Field Evaluation
AQMesh v3.0 - PM

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 04/11/2020 to 06/18/2020[1], three **AQMesh v3.0** (**hereinafter AQMesh**) multi-sensor pods were deployed at the South Coast AQMD stationary ambient monitoring site in Rubidoux and were run side-by-side with Federal Equivalent Method (FEM) instruments measuring the same pollutants
- AQMesh (*3 units tested*):
  - Gas Sensors (evaluated in 2021):
    CO – Electrochemical (Alphasense, non-FEM)
    O_3 – Electrochemical (Alphasense, non-FEM)
    NO – Electrochemical (Alphasense, non-FEM)
    NO_2 – Electrochemical (Alphasense, non-FEM)
    SO_2 – Electrochemical (Alphasense, non-FEM)
  - PM Sensors – Optical Particle Counter (AQMesh OPC v3.0, non-FEM)
  - Each unit measures: CO (ppb), O_3 (ppb), NO, NO_2 and NO_x (ppb), SO_2 (ppb), **$PM_{1.0}$, $PM_{2.5}$ and PM_{10} ($\mu g/m^3$)**, T (°C), RH (%)
  - Unit cost: ~$7,800 as tested (includes 5 gas pods +
  - PM sensor, equipped with a heated inlet), price includes daily data downloads
  - Time resolution: 5-min
  - Units IDs: 0381, 0383, 0385
- South Coast AQMD Reference Instruments:
  - GRIMM (FEM $PM_{2.5}$); cost: $25,000 and up
    - Measures $PM_{1.0}$, $PM_{2.5}$ and PM_{10} ($\mu g/m^3$)
    - Time resolution: 1-min
  - Teledyne API T640 (FEM $PM_{2.5}$); cost: $21,000
    - Measures $PM_{2.5}$ and PM_{10} ($\mu g/m^3$)
    - Time resolution: 1-min
  - Met station (T, RH, P, WS, WD); cost: ~$5,000
    - Time resolution: 1-min

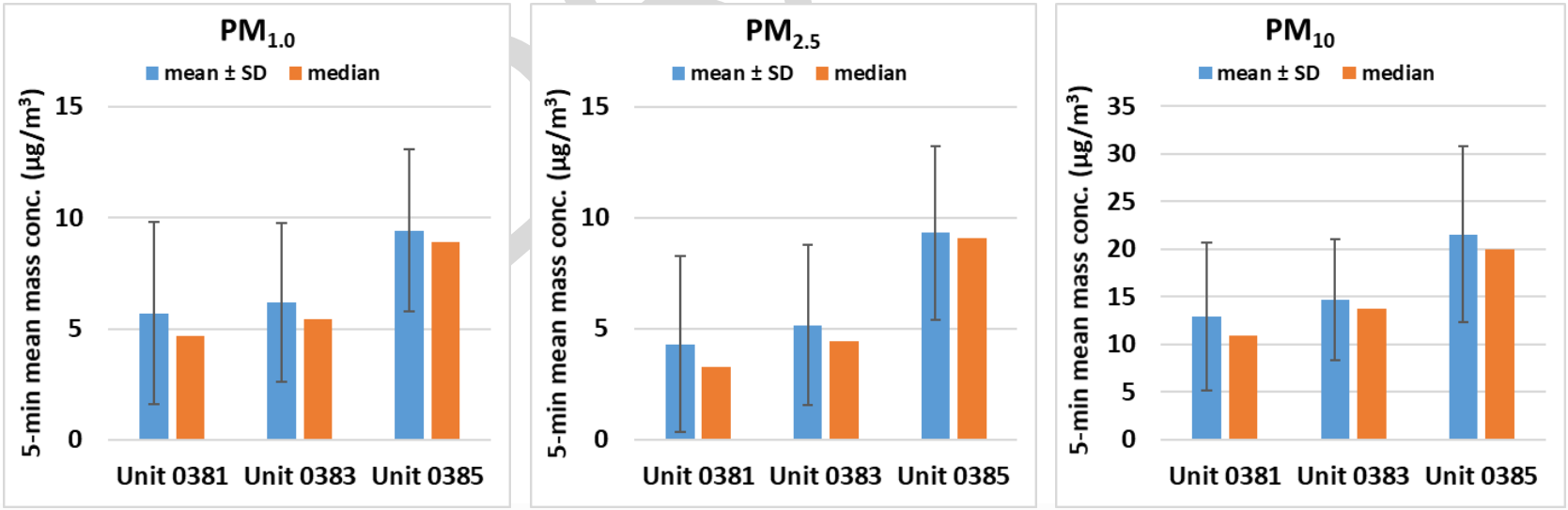
[1]*Note: sensor data were not available between 5/5/2020 and 5/14/2020 due to preventive maintenance activities at the monitoring site*

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 $PM_{1.0}$, $PM_{2.5}$ and PM_{10} from all units was ~ 100%

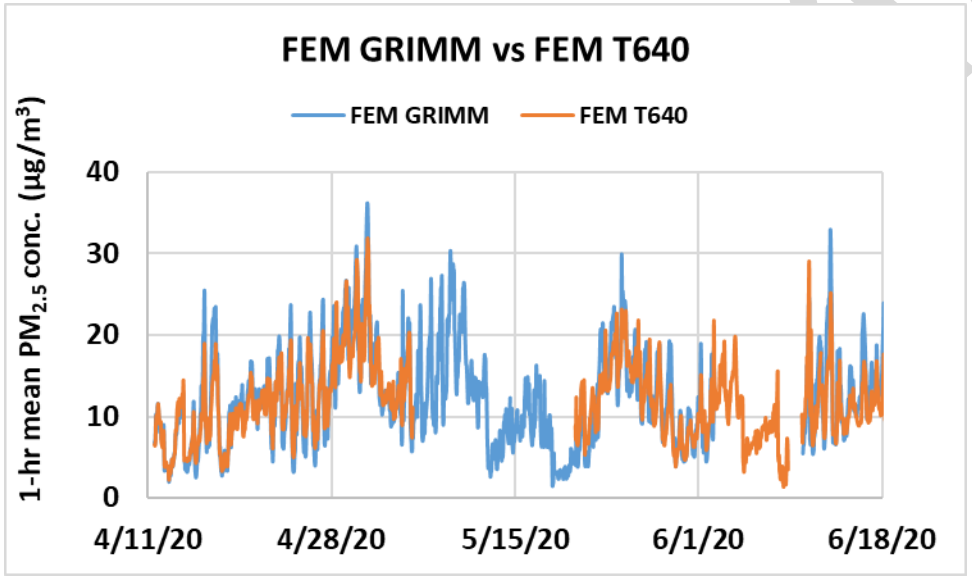
AQMesh; Intra-model Variability

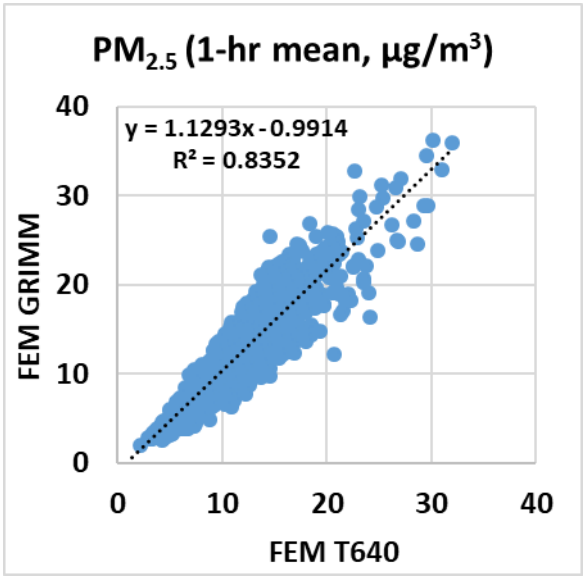
- Absolute intra-model variability was ~ 1.7, 2.2 and 3.7 µg/m^3 for the $PM_{1.0}$, $PM_{2.5}$ and PM_{10} measurements, respectively (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 23, 35 and 23% for the $PM_{1.0}$, $PM_{2.5}$ and PM_{10} measurements, respectively (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

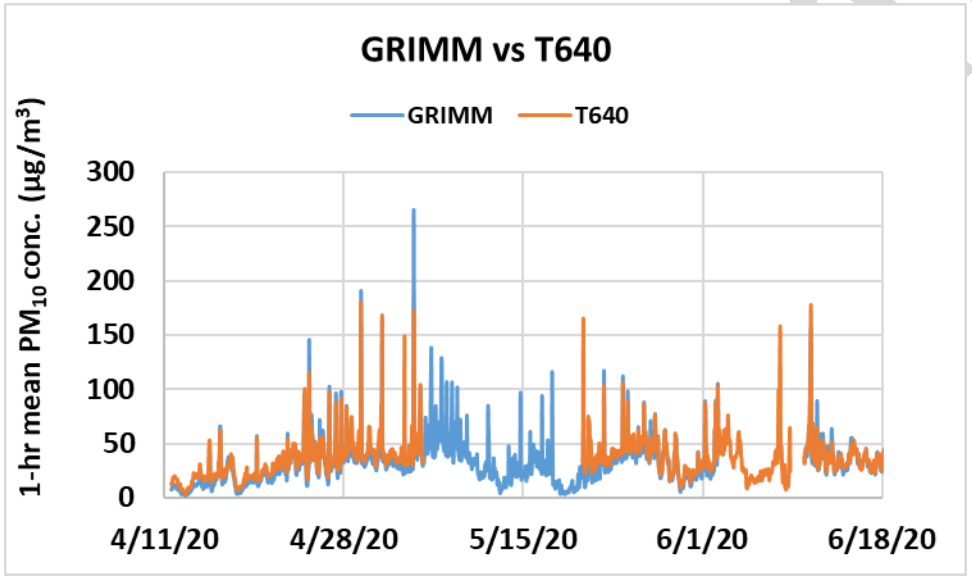
- Basic QA/QC procedures were used to validate the collected data (i.e. obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
- Data recovery for $PM_{2.5}$ from FEM GRIMM and FEM T640 is ~89% and 76%, respectively
- Strong correlations between FEM GRIMM and FEM T640 for $PM_{2.5}$ measurements (R^2 ~ 0.84)

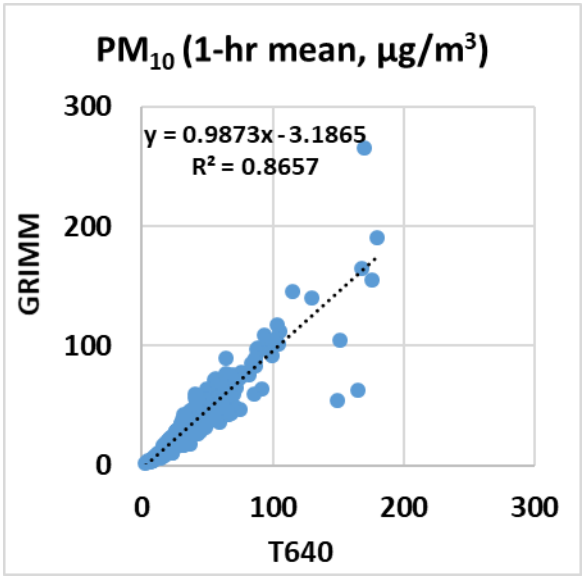




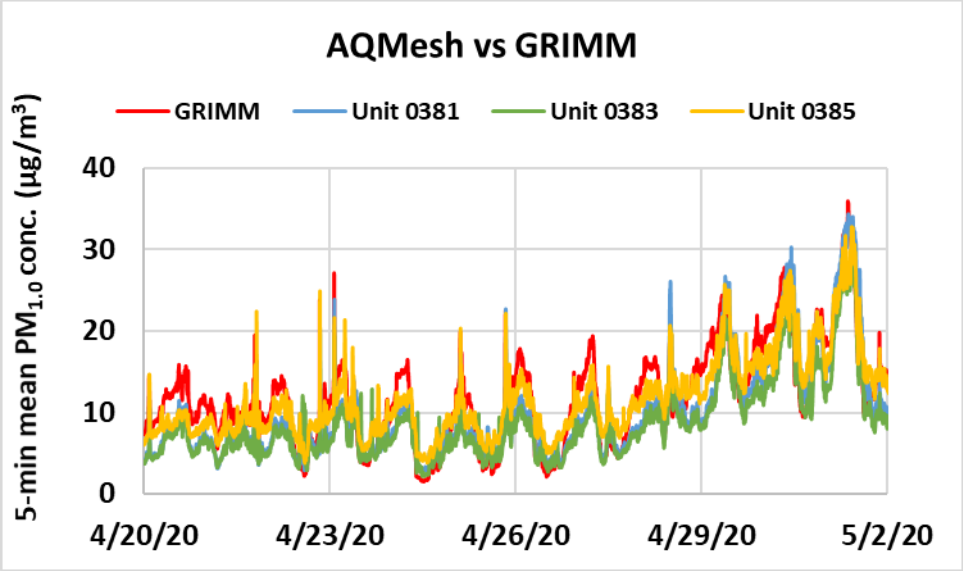
Reference Instruments: PM_{10} GRIMM & T640

- 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 GRIMM and T640 is ~89% and 76%, respectively
- Strong correlations between GRIMM and T640 for PM_{10} measurements (R^2 ~ 0.87)

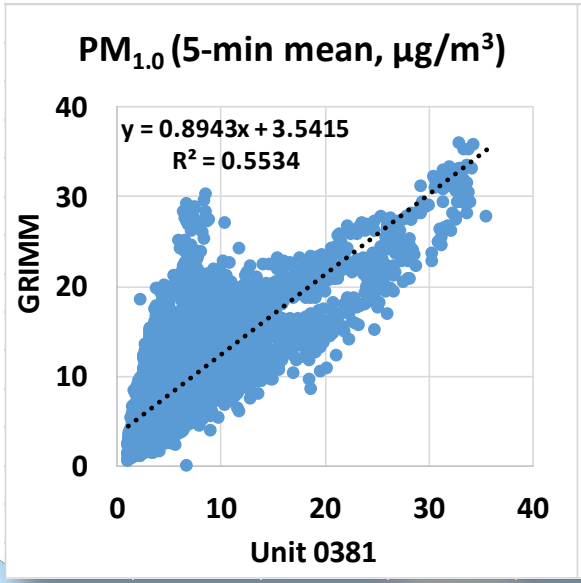


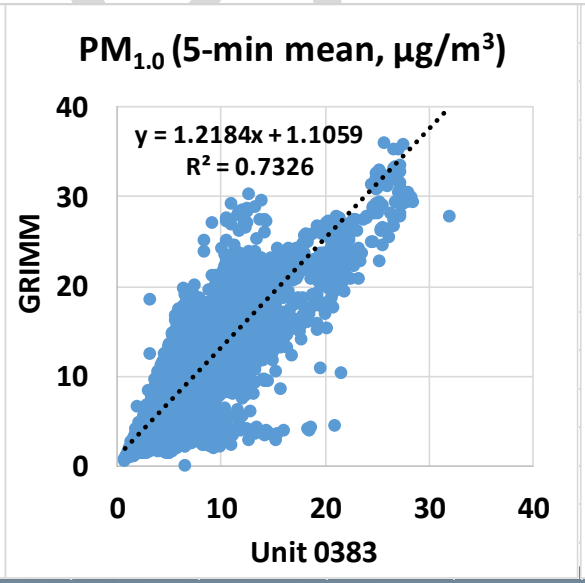


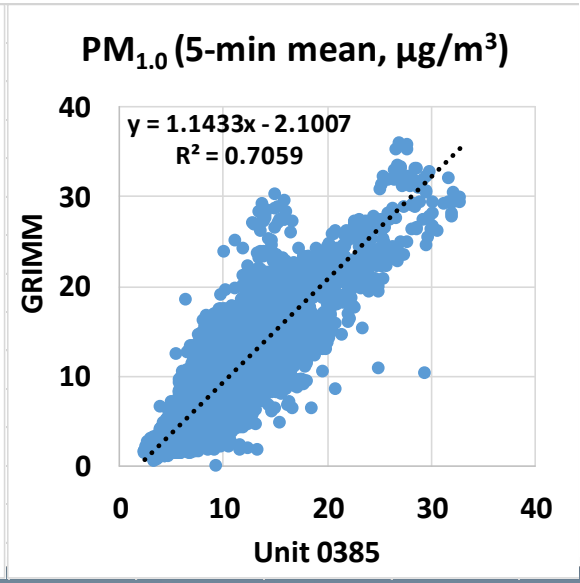
AQMesh vs GRIMM ($PM_{1.0}$; 5-min mean)



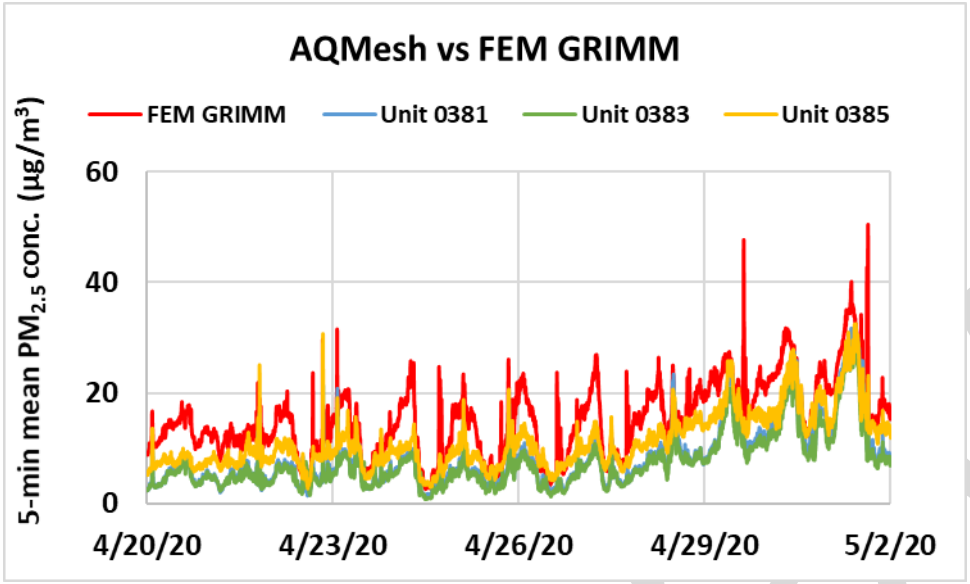
- The AQMesh sensors showed moderate to strong correlations with the corresponding GRIMM data ($0.55 < R^2 < 0.74$)
- Overall, the AQMesh sensors underestimated the $PM_{1.0}$ mass concentrations as measured by the GRIMM
- The AQMesh sensors seemed to track the diurnal $PM_{1.0}$ variations as recorded by the GRIMM



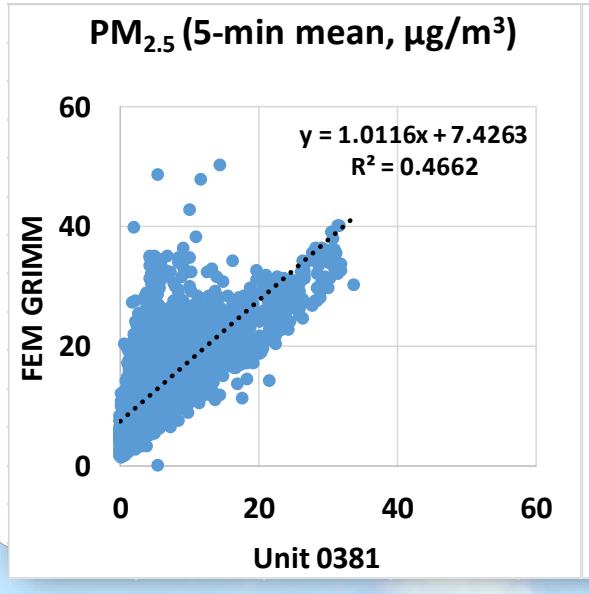


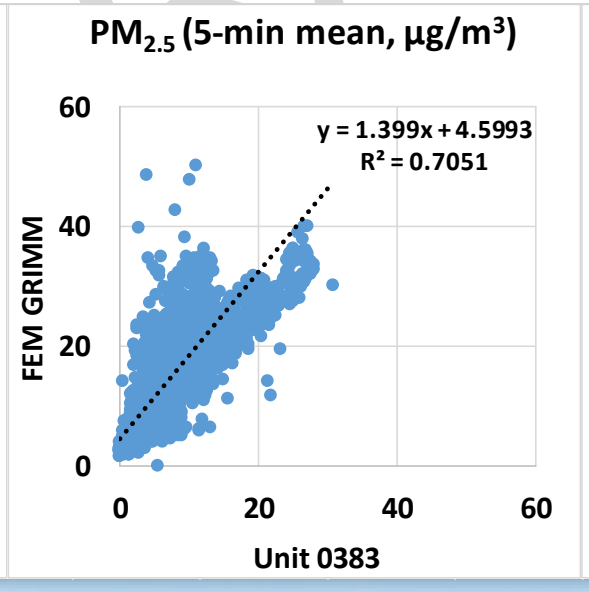


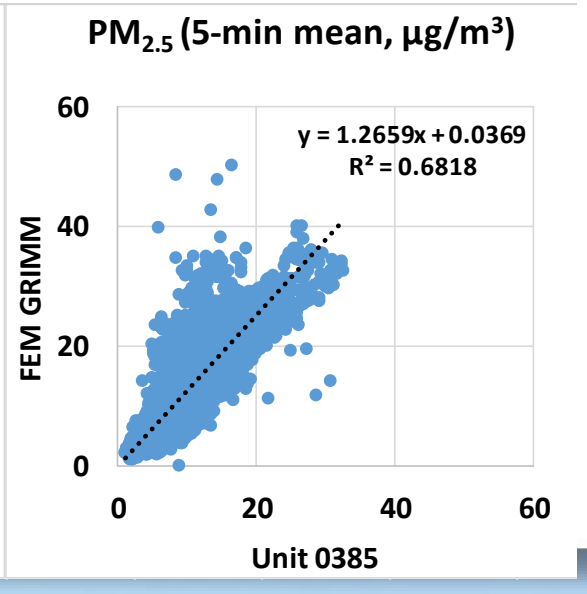
AQMesh vs FEM GRIMM ($PM_{2.5}$; 5-min mean)



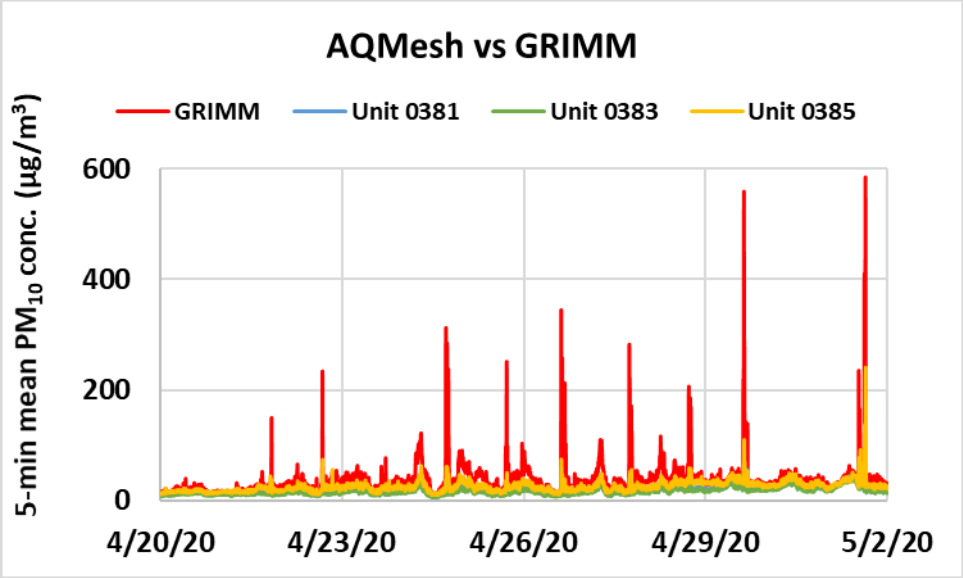
- The AQMesh sensors showed weak to strong correlations with the corresponding FEM GRIMM data ($0.46 < R^2 < 0.71$)
- Overall, the AQMesh sensors underestimated the $PM_{2.5}$ mass concentrations as measured by the FEM GRIMM
- The AQMesh sensors seemed to track the diurnal $PM_{2.5}$ variations as recorded by the FEM GRIMM



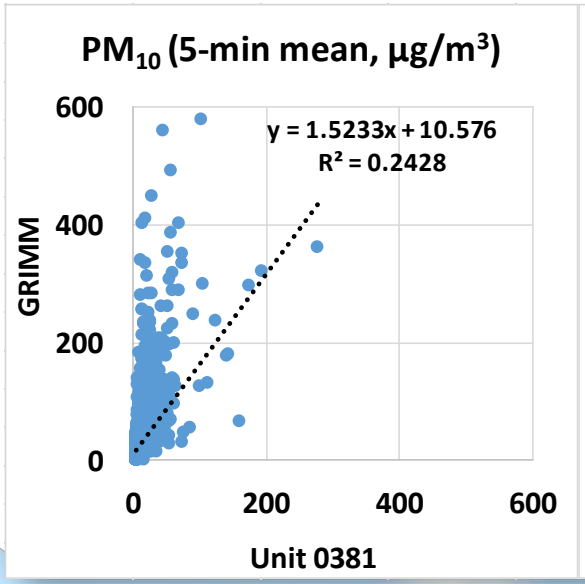


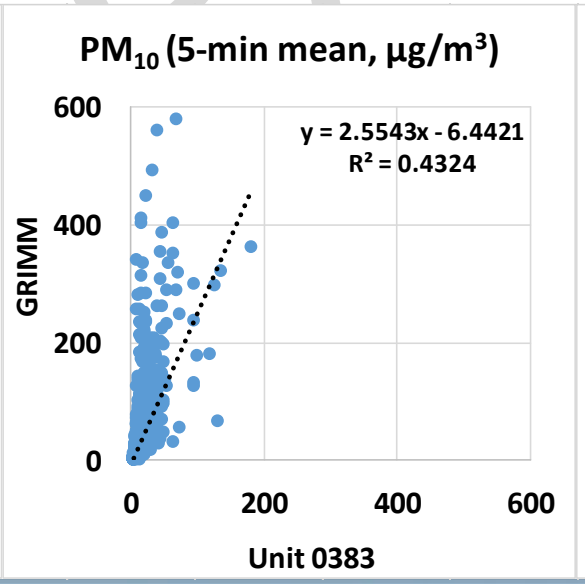


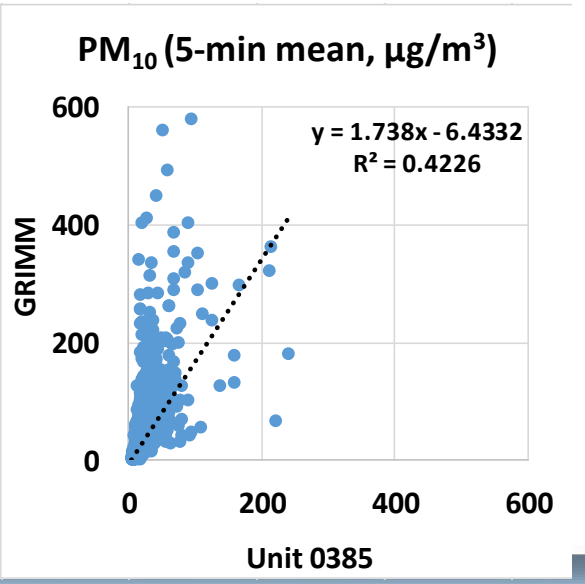
AQMesh vs GRIMM (PM_{10}; 5-min mean)



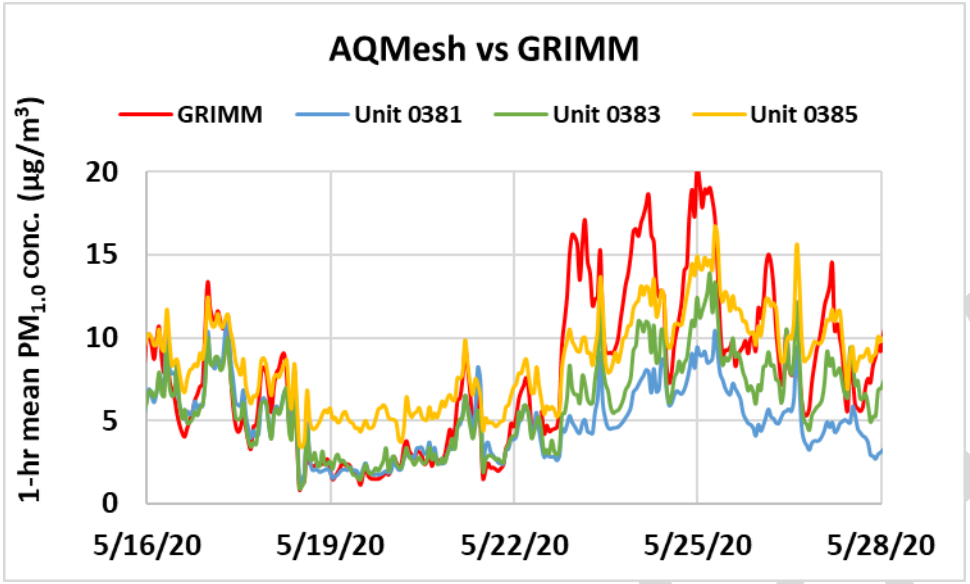
- The AQMesh sensors showed very weak to weak correlations with the corresponding GRIMM data ($0.24 < R^2 < 0.44$)
- Overall, the AQMesh sensors underestimated the PM_{10} mass concentrations as measured by the GRIMM
- The AQMesh sensors did not seem to track the diurnal PM_{10} variations as recorded by the GRIMM



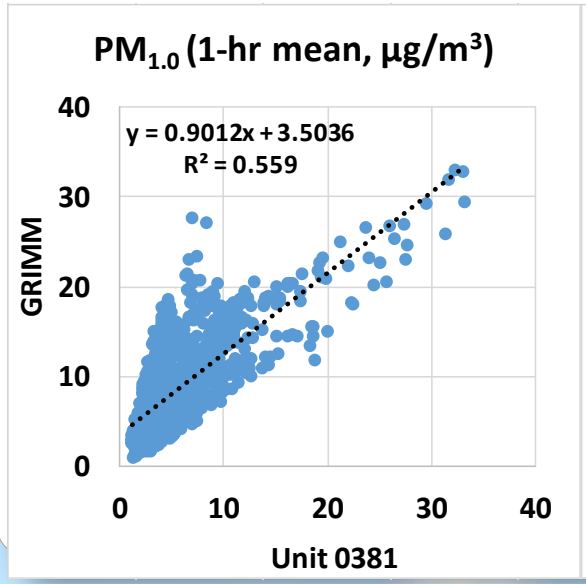


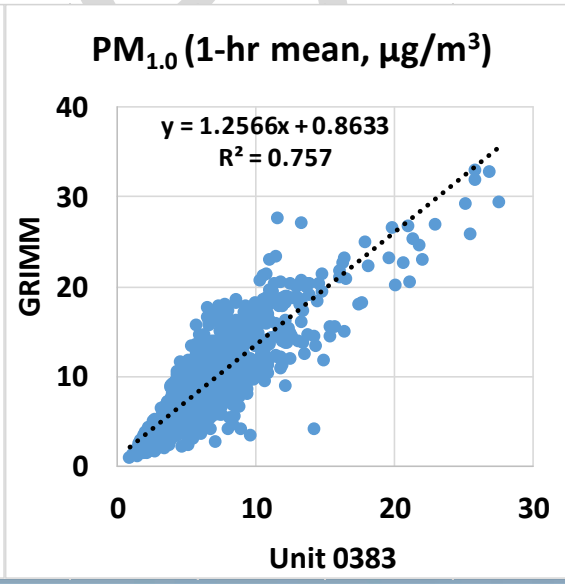


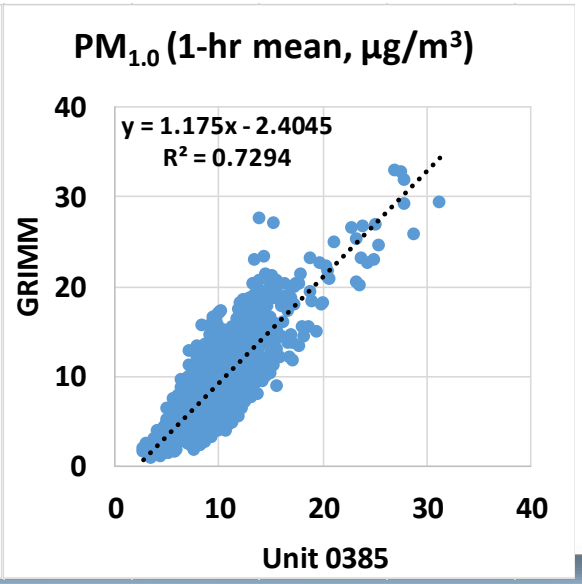
AQMesh vs GRIMM ($PM_{1.0}$; 1-hr mean)



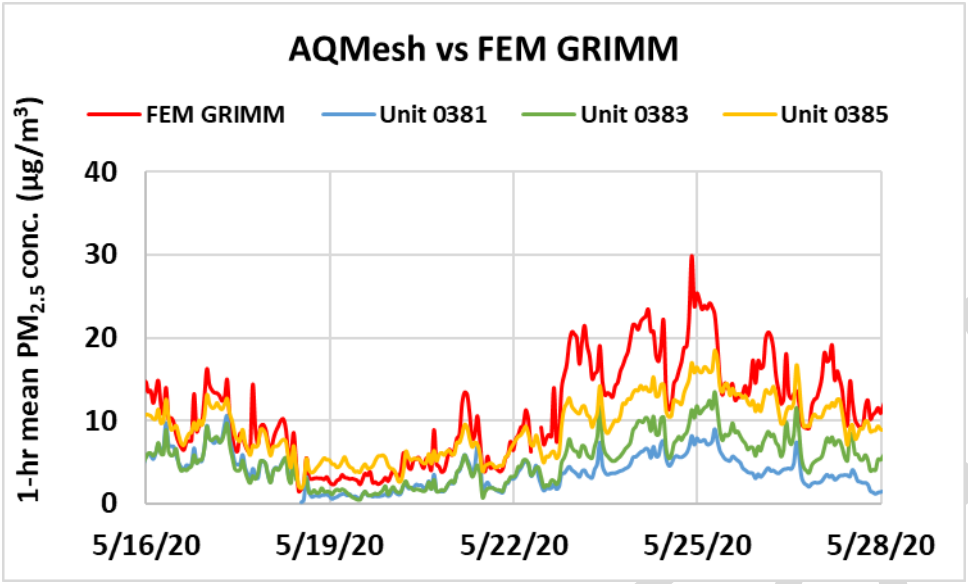
- The AQMesh sensors showed moderate to strong correlations with the corresponding GRIMM data ($0.55 < R^2 < 0.76$)
- Overall, the AQMesh sensors underestimated the $PM_{1.0}$ mass concentrations as measured by the GRIMM
- The AQMesh sensors seemed to track the diurnal $PM_{1.0}$ variations as recorded by the GRIMM



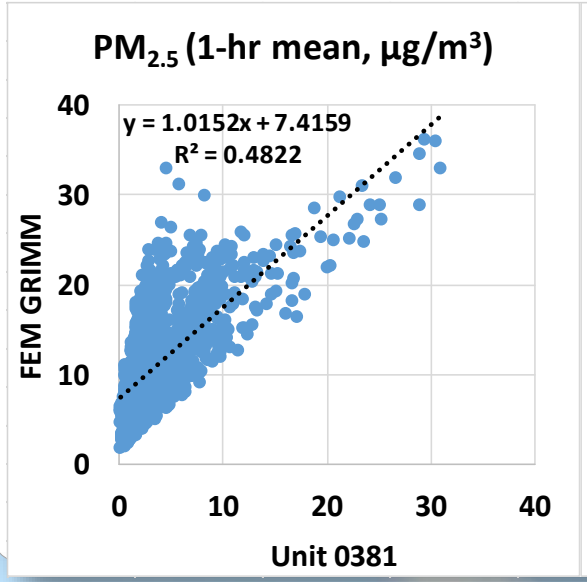


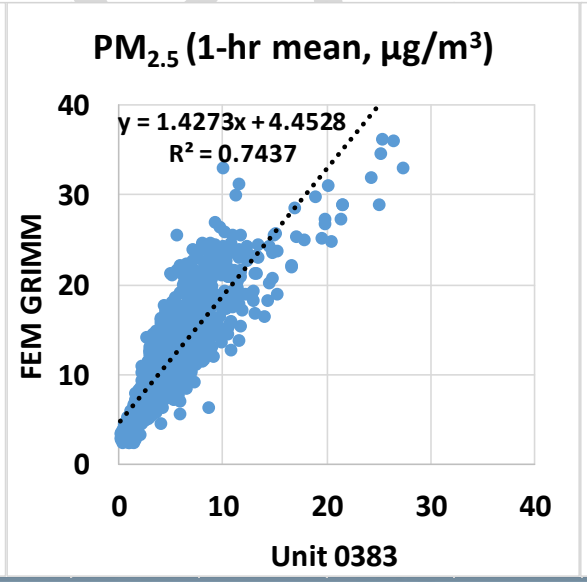


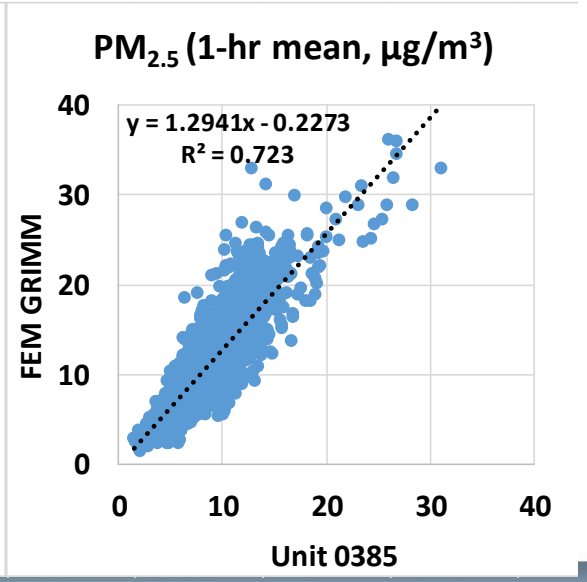
AQMesh vs FEM GRIMM ($PM_{2.5}$; 1-hr mean)



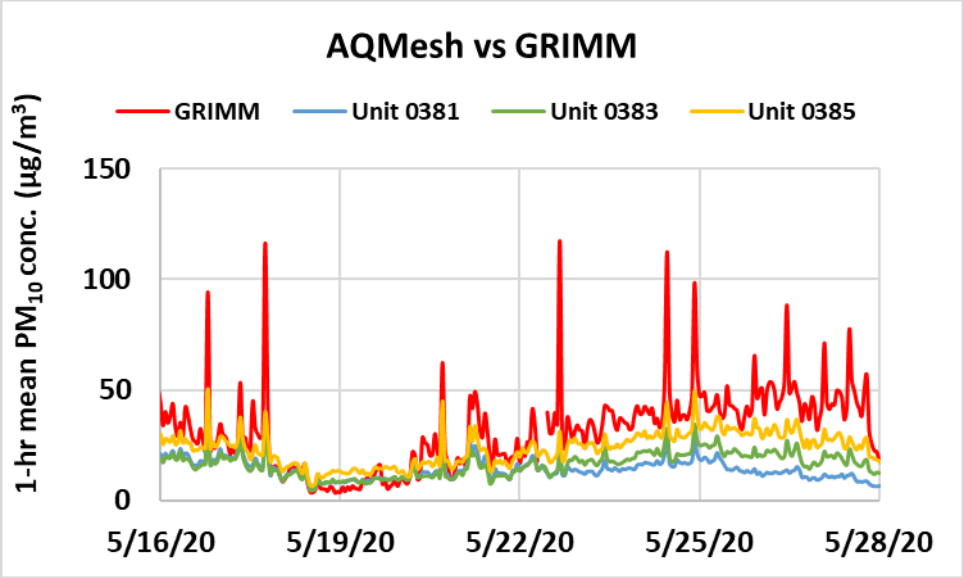
- The AQMesh sensors showed weak to strong correlations with the corresponding FEM GRIMM data ($0.48 < R^2 < 0.75$)
- Overall, the AQMesh sensors underestimated the $PM_{2.5}$ mass concentrations as measured by the FEM GRIMM
- The AQMesh sensors seemed to track the diurnal $PM_{2.5}$ variations as recorded by the FEM GRIMM



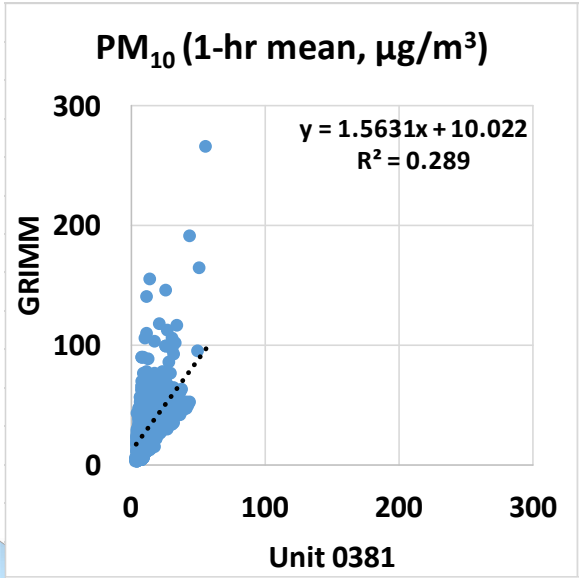


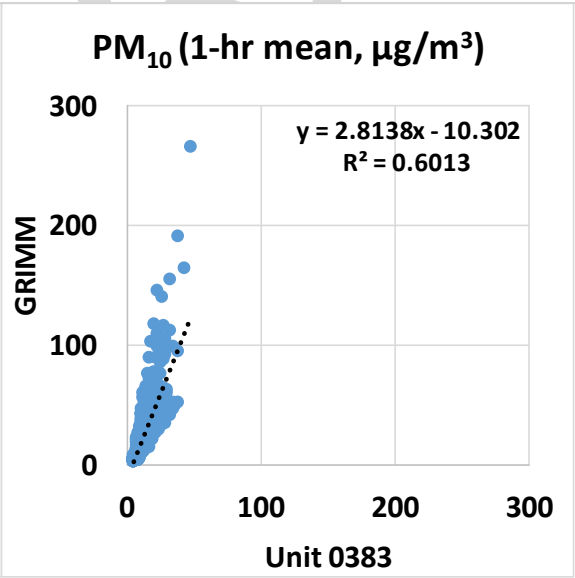


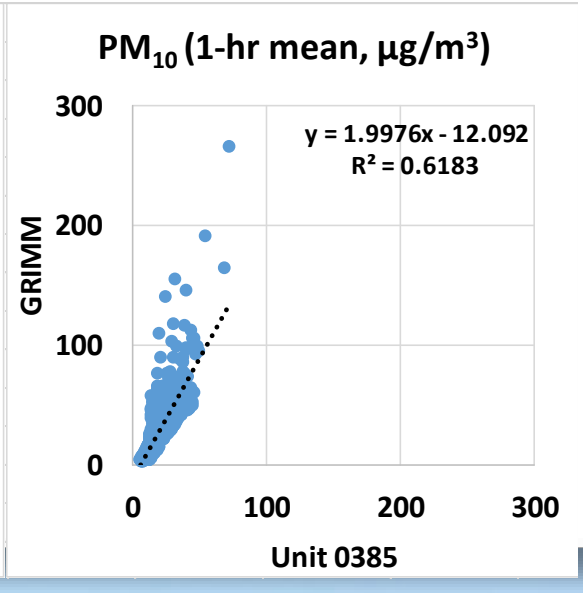
AQMesh vs GRIMM (PM_{10}; 1-hr mean)



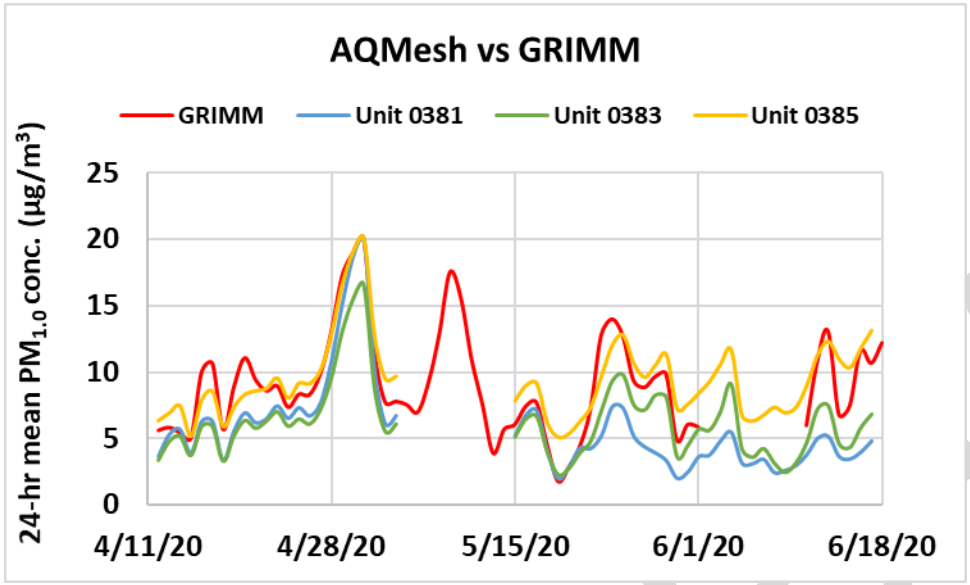
- The AQMesh sensors showed very weak to moderate correlations with the corresponding GRIMM data ($0.28 < R^2 < 0.62$)
- Overall, the AQMesh sensors underestimated the PM_{10} mass concentration as measured by the GRIMM
- The AQMesh sensors seemed to track the diurnal PM_{10} variations as recorded by the GRIMM



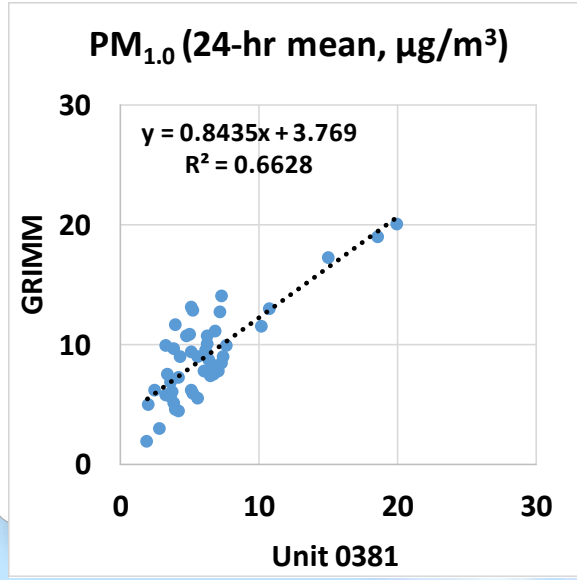


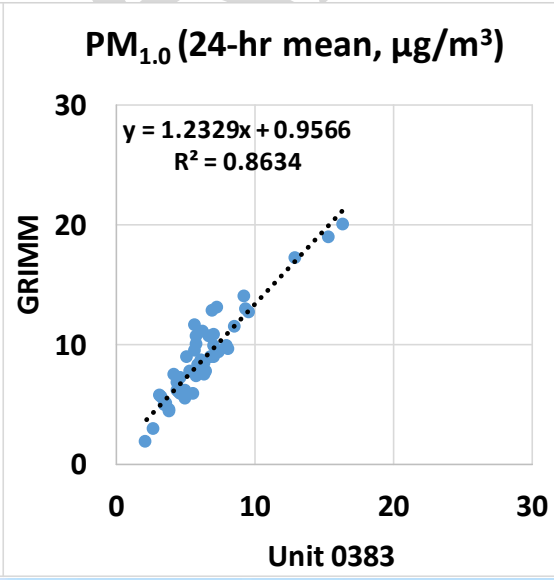


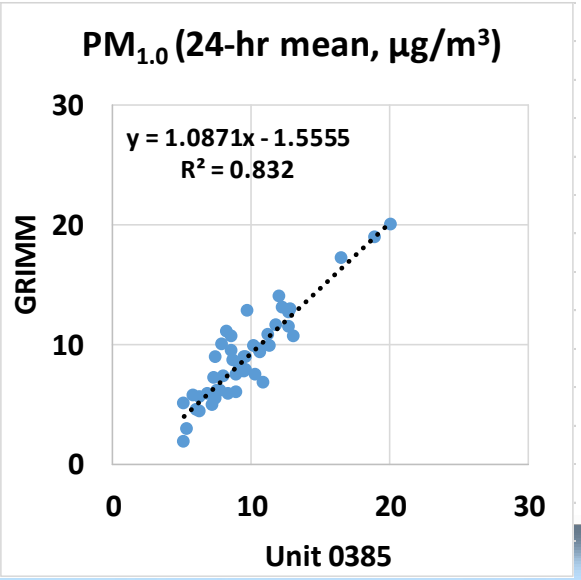
AQMesh vs GRIMM ($PM_{1.0}$; 24-hr mean)



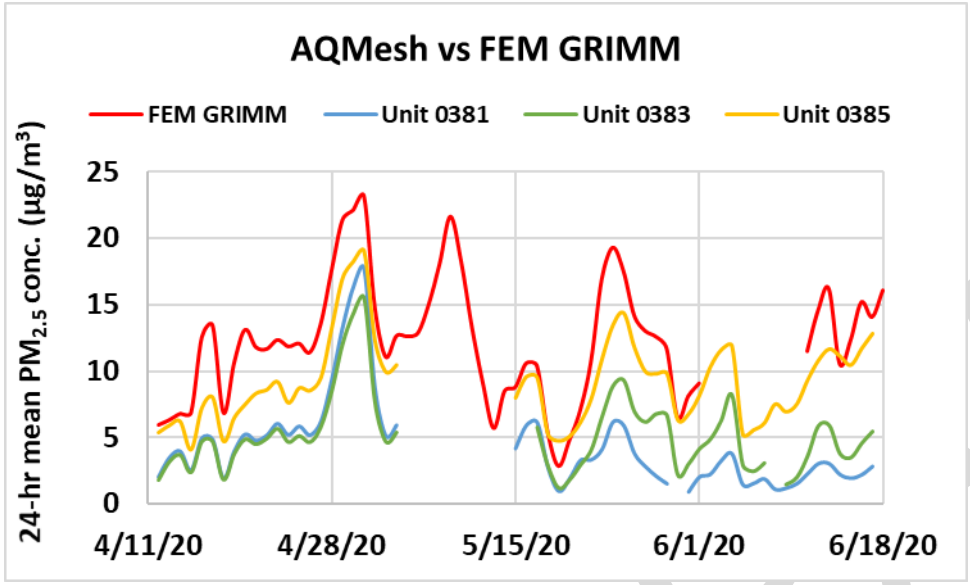
- The AQMesh sensors showed moderate to strong correlations with the corresponding GRIMM data ($0.66 < R^2 \sim 0.87$)
- Overall, the AQMesh sensors underestimated the $PM_{1.0}$ mass concentrations as measured by the GRIMM
- The AQMesh sensors seemed to track the diurnal $PM_{1.0}$ variations as recorded by the GRIMM



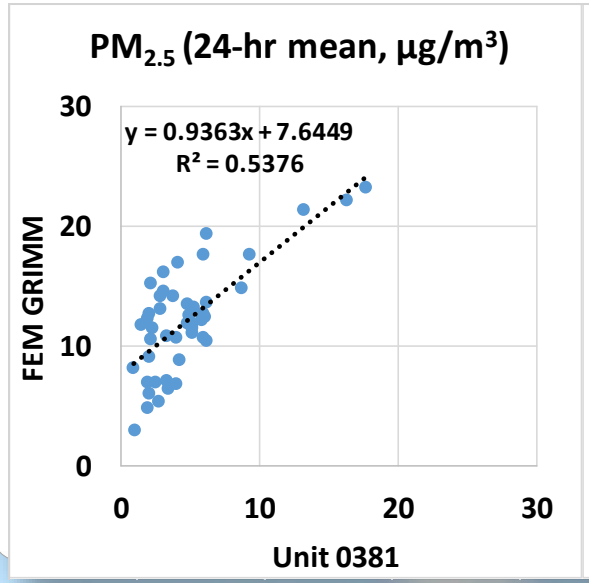


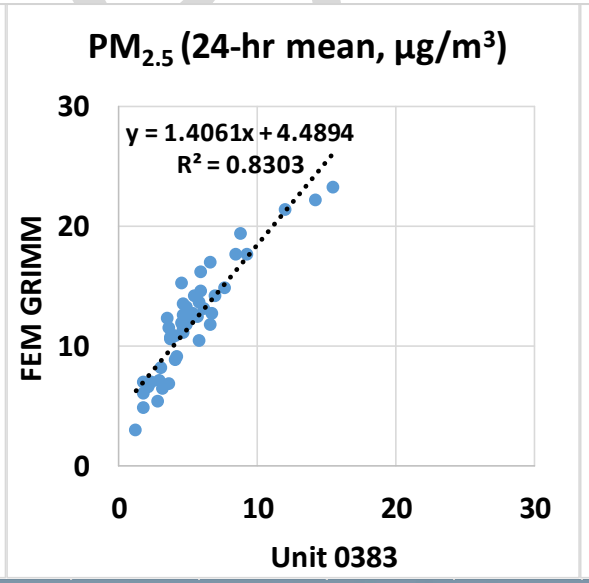


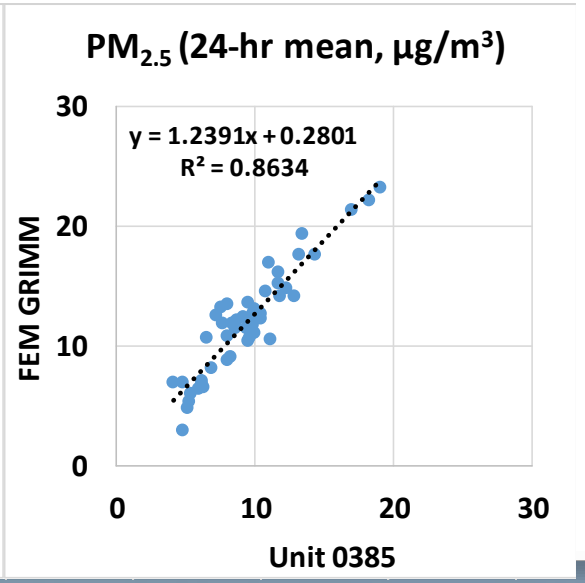
AQMesh vs FEM GRIMM ($PM_{2.5}$; 24-hr mean)



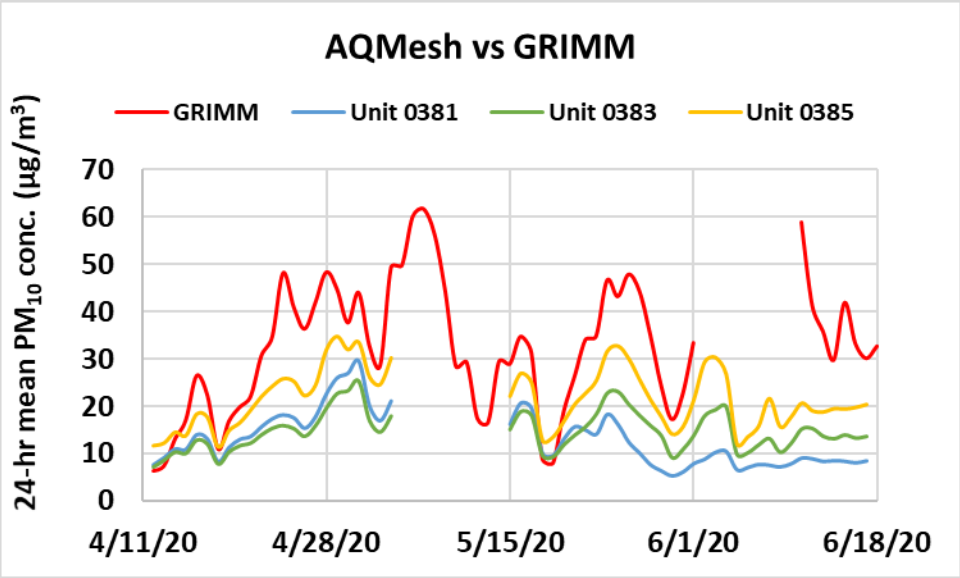
- The AQMesh sensors showed moderate to strong correlations with the corresponding FEM GRIMM data ($0.53 < R^2 < 0.87$)
- Overall, the AQMesh sensors underestimated the $PM_{2.5}$ mass concentrations as measured by the FEM GRIMM
- The AQMesh sensors seemed to track the diurnal $PM_{2.5}$ variations as recorded by the FEM GRIMM



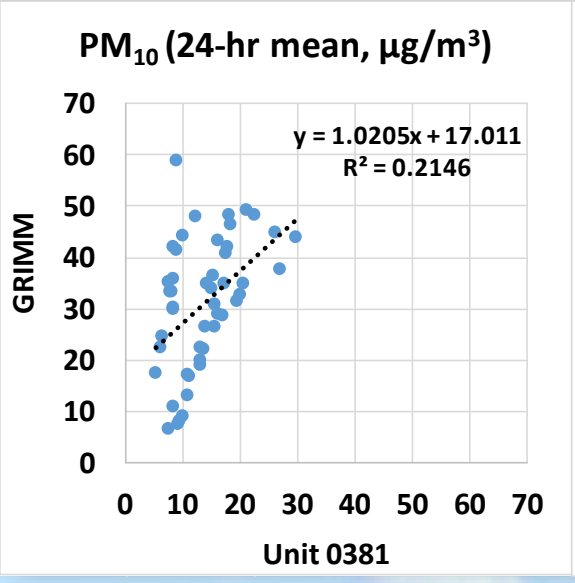


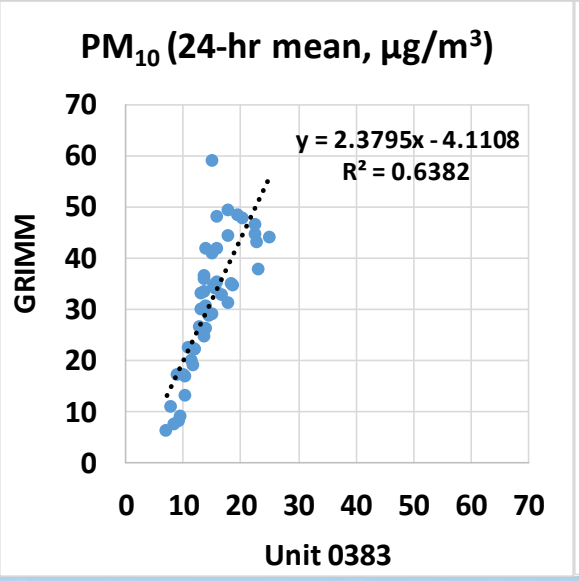


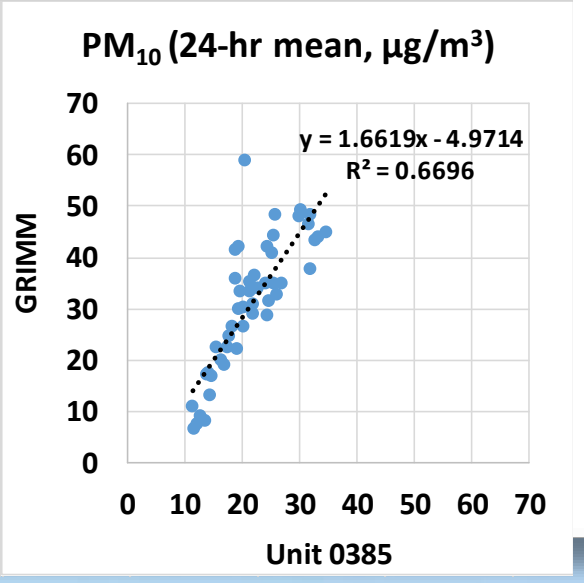
AQMesh vs GRIMM (PM_{10}; 24-hr mean)



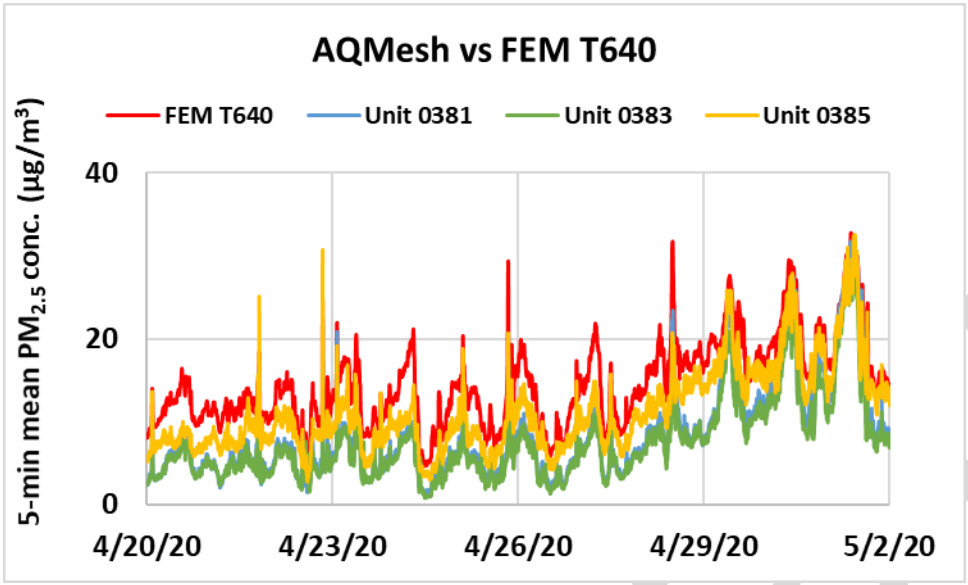
- The AQMesh sensors showed very weak to moderate correlations with the corresponding GRIMM data ($0.22 < R^2 < 0.68$)
- Overall, the AQMesh sensors underestimated the PM_{10} mass concentration as measured by the GRIMM
- The AQMesh sensors seemed to track the diurnal PM_{10} variations as recorded by the GRIMM



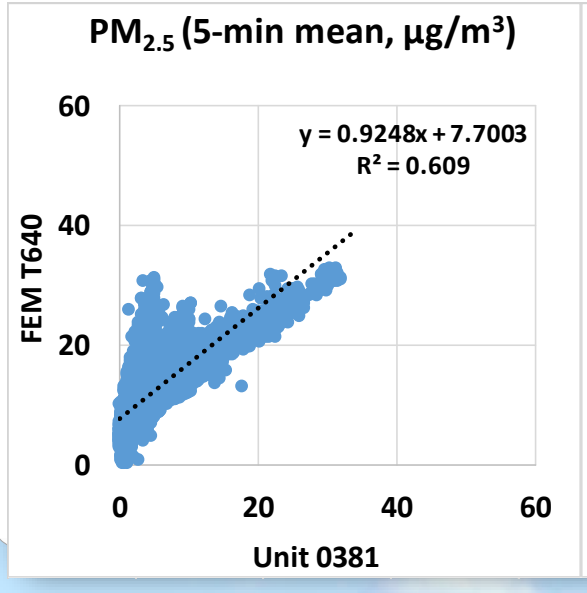


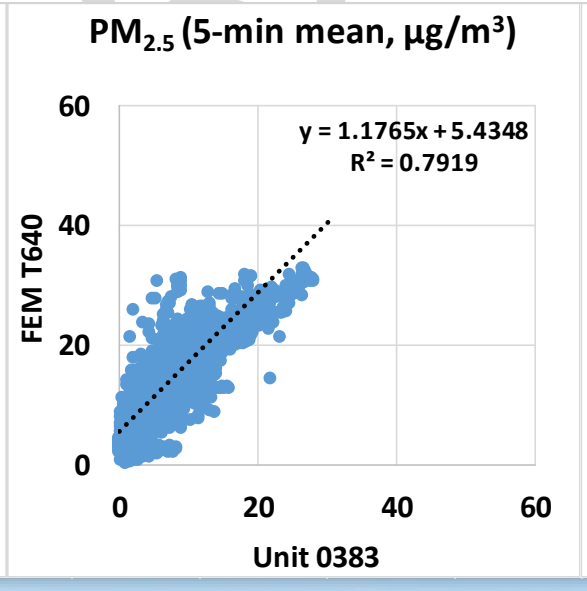


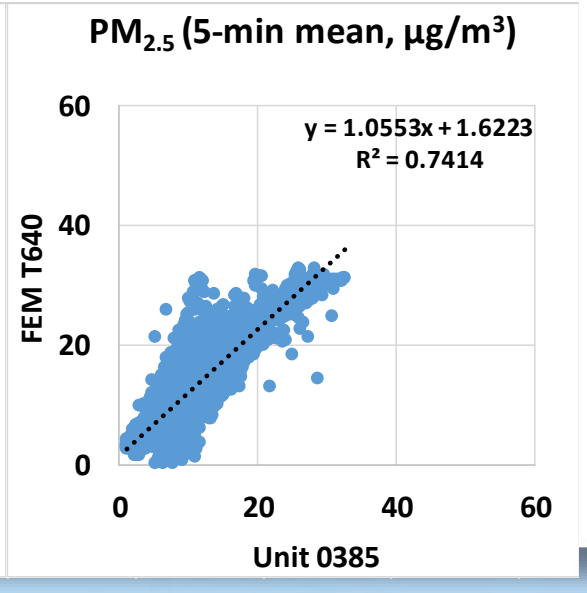
AQMesh vs FEM T640 ($PM_{2.5}$; 5-min mean)



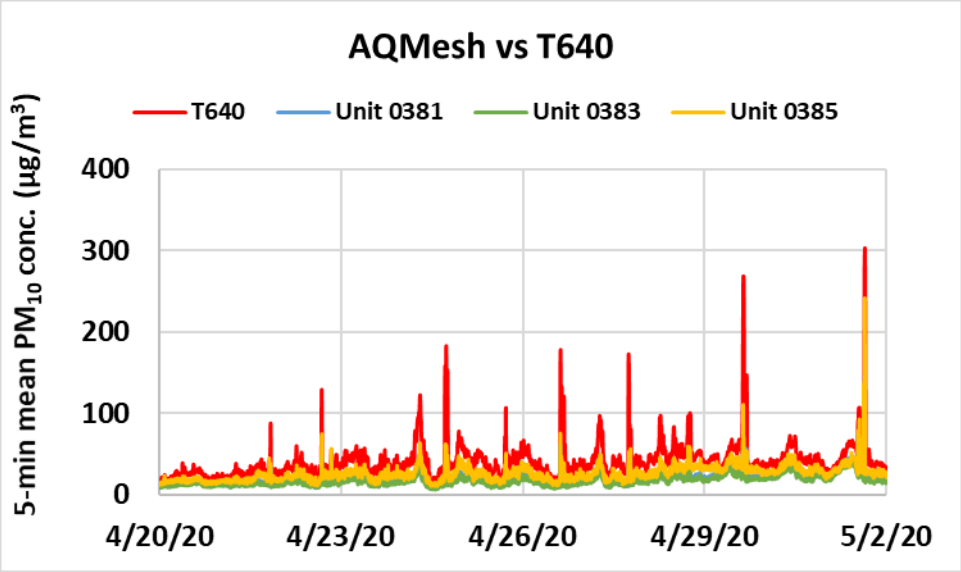
- The AQMesh sensors showed moderate to strong correlations with the corresponding FEM T640 data ($0.60 < R^2 < 0.80$)
- Overall, the AQMesh sensors underestimated the $PM_{2.5}$ mass concentration as measured by the FEM T640
- The AQMesh sensors seemed to track the diurnal $PM_{2.5}$ variations as recorded by the FEM T640



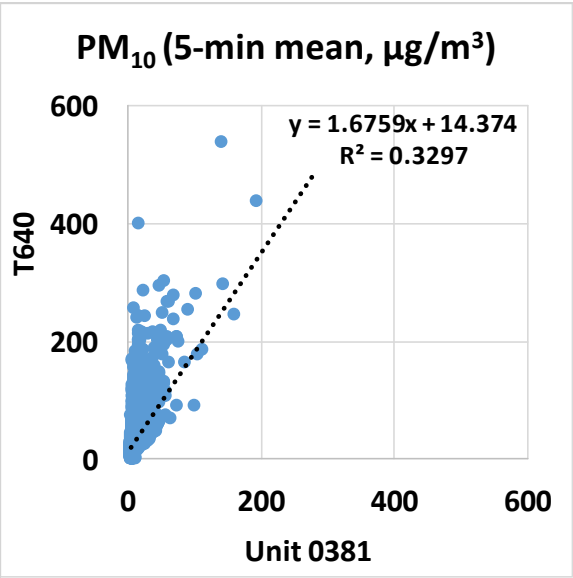


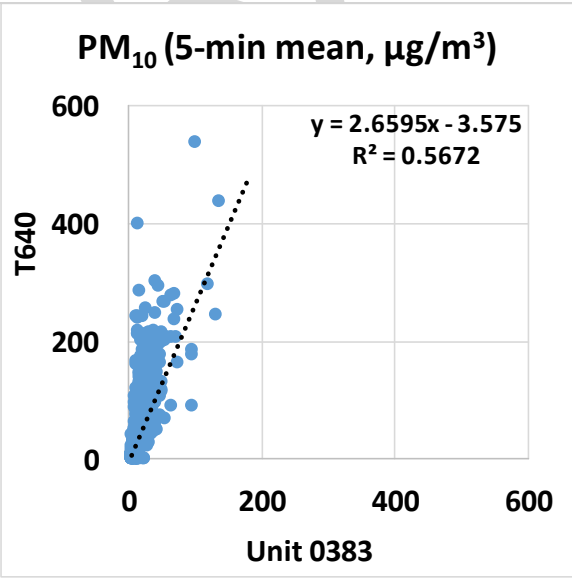


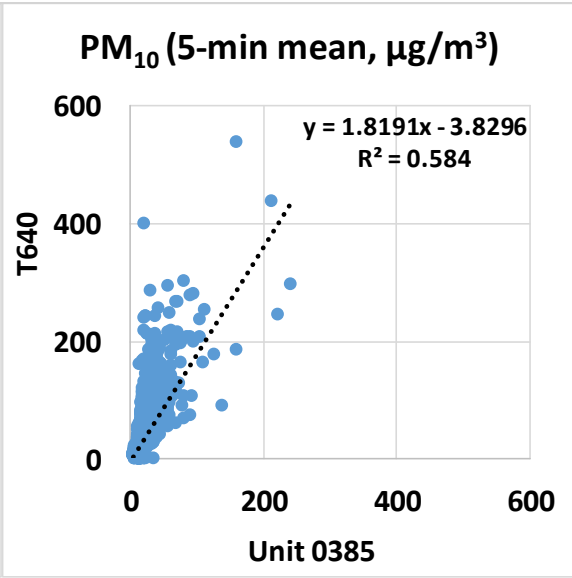
AQMesh vs T640 (PM_{10}; 5-min mean)



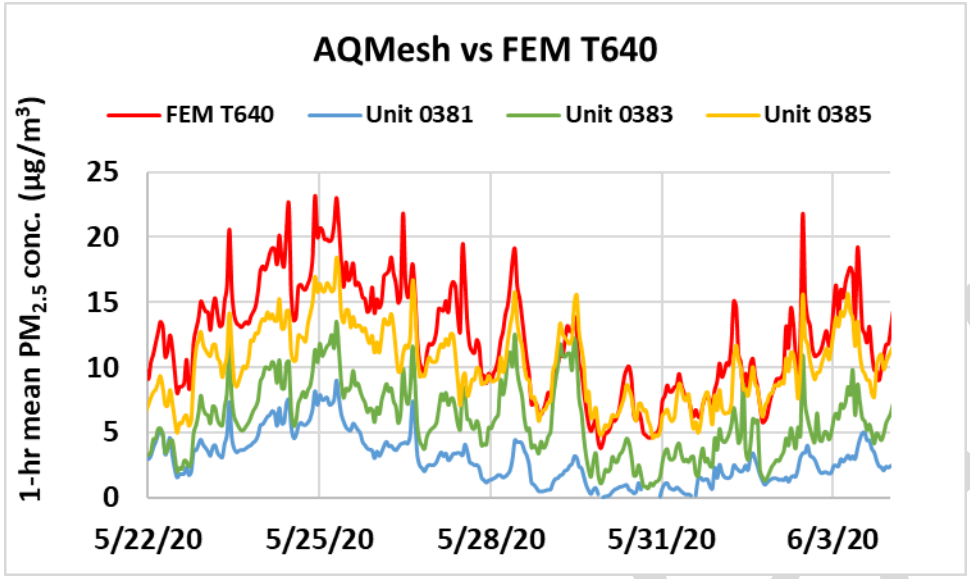
- The AQMesh sensors showed weak to moderate correlations with the corresponding T640 data ($0.32 < R^2 < 0.59$)
- Overall, the AQMesh sensors underestimated the PM_{10} mass concentration as measured by the T640
- The AQMesh sensors seemed to track the diurnal PM_{10} variations as recorded by the T640



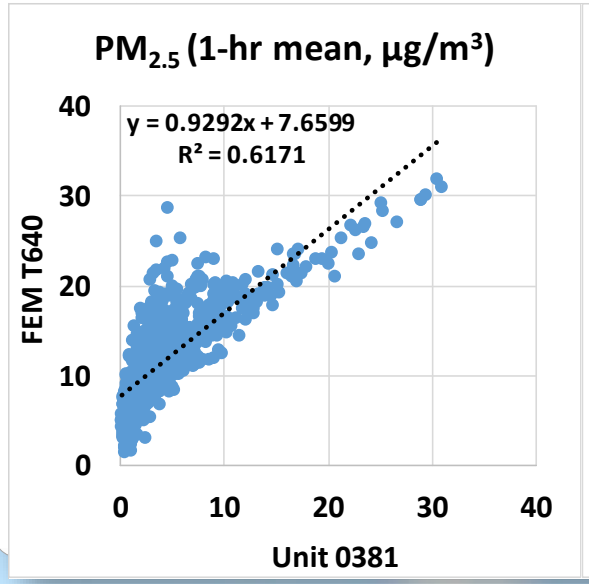


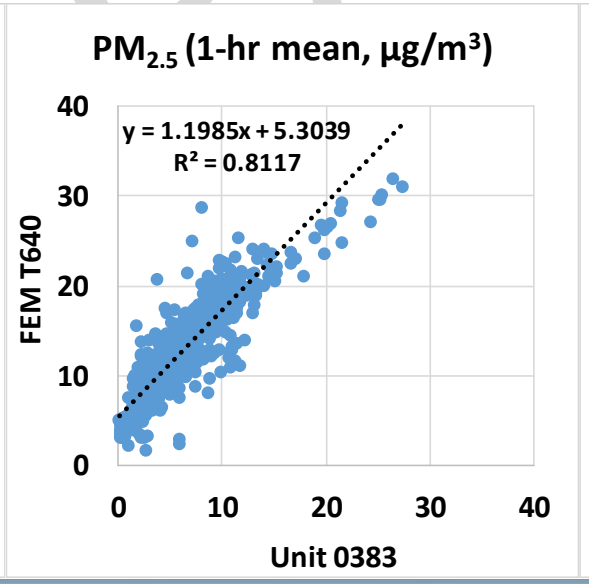


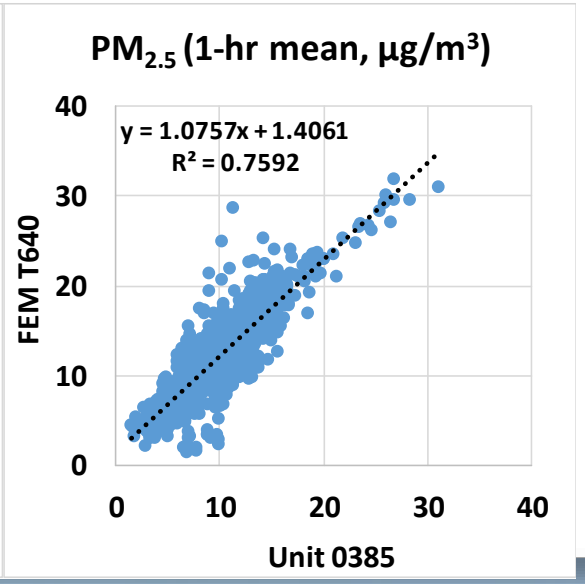
AQMesh vs FEM T640 ($PM_{2.5}$; 1-hr mean)



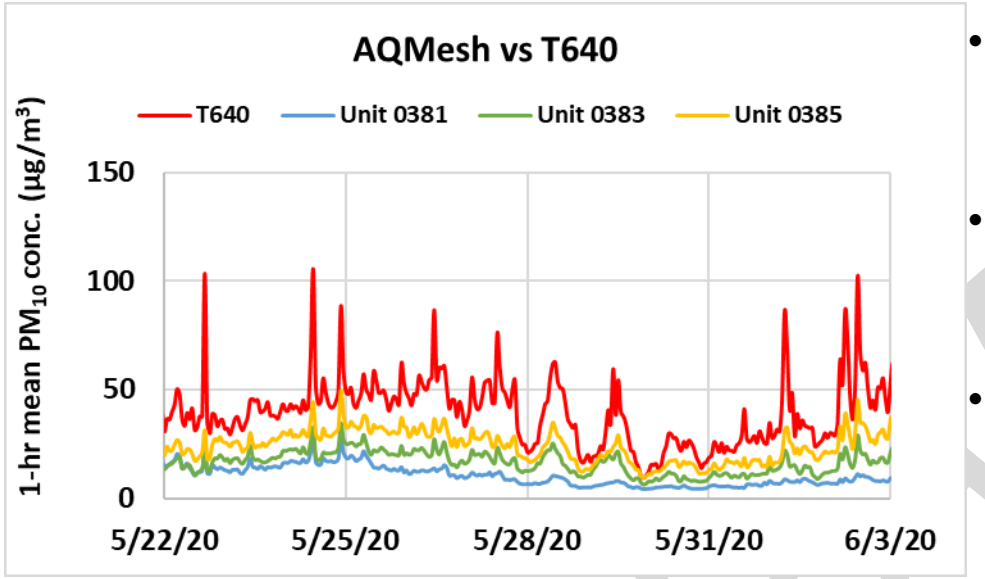
- The AQMesh sensors showed moderate to strong correlations with the corresponding FEM T640 data ($0.61 < R^2 < 0.82$)
- Overall, the AQMesh sensors underestimated the $PM_{2.5}$ mass concentration as measured by the FEM T640
- The AQMesh sensors seemed to track the diurnal $PM_{2.5}$ variations as recorded by the FEM T640



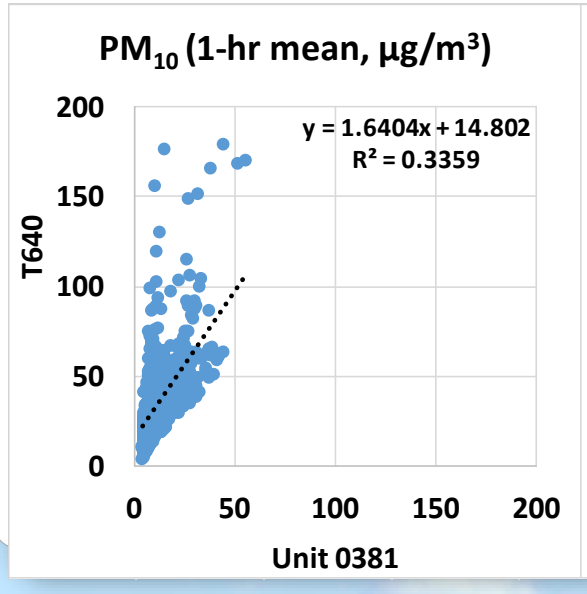


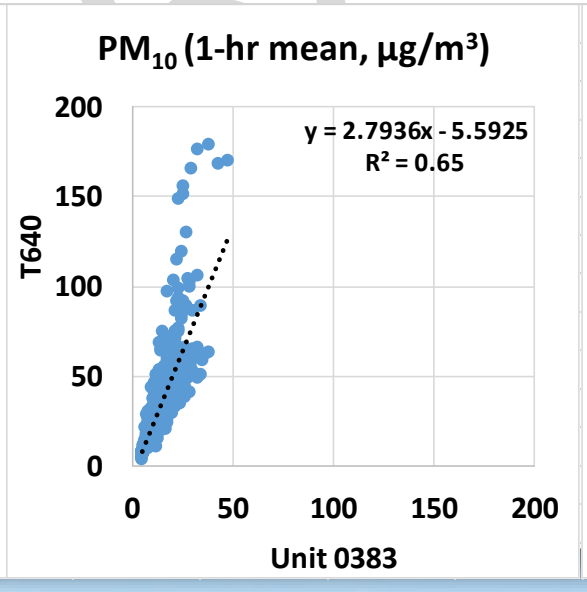


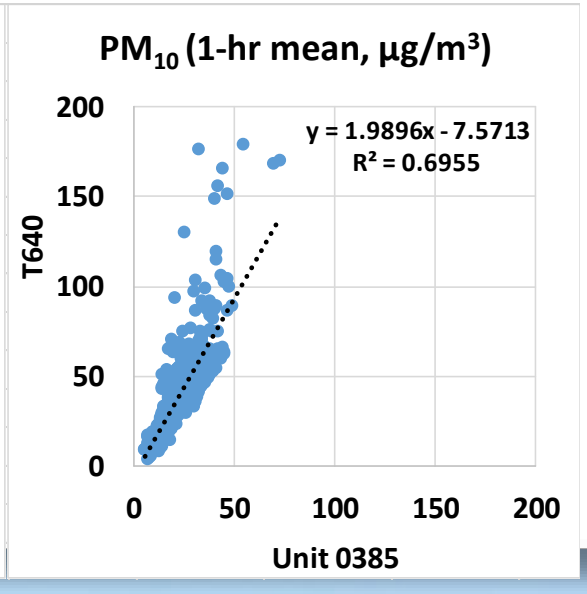
AQMesh vs T640 (PM_{10}; 1-hr mean)



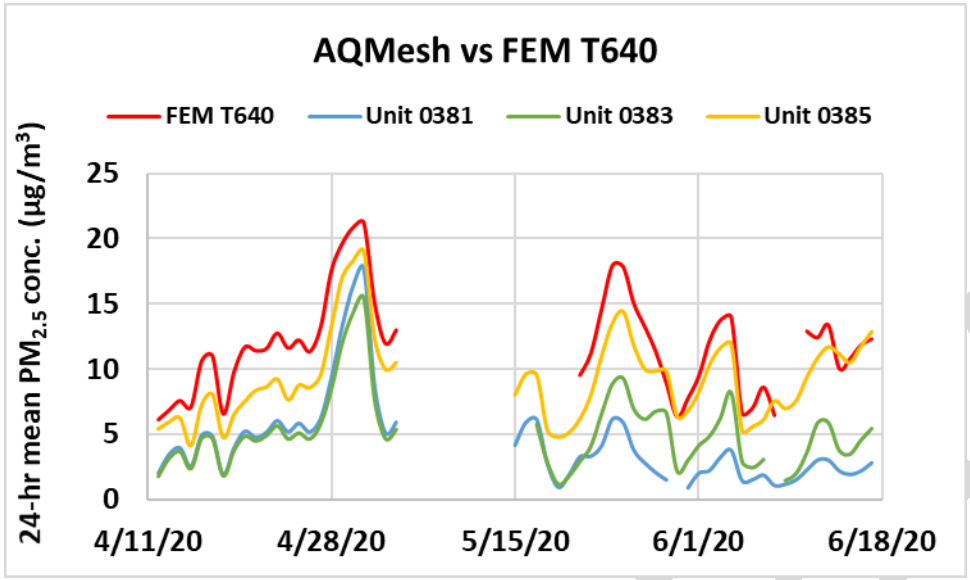
- The AQMesh sensors showed weak to moderate correlations with the corresponding T640 data ($0.33 < R^2 < 0.70$)
- Overall, the AQMesh sensors underestimated the PM_{10} mass concentrations as measured by the T640
- The AQMesh sensors seemed to track the diurnal PM_{10} variations as recorded by the T640



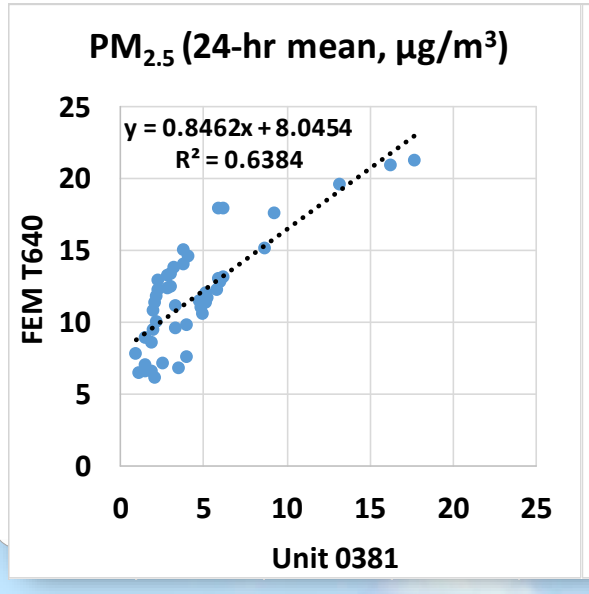


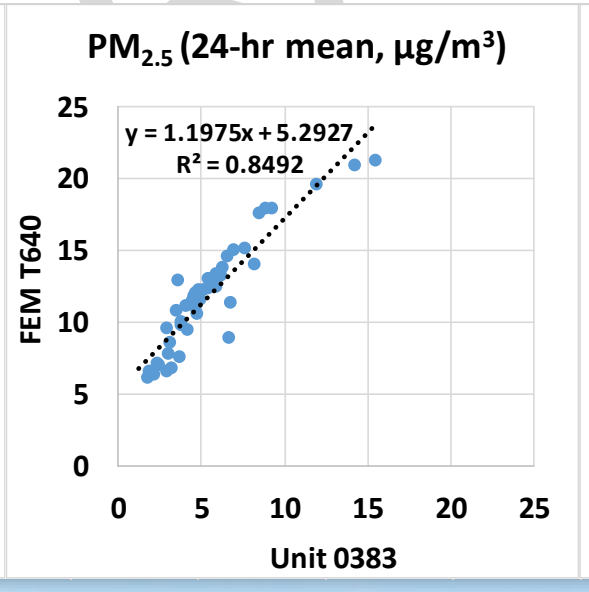


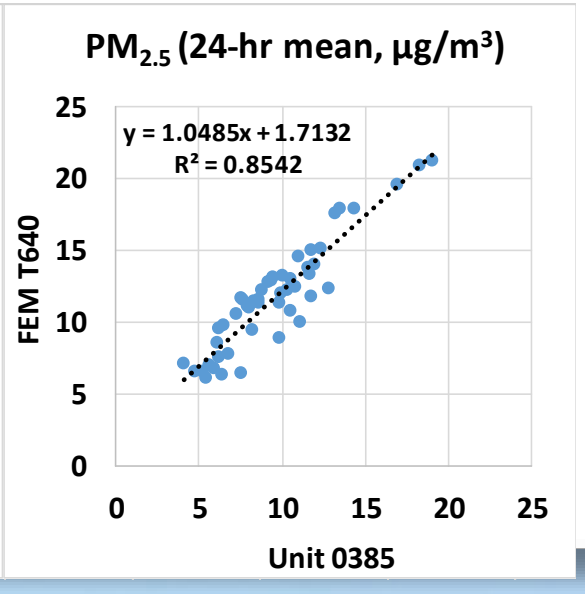
AQMesh vs FEM T640 ($PM_{2.5}$; 24-hr mean)



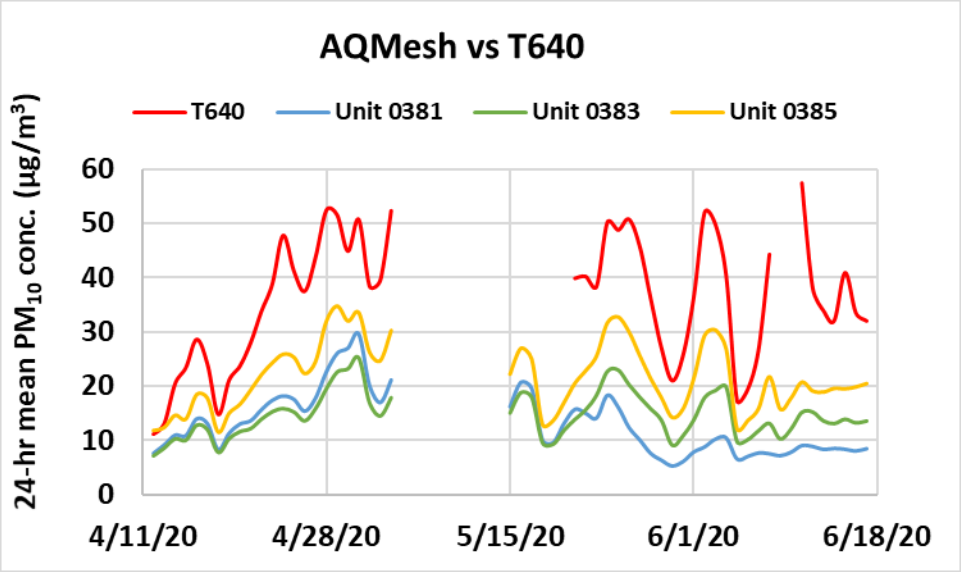
- The AQMesh sensors showed moderate to strong correlations with the corresponding FEM T640 data ($0.63 < R^2 < 0.86$)
- Overall, the AQMesh sensors underestimated the $PM_{2.5}$ mass concentration as measured by the FEM T640
- The AQMesh sensors seemed to track the diurnal $PM_{2.5}$ variations as recorded by the FEM T640



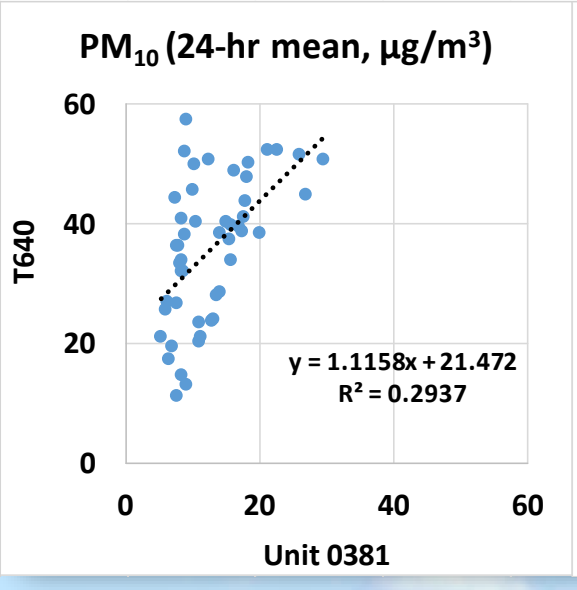


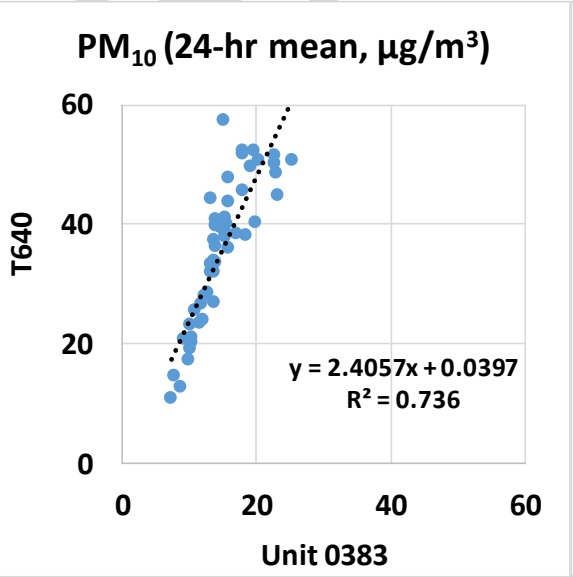


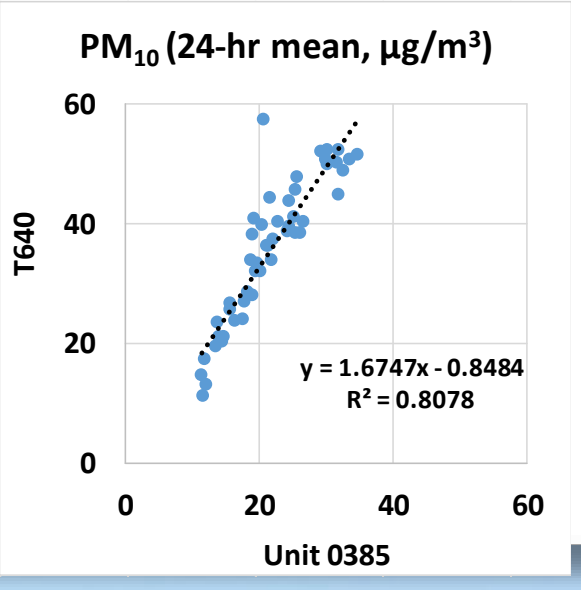
AQMesh vs T640 (PM_{10}; 24-hr mean)



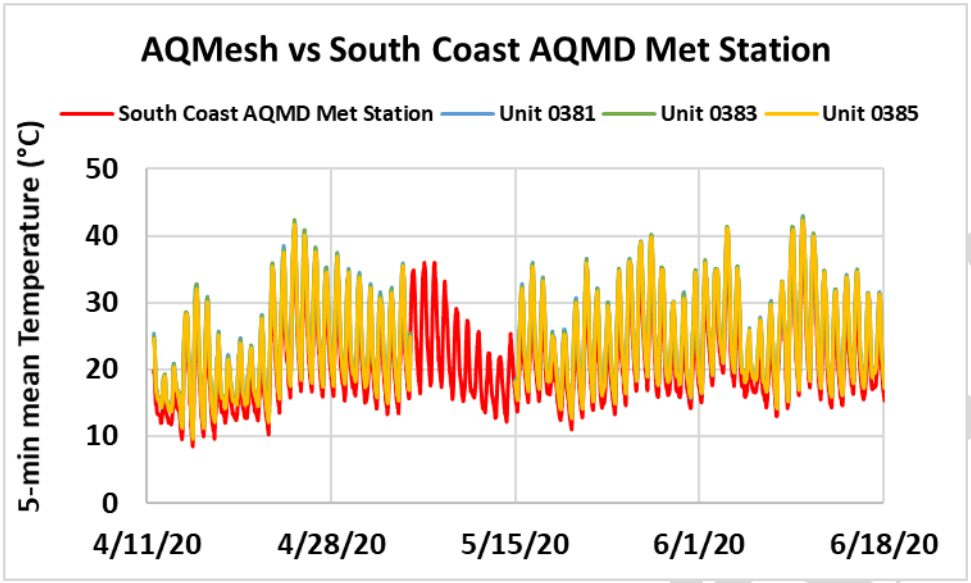
- The AQMesh sensors showed very weak to strong correlations with the corresponding T640 data ($0.29 < R^2 < 0.81$)
- Overall, the AQMesh sensors underestimated the PM_{10} mass concentrations as measured by the T640
- The AQMesh sensors seemed to track the diurnal PM_{10} variations as recorded by the T640



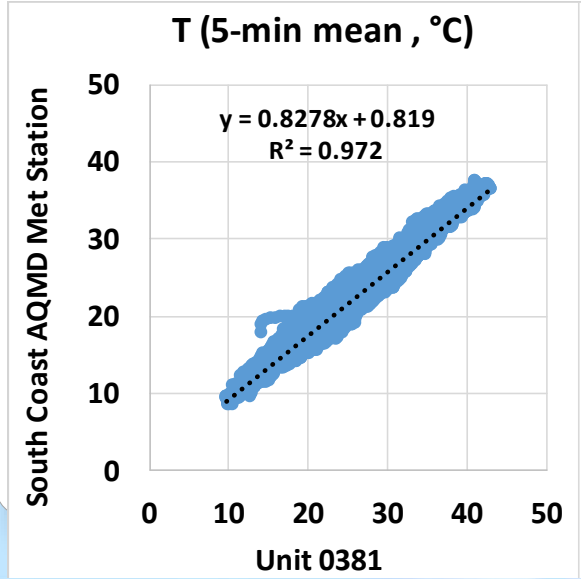


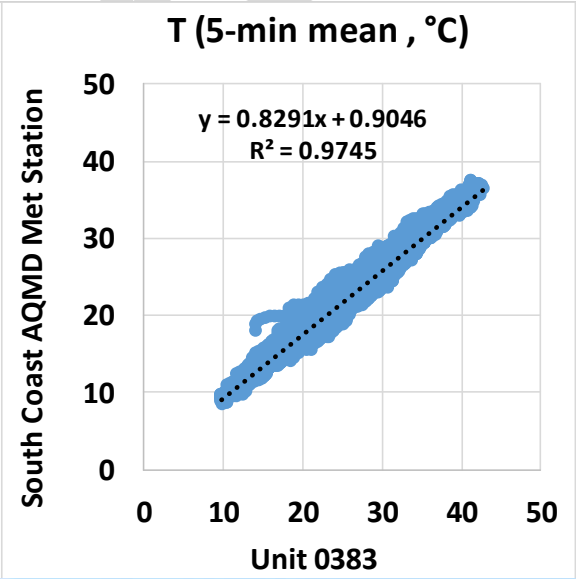


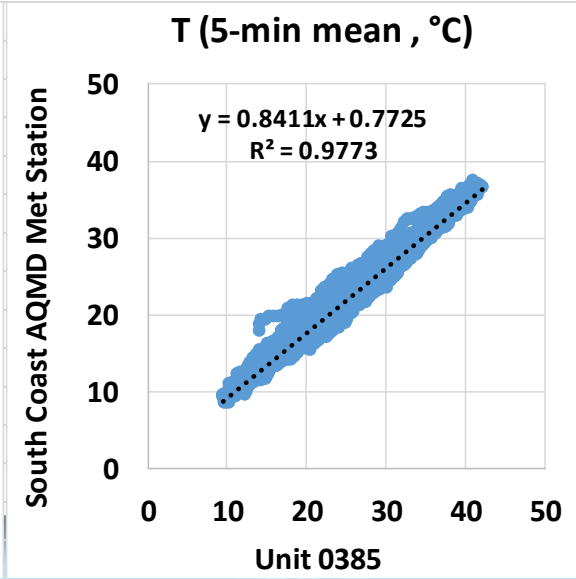
AQMesh vs South Coast AQMD Met Station (Temp; 5-min mean)



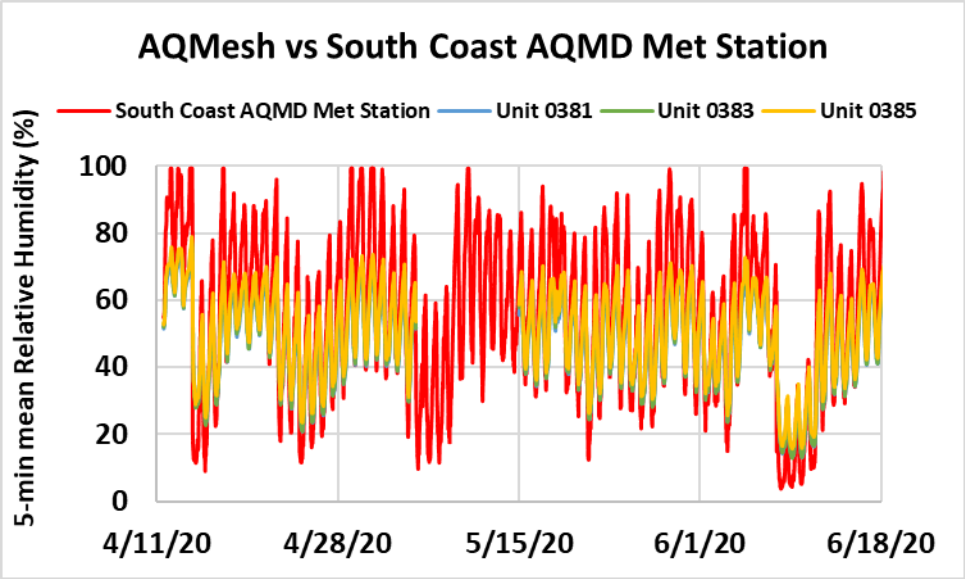
- The AQMesh sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data (R^2 ~ 0.97)
- Overall, the AQMesh sensors overestimated the temperature measurement as recorded by South Coast AQMD Met Station
- The AQMesh sensors seemed to track the diurnal temperature variations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



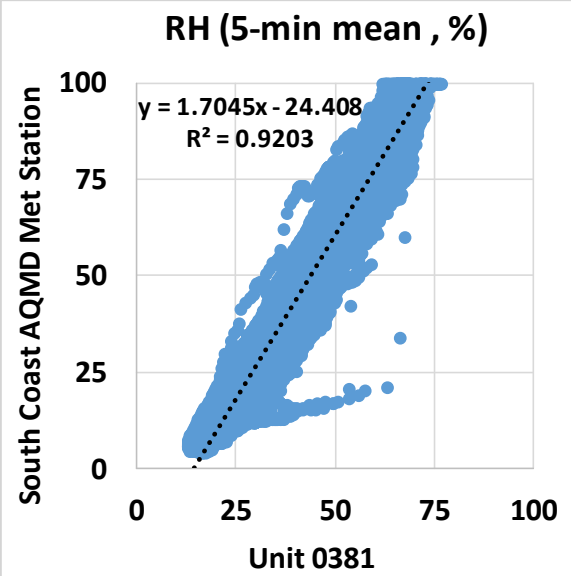


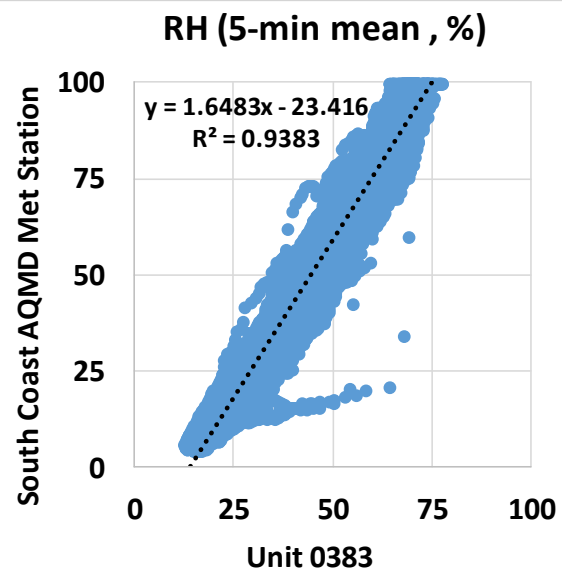


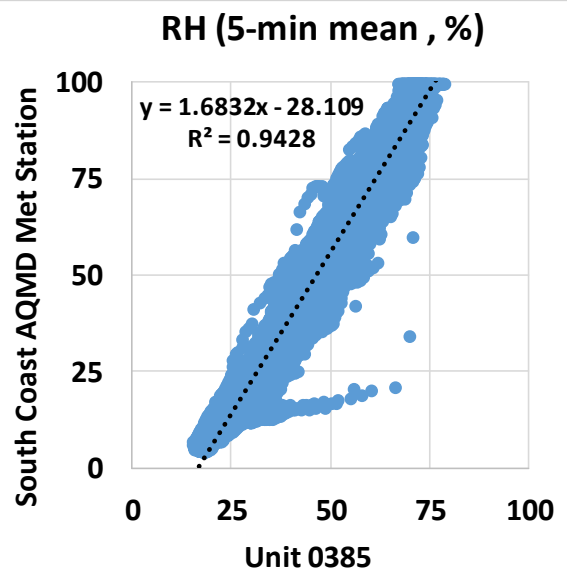
AQMesh vs South Coast AQMD Met Station (RH; 5-min mean)



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







Discussion

- The three **AQMesh** sensors' data recovery for $PM_{1.0}$, $PM_{2.5}$ and PM_{10} from all units was ~ 100%.
- The absolute intra-model variability was ~ 1.7, 2.2, and 3.7 µg/m^3 for the $PM_{1.0}$, $PM_{2.5}$ and PM_{10} measurements, respectively.
- The reference instruments (GRIMM and T640) show strong correlations with each other for $PM_{2.5}$ mass concentration measurements (R^2 ~ 0.84, 1-hr mean) and PM_{10} mass concentration measurements (R^2 ~ 0.87, 1-hr mean).
- $PM_{1.0}$ mass concentrations measured by the AQMesh sensors showed moderate to strong correlations with the corresponding GRIMM data ($0.55 < R^2 < 0.76$, 1-hr mean). The sensors underestimated $PM_{1.0}$ mass concentrations as measured by GRIMM.
- $PM_{2.5}$ mass concentrations measured by the AQMesh sensor showed weak to strong correlations with the corresponding FEM GRIMM and FEM T640 data ($0.48 < R^2 < 0.82$; 1-hr mean). The sensors underestimated $PM_{2.5}$ mass concentrations as measured by FEM GRIMM and FEM T640.
- PM_{10} mass concentrations measured by the AQMesh sensors showed very weak to moderate correlations with the GRIMM ($0.28 < R^2 < 0.62$; 1-hr mean) and T640 data ($0.33 < R^2 < 0.70$; 1-hr mean) and underestimated PM_{10} mass concentrations measured by GRIMM and T640.
- 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