY v1.0 sensors overestimated the temperature measurement as recorded by South Coast AQMD Met Station
- The Aeroqual AQY v1.0 sensors seemed to track the diurnal temperature variations as recorded by South Coast AQMD Met Station



Aeroqual AQY v1.0 vs South Coast AQMD Met Station (RH; 5-min mean)



- Aeroqual AQY v1.0 sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.98$)
- Overall, the Aeroqual AQY v1.0 sensors underestimated the RH measurement as recorded by South Coast AQMD Met Station
- The Aeroqual AQY v1.0 sensors seemed to track the diurnal RH variations as recorded by South Coast AQMD Met Station



Discussion

- The three **Aeroqual AQY v1.0** sensors' data recovery for ozone, NO₂ and PM_{2.5} was ~ 100%; except for the NO₂ measurement from Unit 1094 which was not included in the evaluation
- The absolute intra-model variability was 2.9 ppb, 0.7 ppb and 0.76 µg/m³ for ozone, NO₂ and PM_{2.5}, respectively
- The reference instruments (FEM GRIMM and FEM T640) show very strong correlations with each other for PM_{2.5} mass concentration measurements ($R^2 \sim 0.93$, 1-hr mean)
- During the entire field deployment testing period:
 - Ozone sensors showed very strong correlations with the FEM instrument ($R^2 \sim 0.96$, 5-min mean) and overestimated the corresponding FEM data
 - NO₂ sensors showed moderate to strong correlations with the FRM instrument ($0.60 < R^2 < 0.78$, 5-min mean) and overestimated the corresponding FRM data
 - PM_{2.5} sensors showed strong correlations with the FEM instrument ($R^2 \sim 0.78$ and 0.84 for FEM GRIMM and FEM T640, respectively, 1-hr mean) and underestimated the corresponding FEM data
 - Temperature and relative humidity sensors showed very strong correlations with the South Coast AQMD Met Station data (T: $R^2 \sim 0.94$ and RH: $R^2 \sim 0.98$) 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.
- These results are still preliminary