Field Evaluation
Magnasci SRL uRADMonitor A3 (version HW105) Sensor

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 10/30/2018 to 01/08/2019, three **Magnasci SRL uRADMonitor A3 version HW105 (hereinafter abbreviated as uRADMonitor A3)** sensors were deployed at a South Coast AQMD stationary ambient monitoring site in Rubidoux and were run side-by-side with three reference instruments measuring the same pollutants

- uRADMonitor A3 (*3 units tested*):
  - Particle sensor (optical; non-FEM)
  - PM sensor: Winsen ZH03A
  - Each unit reports: $PM_{1.0}$, $PM_{2.5}$ and PM_{10} (µg/m^3), Temperature (°F), Relative Humidity (%), barometric pressure (hPa)
  - Each unit also measures: formaldehyde (ppm, electrochemical), carbon dioxide (ppm, nondispersive infrared) and volatile organic compounds (VOC, mg/m^3, metal oxide-based)
  - Unit cost: ~$500
  - Time resolution: 1- 9 min
  - Units IDs: 00D3, 00D4, 00D5

- 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

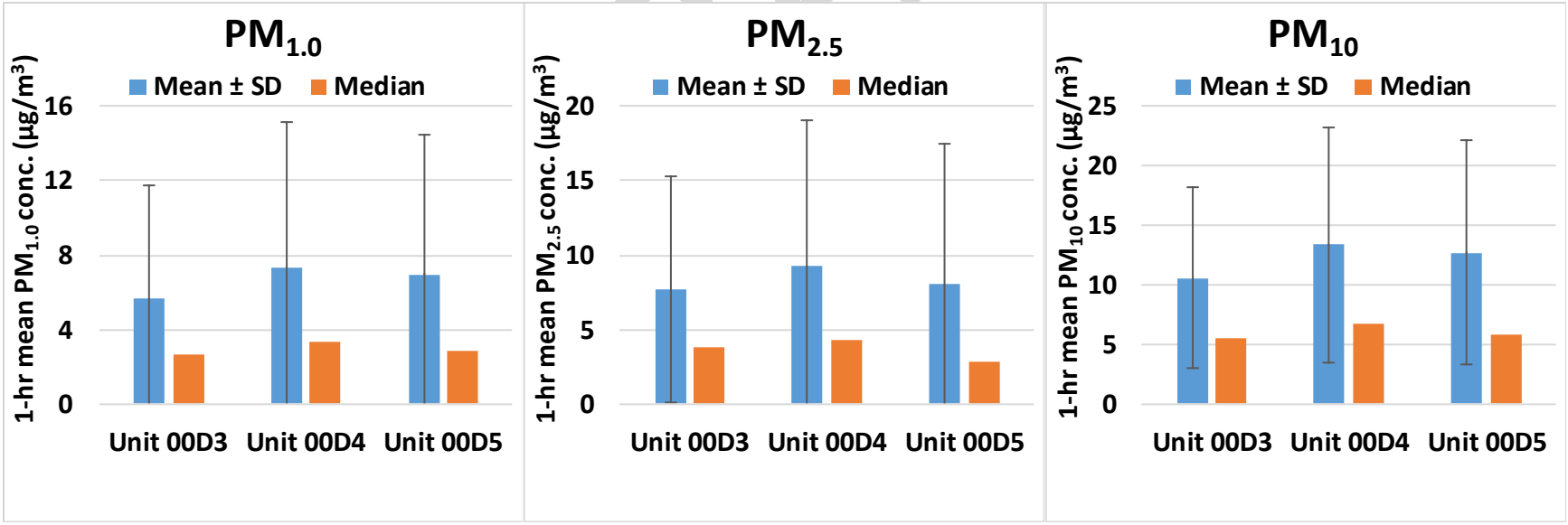
- Teledyne API T640 (*reference instrument*):
  - Optical particle counter (FEM $PM_{2.5}$)
  - Measures $PM_{2.5}$ & PM_{10} (µg/m^3)
  - Unit cost: ~$21,000
  - Time resolution: 1-min

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 00D3, 00D4, and 00D5 is 99.9%, 81.6% and 99.9%, respectively, for all PM fractions. Data recovery is calculated based on the one hour averages due to the fact that the sensors have inconsistent time stamp, limiting comparisons at higher time resolution

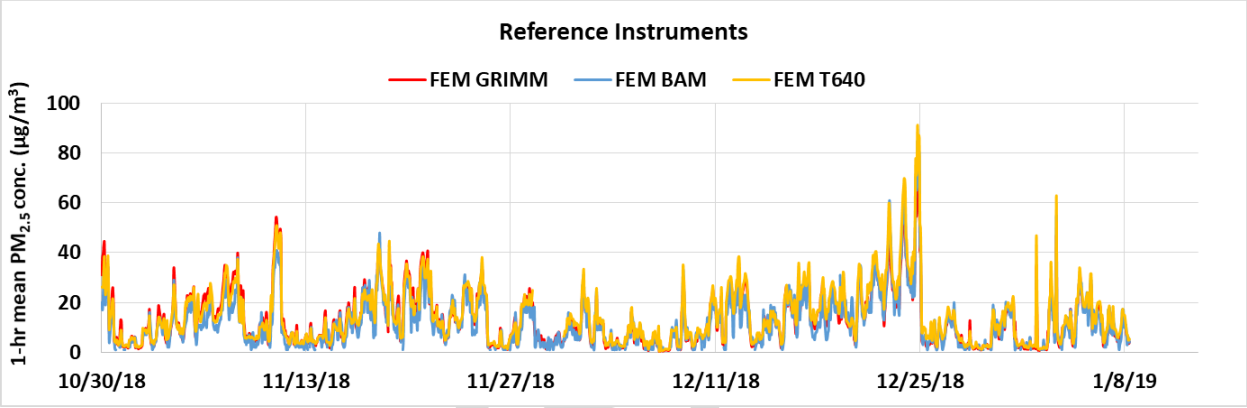
uRADMonitor A3; intra-model variability

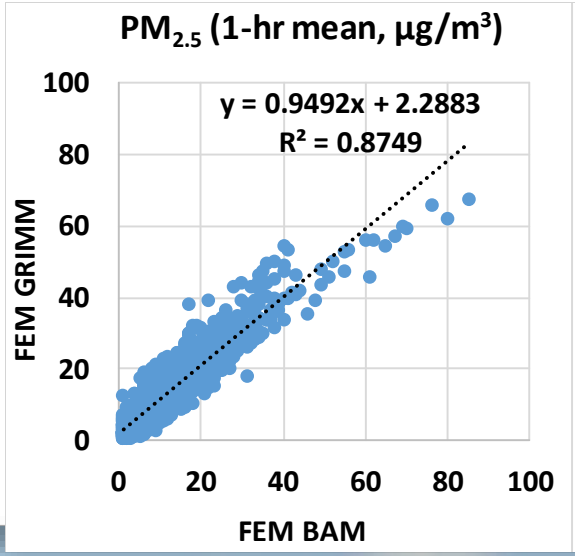
- Moderate measurement variability (19-25%) was observed between the three uRADMonitor A3 units for $PM_{1.0}$, $PM_{2.5}$ and PM_{10}

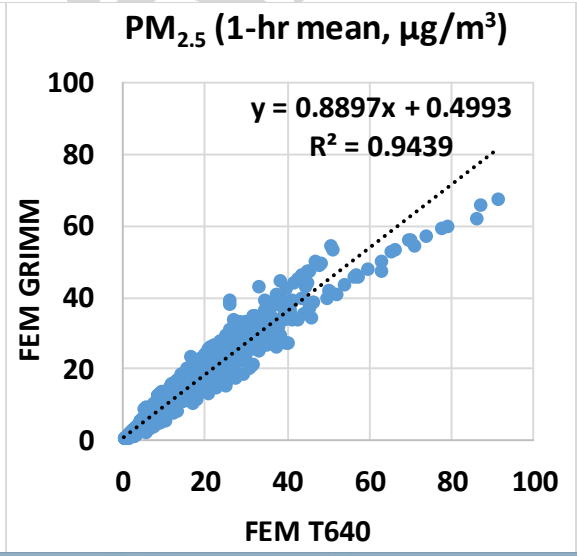


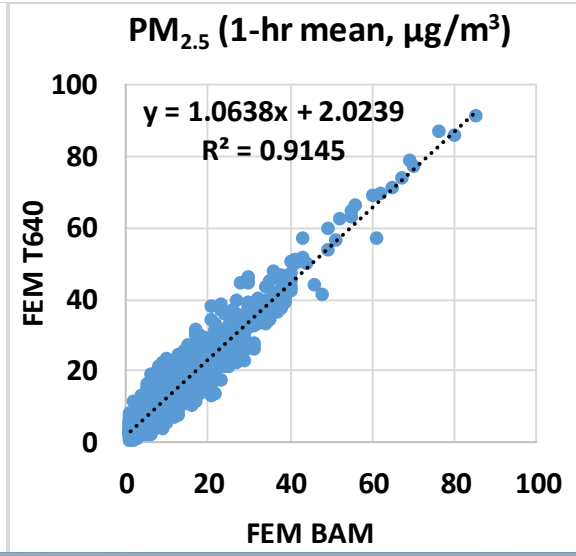
Reference Instruments: $PM_{2.5}$ GRIMM, BAM & T640

- Data recovery for $PM_{2.5}$ from FEM GRIMM, FEM BAM and FEM T640 is 100 %, 99.6 % and 96.7 %, respectively.
- Strong to very strong correlations between the three reference instruments for $PM_{2.5}$ measurements ($0.87 < R^2 < 0.95$) were observed.



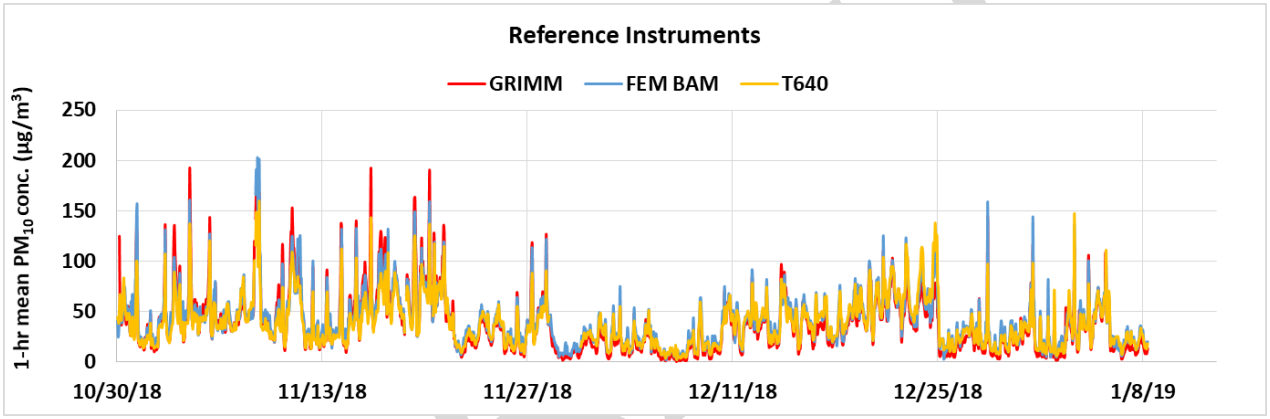


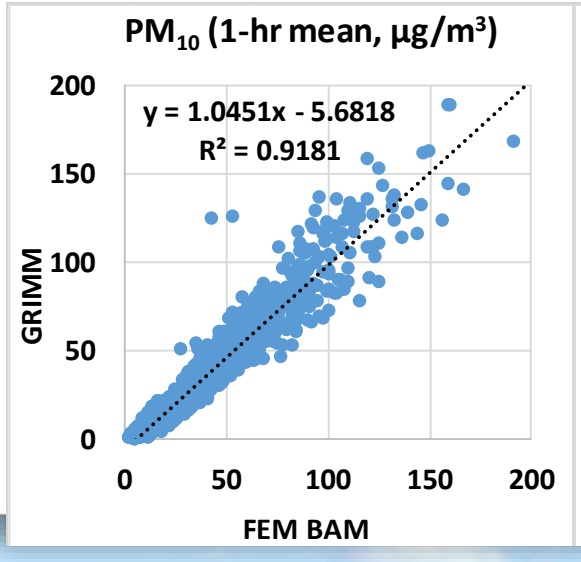


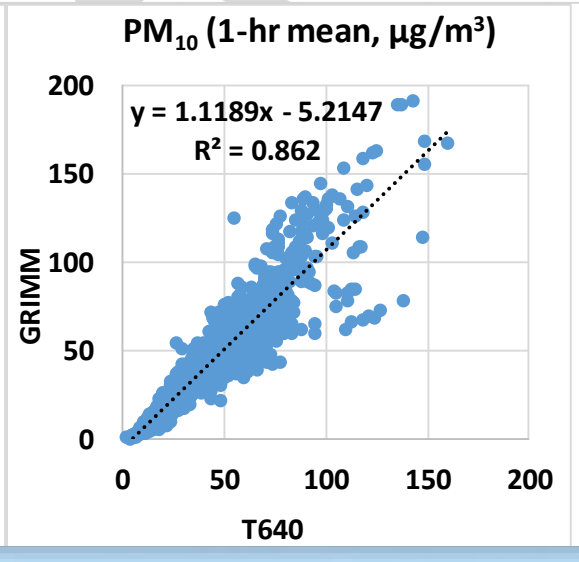


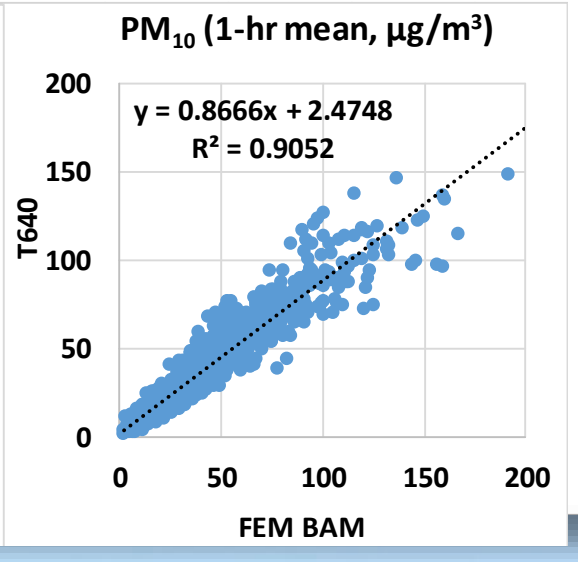
Reference Instruments: PM_{10} GRIMM, BAM & T640

- Data recovery for PM_{10} from GRIMM, FEM BAM and T640 is 100 %, 90.4 % and 96.7 %, respectively.
- Strong to very strong correlations between the three reference instruments for PM_{10} measurements ($0.86 < R^2 < 0.92$) were observed.

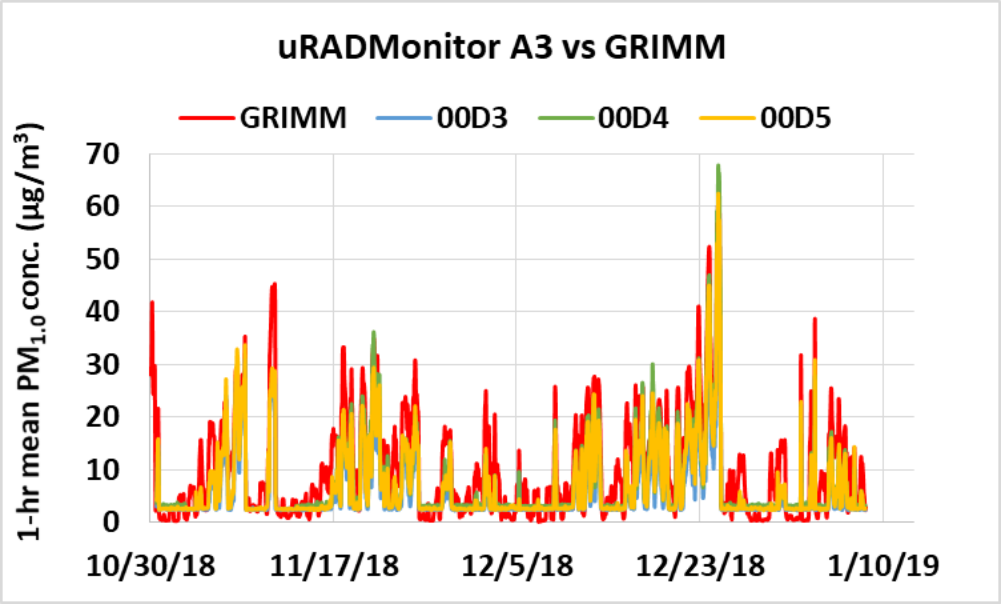




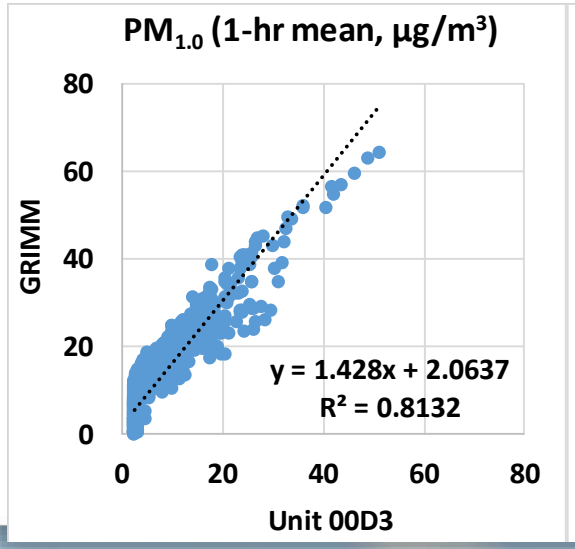


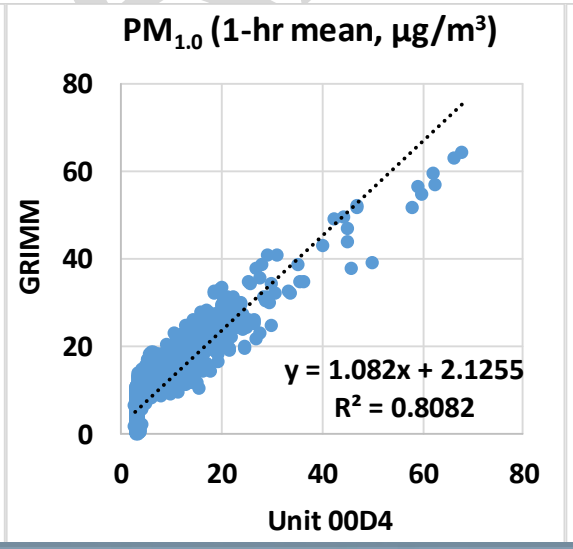


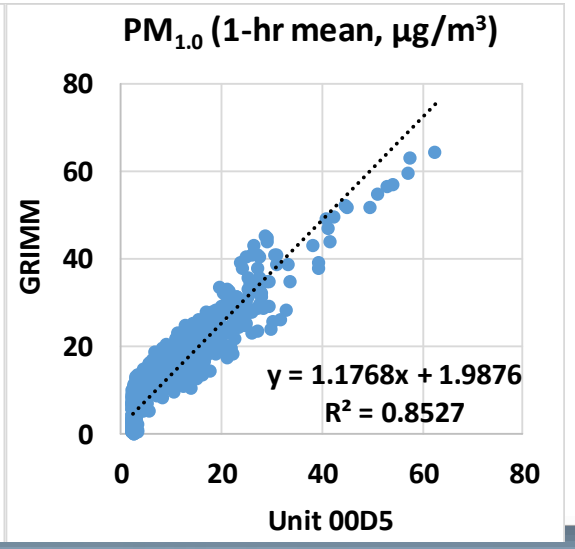
uRADMonitor A3 vs GRIMM ($PM_{1.0}$; 1-hr mean)



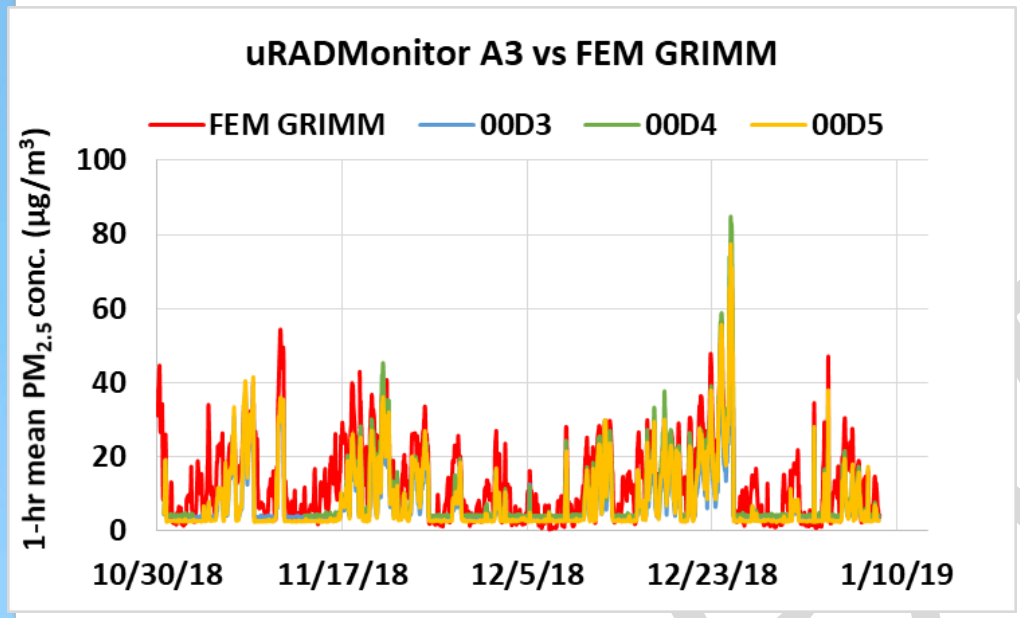
- uRADMonitor A3 sensors show strong correlations with the corresponding GRIMM data (R^2 ~ 0.82) when $PM_{1.0}$ mass concentration is > ~10 µg/m³ as recorded by GRIMM.
- Overall, the uRADMonitor A3 sensors underestimate $PM_{1.0}$ mass concentration as measured by GRIMM.
- The uRADMonitor A3 sensors seem to track well the $PM_{1.0}$ diurnal variations when $PM_{1.0}$ mass concentration is > ~10 µg/m³ and report constant values of ~ 2.4 – 3.2 µg/m³ when $PM_{1.0}$ mass concentration is < ~10 µg/m³ as recorded by GRIMM.



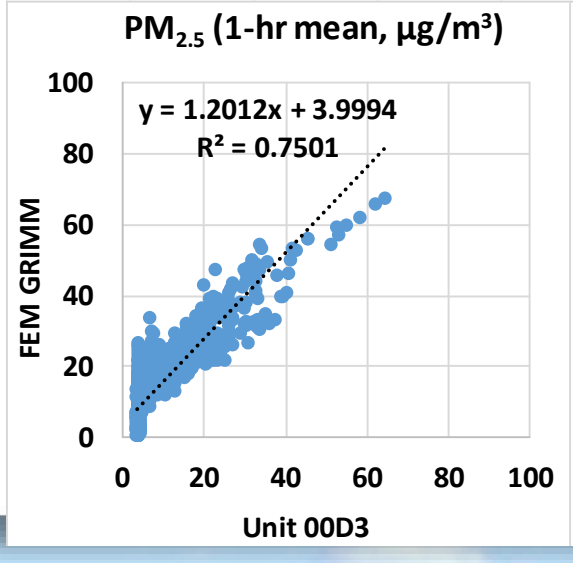


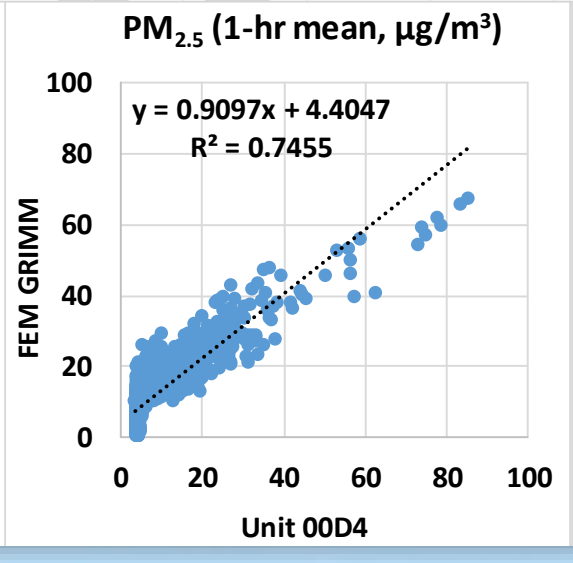


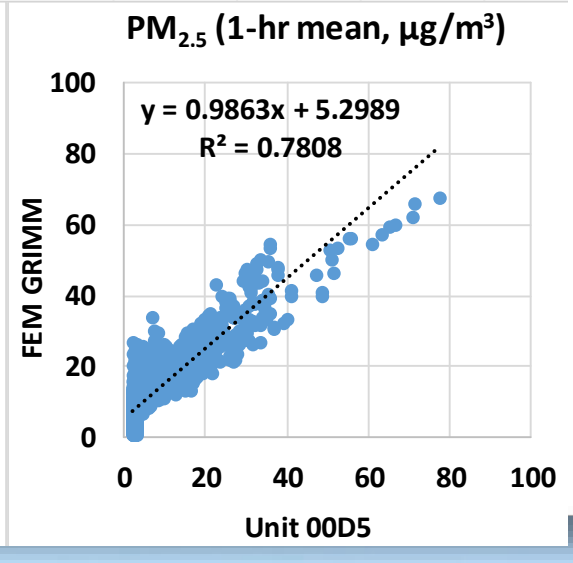
uRADMonitor A3 vs FEM GRIMM ($PM_{2.5}$; 1-hr mean)



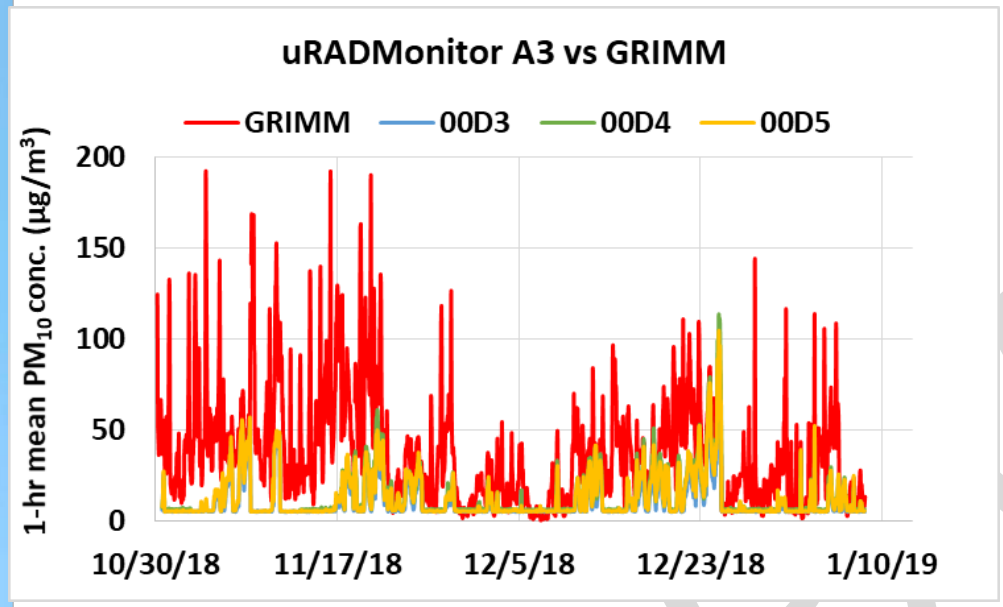
- uRADMonitor A3 sensors show strong correlations with the corresponding FEM GRIMM data (R^2 ~ 0.76) when $PM_{2.5}$ mass concentration is > ~15 µg/m^3 as recorded by FEM GRIMM
- Overall, the uRADMonitor A3 sensors underestimate the $PM_{2.5}$ mass concentrations measured by FEM GRIMM
- The uRADMonitor A3 sensors seem to track well the $PM_{2.5}$ diurnal variations when $PM_{2.5}$ mass concentration is > ~15 µg/m^3 as recorded by FEM GRIMM but report constant values of ~ 2.4-4.4 µg/m^3 when mass concentration is < ~15 µg/m^3



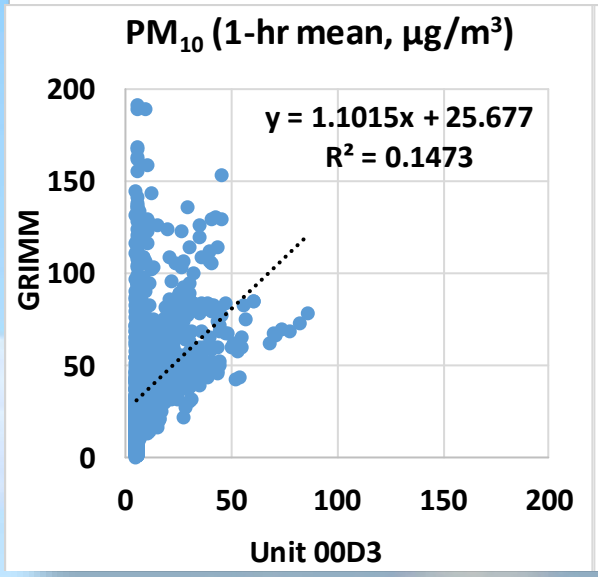


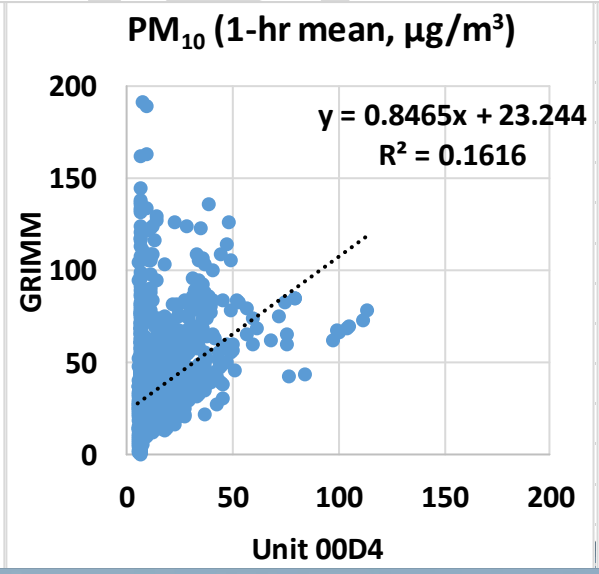


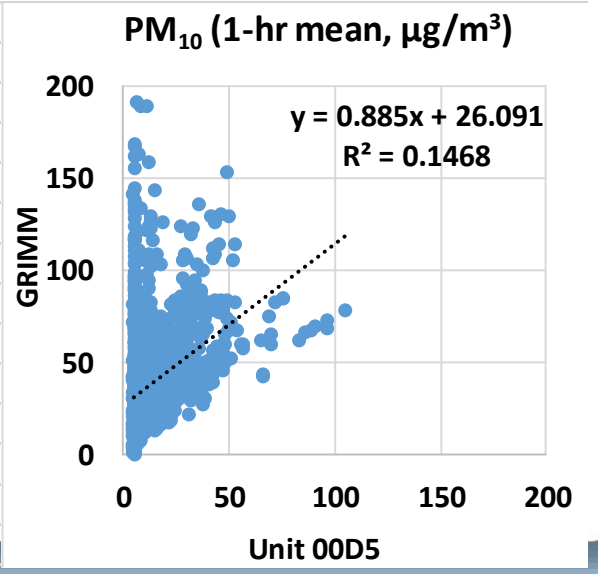
uRADMonitor A3 vs GRIMM (PM_{10}; 1-hr mean)



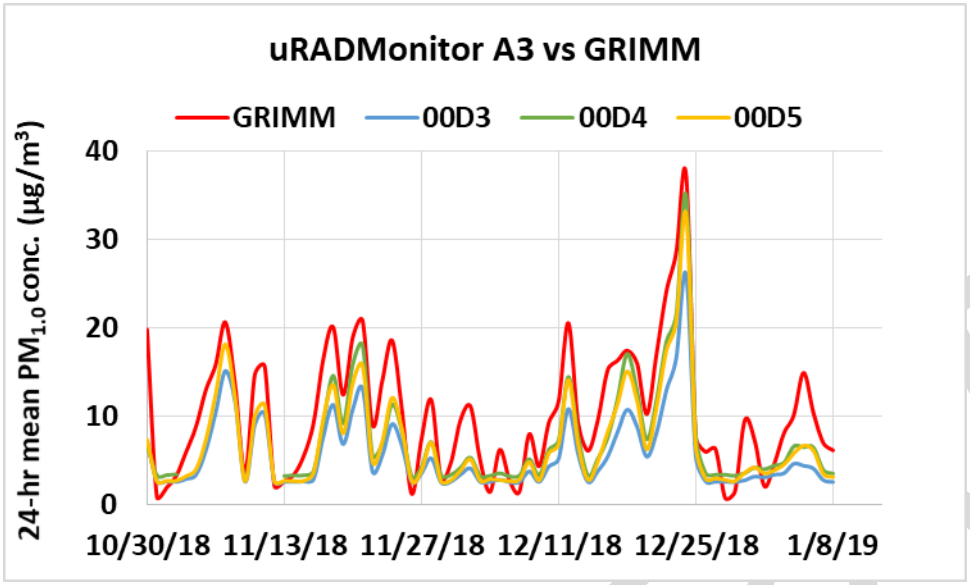
- uRADMonitor A3 sensors show very weak correlations with the corresponding GRIMM data (R^2 ~ 0.15)
- Overall, the uRADMonitor A3 sensors underestimate the PM_{10} mass concentrations measured by GRIMM
- The uRADMonitor A3 sensors seem to modestly track the PM_{10} diurnal variations as recorded by GRIMM when not randomly reporting constant values of ~ 6.9 – 8.4 µg/m³
- during the field deployment period



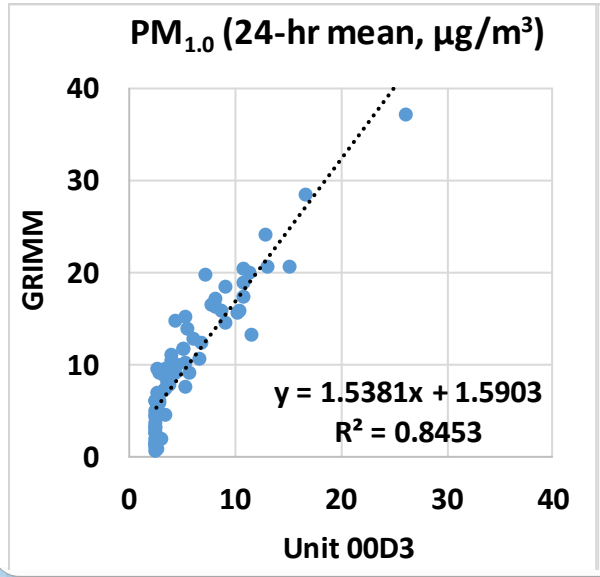


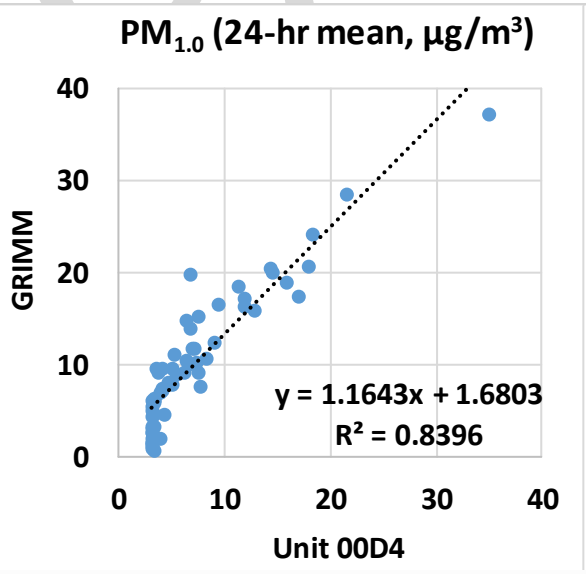


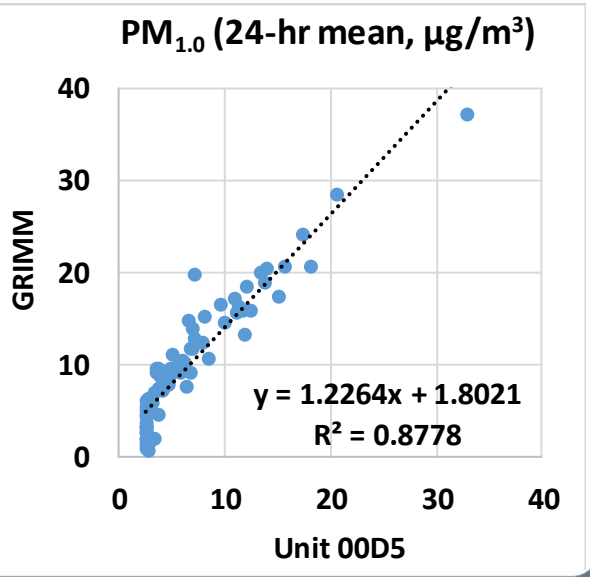
uRADMonitor A3 vs GRIMM ($PM_{1.0}$; 24-hr mean)



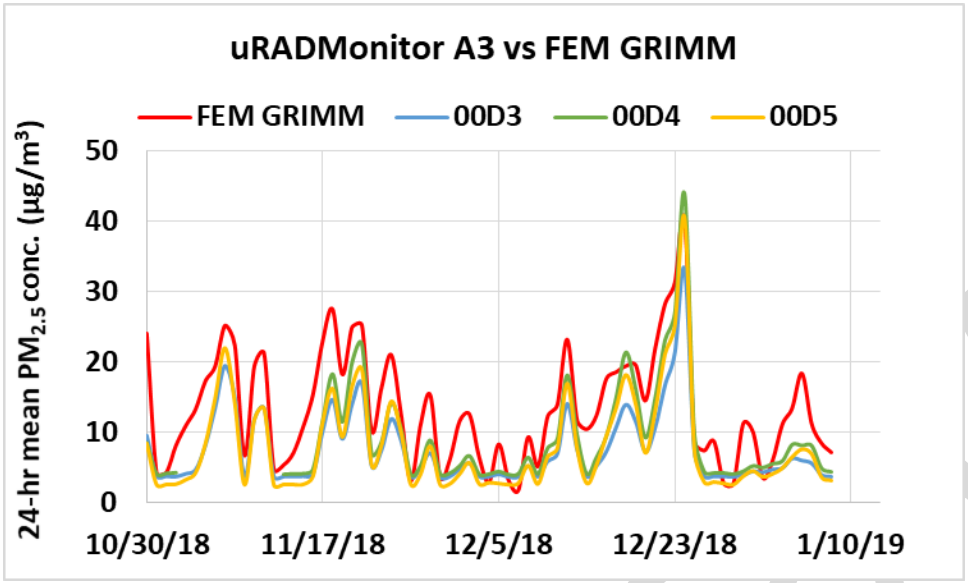
- uRADMonitor A3 sensors show strong correlations with the corresponding GRIMM data (R^2 ~ 0.85) when $PM_{1.0}$ mass concentration is > ~ 6 µg/m³ as recorded by GRIMM
- Overall, the uRADMonitor A3 sensors underestimate $PM_{1.0}$ mass concentration as measured by GRIMM
- The uRADMonitor A3 seem to track well the $PM_{1.0}$ concentration variations when $PM_{1.0}$ mass concentration is > ~ 6 µg/m³ as recorded by GRIMM



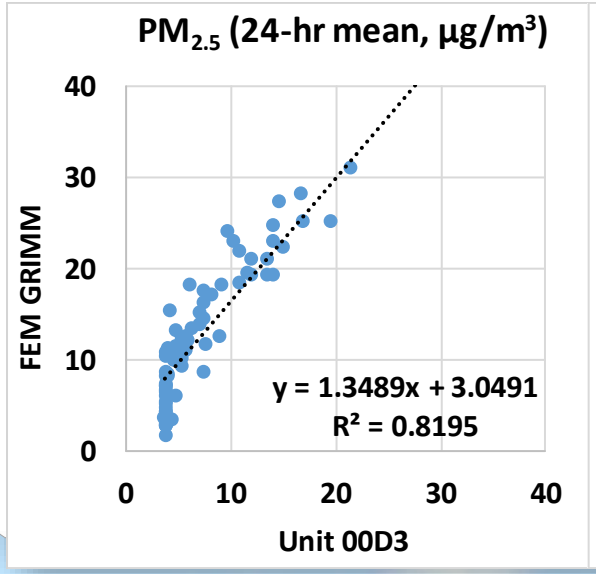


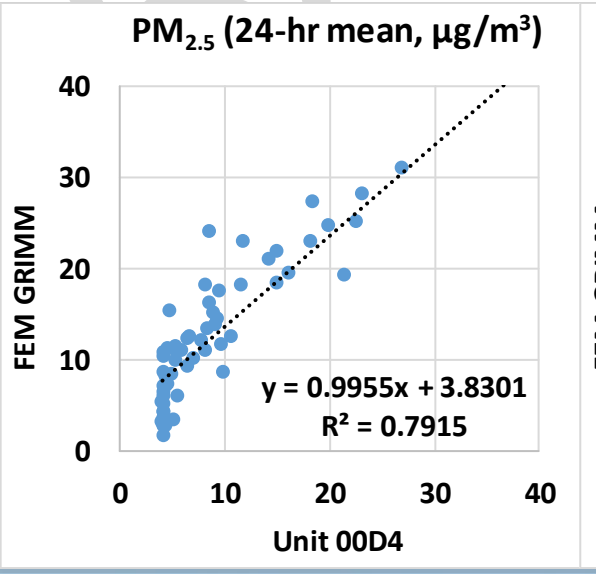


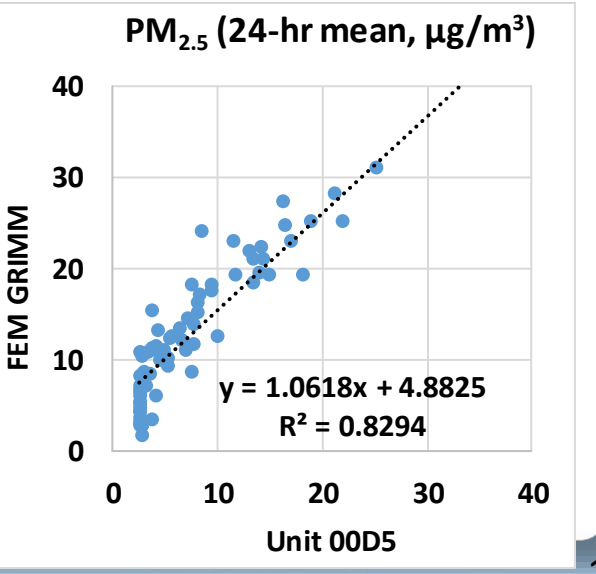
uRADMonitor A3 vs FEM GRIMM ($PM_{2.5}$; 24-hr mean)



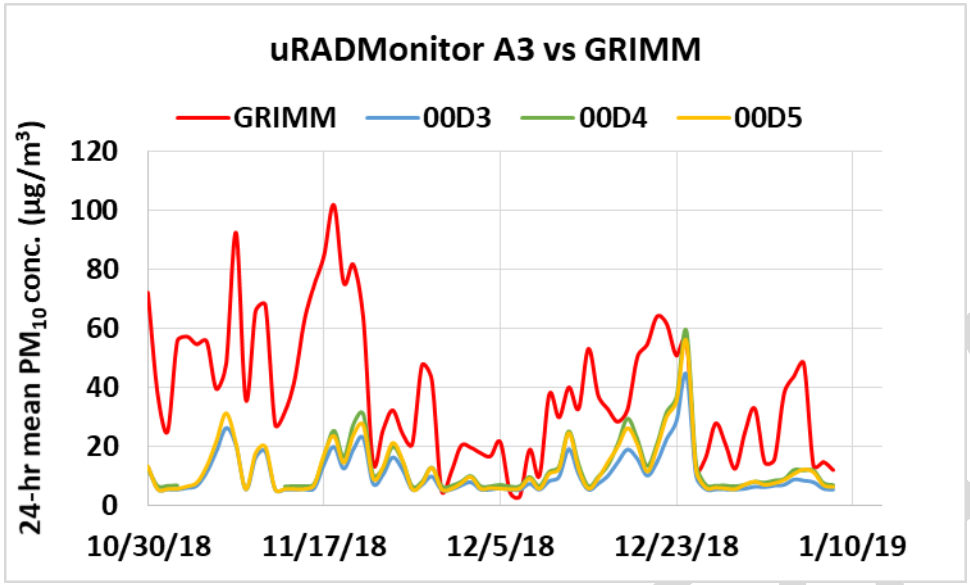
- uRADMonitor A3 sensors show strong correlations with the corresponding FEM GRIMM data (R^2 ~ 0.81) when $PM_{2.5}$ mass concentration is > ~10 µg/m³ as recorded by FEM GRIMM
- Overall, the uRADMonitor A3 sensors underestimate $PM_{2.5}$ mass concentration as measured by FEM GRIMM
- The uRADMonitor A3 seem to track well the $PM_{2.5}$ concentration variations when $PM_{2.5}$ mass concentration is > ~10 µg/m³ and report constant values of ~2.6 – 4 µg/m³ as recorded by FEM GRIMM



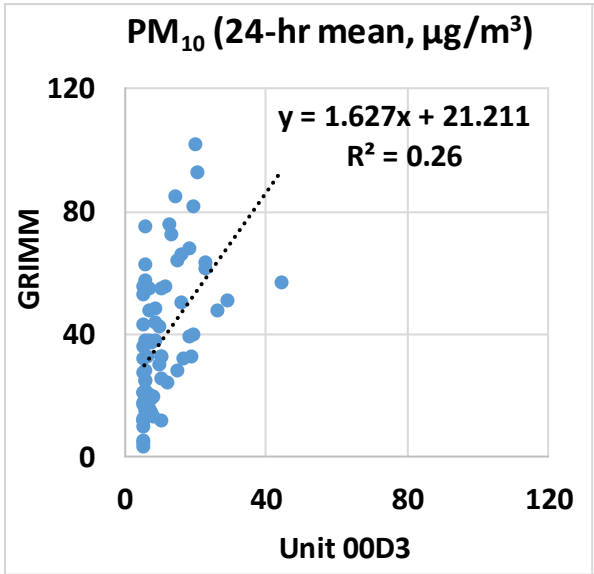


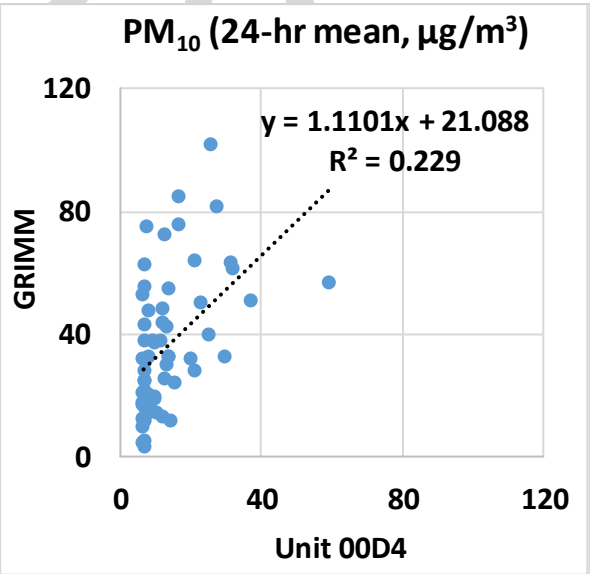


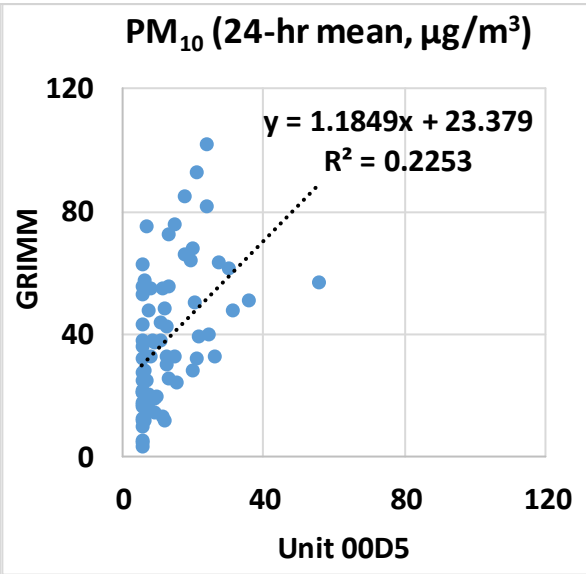
uRADMonitor A3 vs GRIMM (PM_{10}; 24-hr mean)



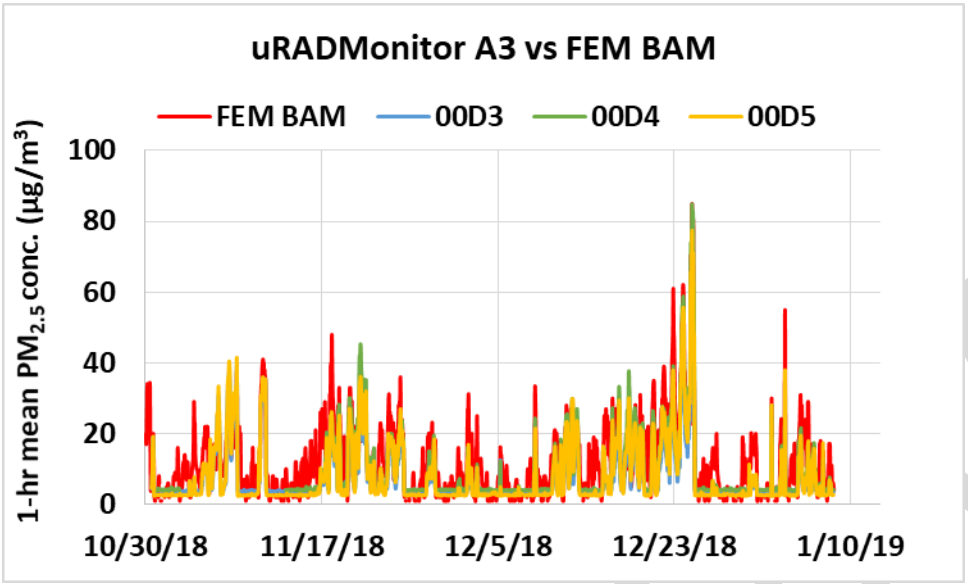
- uRADMonitor A3 sensors show very weak correlations with the corresponding GRIMM data (R^2 ~ 0.24)
- Overall, the uRADMonitor A3 sensors underestimate the PM_{10} mass concentrations measured by GRIMM
- The uRADMonitor A3 sensors do not seem to track the PM_{10} concentration variations as recorded by GRIMM



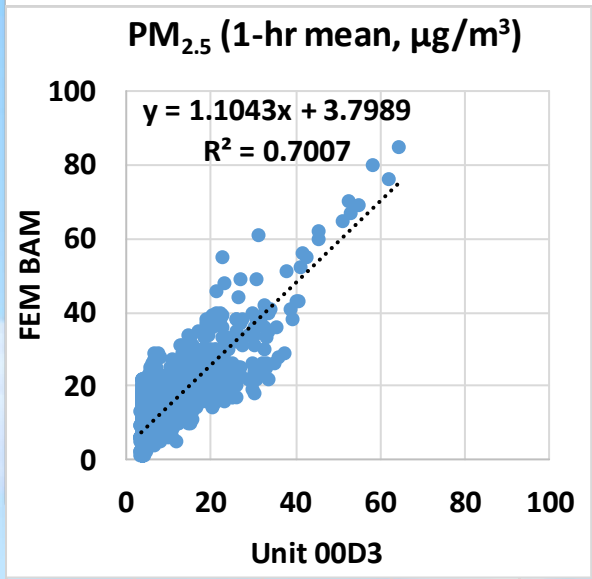


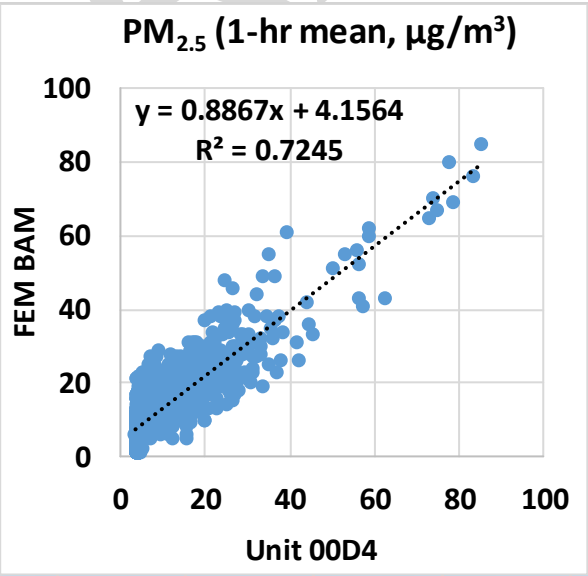


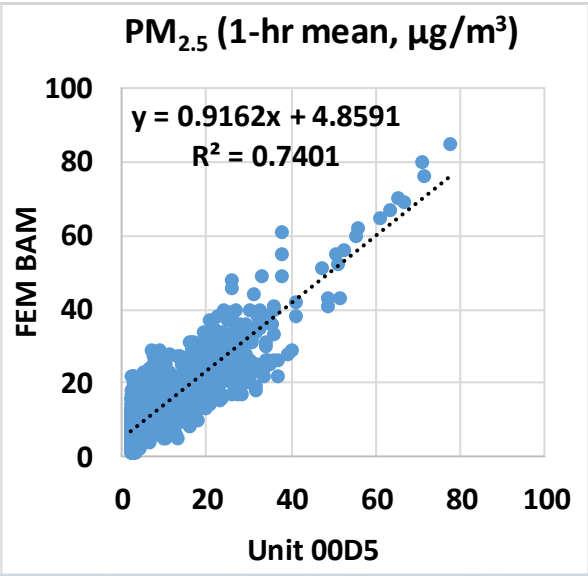
uRADMonitor A3 vs FEM BAM ($PM_{2.5}$; 1-hr mean)



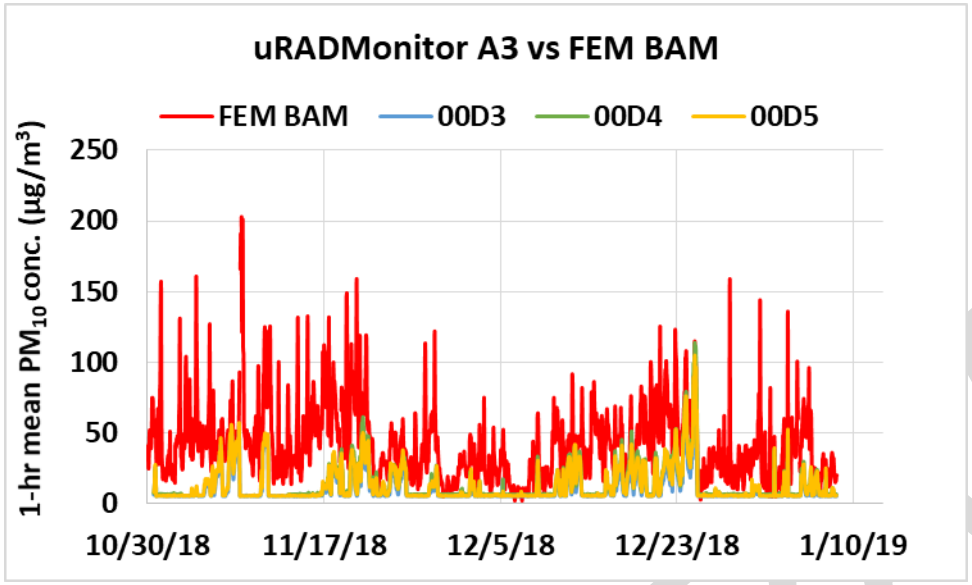
- uRADMonitor A3 sensors show strong correlations with the corresponding FEM BAM data (R^2 ~ 0.72) when $PM_{2.5}$ mass concentration is > ~10 µg/m^3 as recorded by FEM BAM
- Overall, the uRADMonitor A3 sensors underestimate the $PM_{2.5}$ mass concentrations measured by FEM BAM
- The uRADMonitor A3 seem to track the $PM_{2.5}$ diurnal variations when $PM_{2.5}$ mass concentration is > 10 µg/m^3 and report constant values of ~ 2.4 – 3.2 µg/m^3 as recorded by FEM BAM.



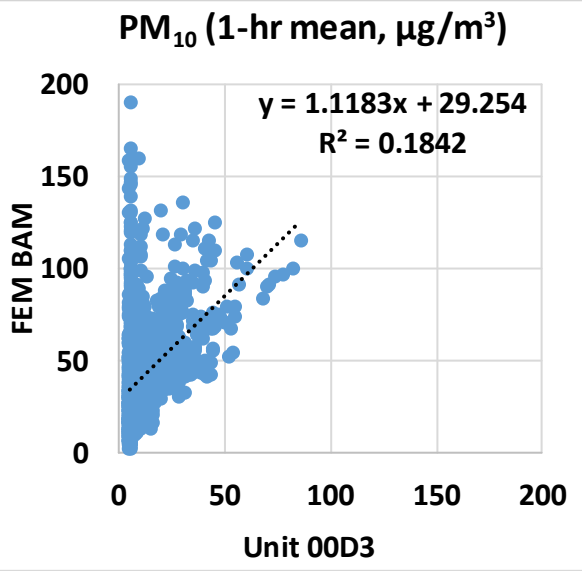


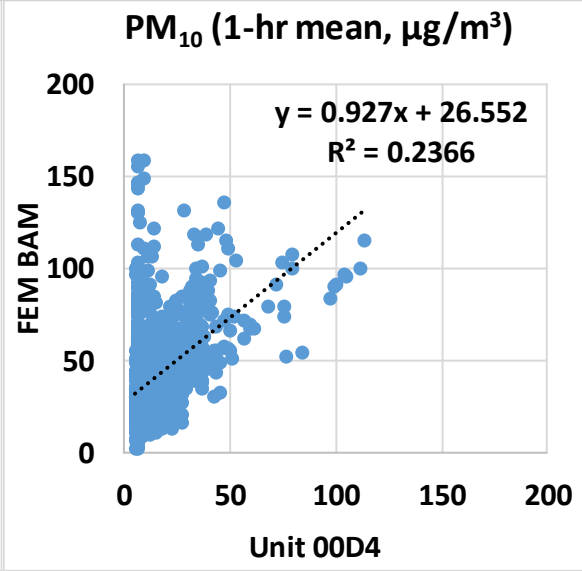


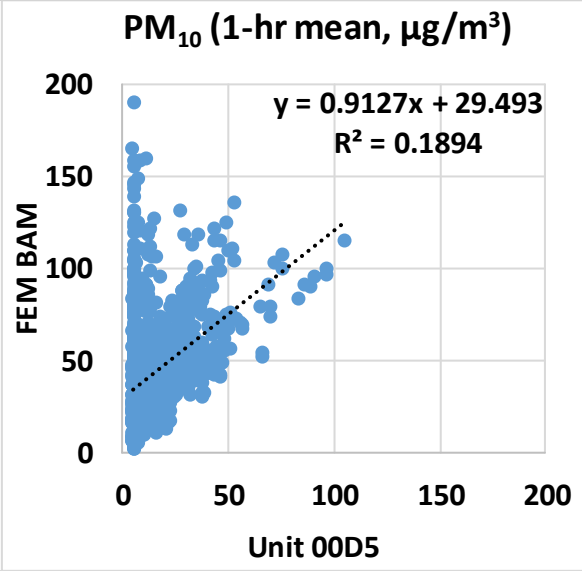
uRADMonitor A3 vs FEM BAM (PM_{10}; 1-hr mean)



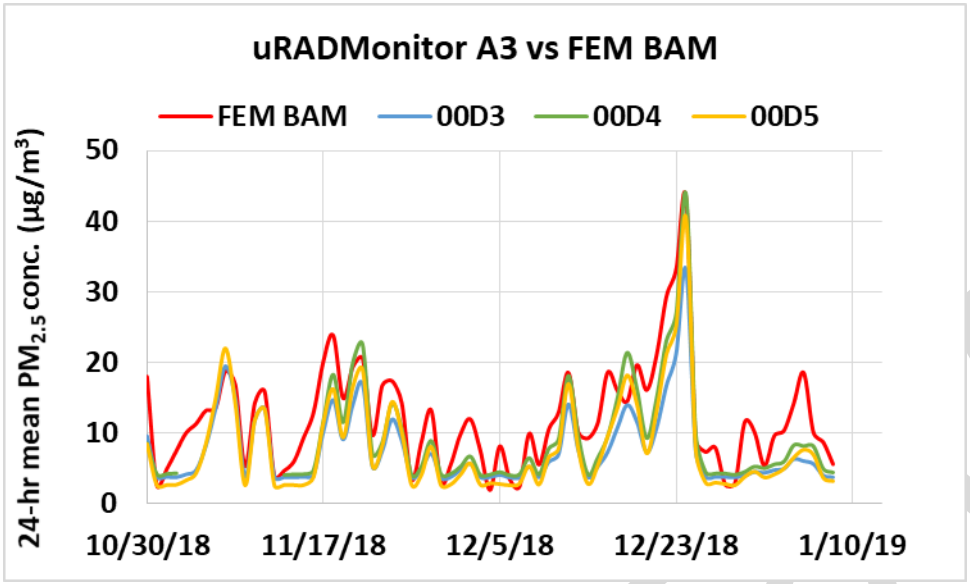
- uRADMonitor A3 sensors show very weak correlations with the corresponding FEM BAM data (R^2 ~ 0.20)
- Overall, the uRADMonitor A3 sensors underestimate the PM_{10} mass concentrations measured by FEM BAM
- The uRADMonitor A3 sensors seem to modestly track the PM_{10} diurnal variations as recorded by FEM BAM when not randomly reporting constant values of ~ 6.9 – 8.4 µg/m³



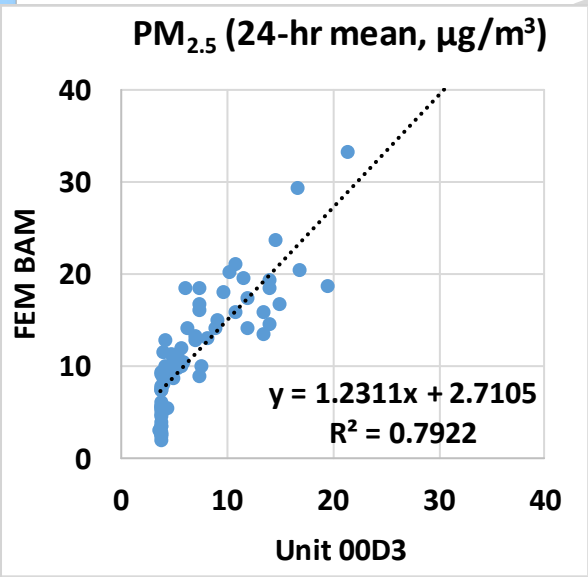


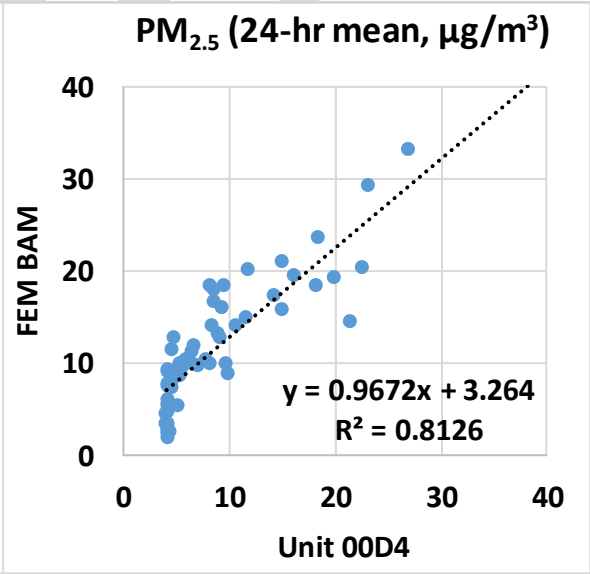


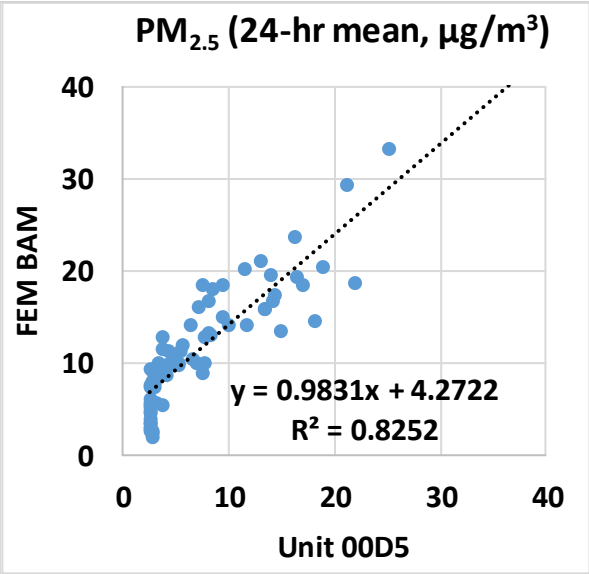
uRADMonitor A3 vs FEM BAM ($PM_{2.5}$; 24-hr mean)



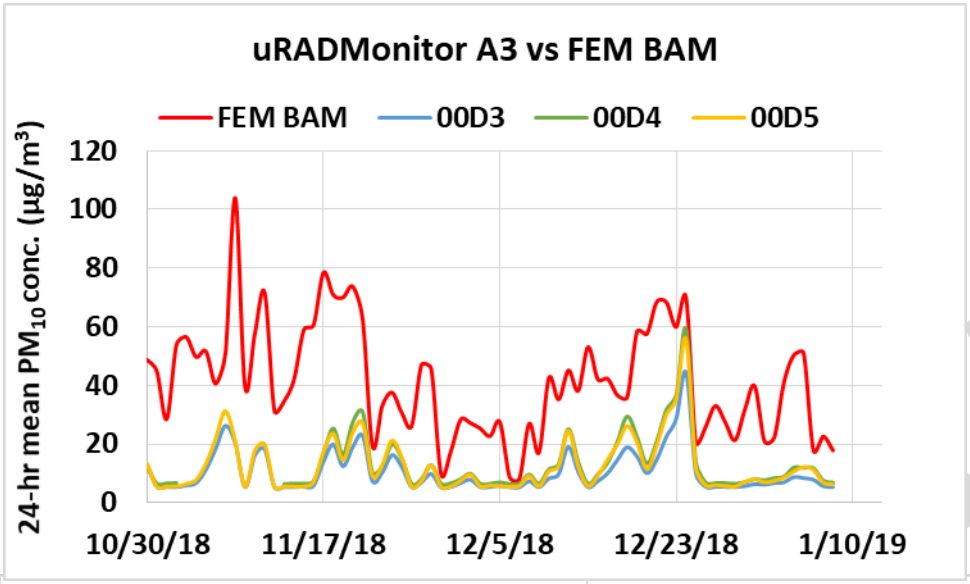
- uRADMonitor A3 sensors show strong correlations with the corresponding FEM BAM data (R^2 ~ 0.81) when $PM_{2.5}$ mass concentration is > ~10 µg/m³ as recorded by FEM BAM
- Overall, the uRADMonitor A3 sensors slightly underestimate the $PM_{2.5}$ mass concentrations measured by FEM BAM
- The uRADMonitor A3 seem to track the $PM_{2.5}$ concentration variations when $PM_{2.5}$ mass concentration is > ~10 µg/m³ and report constant values of ~2.6 – 4 µg/m³ as recorded by FEM BAM



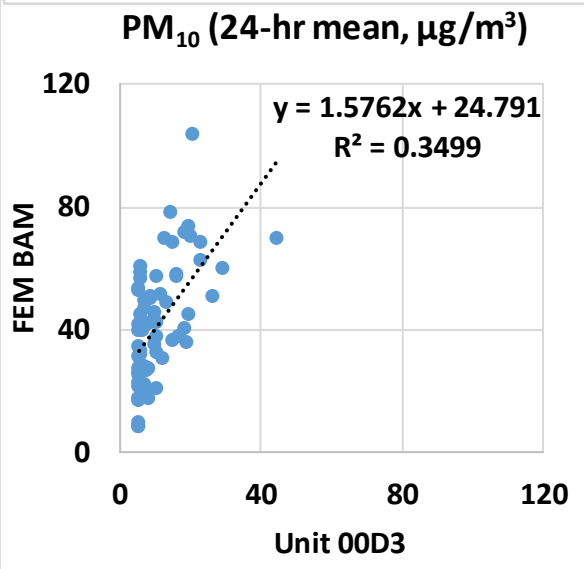


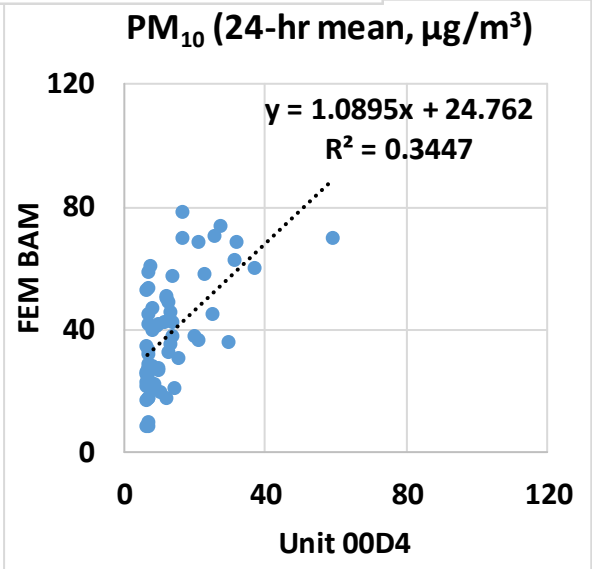


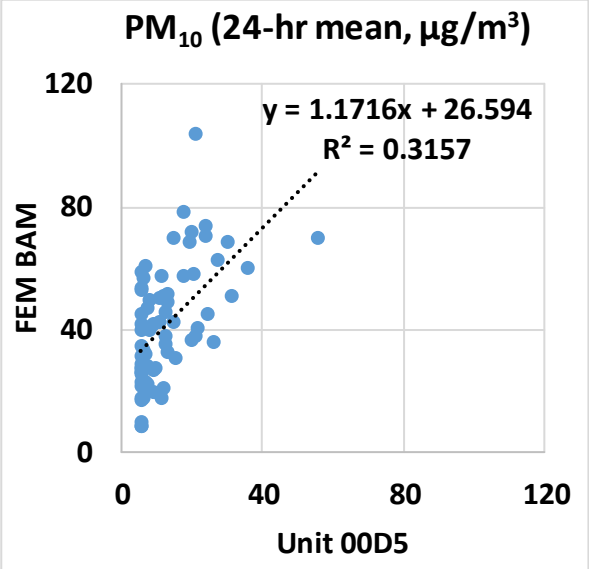
uRADMonitor A3 vs FEM BAM (PM_{10}; 24-hr mean)



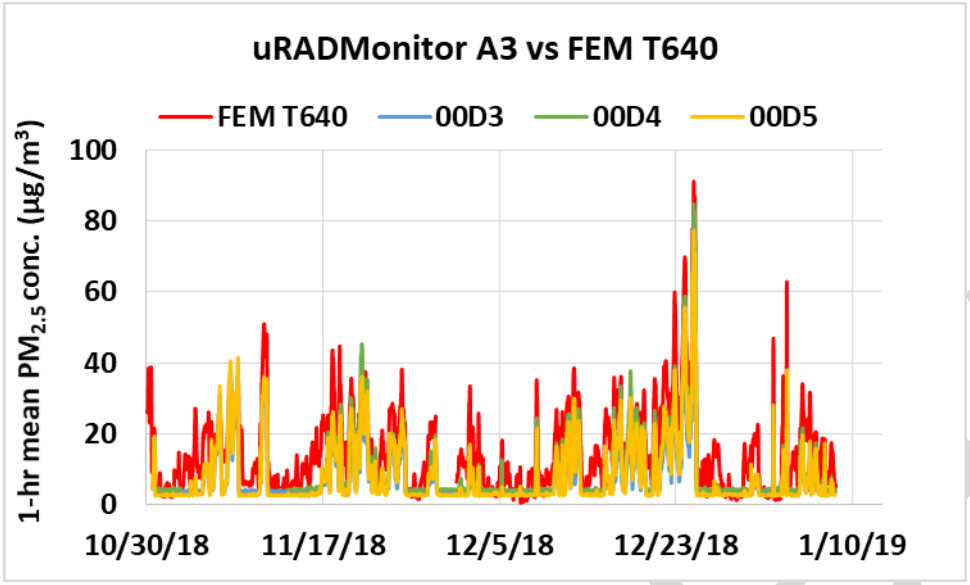
- uRADMonitor A3 sensors show weak correlations with the corresponding FEM BAM data (R^2 ~ 0.34)
- Overall, the uRADMonitor A3 sensors underestimate the PM_{10} mass concentrations measured by FEM BAM
- The uRADMonitor A3 sensors do not seem to track the PM_{10} concentration variations as recorded by FEM BAM



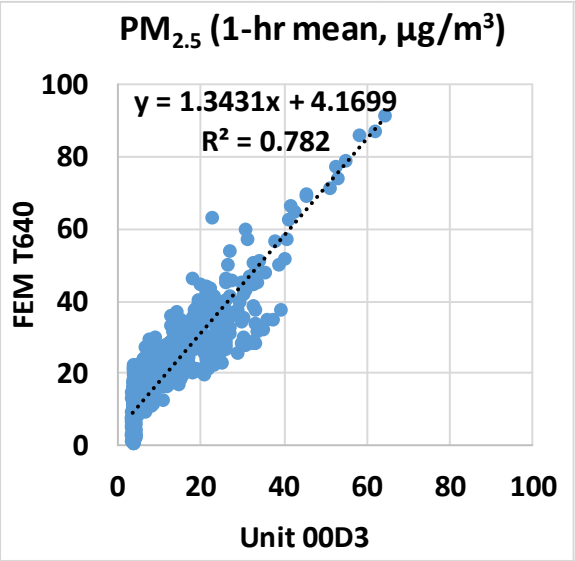


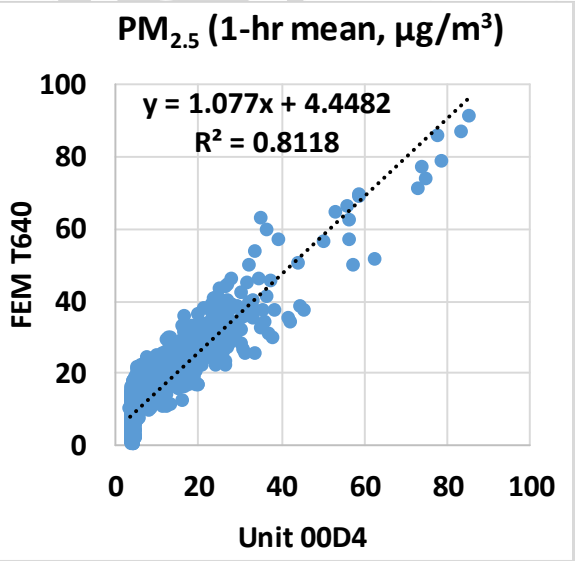


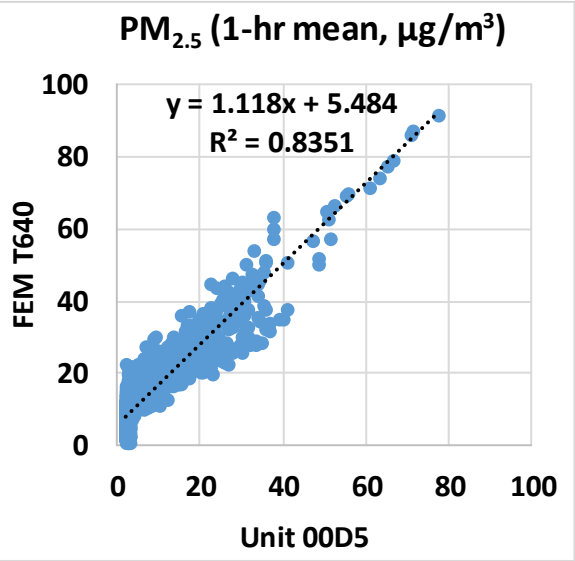
uRADMonitor A3 vs FEM T640 ($PM_{2.5}$; 1-hr mean)



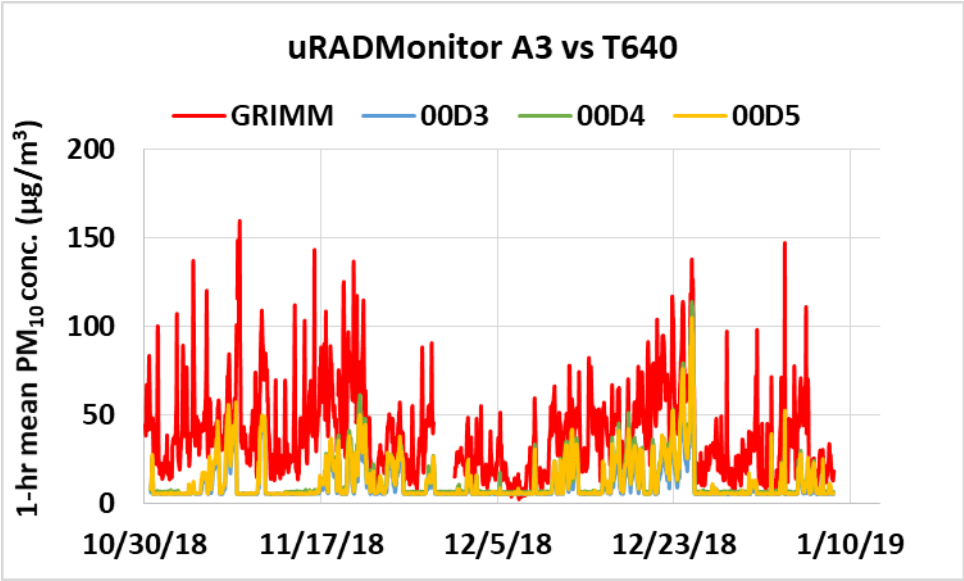
- uRADMonitor A3 sensors show strong correlations with the corresponding FEM T640 data (R^2 ~ 0.81) when $PM_{2.5}$ mass concentration is > 20 µg/m^3 as recorded by FEM T640
- Overall, the uRADMonitor A3 sensors underestimate the $PM_{2.5}$ mass concentrations measured by FEM T640
- The uRADMonitor A3 sensors seem to track well the $PM_{2.5}$ diurnal variations when $PM_{2.5}$ mass concentration is > 20 µg/m^3 and report constant values of ~ 2.4 – 3.2 µg/m^3 as recorded by FEM T640



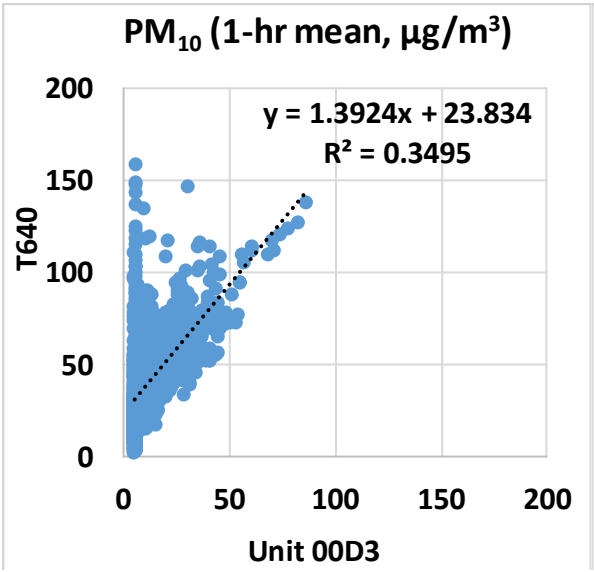


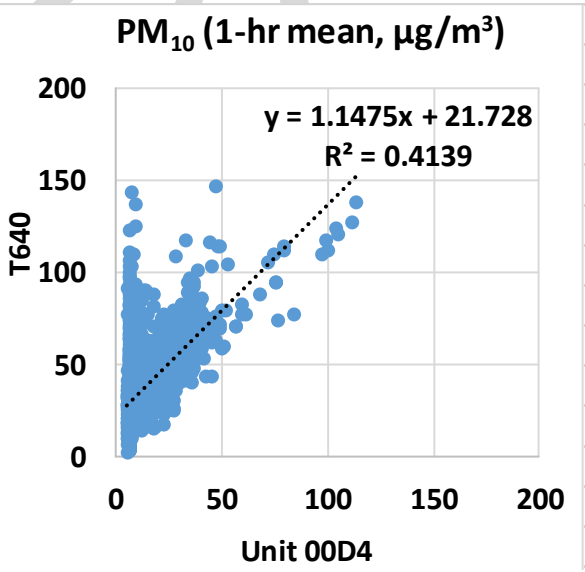


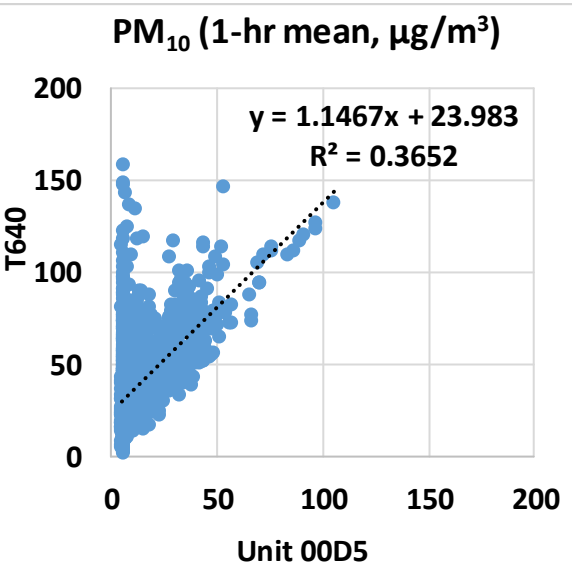
uRADMonitor A3 vs T640 (PM_{10}; 1-hr mean)



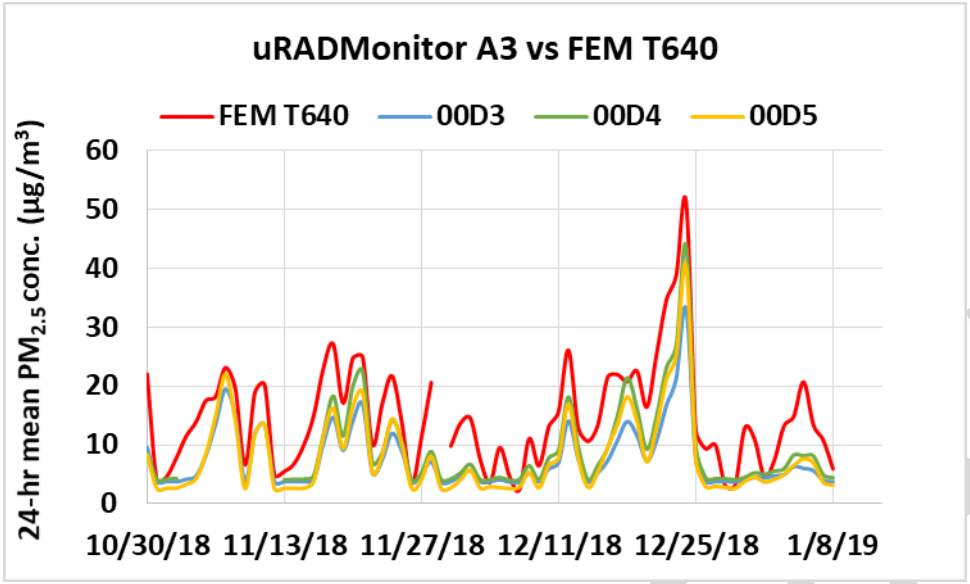
- uRADMonitor A3 sensors show weak correlations with the corresponding T640 data (R^2 ~ 0.38)
- Overall, the uRADMonitor A3 sensors underestimate the PM_{10} mass concentrations measured by T640
- The uRADMonitor A3 sensors seem to modestly track the PM_{10} diurnal variations when not reporting constant values of ~ 5.1 – 6.9 µg/m³



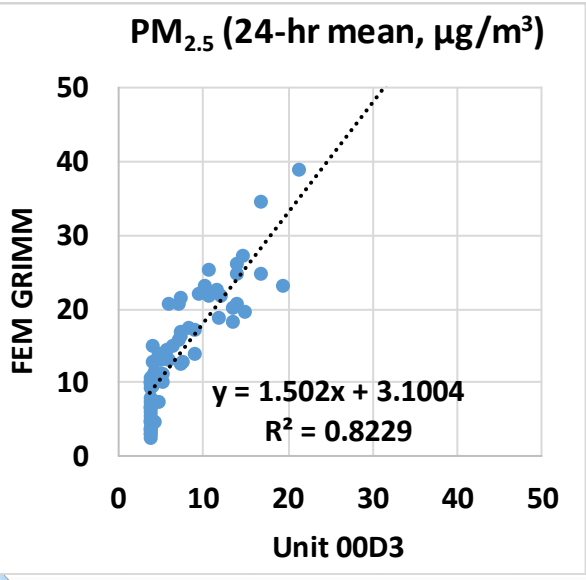


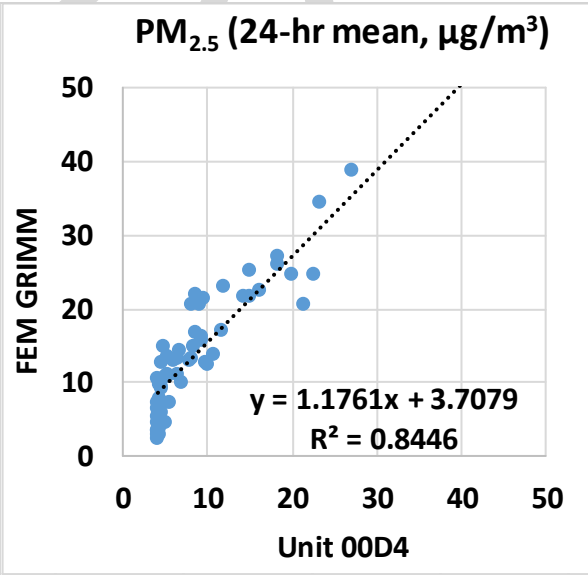


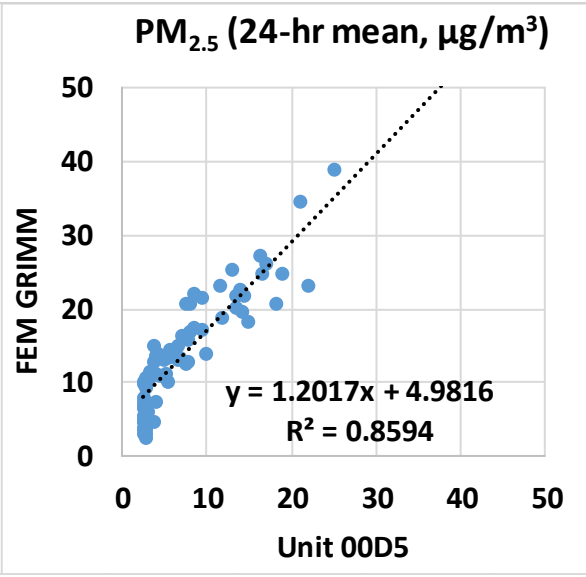
uRADMonitor A3 vs FEM T640 ($PM_{2.5}$; 24-hr mean)



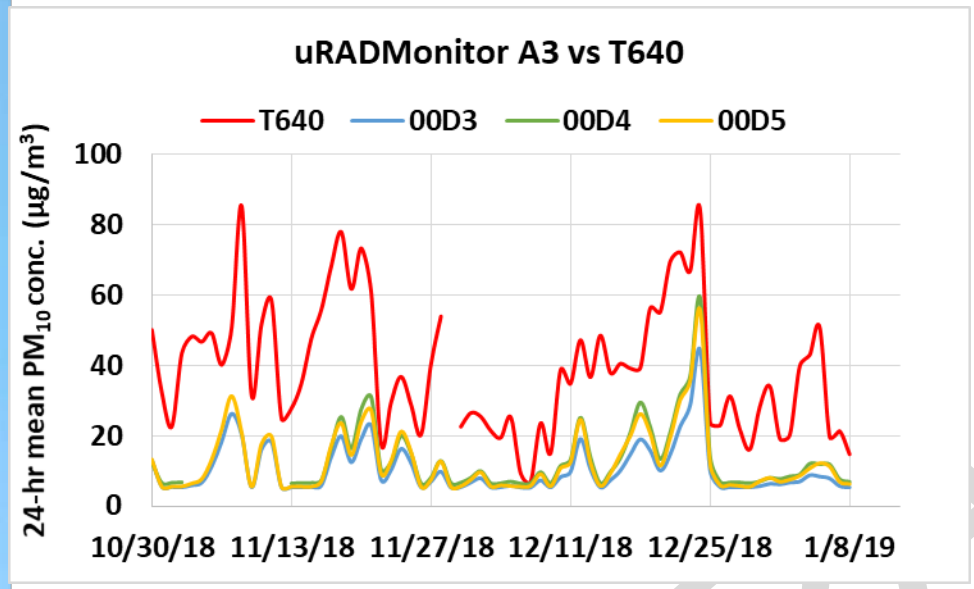
- uRADMonitor A3 sensors show strong correlations with the corresponding FEM T640 data (R^2 ~ 0.84) when $PM_{2.5}$ mass concentration is > ~10 µg/m^3 as recorded by T640
- Overall, the uRADMonitor A3 sensors underestimate the $PM_{2.5}$ mass concentrations measured by FEM T640
- The uRADMonitor A3 sensors seem to modestly track the $PM_{2.5}$ concentration variations as recorded by FEM T640



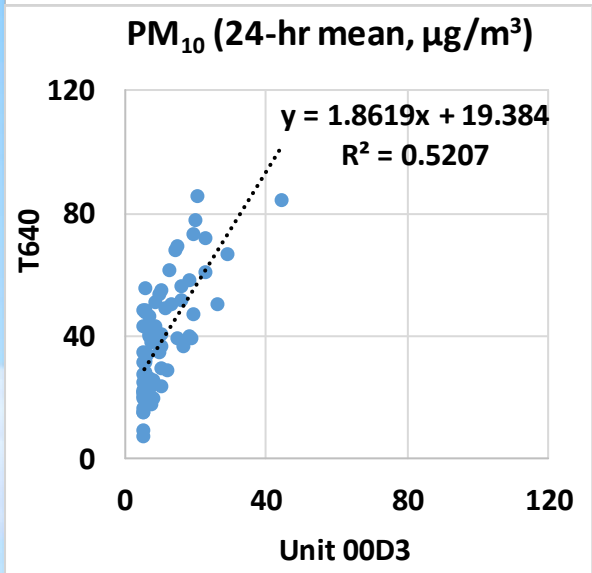


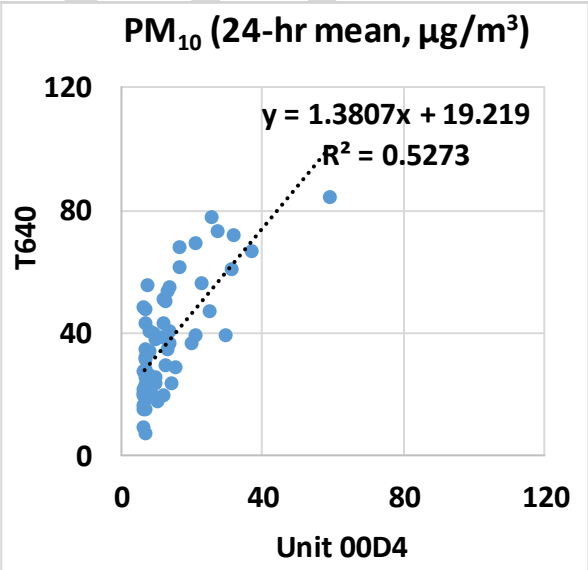


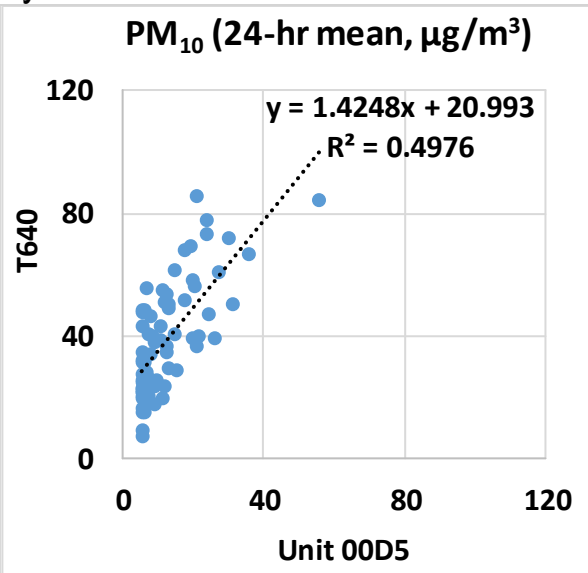
uRADMonitor A3 vs T640 (PM_{10}; 24-hr mean)



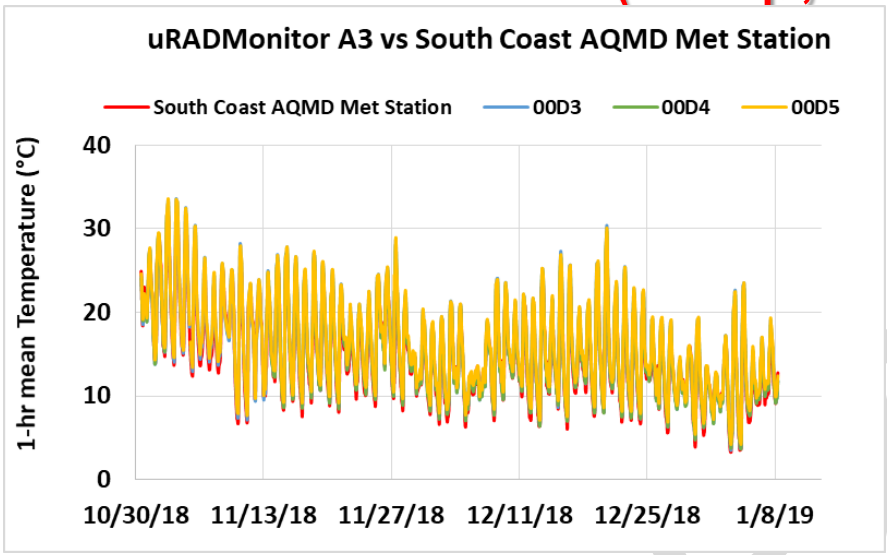
- uRADMonitor A3 sensors show moderate correlations with the corresponding T640 data (R^2 ~ 0.52)
- Overall, the uRADMonitor A3 sensors underestimate the PM_{10} mass concentrations measured by T640
- The uRADMonitor A3 sensors seem to track the PM_{10} concentration variations when $PM_{2.5}$ mass concentration is > ~40 µg/m³ as recorded by T640



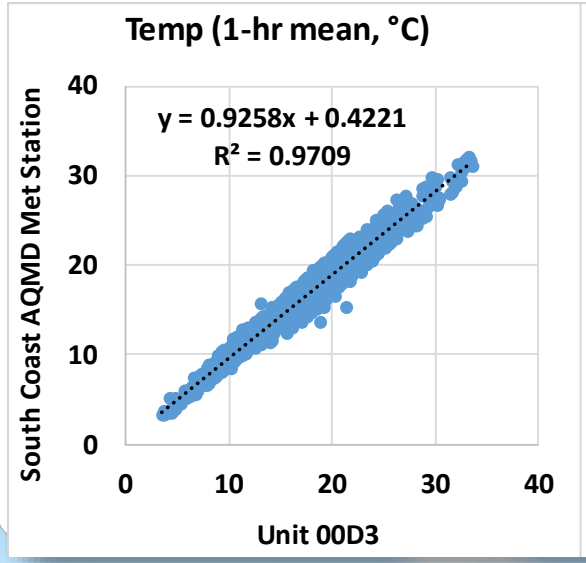


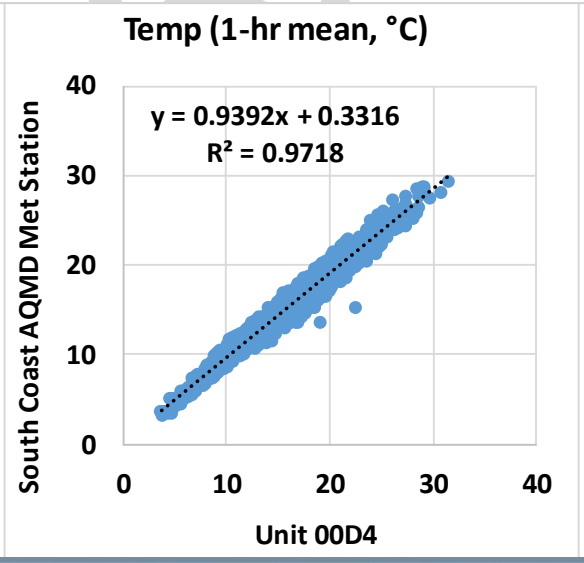


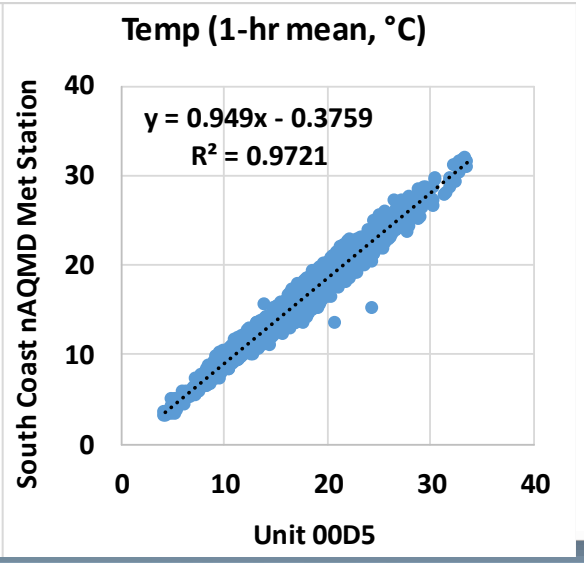
uRADMonitor A3 vs South Coast AQMD Met Station (Temp; 1-hr mean)



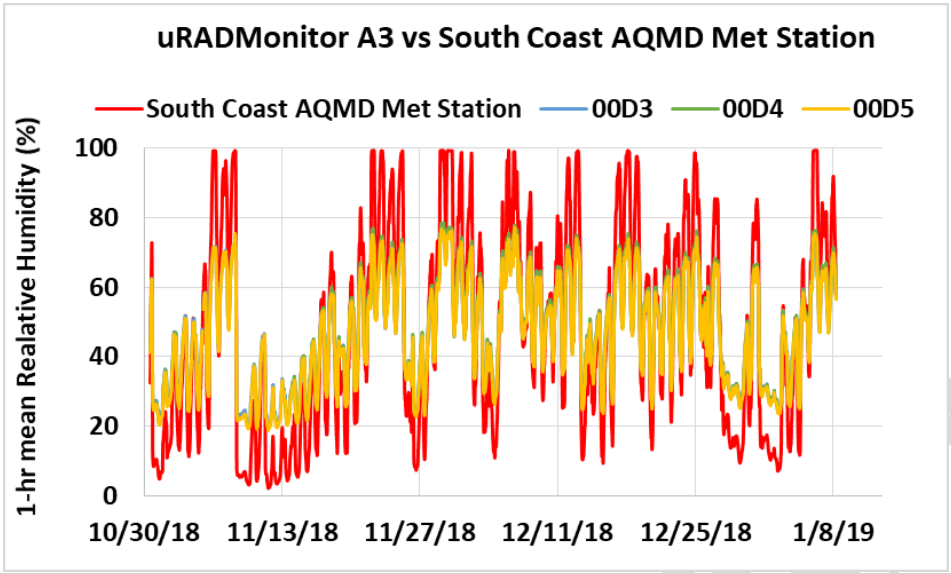
- uRADMonitor A3 temperature measurements show very strong correlations with the corresponding South Coast AQMD Met Station data (R^2 ~ 0.97)
- Overall, the uRADMonitor A3 temperature measurements seem to be quite accurate
- The uRADMonitor A3 sensors seem to track well the temperature diurnal variations as recorded by South Coast AQMD Met Station



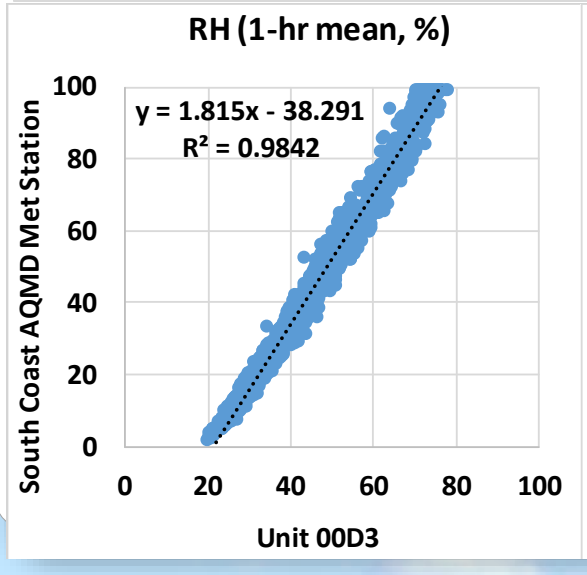


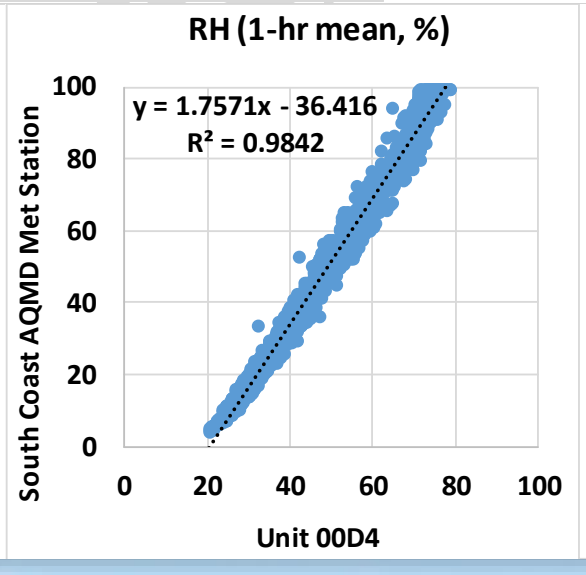


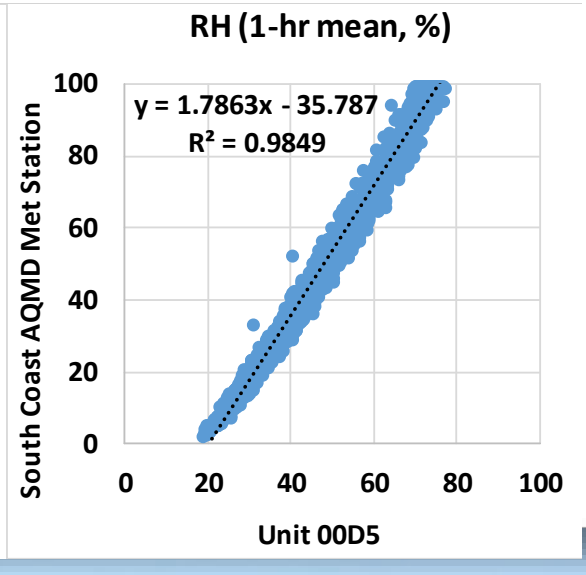
uRADMonitor A3 vs South Coast AQMD Met Station (RH; 1-hr mean)



- The uRADMonitor A3 RH measurements show very strong correlations with the corresponding South Coast AQMD Met Station data (R^2 ~ 0.98)
- Overall, the uRADMonitor A3 RH measurements underestimate at RHs > 40% and overestimate at RHs < 40%, as recorded by the South Coast AQMD Met Station
- The uRADMonitor A3 sensors seem to track well the RH diurnal variations as recorded by South Coast AQMD Met Station







Discussion

- The three **uRADMonitor A3** sensors' data recovery from units 00D3, 00D4, and 00D5 is 99.9%, 81.6% and 99.9%, respectively, for all PM fractions. Data recovery is calculated based on the one hour averages due to the fact that the sensors have inconsistent time stamp, limiting comparisons at higher time resolution
- The three sensors showed moderate intra-model variability (19% to 25%)
- The reference instruments (GRIMM, BAM and T640) show very strong correlations with each other for both $PM_{2.5}$ (R^2 ~ 0.91) and PM_{10} (R^2 ~ 0.90) mass concentration measurements (1-hr mean)
- PM sensor data is accessed via analog, converting sensor voltage readings to mass concentrations in µg/m^3; this represents $PM_{2.5}$ mass concentrations, $PM_{1.0}$ and PM_{10} mass concentrations are extrapolated from $PM_{2.5}$ values using a linear model. The analog readings will impose some limitation on resolution and limits of detection for PM mass concentrations.
- $PM_{1.0}$ mass concentration measurements measured by uRADMonitor A3 sensors show strong correlations with the corresponding GRIMM values (R^2 ~ 0.82, 1-hr mean) when $PM_{1.0}$ mass concentration is > ~10 µg/m^3 and underestimate $PM_{1.0}$ mass concentration measured by the GRIMM
- $PM_{2.5}$ mass concentration measurements measured by uRADMonitor A3 sensors show strong correlations with the corresponding FEM GRIMM, FEM BAM and FEM T640 (R^2 ~ 0.76, 0.72 and 0.81, respectively, 1-hr mean) when $PM_{2.5}$ mass concentration is > ~10 - 20 µg/m^3 and underestimate $PM_{2.5}$ mass concentration measured by the FEM GRIMM, FEM BAM and FEM T640
- PM_{10} mass concentration measurements measured by uRADMonitor A3 sensors show very weak to weak correlations with the corresponding GRIMM, FEM BAM and T640 (R^2 ~ 0.15 , 0.20 and 0.38, respectively, 1-hr mean) and underestimate PM_{10} mass concentration measured by the reference instruments
- 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