Field Evaluation
Atmotube Pro

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 01/07/2020 to 03/11/2020, three **Atmotube Pro** 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) instruments measuring the same pollutants

- Atmotube Pro (*3 units tested*):
  - Particle sensor: optical; non-FEM (model SPS30, Sensirion)
  - Each unit reports: $PM_{1.0}$, $PM_{2.5}$ and PM_{10} (µg/m^3), temperature (°C), RH (%), pressure (mm Hg), VOC (ppm)
  - Unit cost: $189
  - Time resolution: 1-min
  - Units IDs: E7E0, 05AB, 6C77

- MetOne BAM (*reference instrument*):
  - Beta-attenuation monitor (FEM $PM_{2.5}$ & PM_{10})
  - Measures $PM_{2.5}$ & PM_{10} (µg/m^3)
  - Unit cost: ~$20,000
  - Time resolution: 1-hr

- GRIMM (*reference instrument*):
  - Optical particle counter (FEM $PM_{2.5}$)
  - Measures $PM_{1.0}$, $PM_{2.5}$, and PM_{10} (µg/m^3)
  - Cost: ~$25,000 and up
  - Time resolution: 1-min

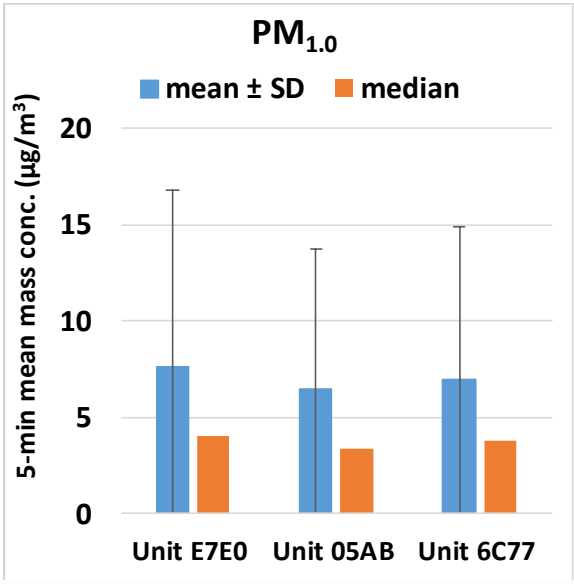
- Met station (T, RH, P, WS, WD), cost: ~$5,000
  - Time resolution: 1-min

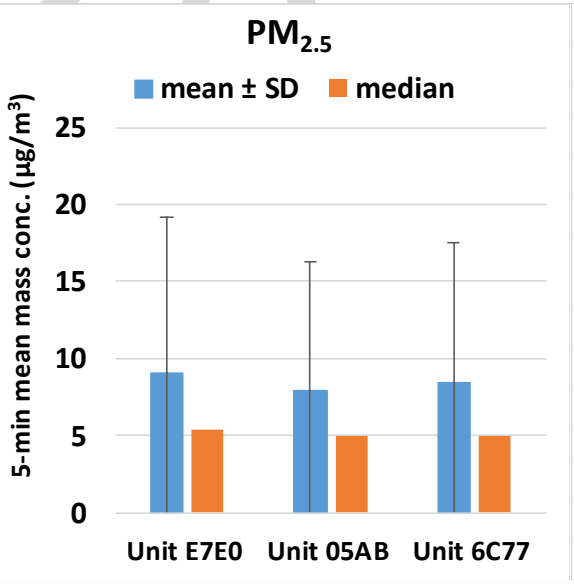
Data validation & recovery

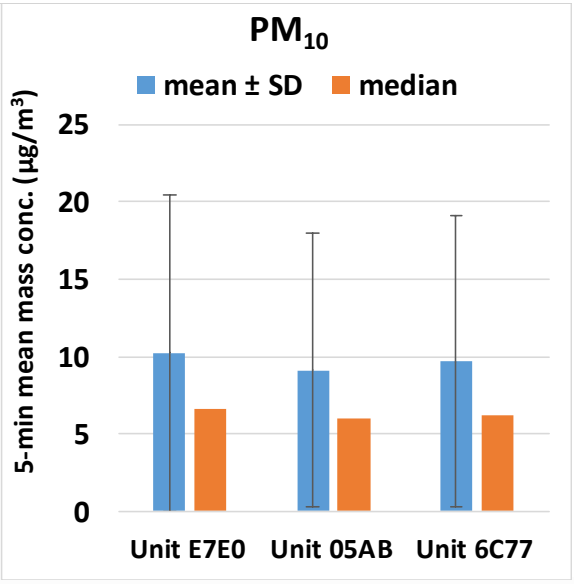
- Basic QA/QC procedures were used to validate the collected data (i.e. obvious outliers, negative values and invalid data-points were eliminated from the data-set)
- Data recovery from units E7E0, 05AB, 6C77 was ~ 92%, ~ 94% and ~ 94%, respectively, for all PM measurements

Atmotube Pro; intra-model variability

- Absolute intra-model variability was ~ 0.56, 0.57 and 0.54 µg/m^3 for $PM_{1.0}$, $PM_{2.5}$ and $PM_{10,}$ respectively (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 8.0%, 6.7% and 5.6 % for $PM_{1.0}$, $PM_{2.5}$ and $PM_{10,}$ respectively (calculated as the absolute intra-model variability relative to the mean of the three sensor means)

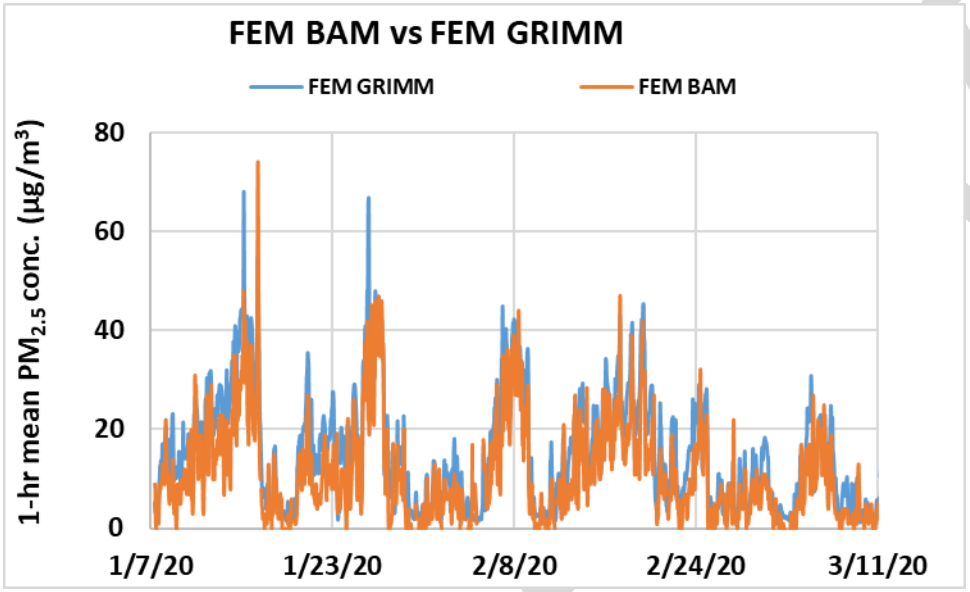


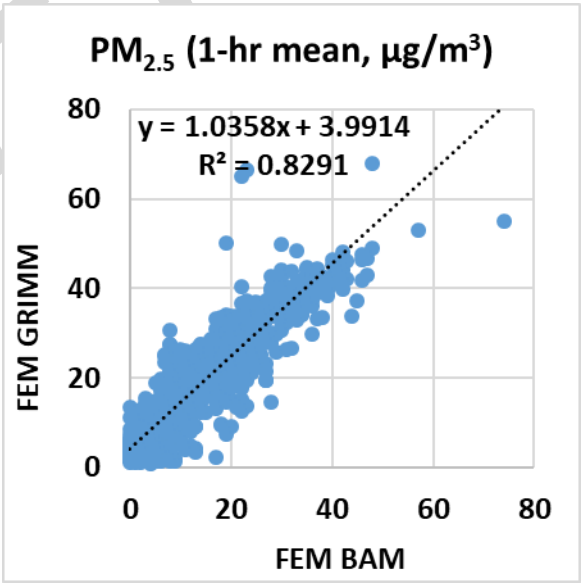




Reference Instruments: $PM_{2.5}$ FEM GRIMM and FEM BAM

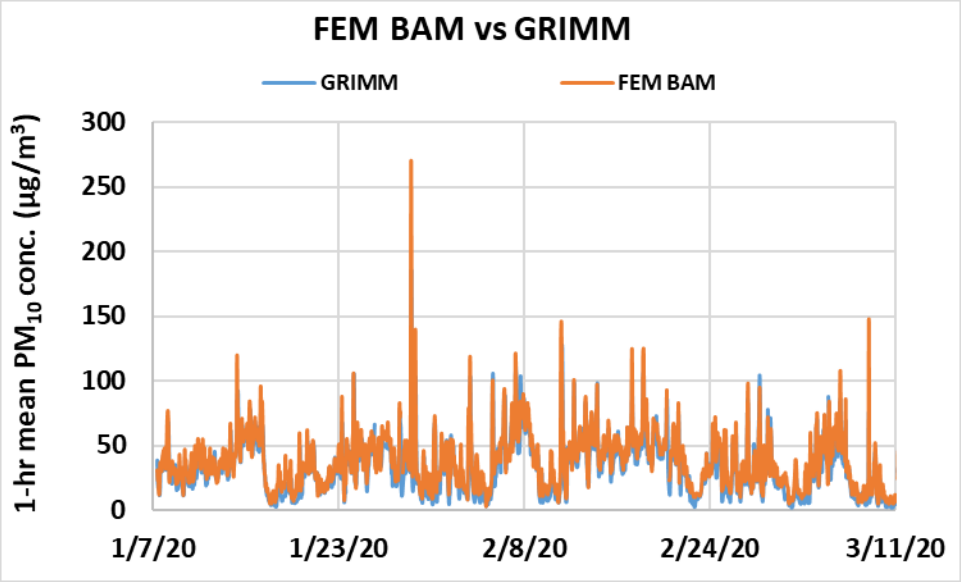
- Data recovery for $PM_{2.5}$ from FEM GRIMM and FEM BAM was ~ 99% and 92%, respectively.
- Strong correlations between the reference instruments for $PM_{2.5}$ measurements (R^2 ~ 0.83) were observed.

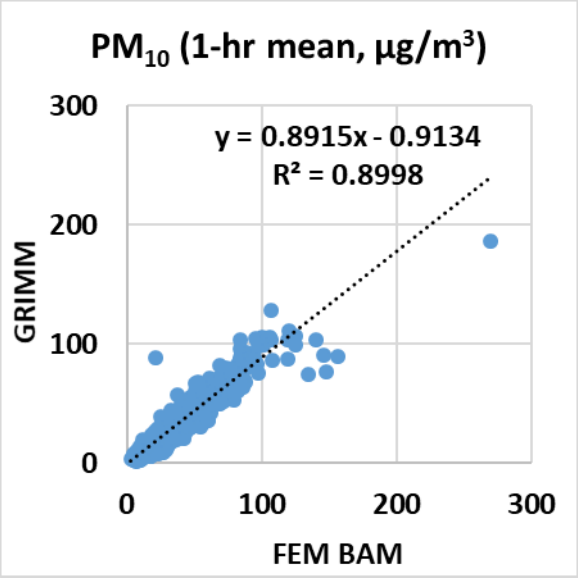




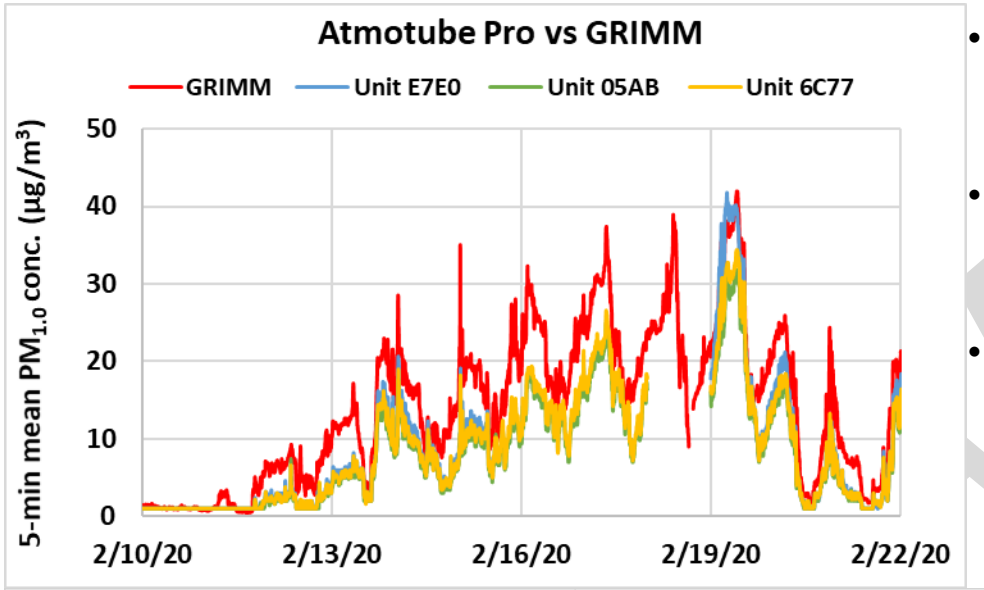
Reference Instruments: PM_{10} GRIMM and FEM BAM

- Data recovery for PM_{10} from GRIMM and FEM BAM was ~99%.
- Very strong correlations between the reference instruments for PM_{10} measurements (R^2 ~ 0.90) were observed.

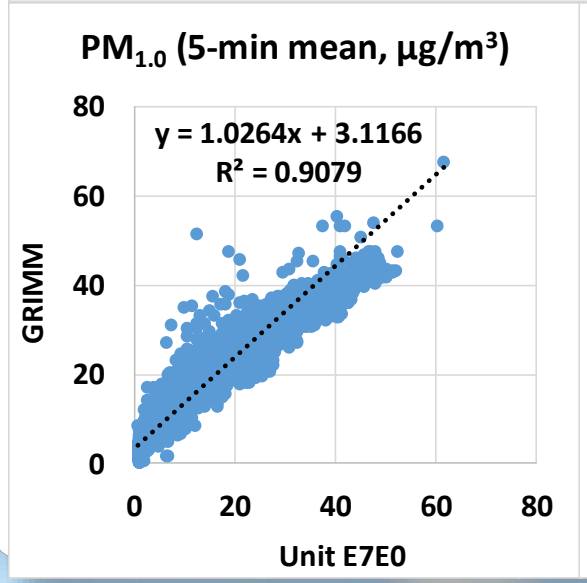


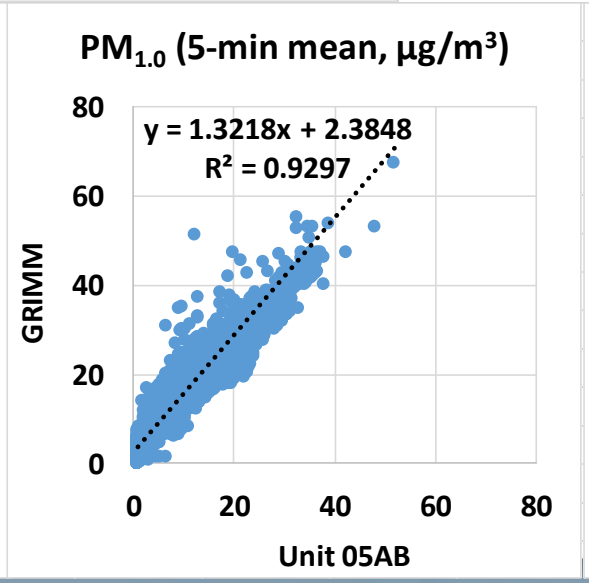


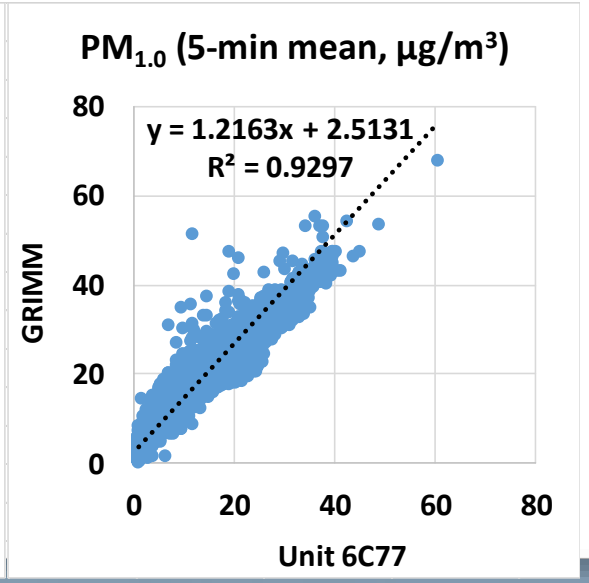
Atmotube Pro vs GRIMM ($PM_{1.0}$; 5-min mean)



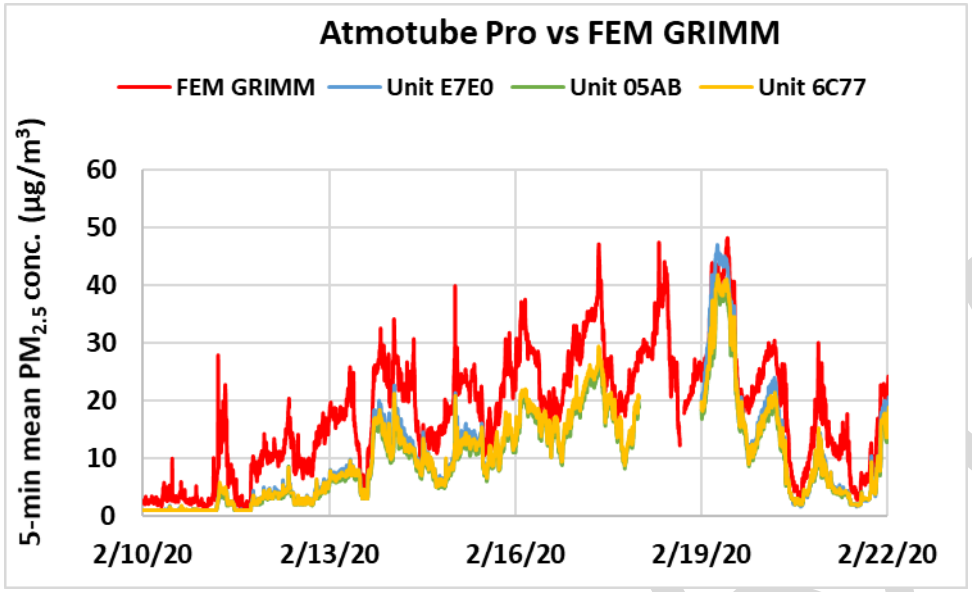
- Atmotube Pro sensors showed very strong correlations with the corresponding GRIMM data (R^2 ~ 0.92)
- Overall, the Atmotube Pro sensors underestimated the $PM_{1.0}$ mass concentrations as measured by GRIMM
- The Atmotube Pro sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by GRIMM



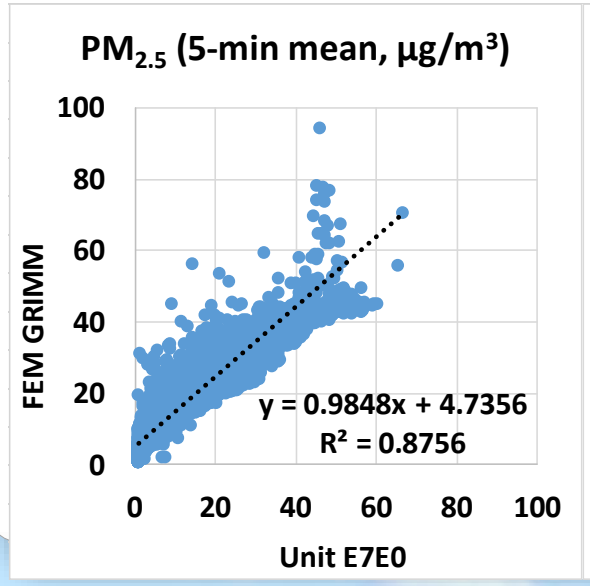


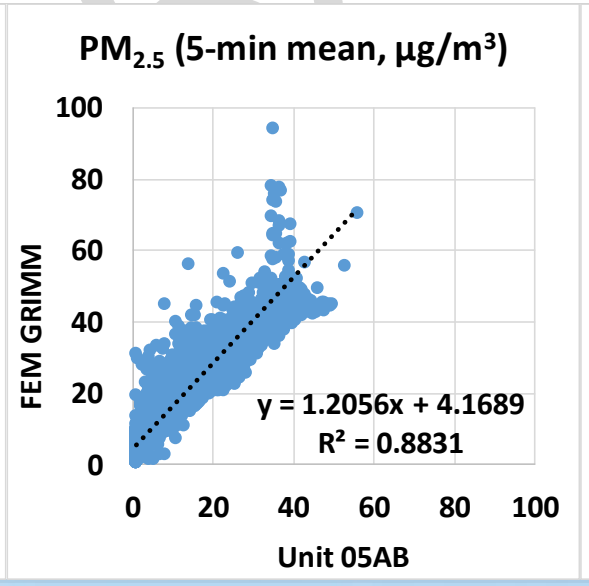


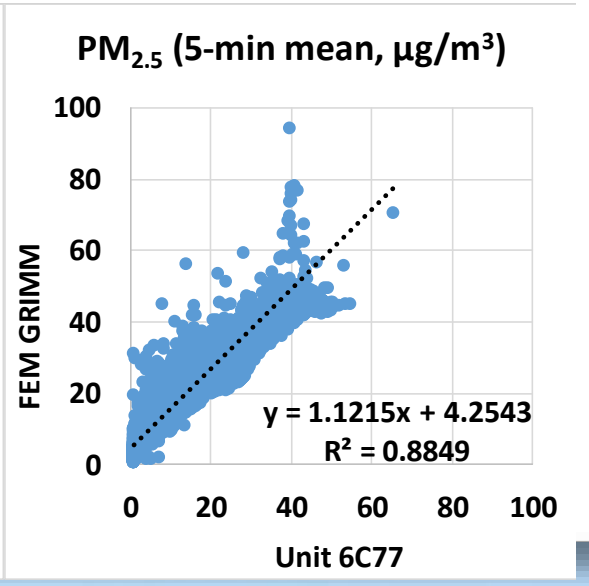
Atmotube Pro vs FEM GRIMM ($PM_{2.5}$; 5-min mean)



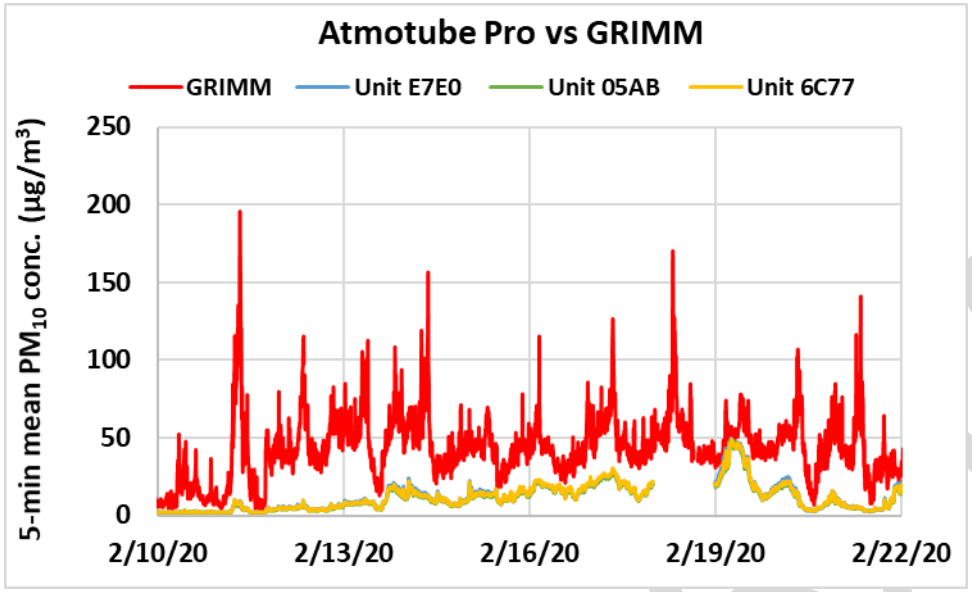
- Atmotube Pro sensors showed strong correlations with the corresponding FEM GRIMM data (R^2 ~ 0.88)
- Overall, the Atmotube Pro sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM GRIMM
- The Atmotube Pro sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded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



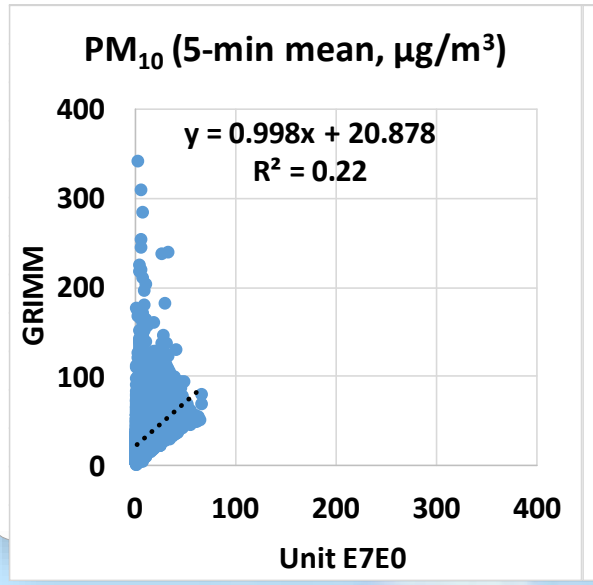


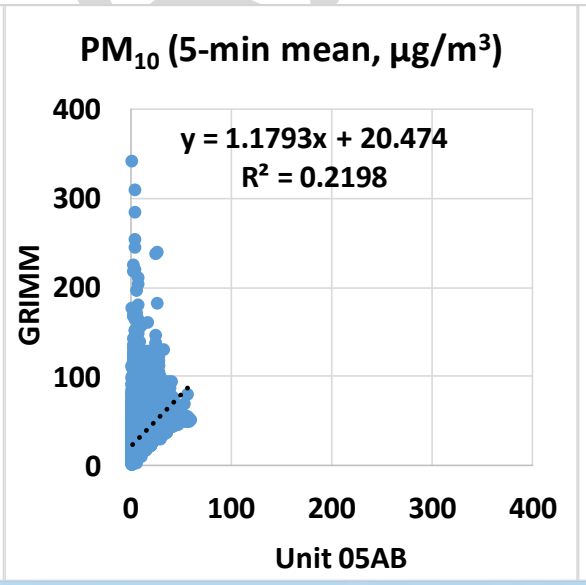


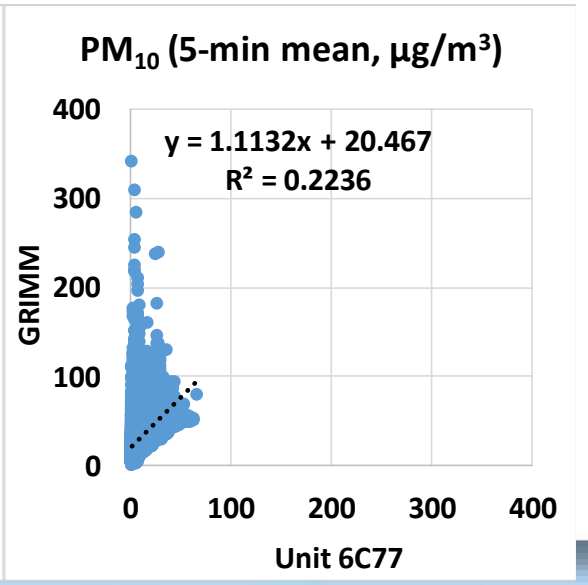
Atmotube Pro vs GRIMM (PM_{10}; 5-min mean)



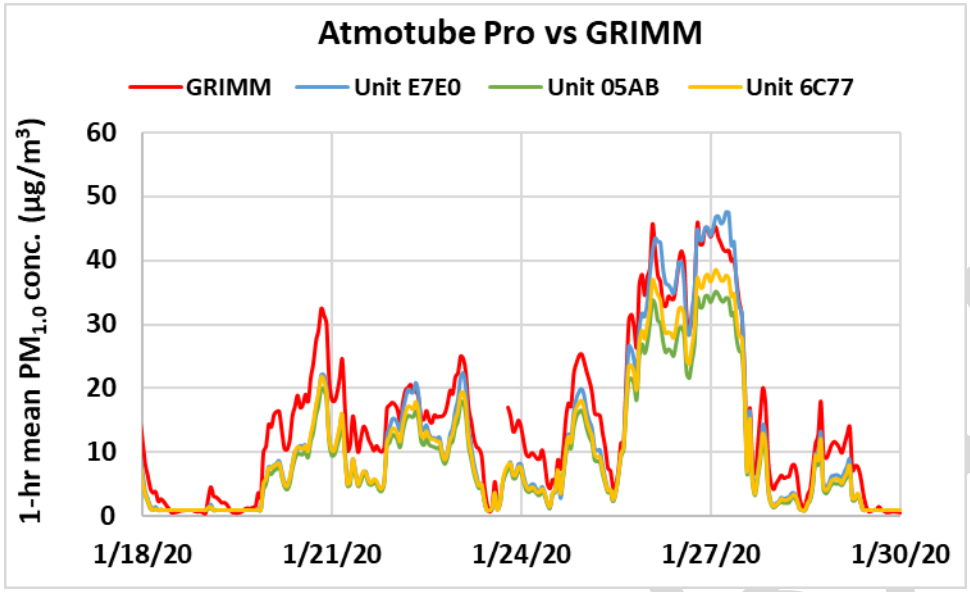
- Atmotube Pro sensors showed very weak correlations with the corresponding GRIMM data (R^2 ~ 0.22)
- Overall, the Atmotube Pro sensors underestimated the PM_{10} mass concentrations measured by GRIMM
- The Atmotube Pro sensors did not seem to track the PM_{10} diurnal variations as recorded by GRIMM



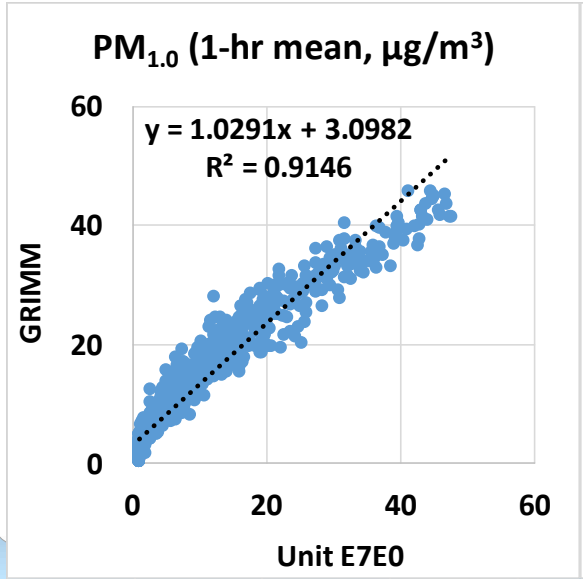


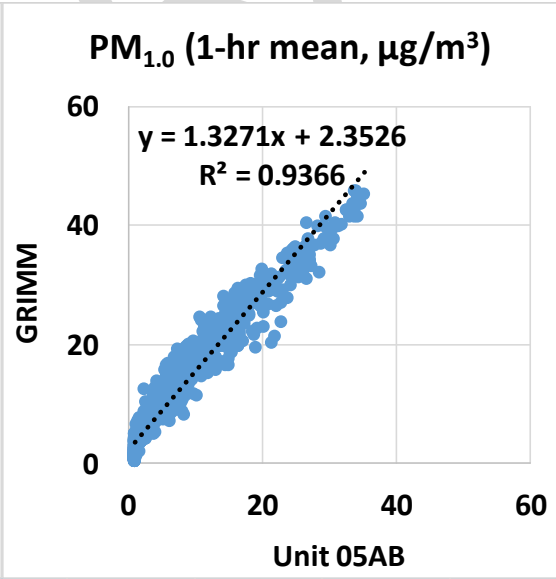


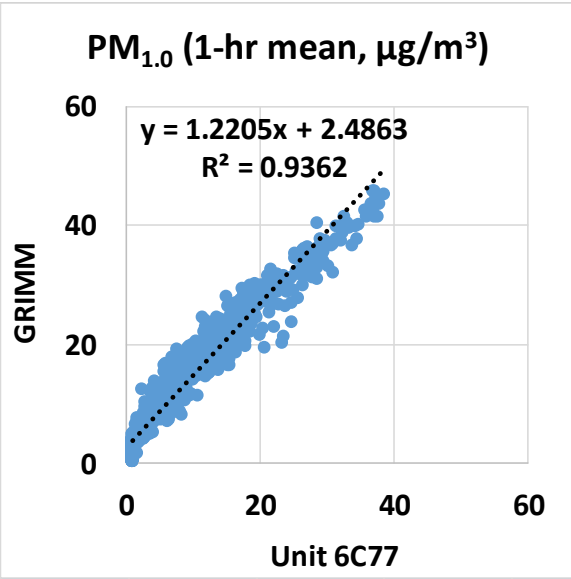
Atmotube Pro vs GRIMM ($PM_{1.0}$; 1-hr mean)



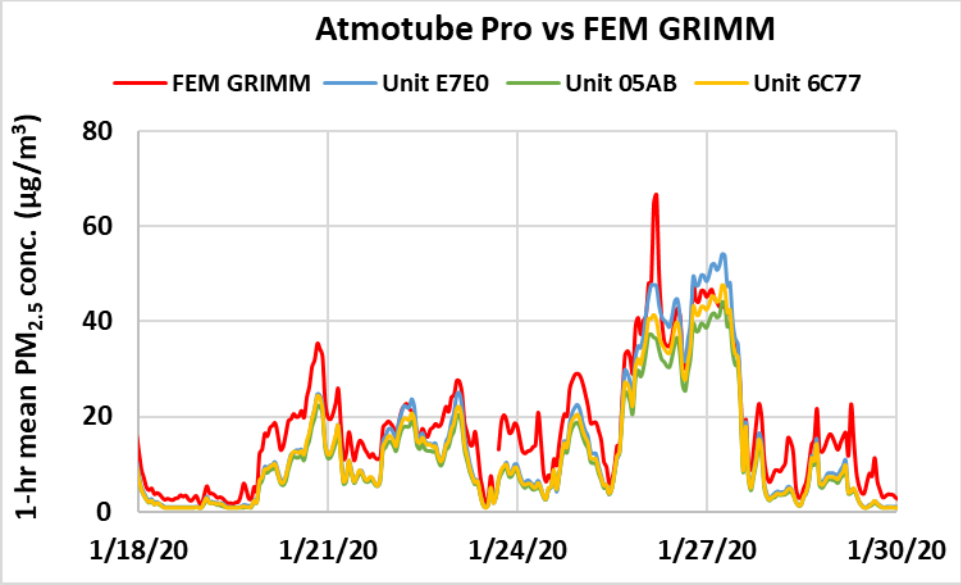
- Atmotube Pro sensors showed very strong correlations with the corresponding GRIMM data (R^2 ~ 0.93)
- Overall, the Atmotube Pro sensors underestimated the $PM_{1.0}$ mass concentrations as measured by GRIMM
- The Atmotube Pro sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by GRIMM



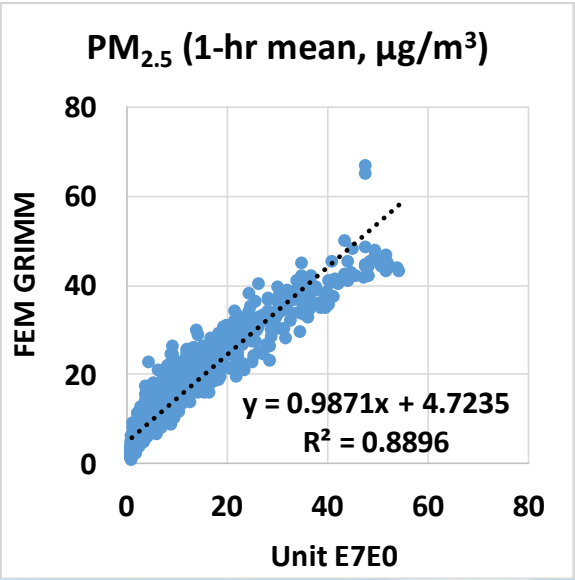


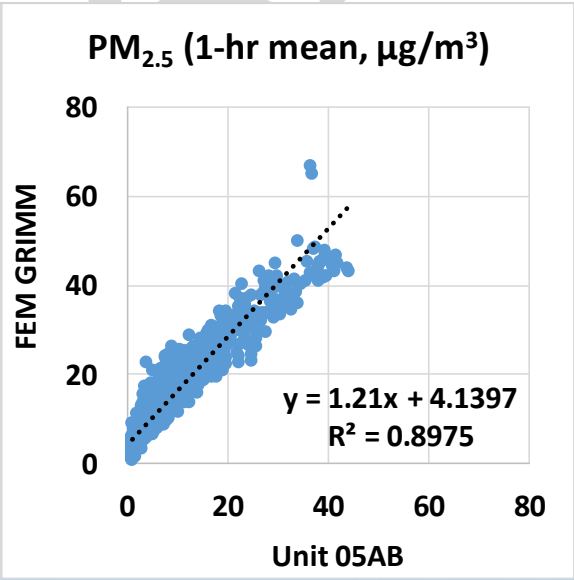


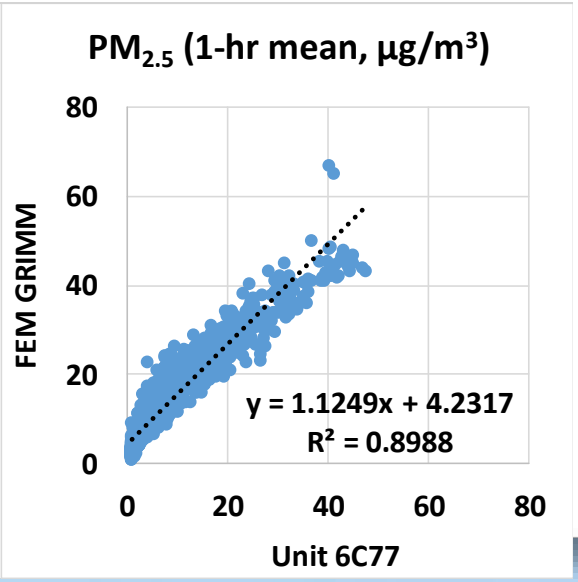
Atmotube Pro vs FEM GRIMM ($PM_{2.5}$; 1-hr mean)



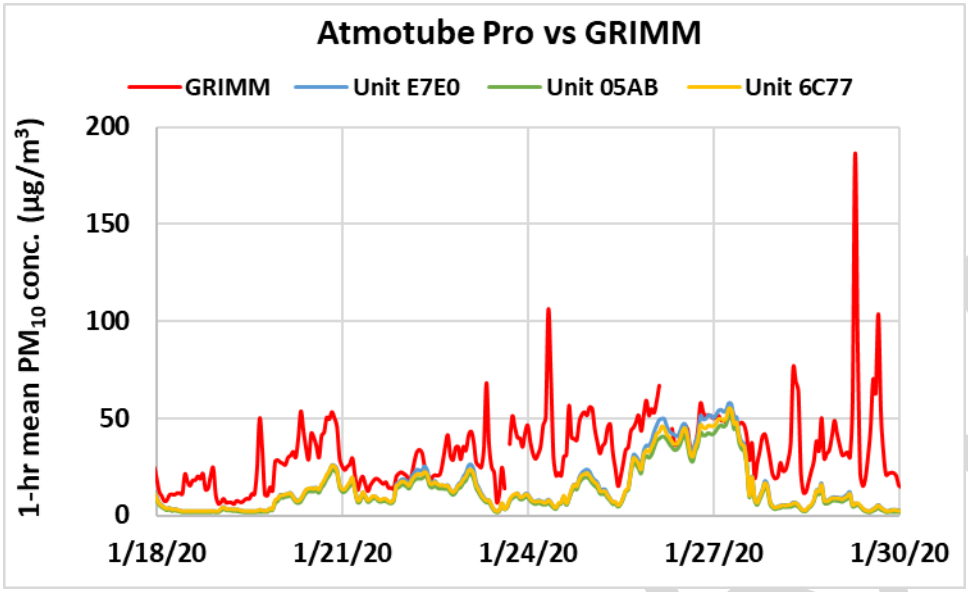
- Atmotube Pro sensors showed strong correlations with the corresponding FEM GRIMM data (R^2 ~ 0.89)
- Overall, the Atmotube Pro sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM GRIMM
- The Atmotube Pro sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded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



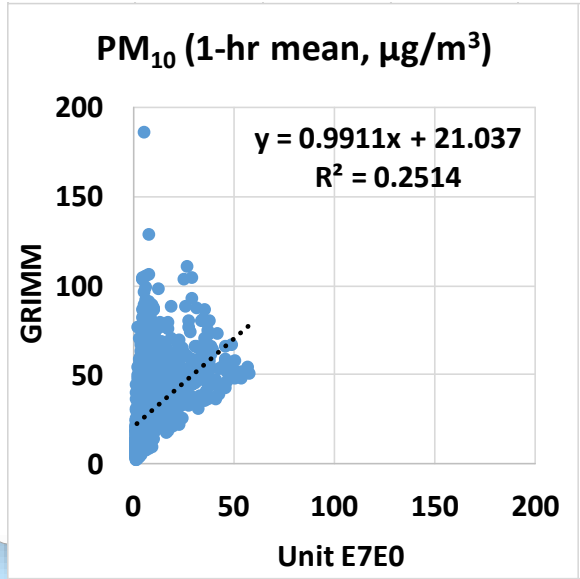


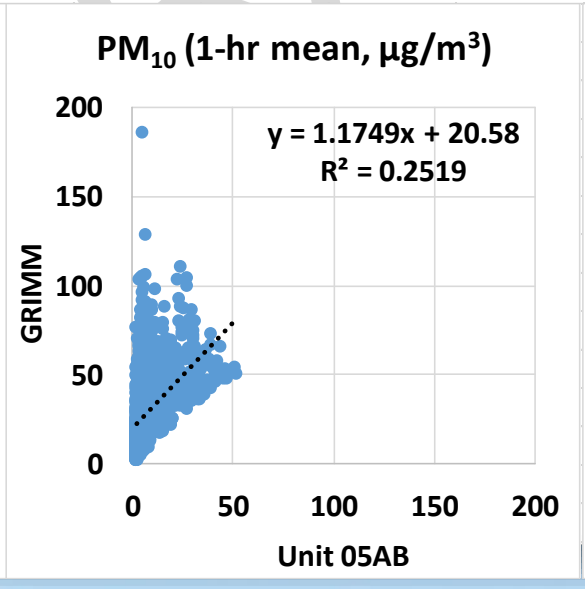


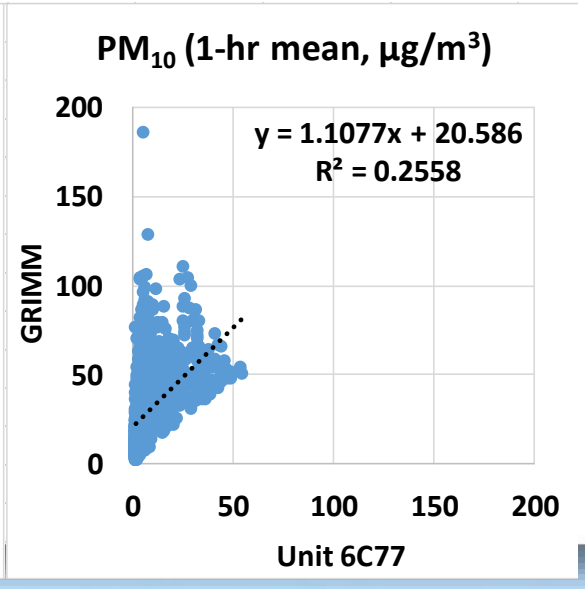
Atmotube Pro vs GRIMM (PM_{10}; 1-hr mean)



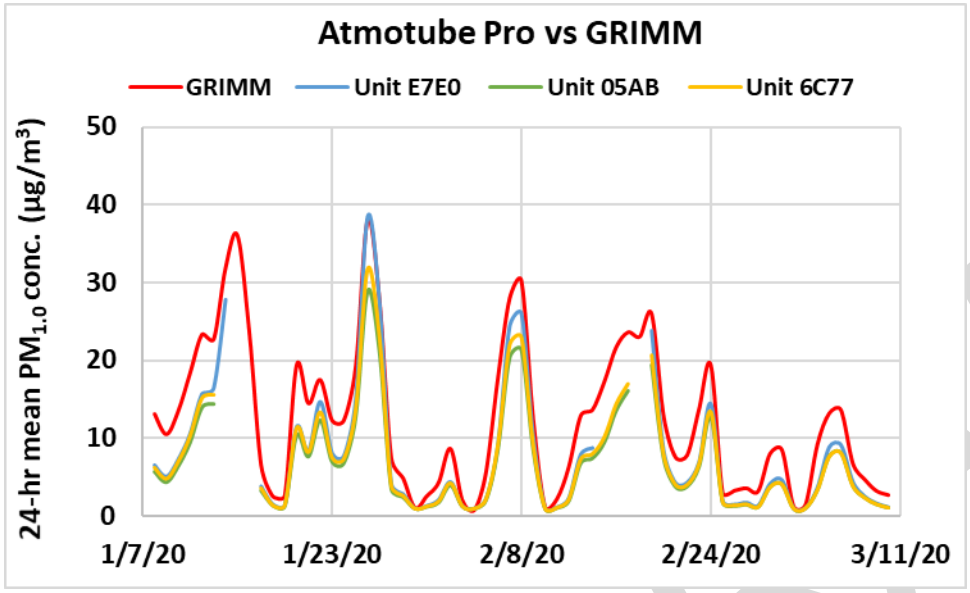
- Atmotube Pro sensors showed very weak with the corresponding GRIMM data (R^2 ~ 0.25)
- Overall, the Atmotube Pro sensors underestimated the PM_{10} mass concentrations measured by GRIMM
- The Atmotube Pro sensors did not seem to track the PM_{10} diurnal variations as recorded by GRIMM



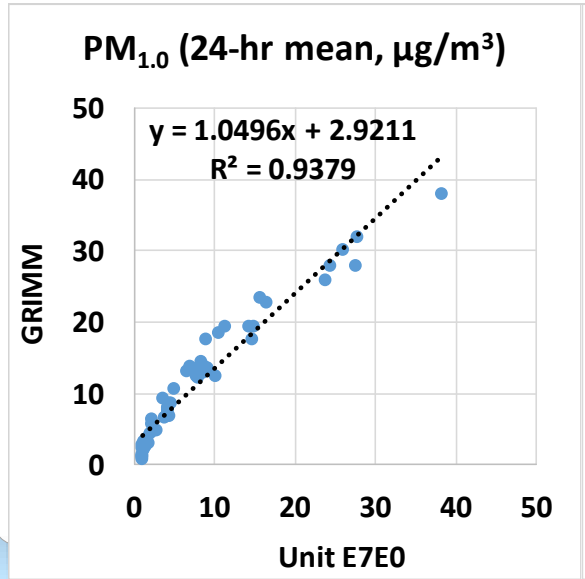


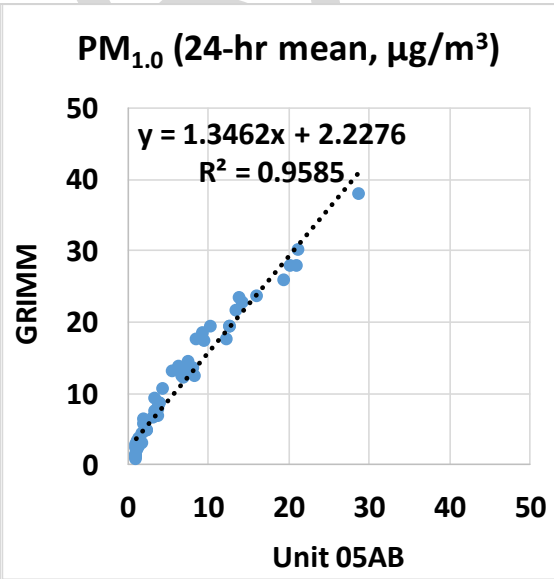


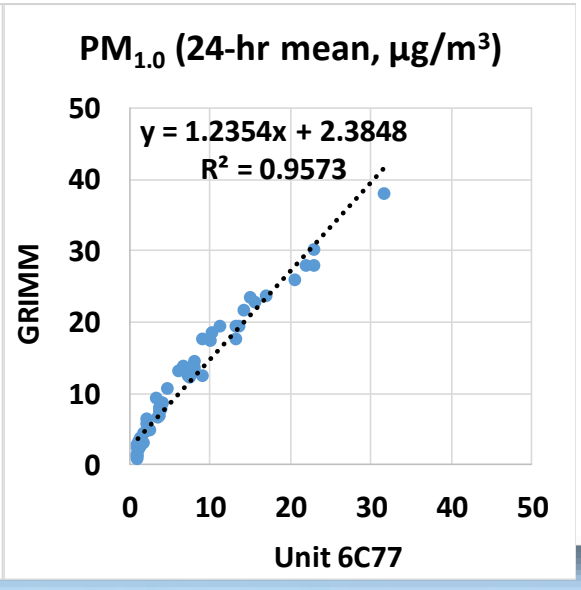
Atmotube Pro vs GRIMM ($PM_{1.0}$; 24-hr mean)



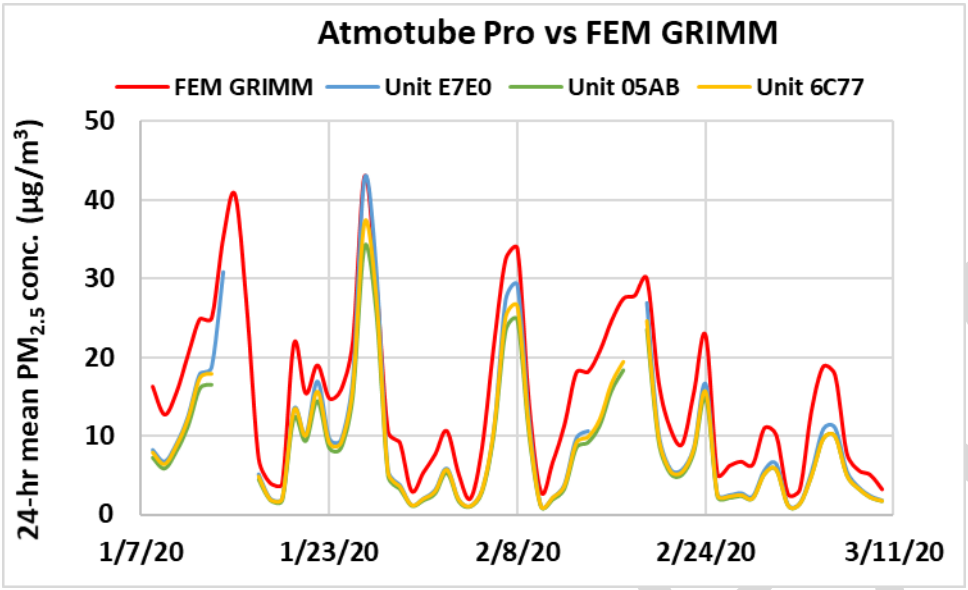
- Atmotube Pro sensors showed very strong correlations with the corresponding GRIMM data (R^2 ~ 0.95)
- Overall, the Atmotube Pro sensors underestimated the $PM_{1.0}$ mass concentrations as measured by GRIMM
- The Atmotube Pro sensors seemed to track the $PM_{1.0}$ diurnal variations as recorded by GRIMM



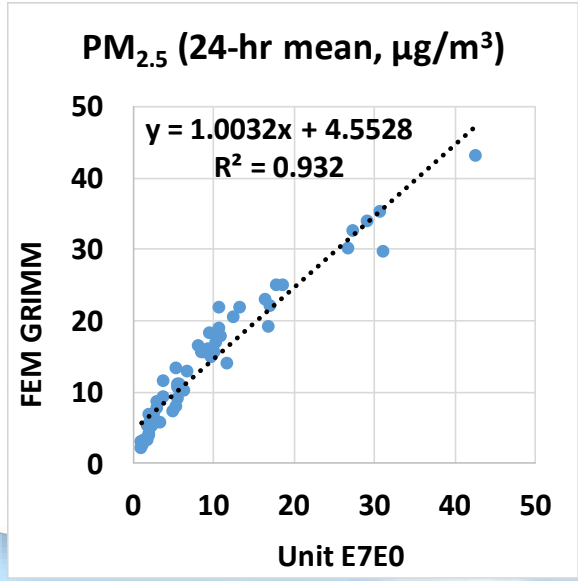


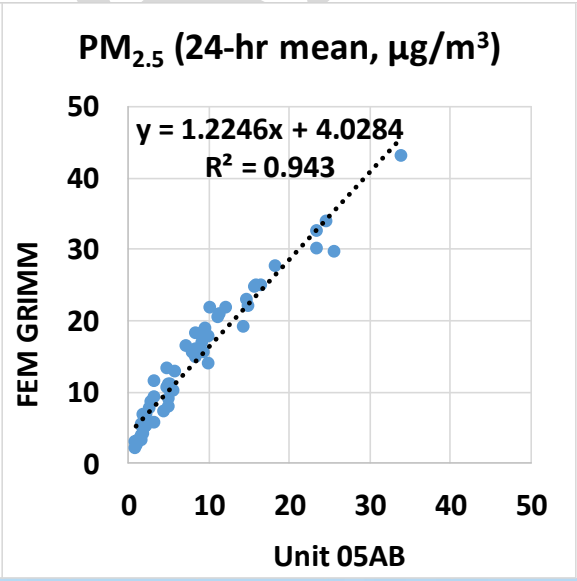


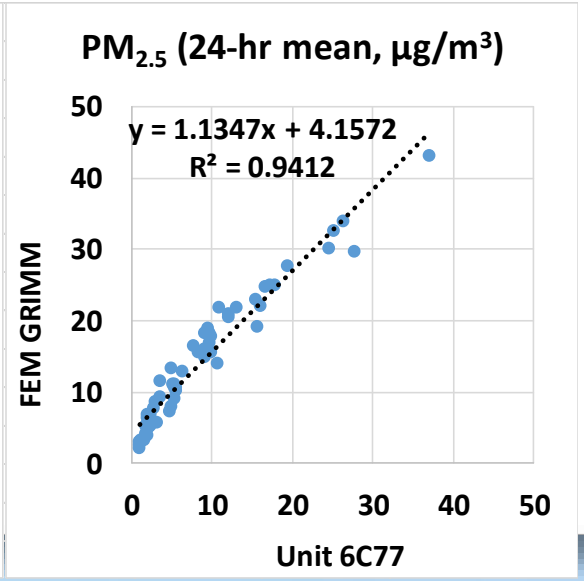
Atmotube Pro vs FEM GRIMM ($PM_{2.5}$; 24-hr mean)



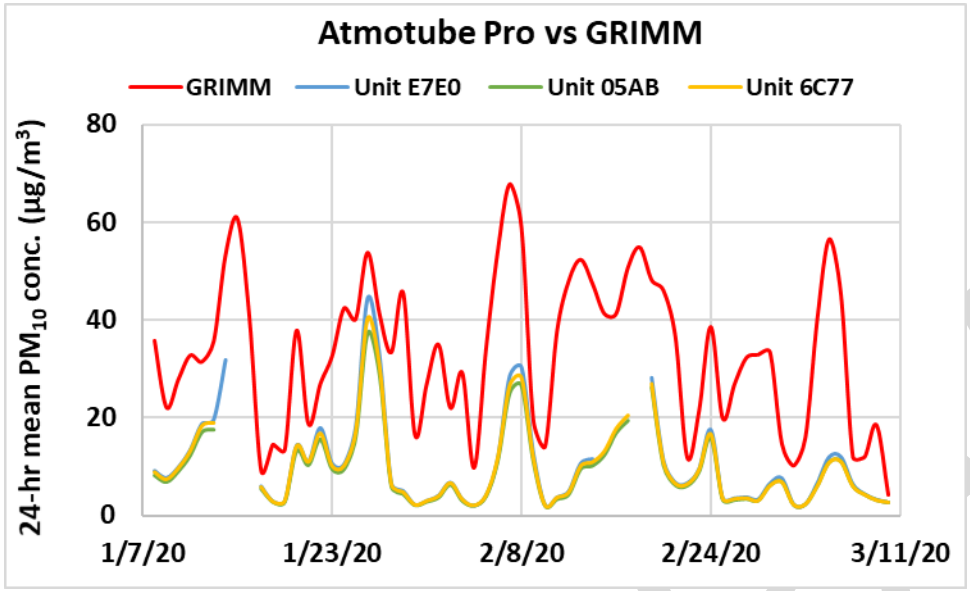
- Atmotube Pro sensors showed very strong correlations with the corresponding FEM GRIMM data (R^2 ~ 0.94)
- Overall, the Atmotube Pro sensors underestimated the $PM_{2.5}$ mass concentrations as measured by FEM GRIMM
- The Atmotube Pro sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM



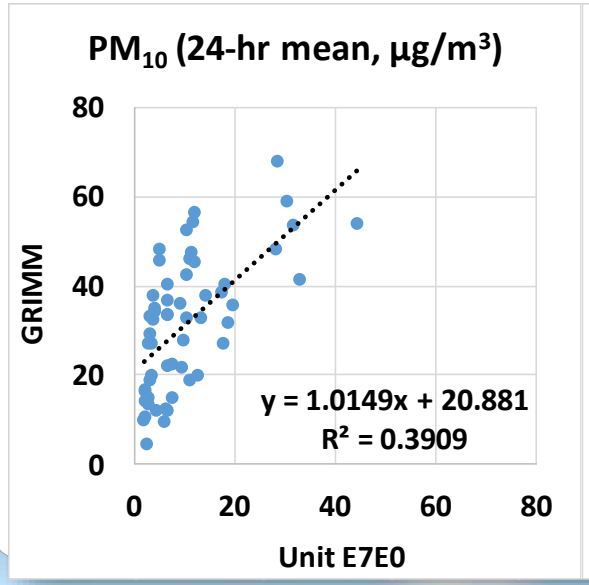


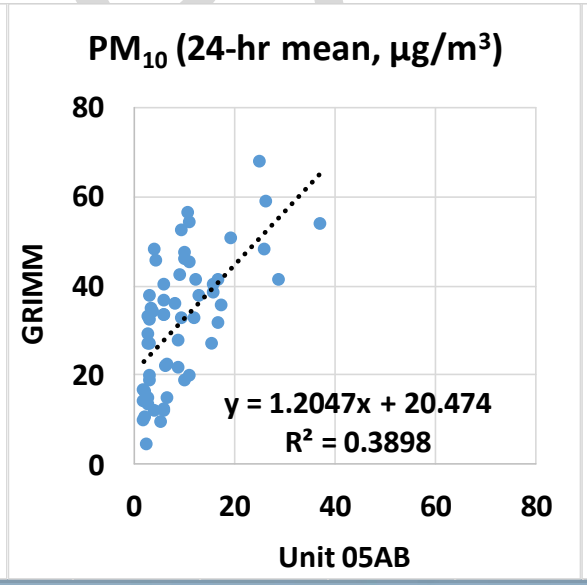


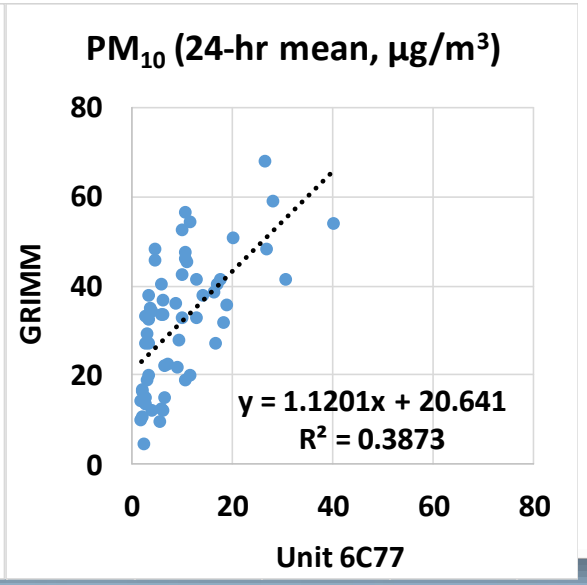
Atmotube Pro vs GRIMM (PM_{10}; 24-hr mean)



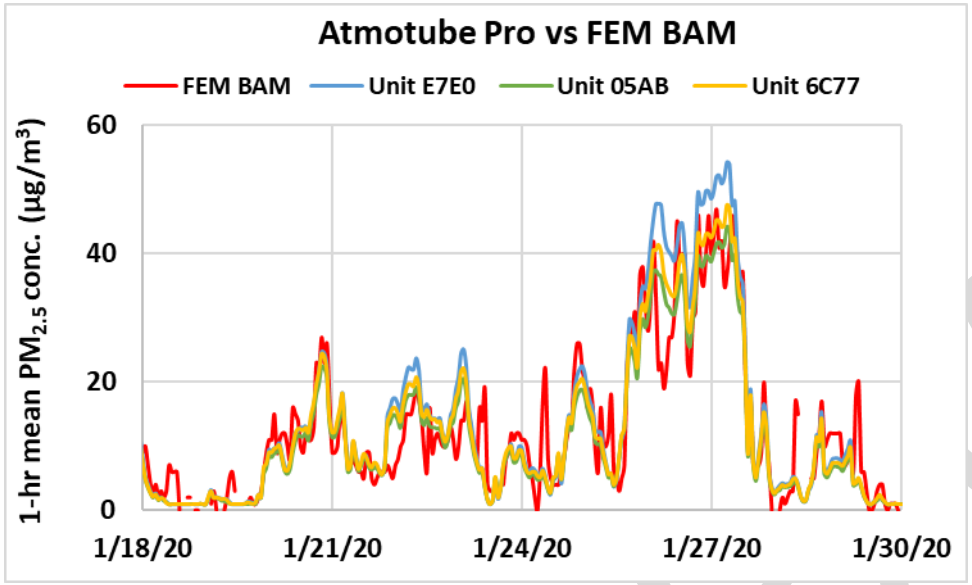
- Atmotube Pro sensors showed weak correlations with the corresponding GRIMM data (R^2 ~ 0.39)
- Overall, the Atmotube Pro sensors underestimated the PM_{10} mass concentrations measured by GRIMM
- The Atmotube Pro sensors did not seem to track the PM_{10} diurnal variations as recorded by GRIMM



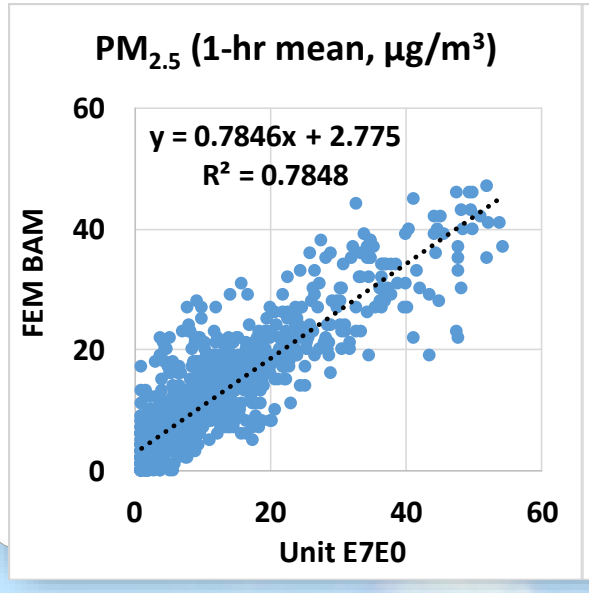


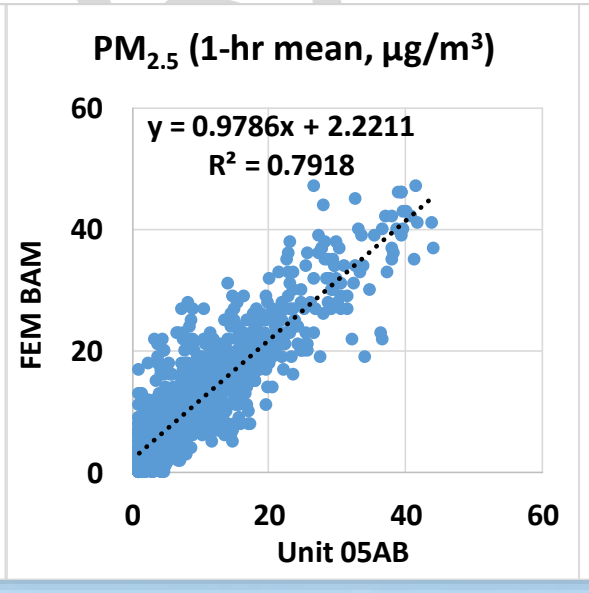


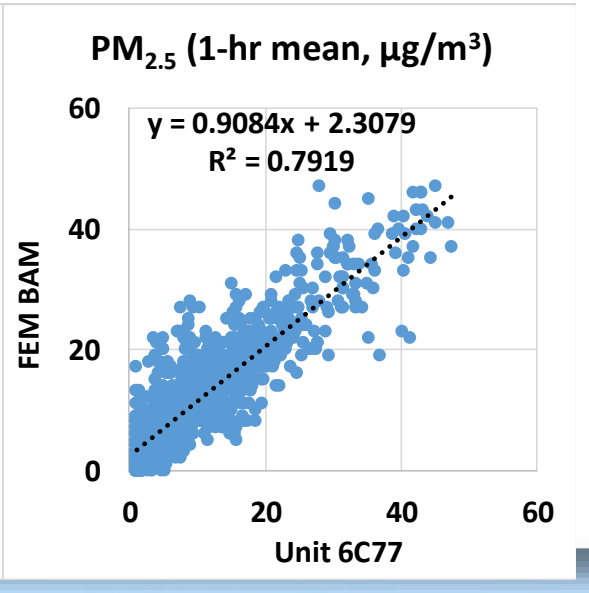
Atmotube Pro vs FEM BAM ($PM_{2.5}$; 1-hr mean)



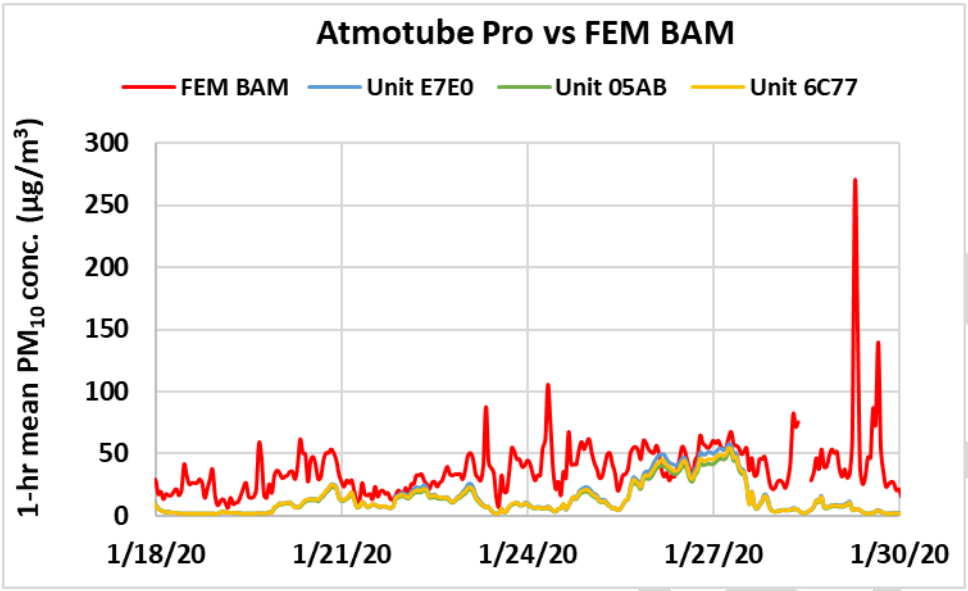
- Atmotube Pro sensors showed strong correlations with the corresponding FEM BAM data (R^2 ~ 0.79)
- Overall, the Atmotube Pro sensors underestimated the $PM_{2.5}$ mass concentrations when $PM_{2.5}$ mass concentrations were lower than 20 µg/m^3 and overestimated the $PM_{2.5}$ mass concentrations when $PM_{2.5}$ mass concentrations were higher than 20 µg/m^3 as measured by FEM BAM
- The Atmotube Pro sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM BAM



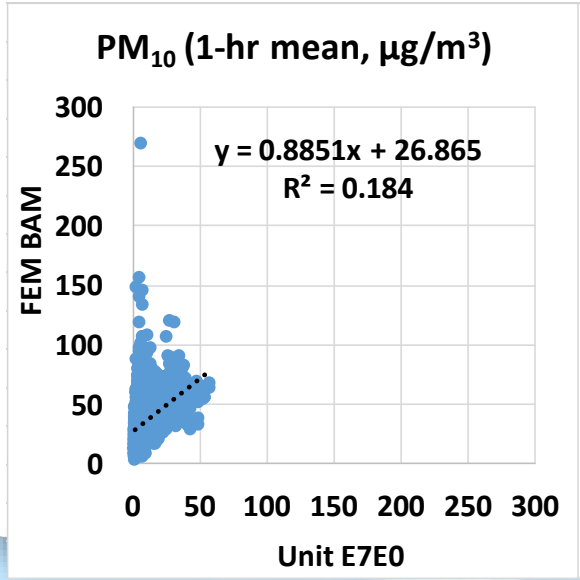


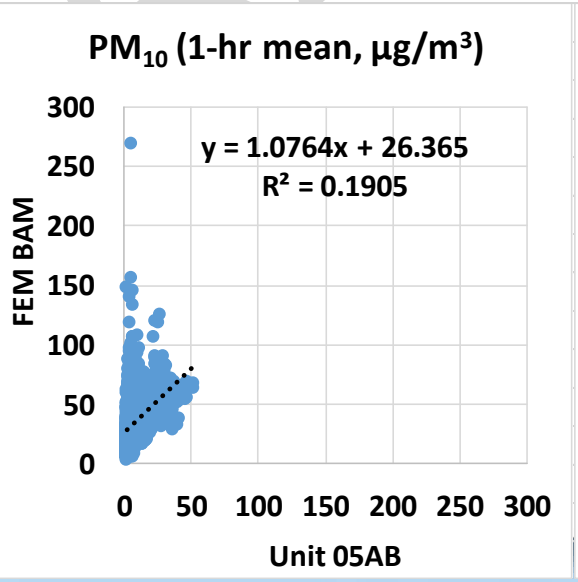


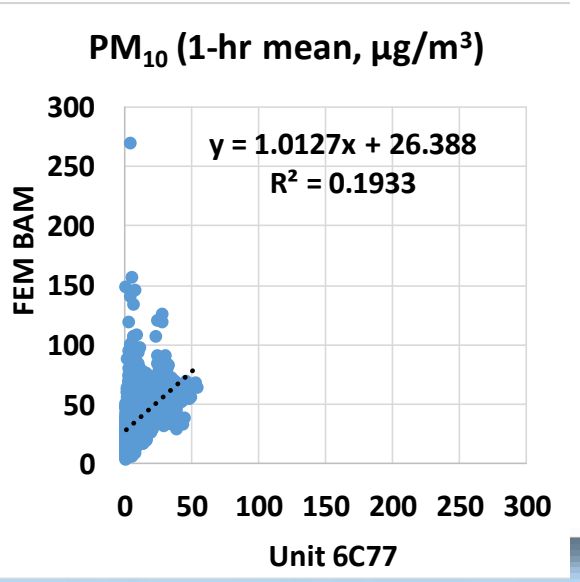
Atmotube Pro vs FEM BAM (PM_{10}; 1-hr mean)



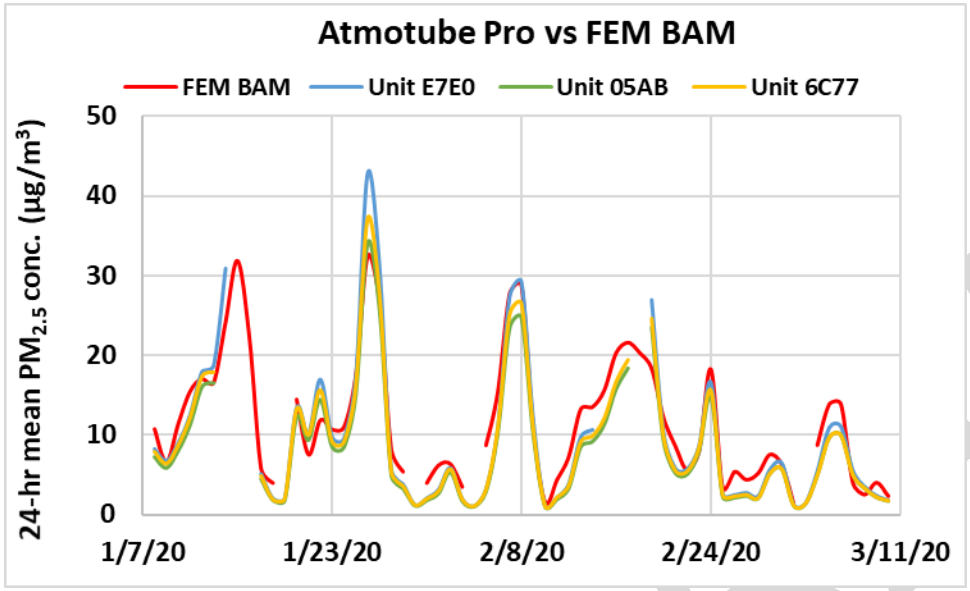
- Atmotube Pro sensors showed very weak correlations with the corresponding FEM BAM data (R^2 ~ 0.19)
- Overall, the Atmotube Pro sensors underestimated the PM_{10} mass concentrations measured by FEM BAM
- The Atmotube Pro sensors did not seem to track the PM_{10} diurnal variations as recorded by FEM BAM



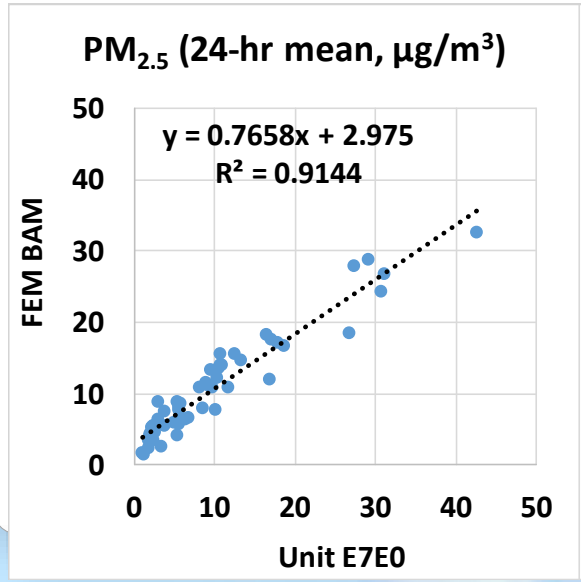


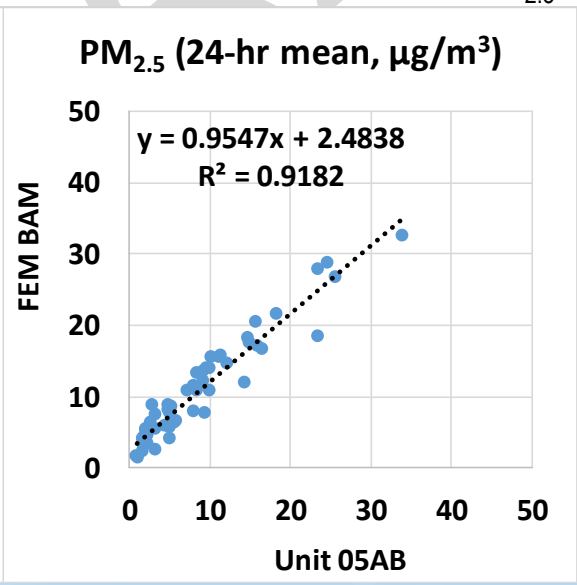


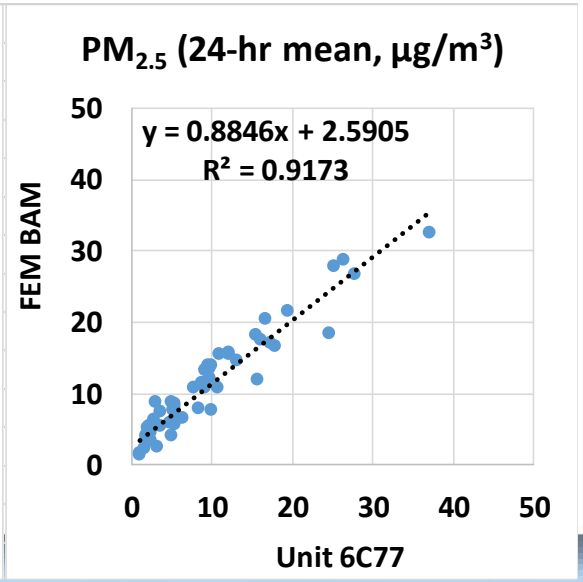
Atmotube Pro vs FEM BAM ($PM_{2.5}$; 24-hr mean)



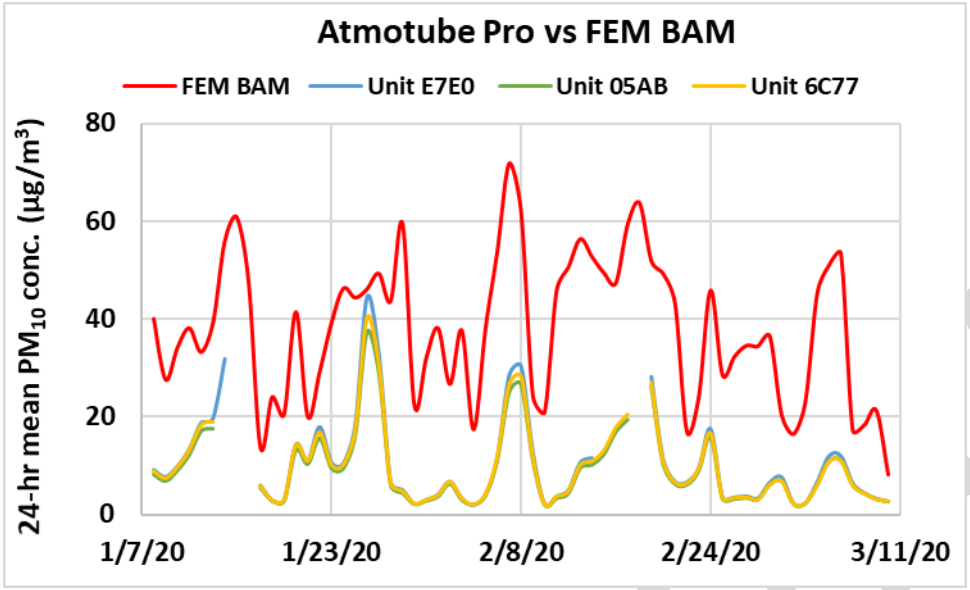
- Atmotube Pro sensors showed very strong correlations with the corresponding FEM BAM data (R^2 ~ 0.91)
- Overall, the Atmotube Pro sensors underestimated the $PM_{2.5}$ mass concentrations when $PM_{2.5}$ mass concentrations were lower than 20 µg/m^3 and overestimated the $PM_{2.5}$ mass concentrations when $PM_{2.5}$ mass concentrations were higher than 20 µg/m^3 as measured by FEM BAM
- The Atmotube Pro sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM BAM



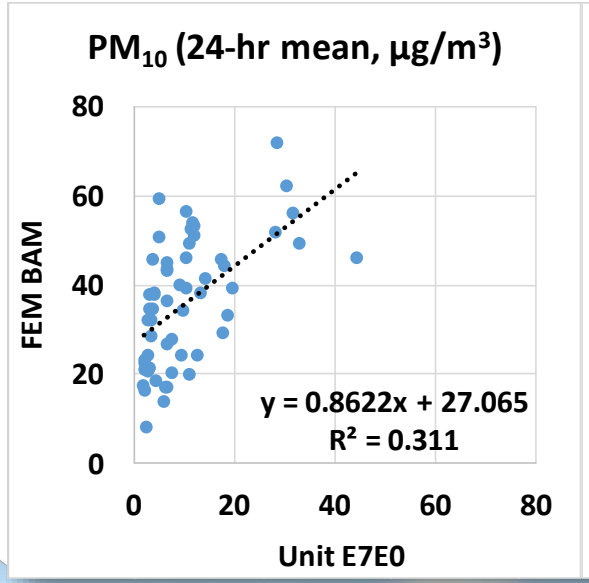


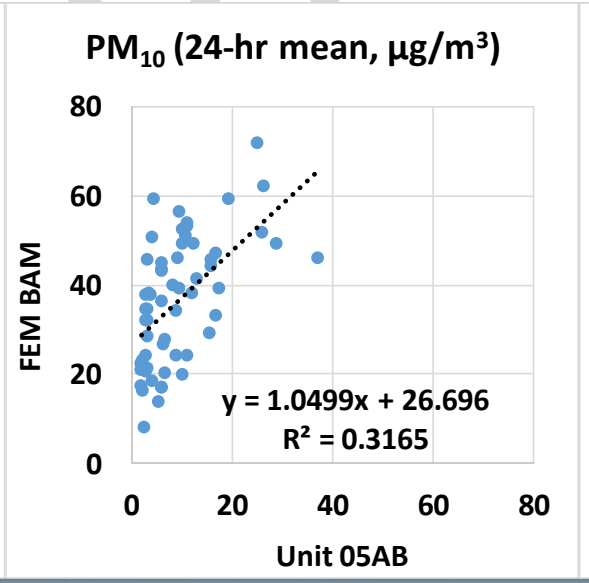


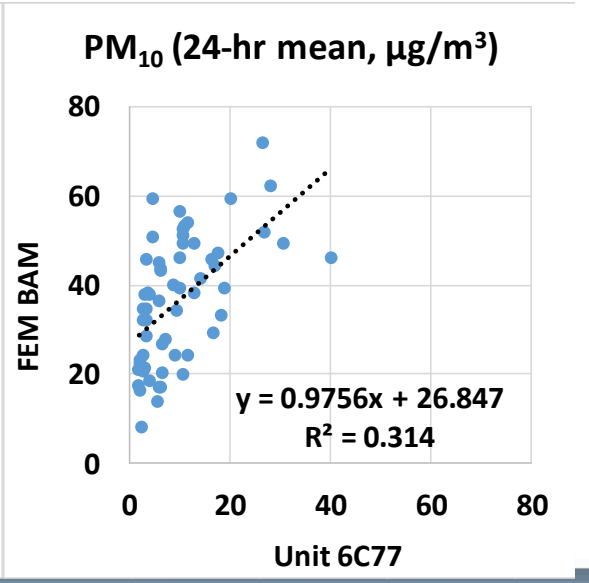
Atmotube Pro vs FEM BAM (PM_{10}; 24-hr mean)



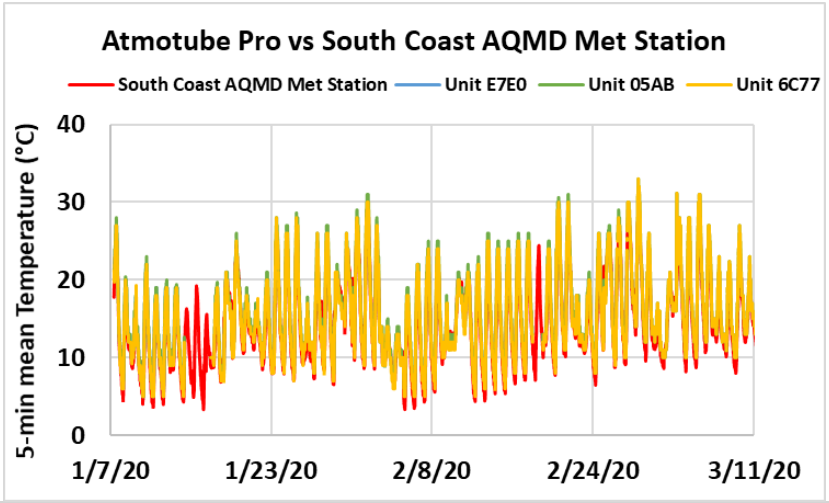
- Atmotube Pro sensors showed weak correlations with the corresponding FEM BAM data (R^2 ~ 0.31)
- Overall, the Atmotube Pro sensors underestimated the PM_{10} mass concentrations measured by FEM BAM
- The Atmotube Pro sensors did not seem to track the PM_{10} diurnal variations as recorded by FEM BAM



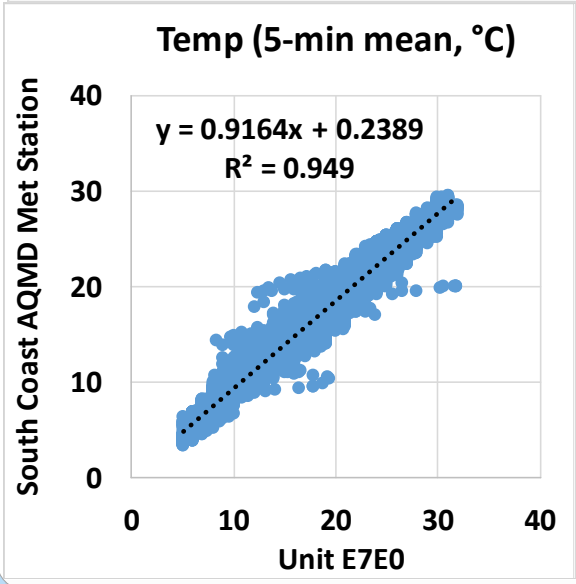


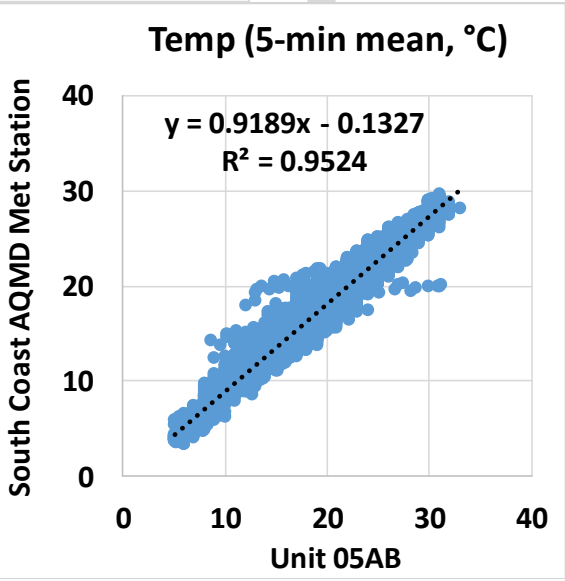


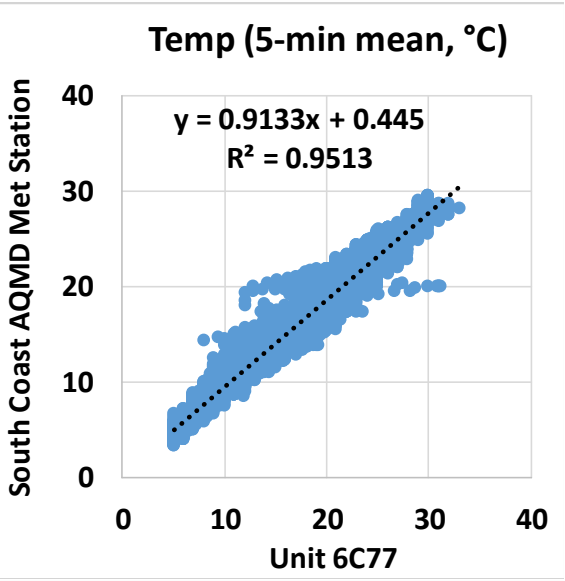
Atmotube Pro vs South Coast AQMD Met Station (Temp; 5-min mean)



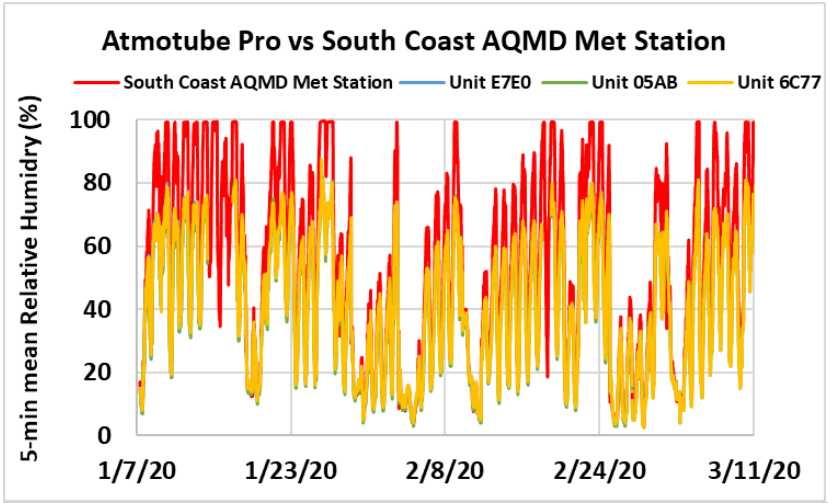
- Atmotube Pro temperature measurements showed very strong correlations with the corresponding South Coast AQMD Met Station data (R^2 ~ 0.95)
- Overall, the Atmotube Pro temperature measurements overestimated the corresponding South Coast AQMD Met Station data
- The Atmotube Pro sensors seemed to track well the temperature diurnal variations as recorded by South Coast AQMD Met Station



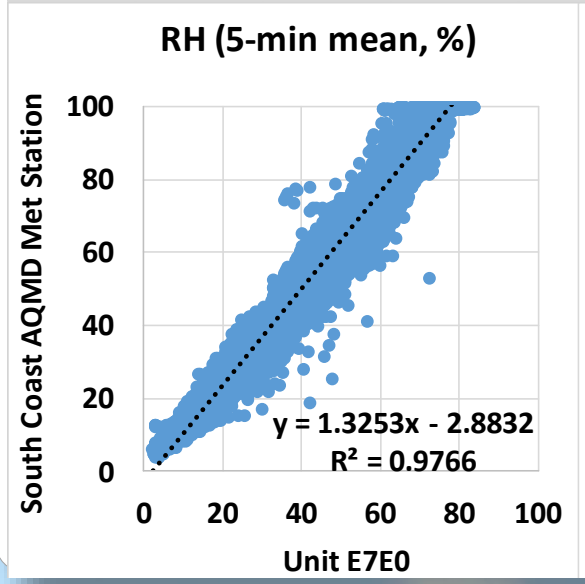


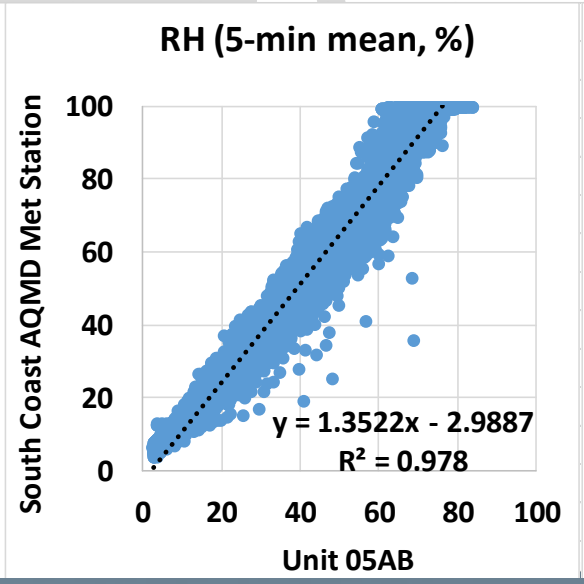


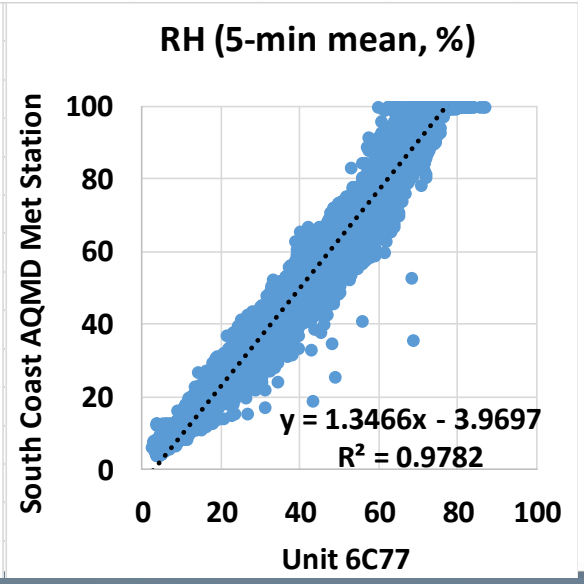
Atmotube Pro vs South Coast AQMD Met Station (RH; 5-min mean)



- Atmotube Pro RH measurements showed very strong correlations with the corresponding South Coast AQMD Met Station data (R^2 ~ 0.97)
- Overall, the Atmotube Pro RH measurements underestimated the corresponding South Coast AQMD Met Station data
- The Atmotube Pro sensors seemed to track well the RH diurnal variations as recorded by South Coast AQMD Met Station







Discussion

- The three **Atmotube Pro** sensors' data recovery from units E7E0, 05AB, 6C77 was ~ 92%, ~ 94% and ~ 94%, respectively, for all PM measurements
- The absolute intra-model variability was ~ 0.56, 0.57 and 0.54 µg/m^3 for $PM_{1.0}$, $PM_{2.5}$ and $PM_{10,}$ respectively
- Strong to very strong correlations between GRIMM and BAM for $PM_{2.5}$ (R^2 ~ 0.83, 1-hr mean) and PM_{10} (R^2 ~ 0.90, 1-hr mean) mass concentration measurements
- $PM_{1.0}$ mass concentrations measured by Atmotube Pro sensors showed very strong correlations with the corresponding GRIMM data (R^2 ~ 0.93, 1-hr mean). The sensors underestimated $PM_{1.0}$ mass concentrations as measured by GRIMM
- $PM_{2.5}$ mass concentrations measured by Atmotube Pro sensors showed strong correlations with the corresponding FEM GRIMM and FEM BAM data (R^2 ~ 0.89 and 0.79, respectively, 1-hr mean). The sensors underestimated $PM_{2.5}$ mass concentrations as measured by FEM GRIMM. The sensors underestimated $PM_{2.5}$ mass concentrations when $PM_{2.5}$ mass concentrations were lower than 20 µg/m^3 and overestimated $PM_{2.5}$ mass concentrations when $PM_{2.5}$ mass concentrations were higher than 20 µg/m^3 as measured by FEM BAM
- PM_{10} mass concentrations measured by Atmotube Pro sensors showed very weak correlations with the corresponding GRIMM and FEM BAM data (R^2 ~ 0.25 and 0.19, respectively; 1-hr mean) and underestimated PM_{10} mass concentrations measured by GRIMM and FEM BAM
- No sensor calibration was performed by South Coast AQMD Staff prior to the beginning of this test
- 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