

Field Evaluation Sensirion Nubo



Background

- From 12/27/2019 to 02/27/2020, three **Sensirion Nubo** 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
- Sensirion Nubo (3 units tested):
 - Particle sensor: **optical; non-FEM (model: SPS30, Sensirion)**
 - Each unit reports: PM_{1.0} and PM_{2.5} (µg/m³), temperature (°C), RH (%), dew point (°C)
 - PM₁₀ algorithm measurement is currently under development by the manufacturer
 - **Unit cost: \$2000 per unit with a yearly SaaS at \$500**
 - Time resolution: 1-min
 - Units IDs: 2A3E, 1743, 051E
- MetOne BAM (reference instrument):
 - Beta-attenuation monitor (**FEM PM_{2.5} & PM₁₀**)
 - Measures PM_{2.5} & PM₁₀ (µg/m³)
 - **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 PM₁₀ (µg/m³)
 - **Cost: ~\$25,000 and up**
 - Time resolution: 1-min
- Met station (T, RH, P, WS, WD), **cost: ~\$5,000**
 - Time resolution: 1-min

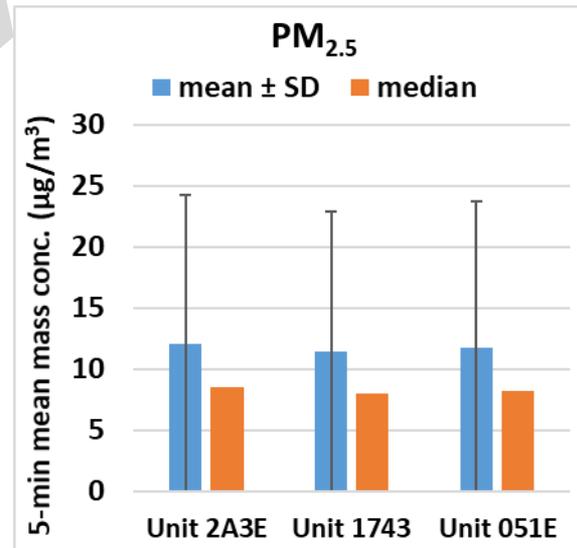
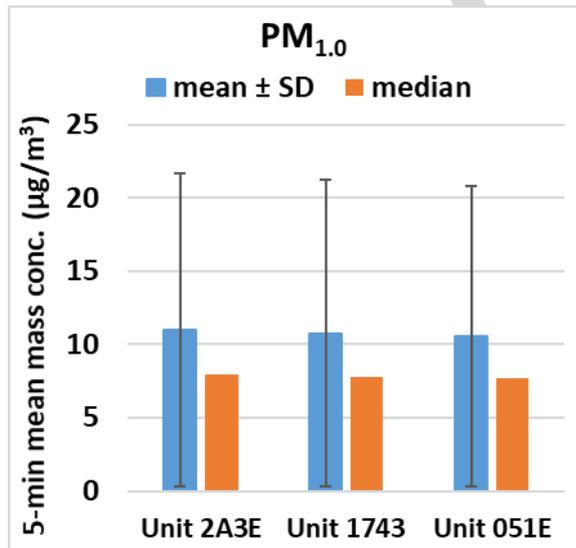


Data validation & recovery

- 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 2A3E, 1743, 051E was ~97% for all PM measurements

Sensirion Nubo; intra-model variability

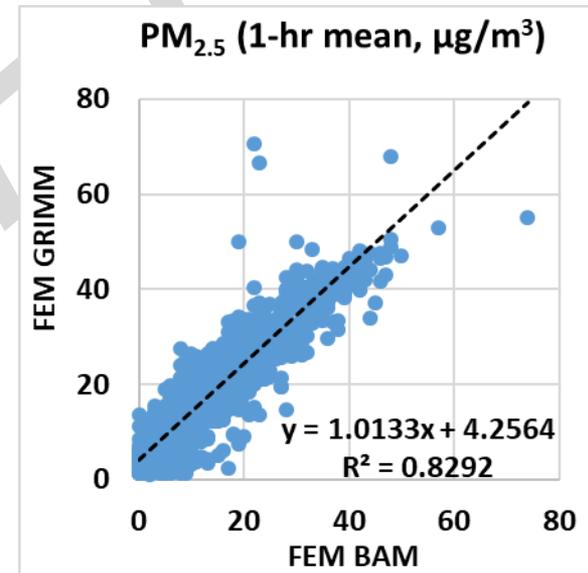
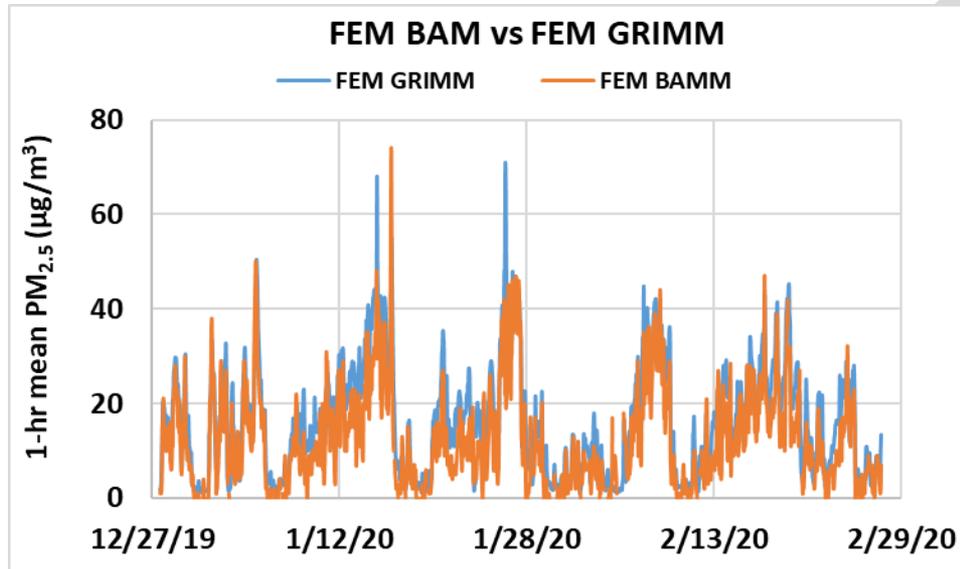
- Absolute intra-model variability was ~ 0.21, and 0.33 $\mu\text{g}/\text{m}^3$ for $\text{PM}_{1.0}$, and $\text{PM}_{2.5}$, respectively (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 1.9% and 2.9 % for $\text{PM}_{1.0}$, and $\text{PM}_{2.5}$, respectively (calculated as the absolute intra-model variability relative to the mean of the three sensor means)



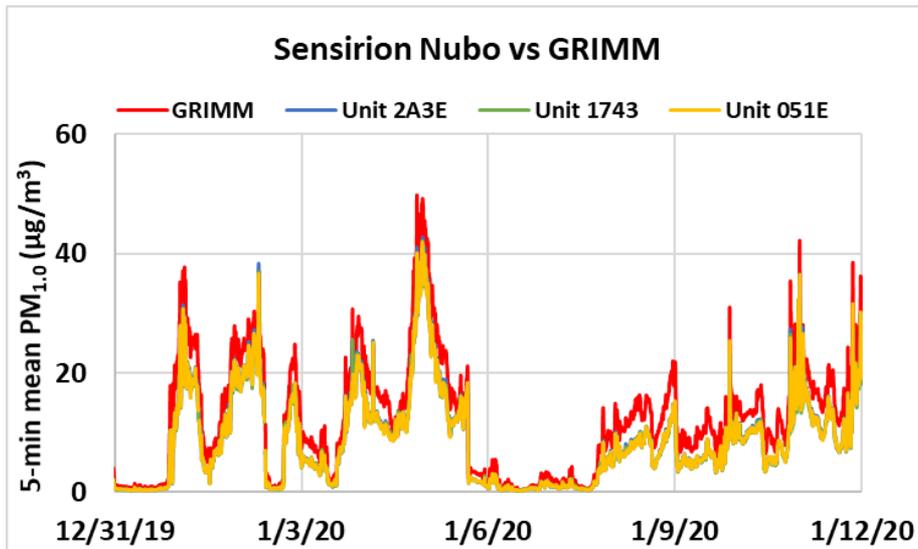
Reference Instruments: PM_{2.5}

GRIMM & BAM

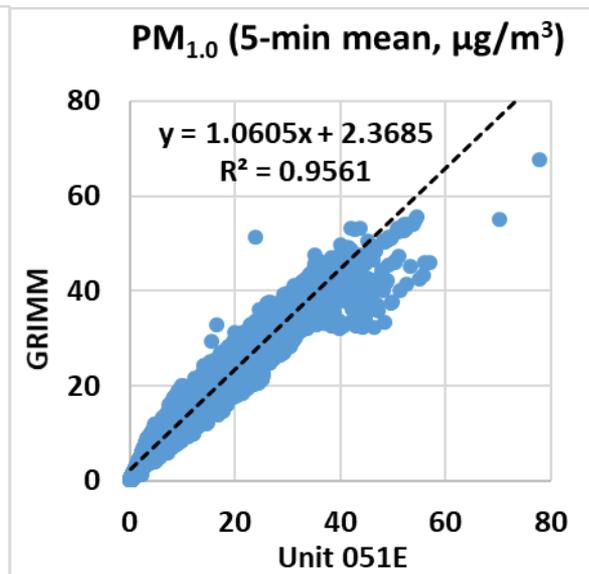
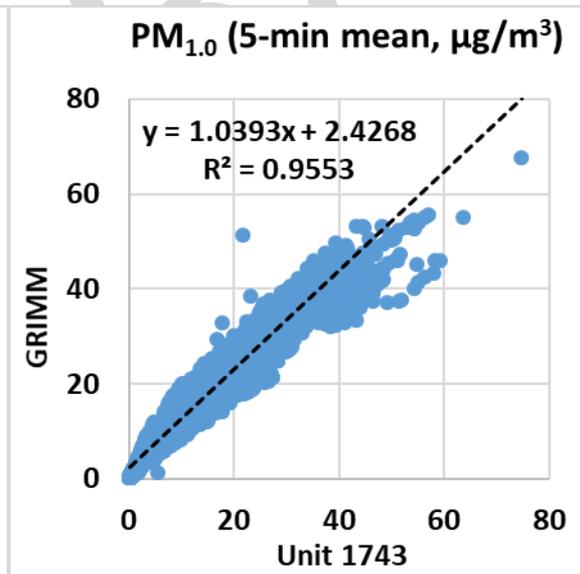
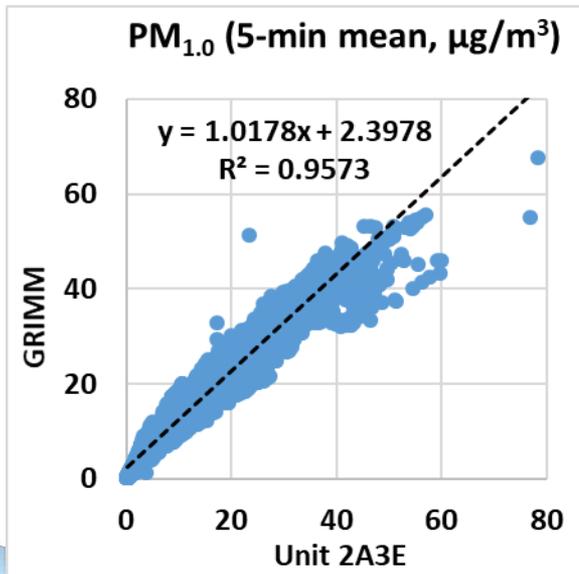
- Data recovery for PM_{2.5} from FEM GRIMM and FEM BAM was ~ 99.8% and 92.4%, respectively.
- Strong correlations between FEM GRIMM and FEM BAM for PM_{2.5} measurements ($R^2 \sim 0.83$) were observed.



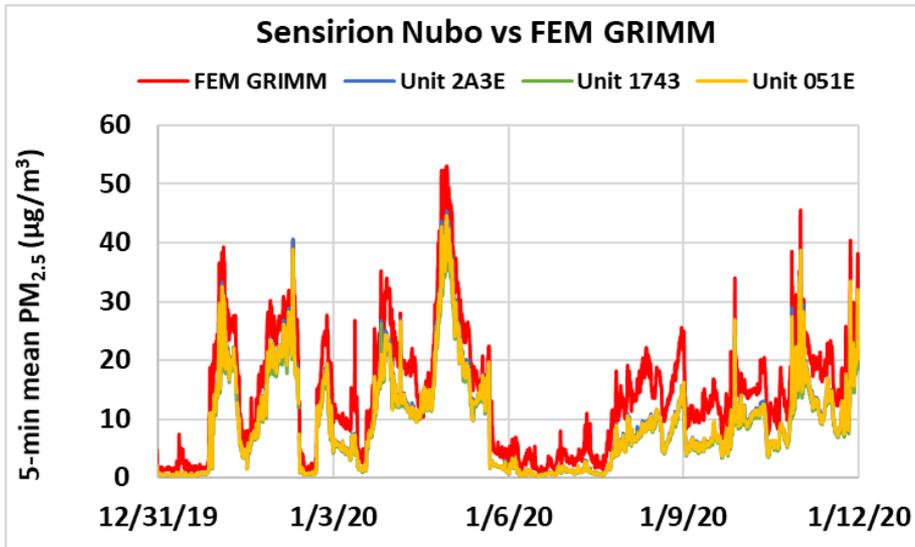
Sensirion Nubo vs GRIMM (PM_{1.0}; 5-min mean)



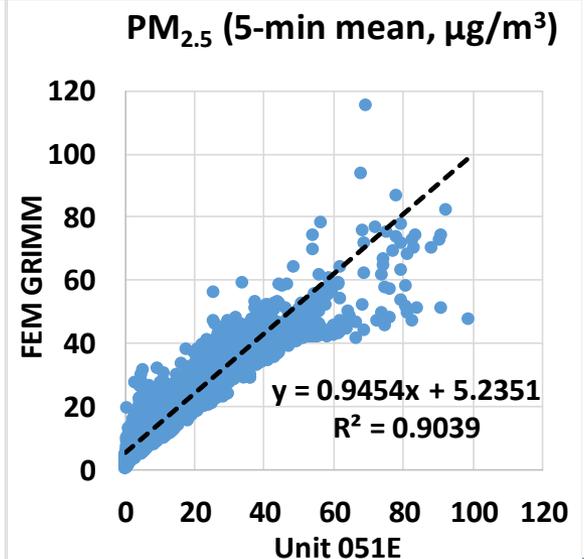
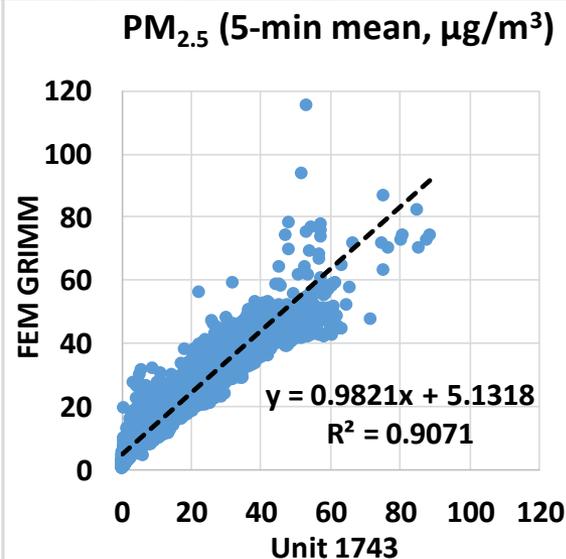
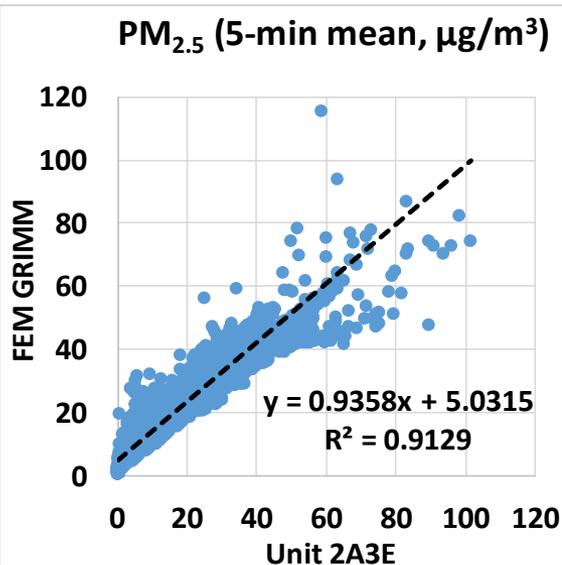
- Sensirion Nubo sensors showed very strong correlations with the corresponding GRIMM data ($R^2 \sim 0.96$)
- Overall, the Sensirion Nubo sensors underestimated the PM_{1.0} mass concentrations as measured by GRIMM
- The Sensirion Nubo sensors seemed to track the PM_{1.0} diurnal variations as recorded by GRIMM



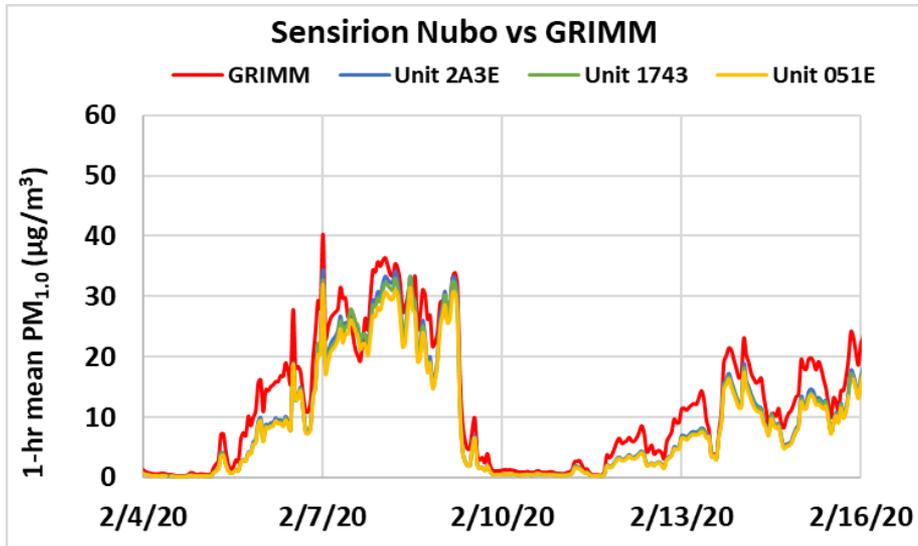
Sensirion Nubo vs FEM GRIMM (PM_{2.5}; 5-min mean)



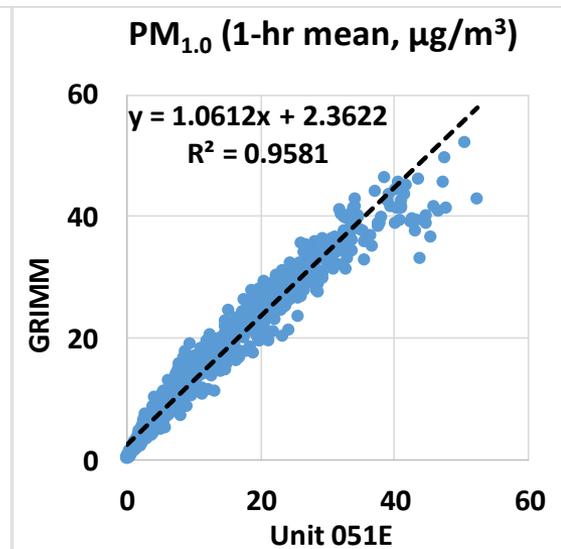
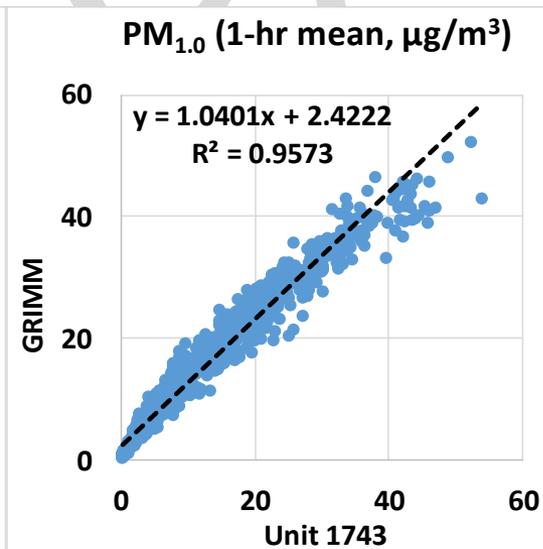
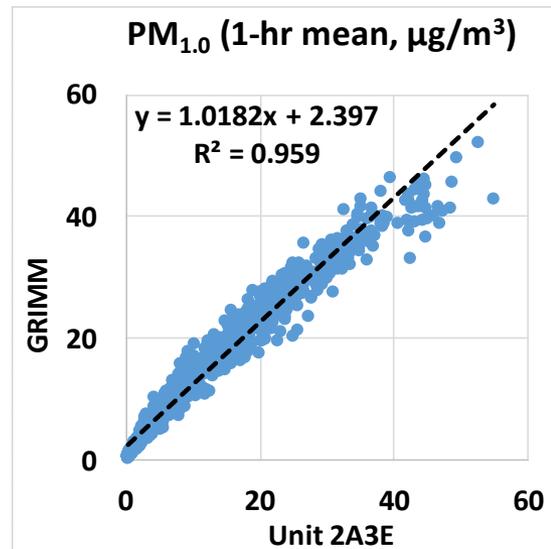
- Sensirion Nubo sensors showed very strong correlations with the corresponding FEM GRIMM data ($R^2 \sim 0.91$)
- Overall, the Sensirion Nubo sensors underestimated the PM_{2.5} mass concentrations as measured by FEM GRIMM
- The Sensirion Nubo sensors seemed to track the PM_{2.5} diurnal variations as recorded by FEM GRIMM



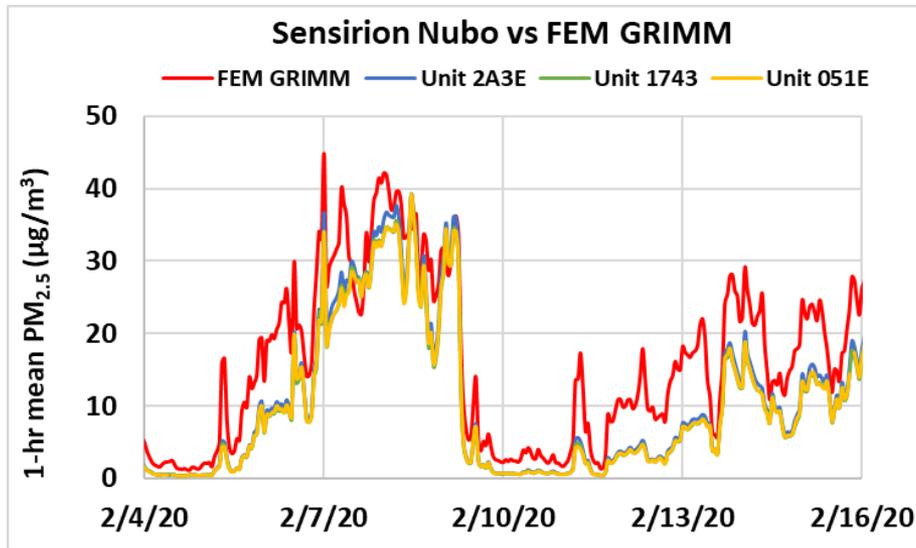
Sensirion Nubo vs GRIMM (PM_{1.0}; 1-hr mean)



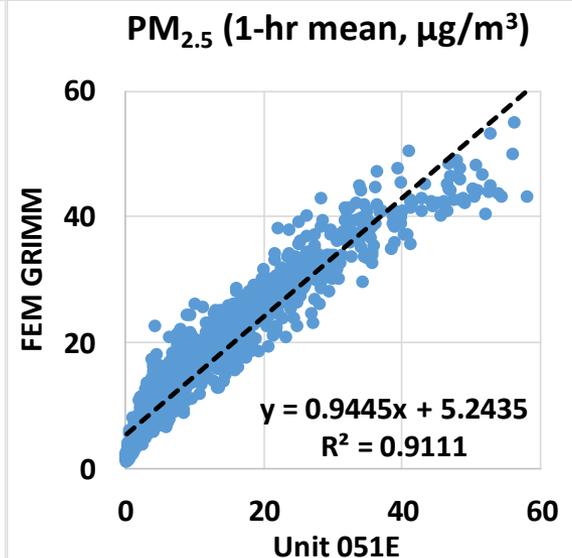
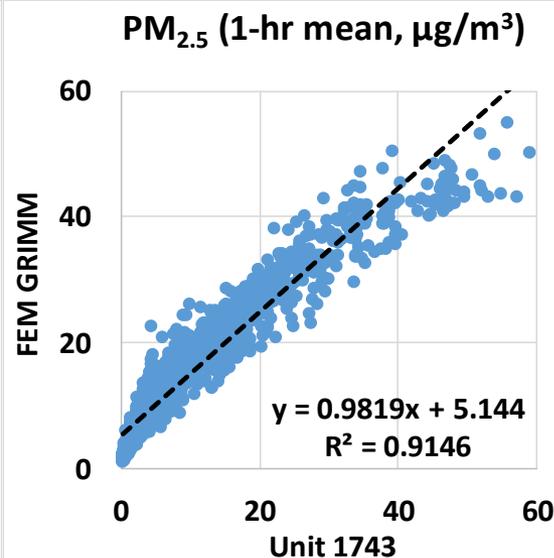
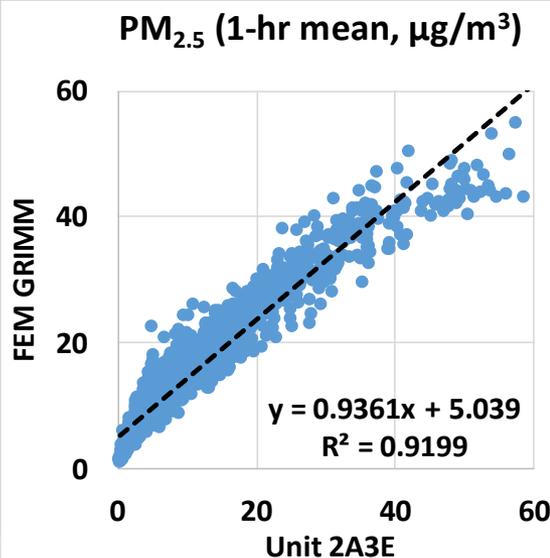
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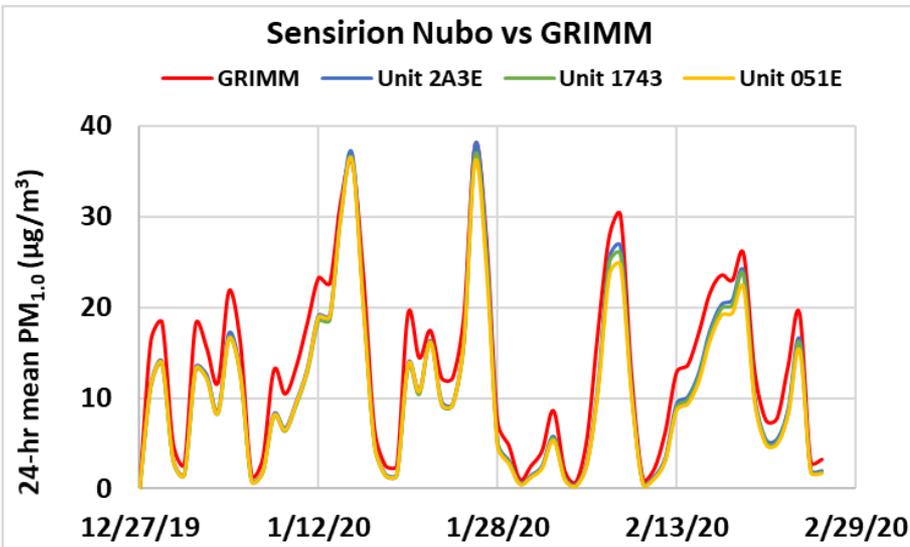
Sensirion Nubo vs FEM GRIMM (PM_{2.5}; 1-hr mean)



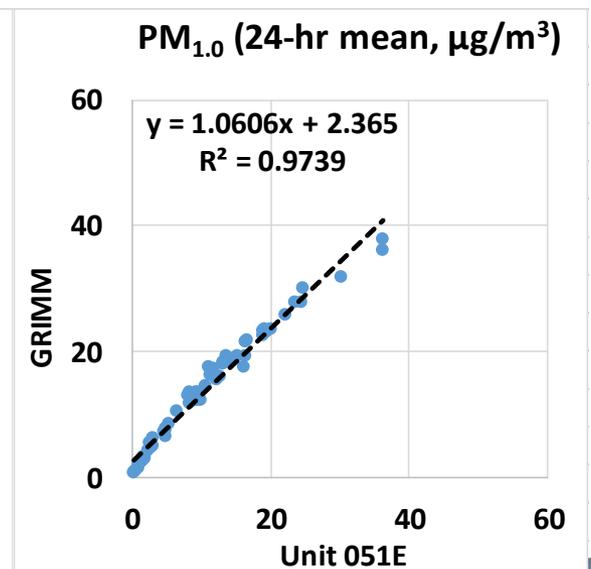
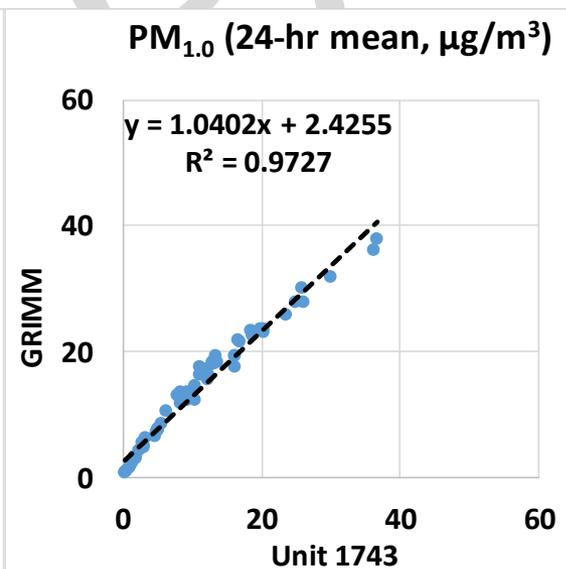
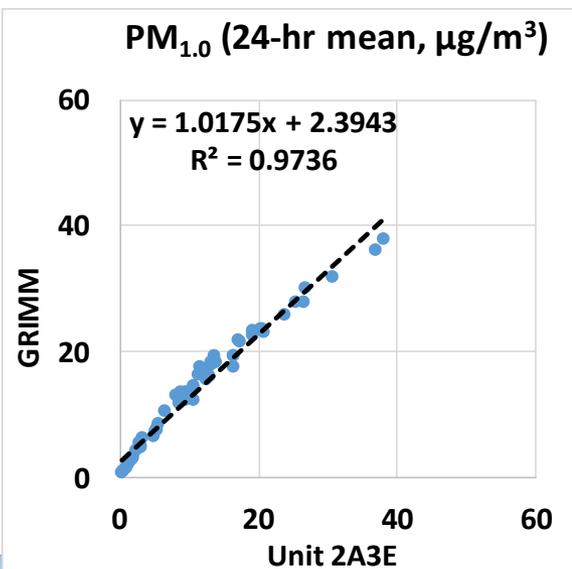
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- Overall, the Sensirion Nubo sensors underestimated the PM_{2.5} mass concentrations as measured by FEM GRIMM
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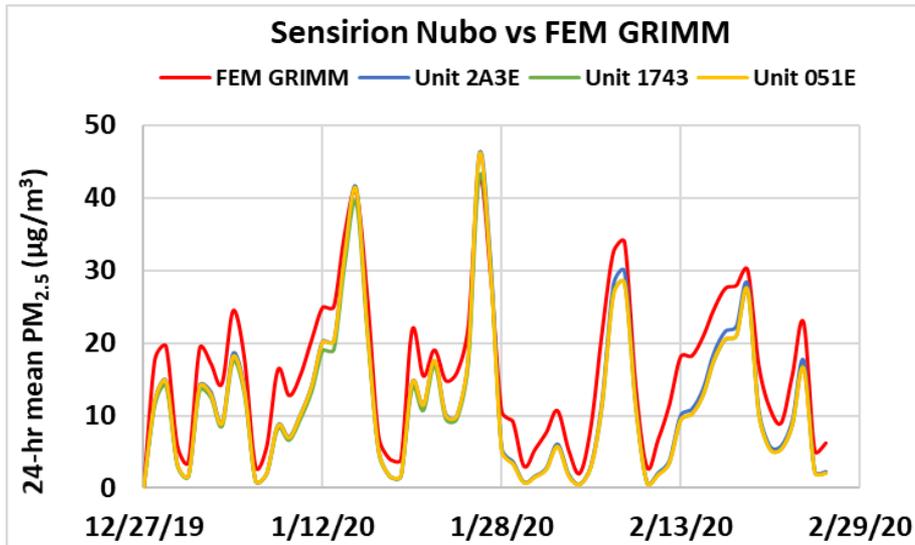
Sensirion Nubo vs GRIMM (PM_{1.0}; 24-hr mean)



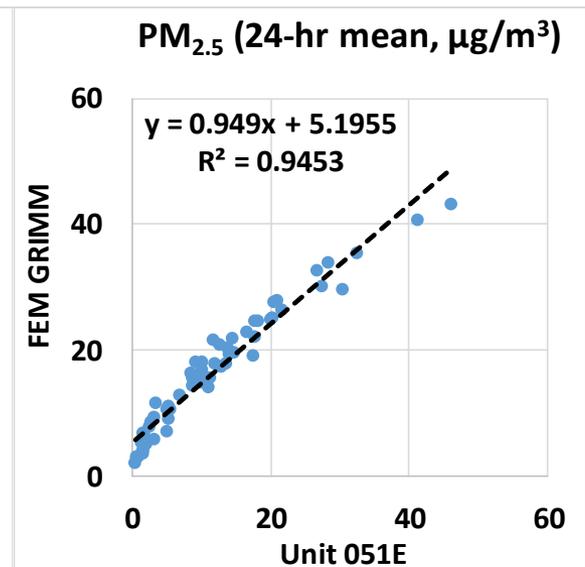
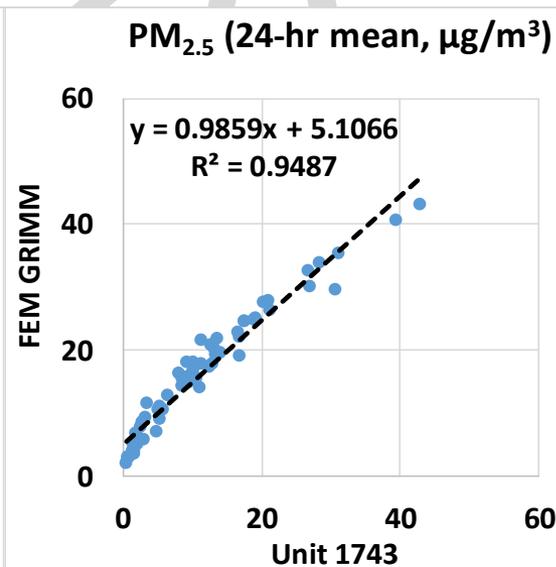
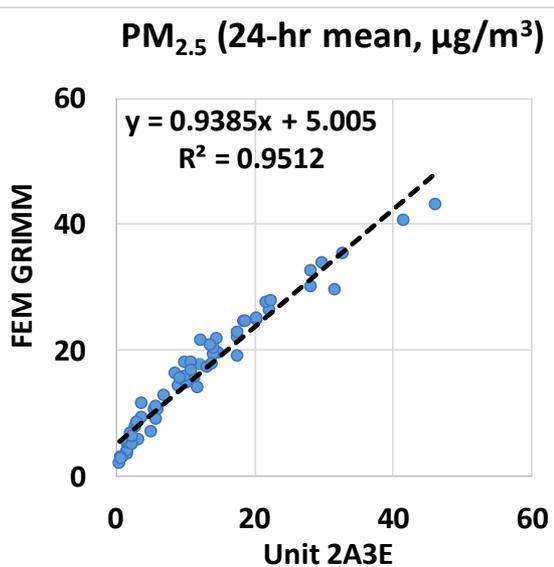
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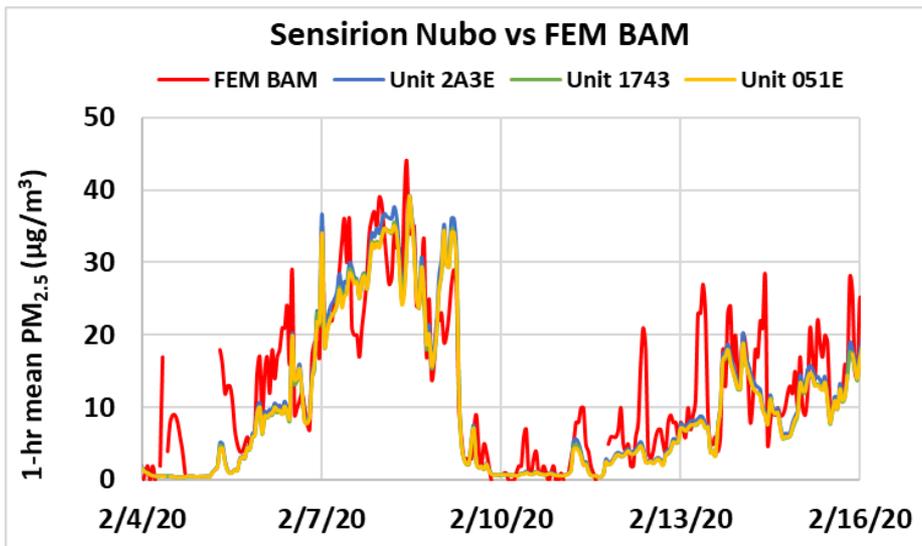
Sensirion Nubo vs FEM GRIMM (PM_{2.5}; 24-hr mean)



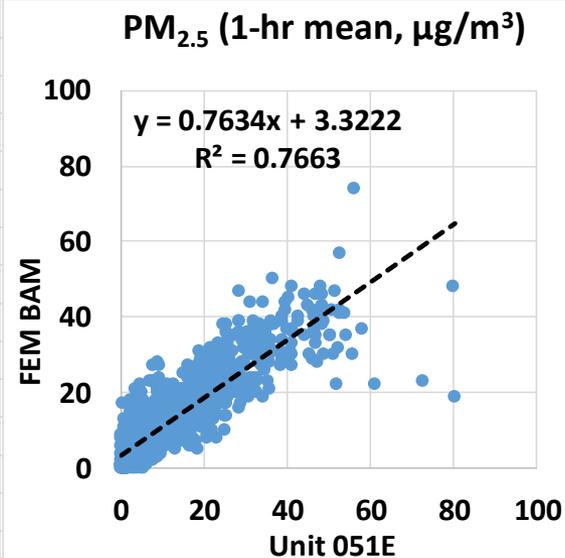
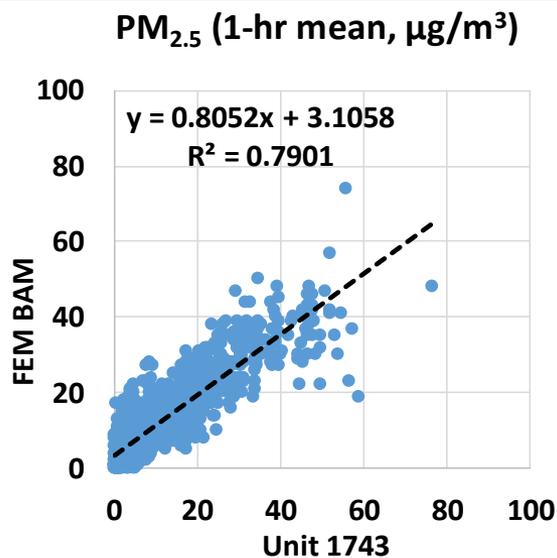
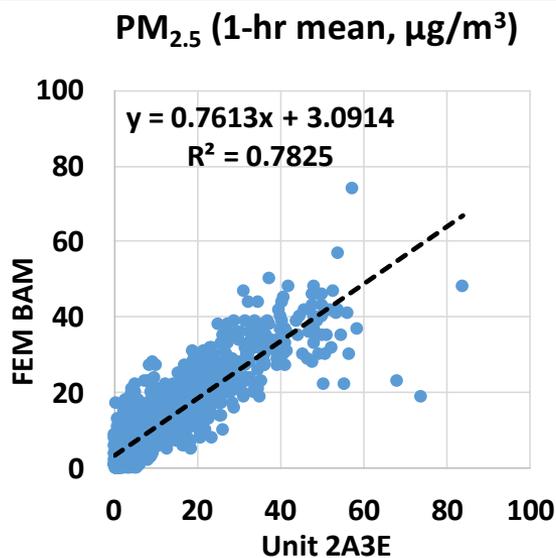
- Sensirion Nubo sensors showed very strong correlations with the corresponding FEM GRIMM data ($R^2 \sim 0.95$)
- Overall, the Sensirion Nubo sensors underestimated the PM_{2.5} mass concentrations as measured by FEM GRIMM
- The Sensirion Nubo sensors seemed to track the PM_{2.5} diurnal variations as recorded by FEM GRIMM



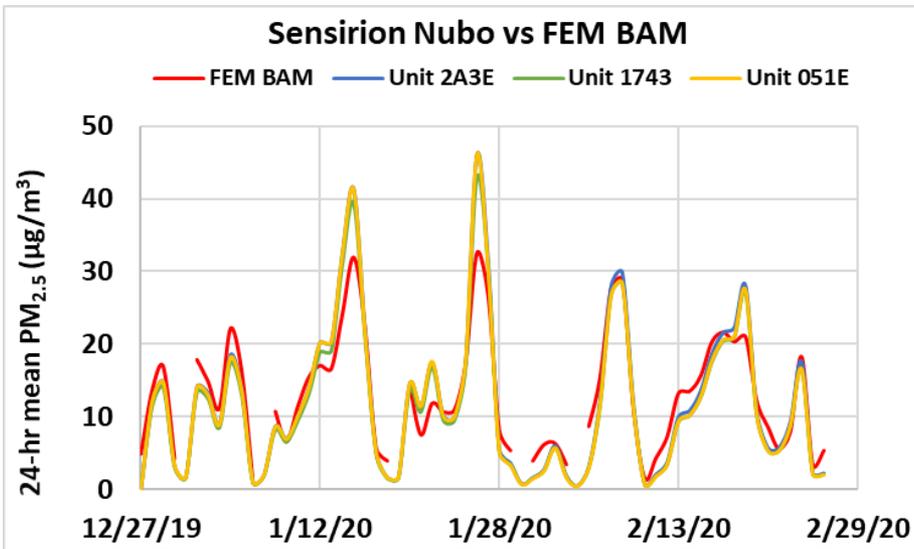
Sensirion Nubo vs FEM BAM (PM_{2.5}; 1-hr mean)



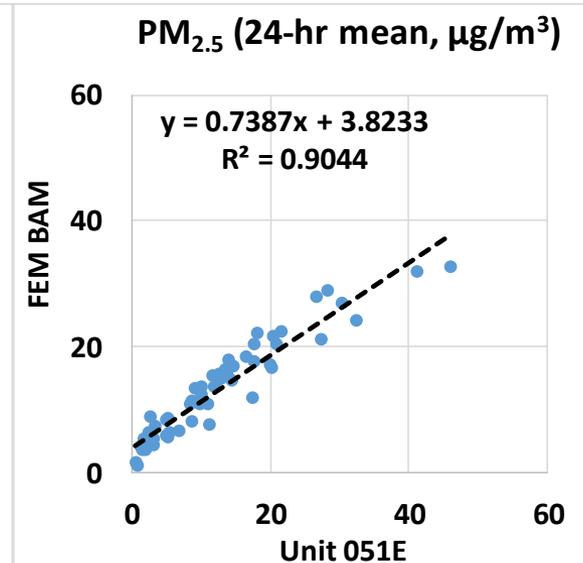
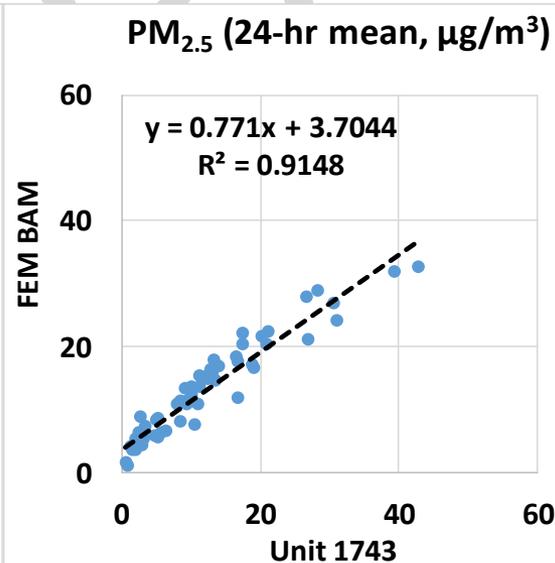
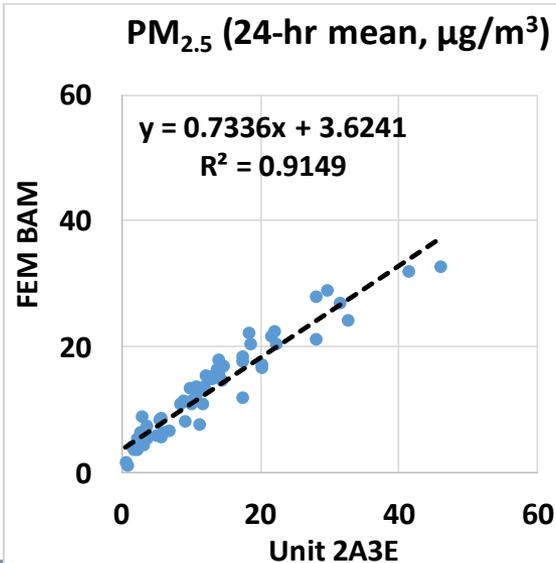
- Sensirion Nubo sensors showed strong correlations with the corresponding FEM BAM data ($R^2 \sim 0.78$)
- Overall, the Sensirion Nubo sensors overestimated the PM_{2.5} mass concentrations when PM_{2.5} mass concentrations were $> 15 \mu\text{g}/\text{m}^3$ as measured by FEM BAM
- The Sensirion Nubo sensors seemed to track the PM_{2.5} diurnal variations as recorded by FEM BAM



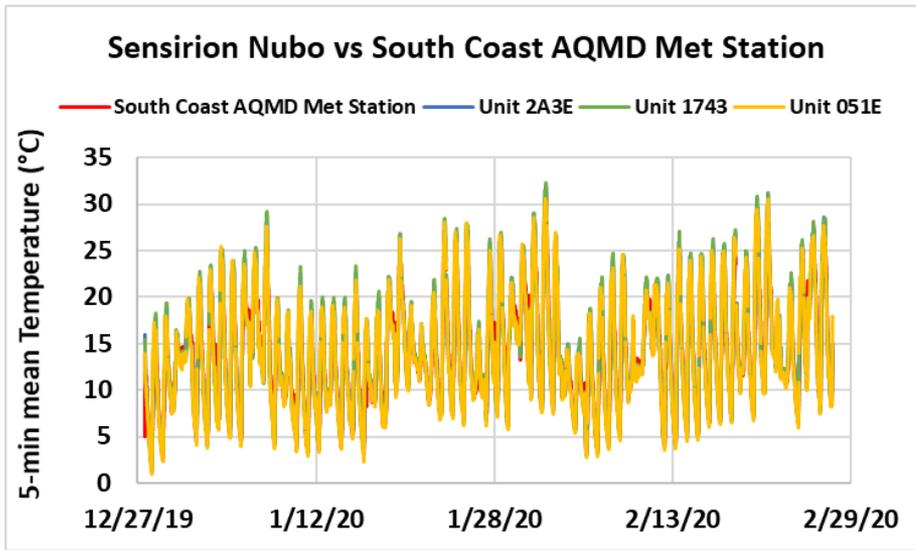
Sensirion Nubo vs FEM BAM (PM_{2.5}; 24-hr mean)



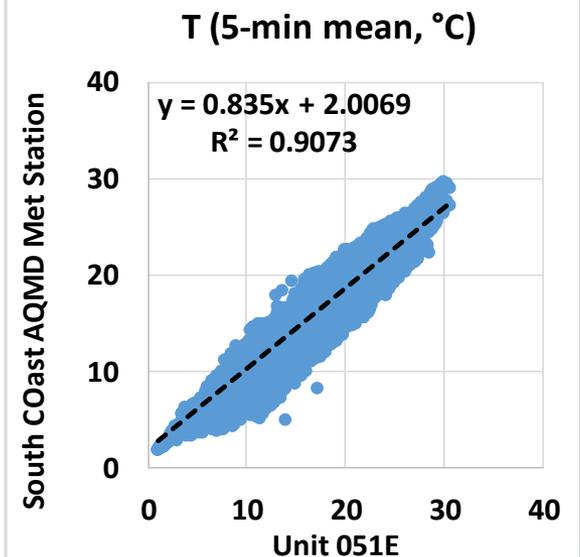
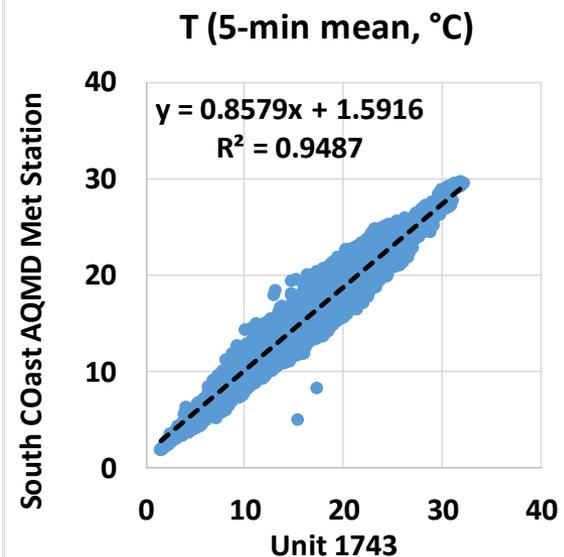
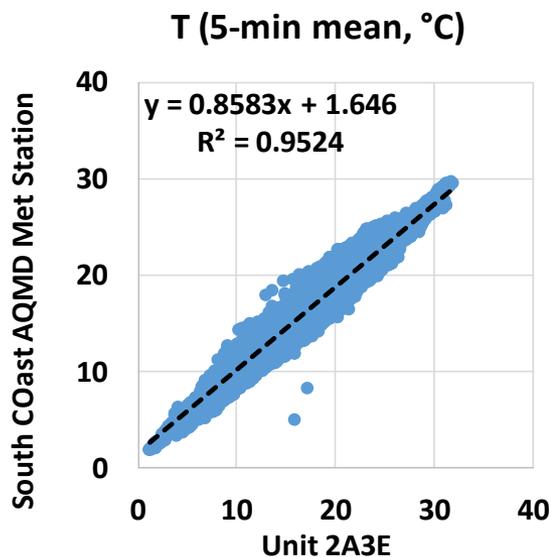
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- Overall, the Sensirion Nubo sensors overestimated the PM_{2.5} mass concentrations when PM_{2.5} mass concentrations were $> 15 \mu\text{g}/\text{m}^3$ as measured by FEM BAM
- The Sensirion Nubo sensors seemed to track the PM_{2.5} diurnal variations as recorded by FEM BAM



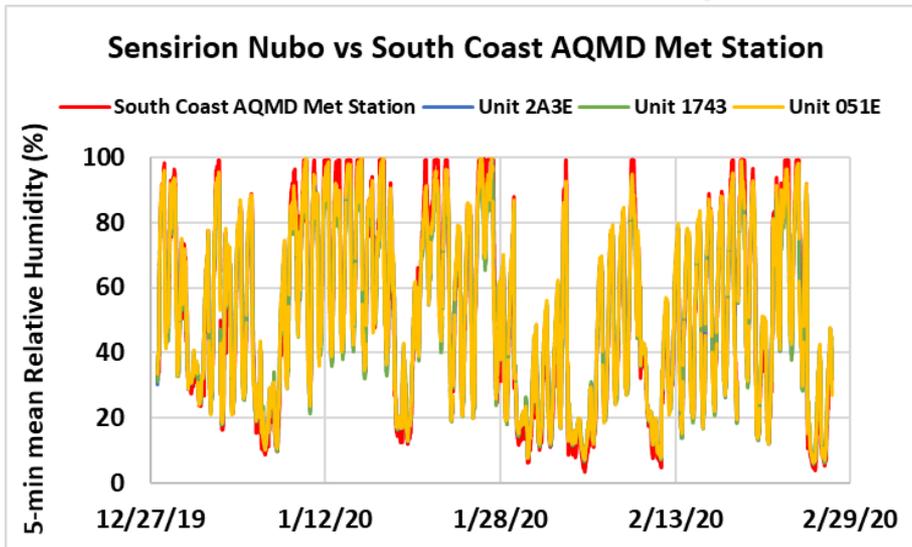
Sensirion Nubo vs South Coast AQMD Met Station Station (Temp; 5-min mean)



- Sensirion Nubo temperature measurements showed very strong correlations with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.94$)
- Overall, the Sensirion Nubo temperature measurements overestimated the corresponding South Coast AQMD Met Station data
- The Sensirion Nubo sensors seemed to track well the temperature diurnal variations as recorded by South Coast AQMD Met Station



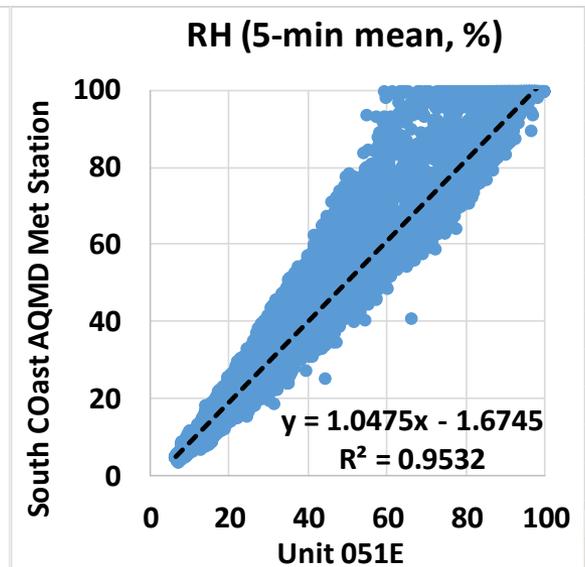
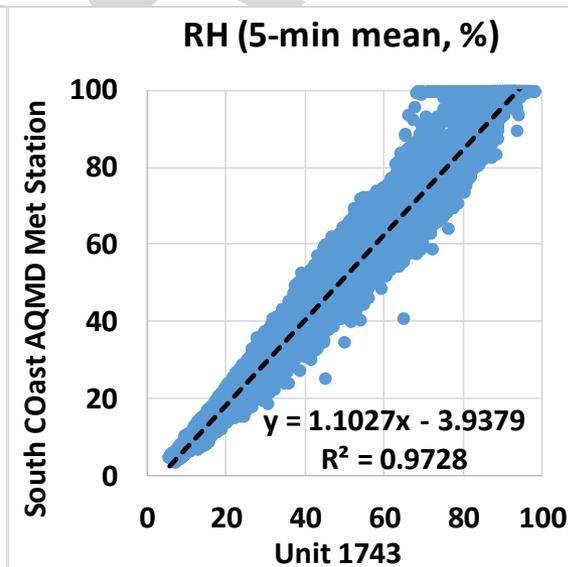
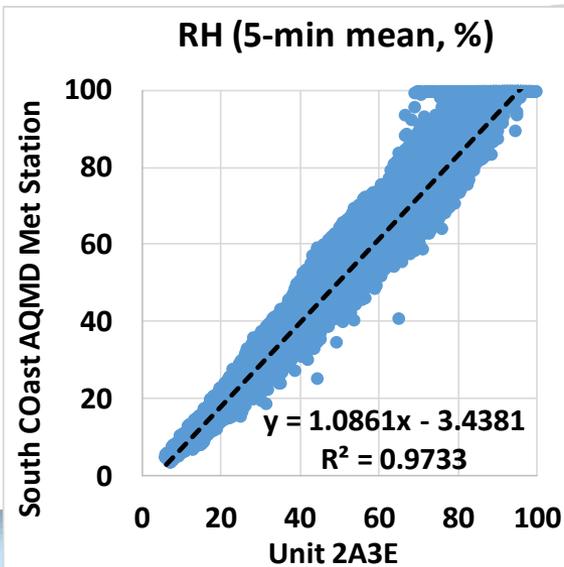
Sensirion Nubo vs South Coast AQMD Met Station (RH; 5-min mean)



Sensirion Nubo RH measurements showed very strong correlations with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.97$)

Overall, the Sensirion Nubo RH measurements underestimated the corresponding South Coast AQMD Met Station data

The Sensirion Nubo sensors seemed to track well the RH diurnal variations as recorded by South Coast AQMD Met Station



Discussion

- The three **Sensirion Nubo** sensors' data recovery from all units was ~ 97% for all PM measurements
- The intra-model variability was ~ 0.21, and 0.33 $\mu\text{g}/\text{m}^3$ for $\text{PM}_{1.0}$, and $\text{PM}_{2.5}$, respectively
- Strong correlations between FEM BAM and FEM GRIMM for $\text{PM}_{2.5}$ mass concentration measurements ($R^2 \sim 0.83$, 1-hr mean)
- $\text{PM}_{1.0}$ mass concentration measurements measured by Sensirion Nubo sensors showed very strong correlations with the corresponding GRIMM data ($R^2 \sim 0.96$, 1-hr mean). The sensors underestimated $\text{PM}_{1.0}$ mass concentrations as measured by GRIMM
- $\text{PM}_{2.5}$ mass concentration measurements measured by Sensirion Nubo sensors showed strong to very strong correlations with the corresponding, FEM BAM and FEM GRIMM data ($R^2 \sim 0.78$ and 0.91, respectively, 1-hr mean). The sensors underestimated $\text{PM}_{2.5}$ mass concentrations as measured by FEM GRIMM; and overestimated $\text{PM}_{2.5}$ mass concentrations when $\text{PM}_{2.5}$ mass concentrations were higher than 15 $\mu\text{g}/\text{m}^3$ as measured by 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