Field Evaluation
Lunar Outpost Canary-S

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 06/26/2019 to 08/29/2019, three **Lunar Outpost Canary-S** (hereinafter **Canary-S**) 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

- Canary-S (*3 units tested*):
  - Particle sensor: optical; non-FEM (PMS 5003)
  - Each unit reports: $PM_{1.0}$, $PM_{2.5}$ and PM_{10} ($\mu g/m^3$), *temperature (F), *RH (%)
  - Also measures (optional) VOC, NO_2, ozone, carbon monoxide, carbon dioxide, sulfur dioxide, wind speed, wind direction
  - Unit cost: $1295 (with solar option); $1070 (without solar option)
  - Time resolution: 1-min
  - Units IDs: 1, 2, 3

* Units measure internal temperature and relative humidity

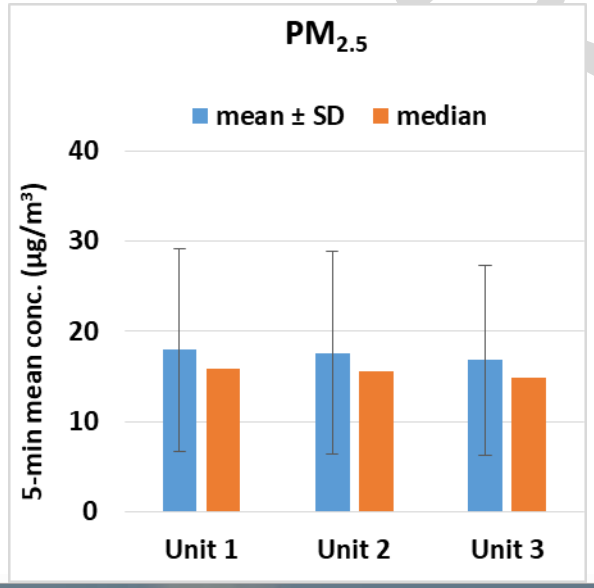
- **South Coast AQMD Reference instruments:**
  - MetOne BAM (FEM $PM_{2.5}$ & PM_{10}), cost: ~$20,000
    - Time resolution: 1-hr
  - Teledyne T640 (FEM $PM_{2.5}$), cost: ~$21,000
    - Time resolution: 1-min
  - Met station (T, RH, P, WS, WD), cost: ~$5,000
    - Time resolution: 1-min

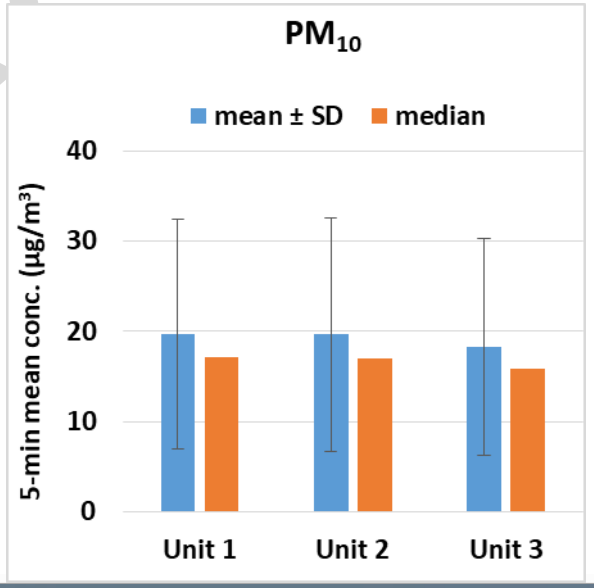
Data validation & recovery

- 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 1, 2, 3 was ~100% for all PM measurements

Canary-S; intra-model variability

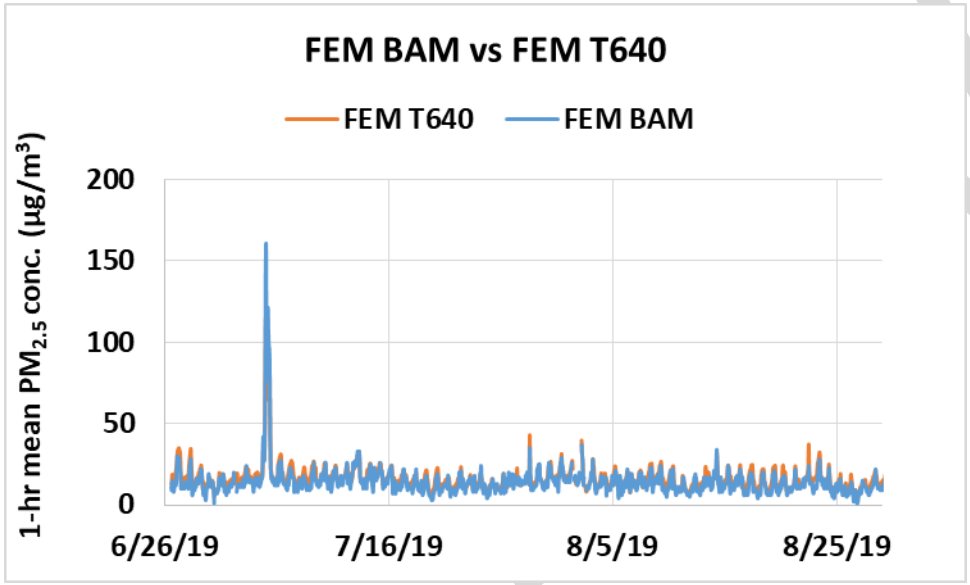
- Absolute intra-model variability was ~ 0.57 and 0.82 µg/m^3 for $PM_{2.5}$ and $PM_{10,}$ respectively (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 3.3 and 4.3 % for $PM_{2.5}$ and $PM_{10,}$ respectively (calculated as the absolute intra-model variability relative to the mean of the three sensor means)

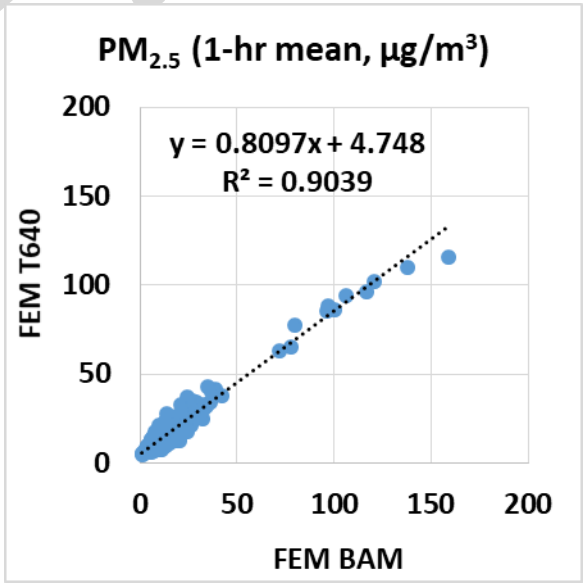




Reference Instruments: $PM_{2.5}$ BAM & T640

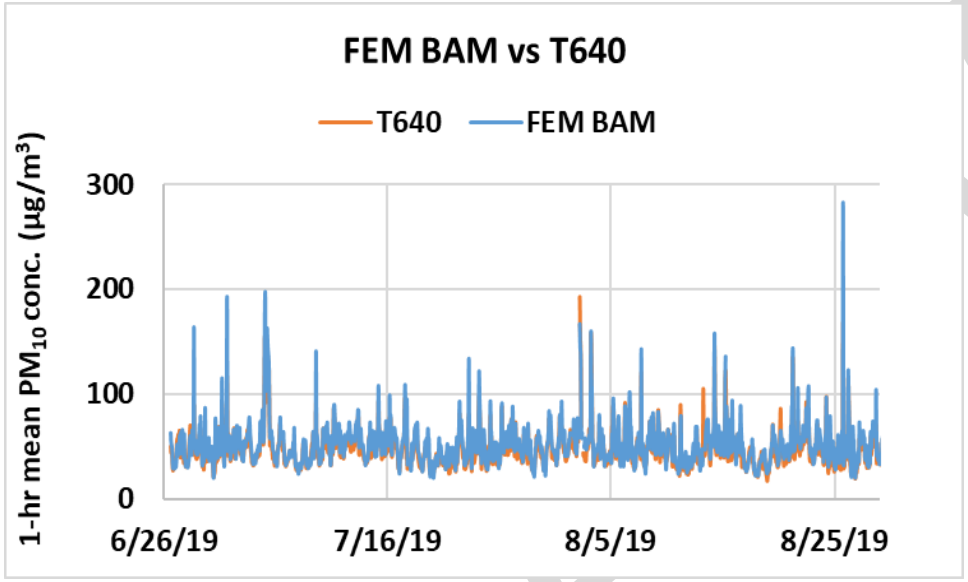
- Data recovery for $PM_{2.5}$ from FEM BAM and FEM T640 was 99% and 100%, respectively.
- Very strong correlations between the reference instruments for $PM_{2.5}$ measurements (R^2 ~ 0.90) were observed.

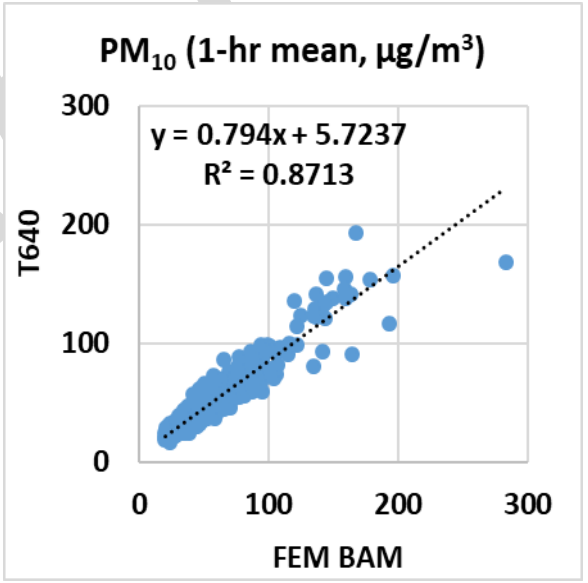




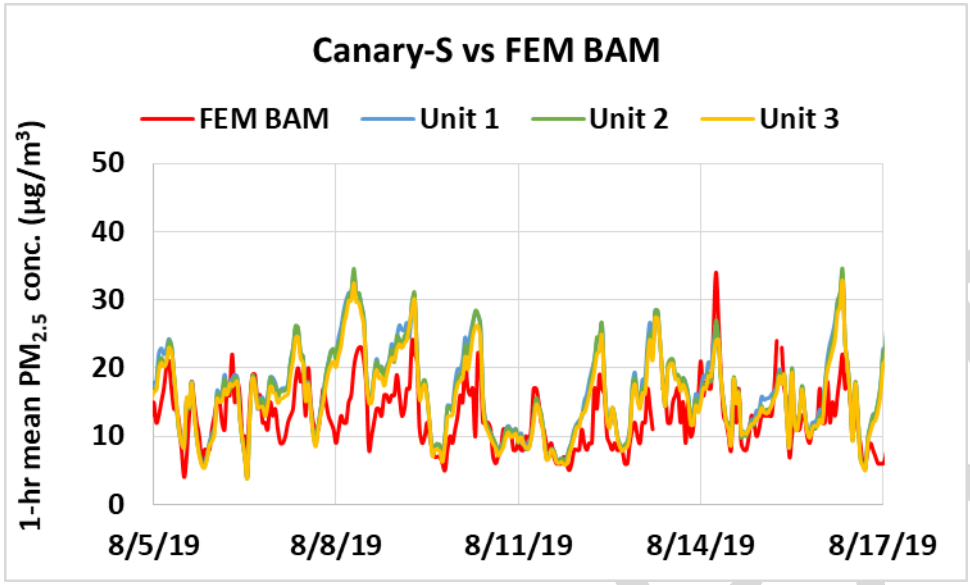
Reference Instruments: PM_{10} BAM & T640

- Data recovery for PM_{10} from FEM BAM and T640 was 99% and 100%, respectively.
- Strong correlations between the reference instruments for PM_{10} measurements (R^2 ~ 0.87) were observed.

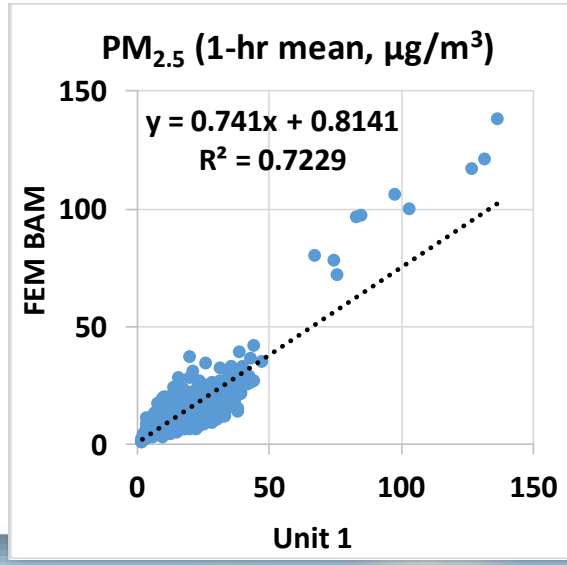


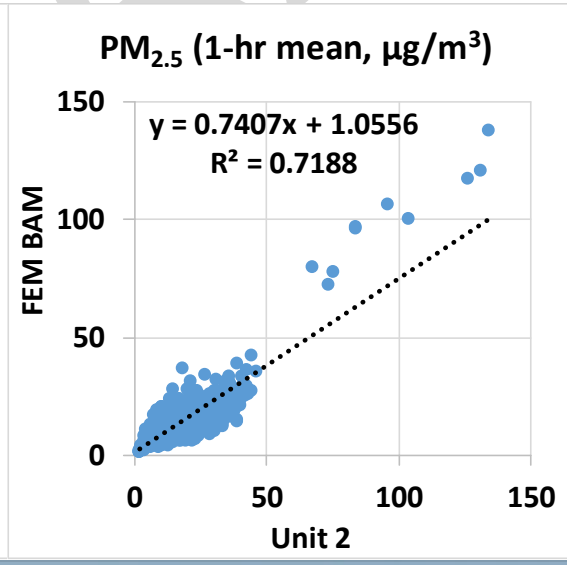


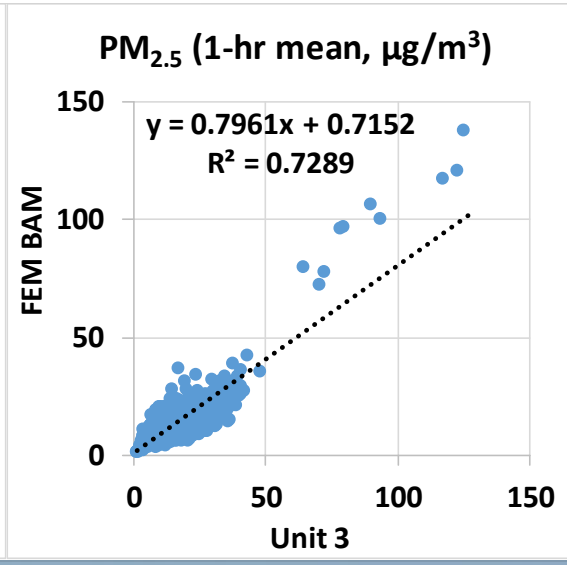
Canary-S vs FEM BAM ($PM_{2.5}$; 1-hr mean)



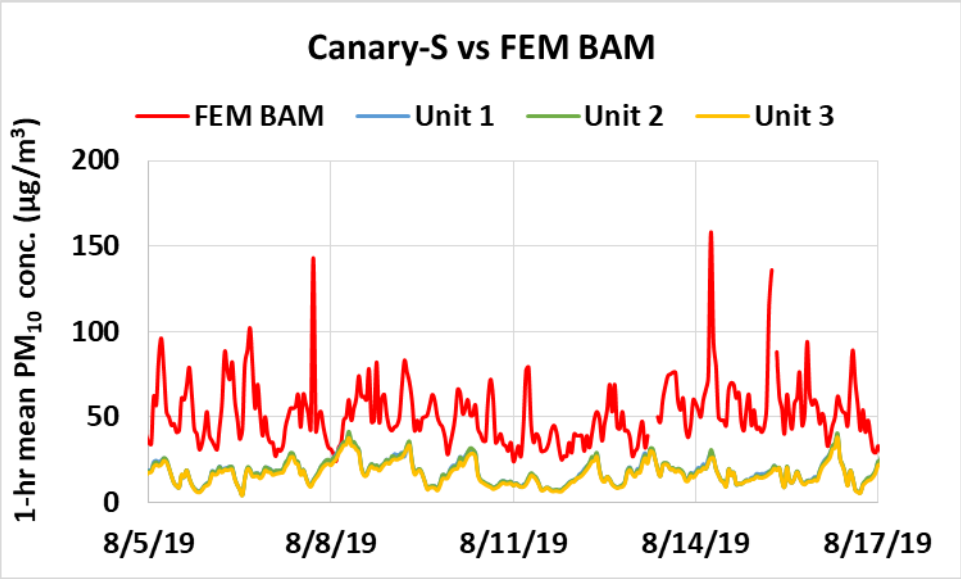
- Canary-S sensors showed strong correlations with the corresponding FEM BAM data (R^2 ~ 0.72)
- Overall, the Canary-S sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM BAM
- The Canary-S sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM BAM



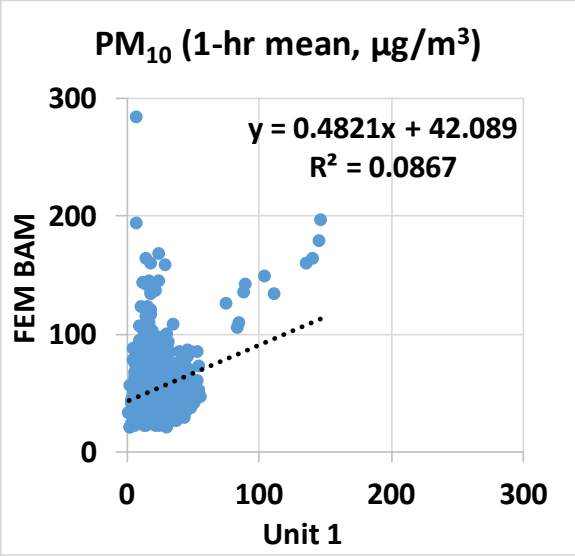


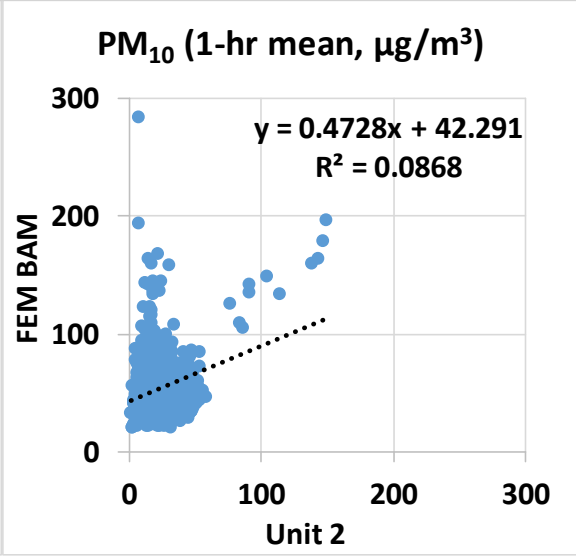


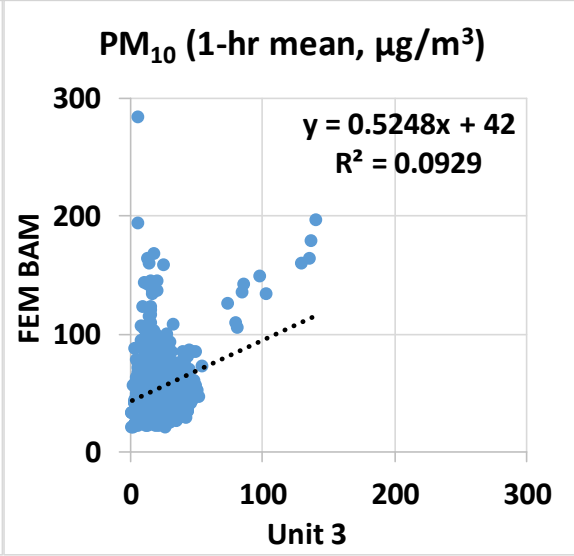
Canary-S vs FEM BAM (PM_{10}; 1-hr mean)



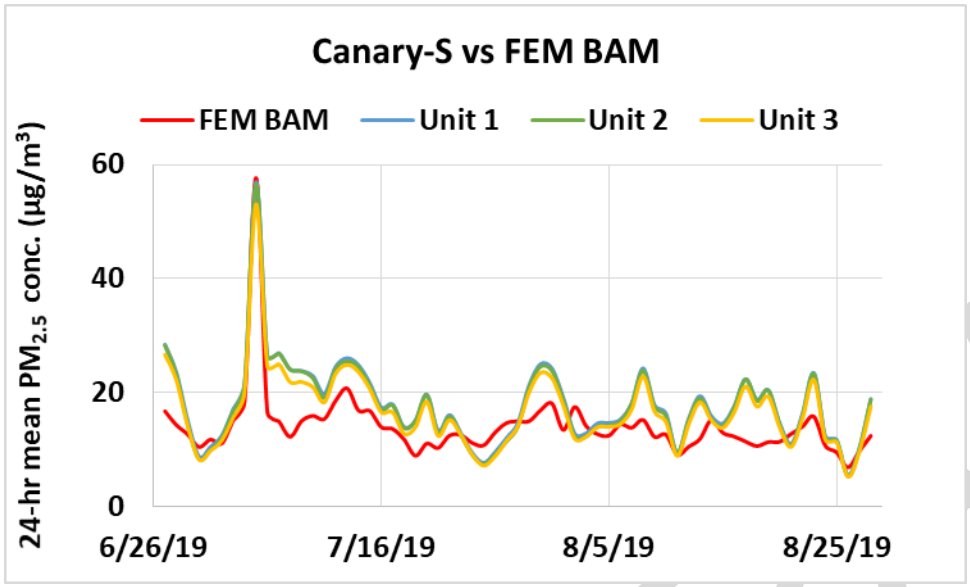
- Canary-S sensors did not correlate with the corresponding FEM BAM data (R^2 ~ 0.09)
- Overall, the Canary-S sensors underestimated the PM_{10} mass concentrations measured by FEM BAM
- The Canary-S sensors did not seem to track the PM_{10} diurnal variations as recorded by FEM BAM



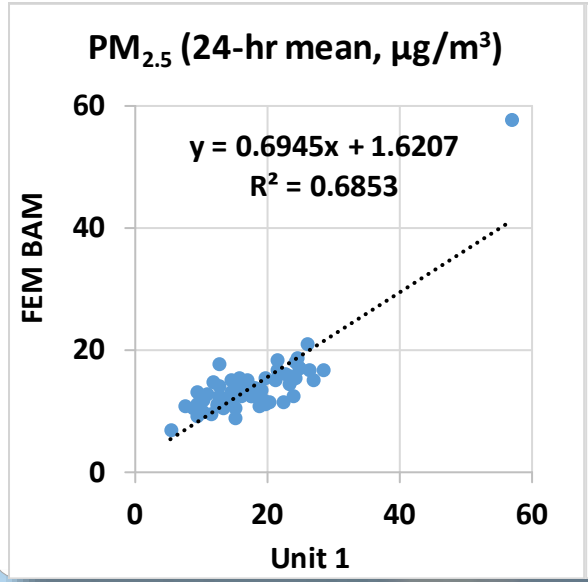


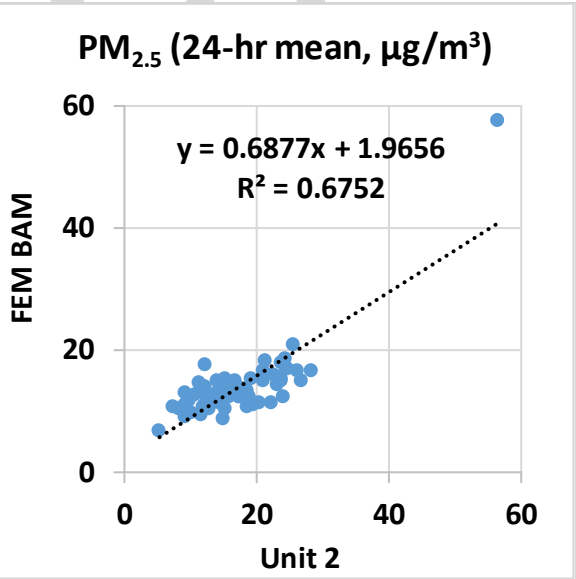


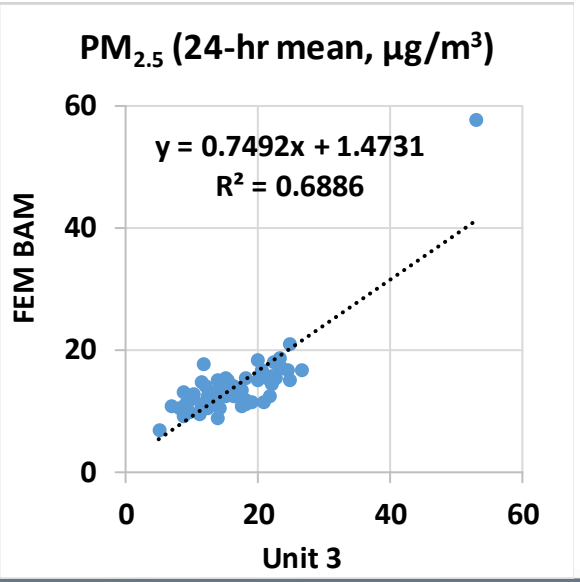
Canary-S vs FEM BAM ($PM_{2.5}$; 24-hr mean)



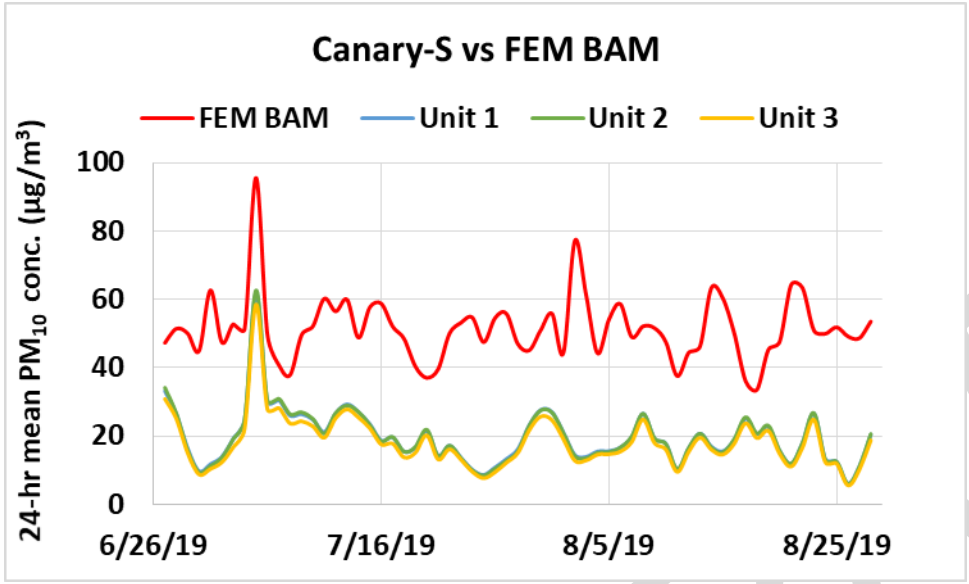
- Canary-S sensors showed moderate correlations with the corresponding FEM BAM data (R^2 ~ 0.68)
- Overall, the Canary-S sensors overestimated the $PM_{2.5}$ mass concentrations as measured by FEM BAM
- The Canary-S sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM BAM



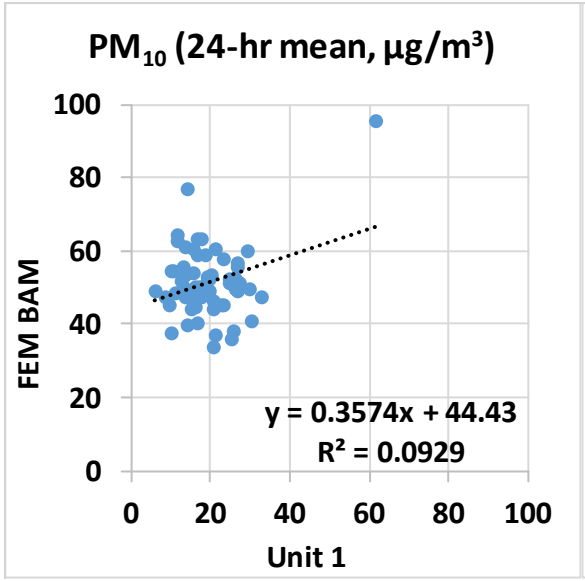


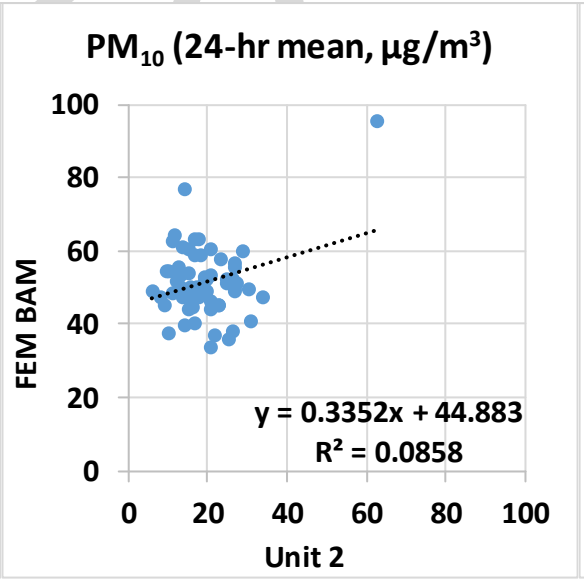


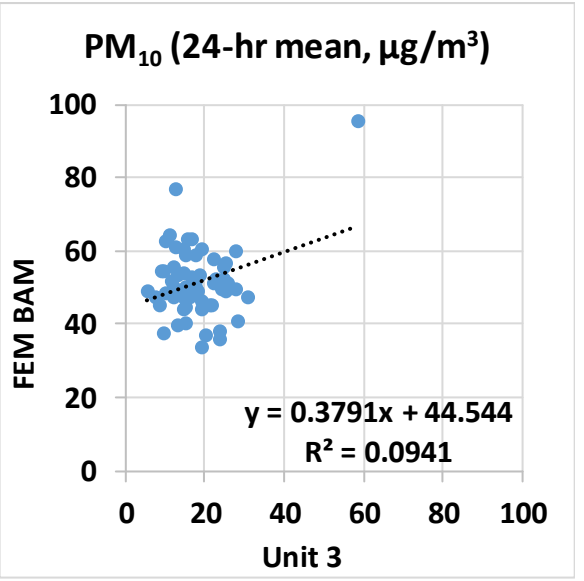
Canary-S vs FEM BAM (PM_{10}; 24-hr mean)



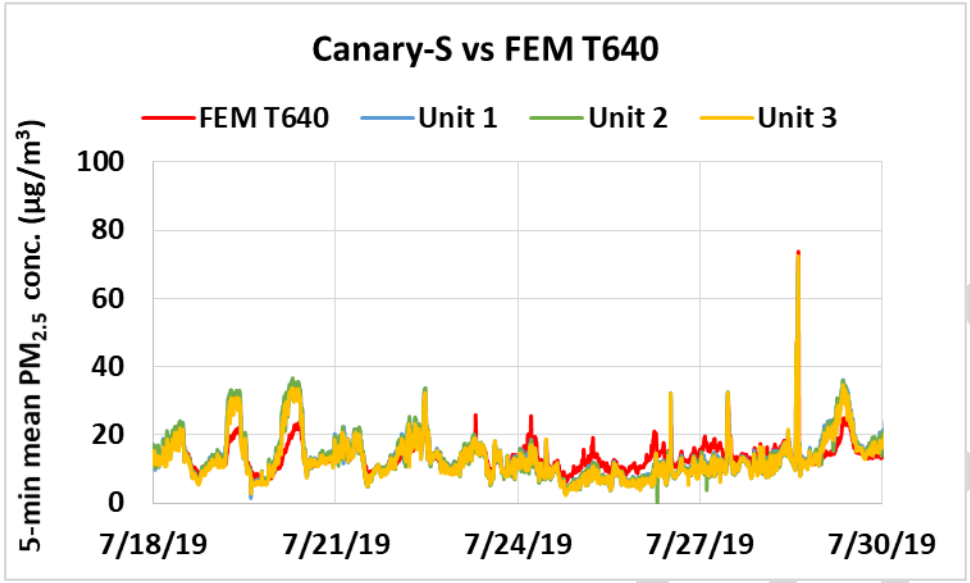
- Canary-S sensors did not correlate with the corresponding FEM BAM data (R^2 ~ 0.09)
- Overall, the Canary-S sensors underestimated the PM_{10} mass concentrations measured by FEM BAM
- The Canary-S sensors did not seem to track the PM_{10} diurnal variations as recorded by FEM BAM



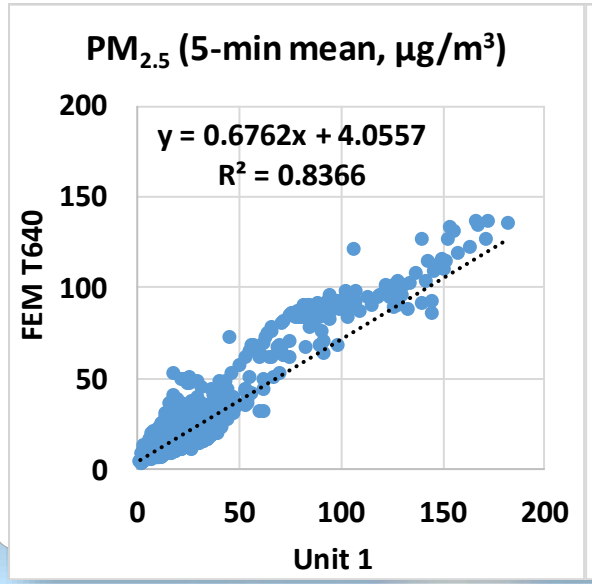


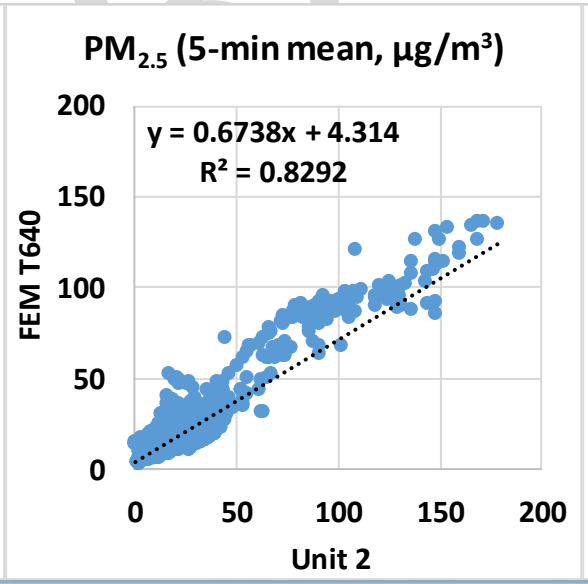


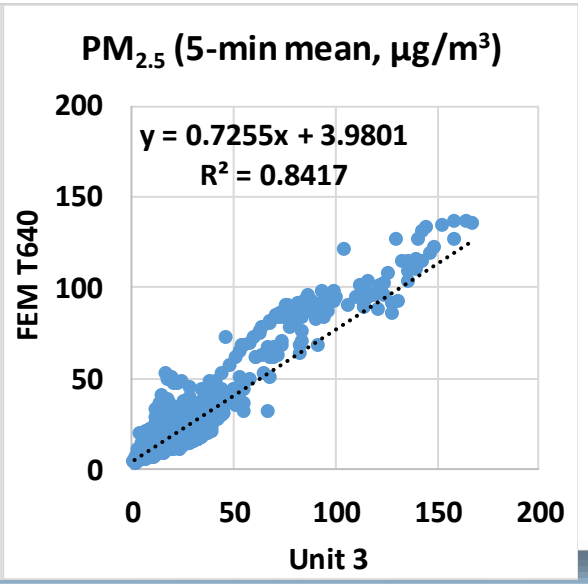
Canary-S vs FEM T640 ($PM_{2.5}$; 5-min mean)



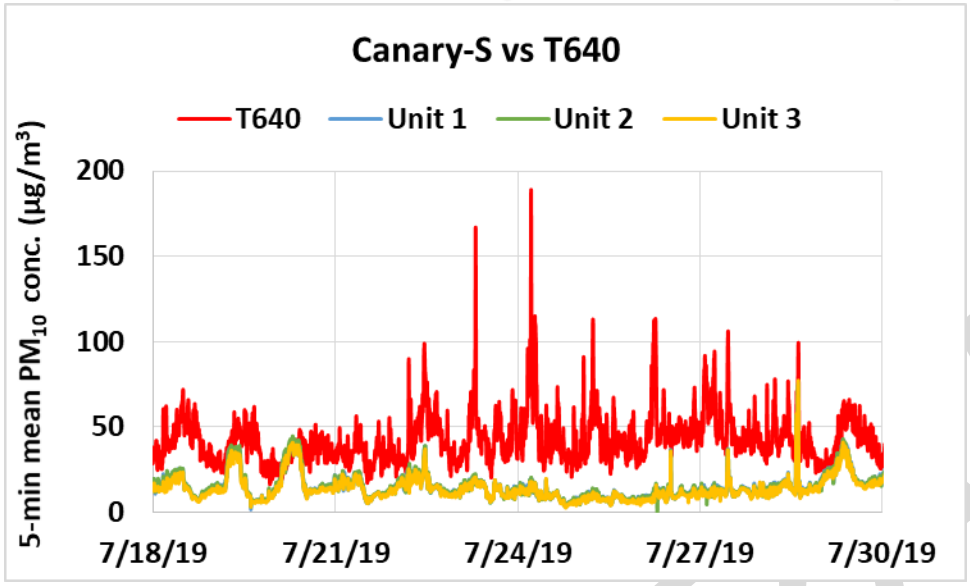
- Canary-S sensors showed strong correlations with the corresponding FEM T640 data (R^2 ~ 0.83)
- Overall, the Canary-S sensors overestimated the $PM_{2.5}$ mass concentrations measured by FEM T640
- The Canary-S sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



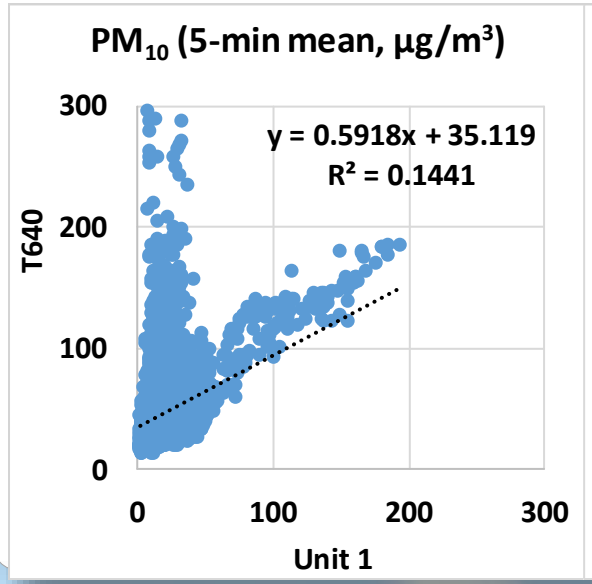


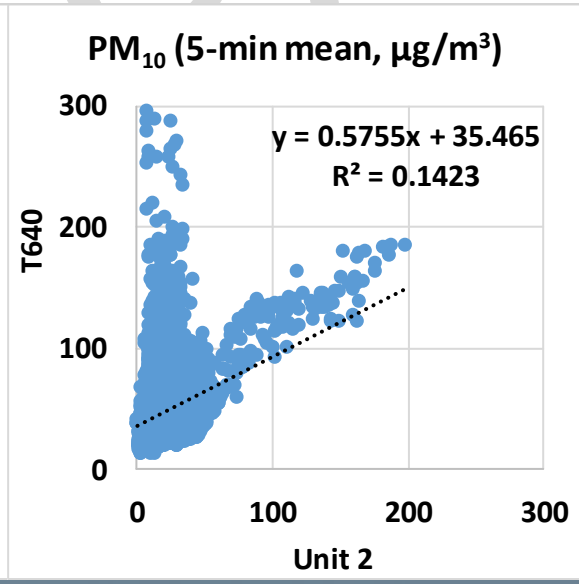


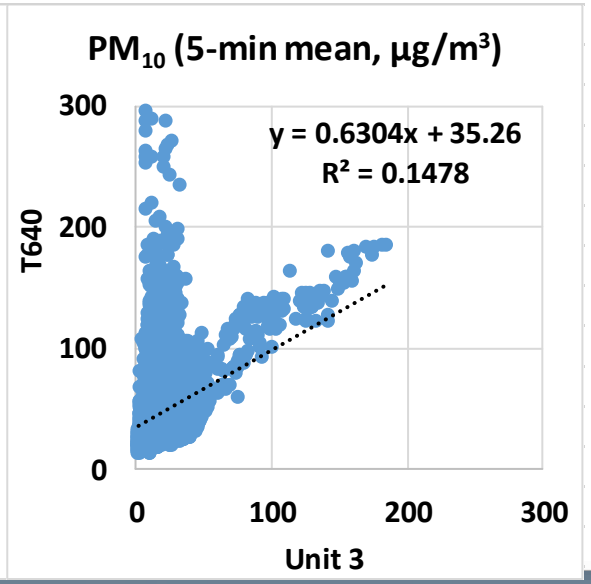
Canary-S vs T640 (PM_{10}; 5-min mean)



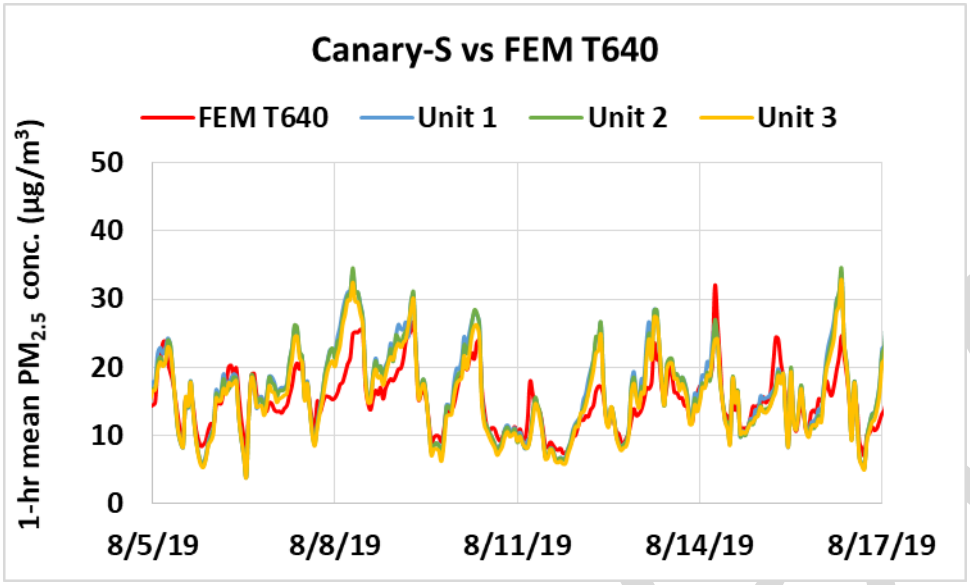
- Canary-S sensors showed very weak correlations with the corresponding T640 data (R^2 ~ 0.14)
- Overall, the Canary-S sensors underestimated the PM_{10} mass concentrations measured by T640
- The Canary-S sensors did not seem to track the PM_{10} diurnal variations as recorded by T640



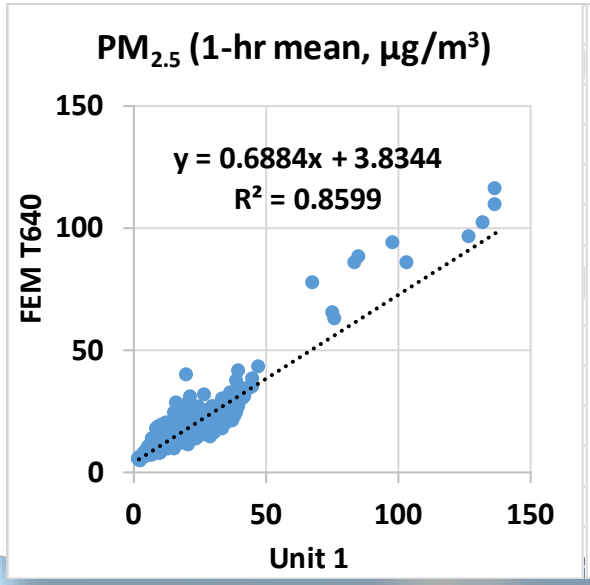


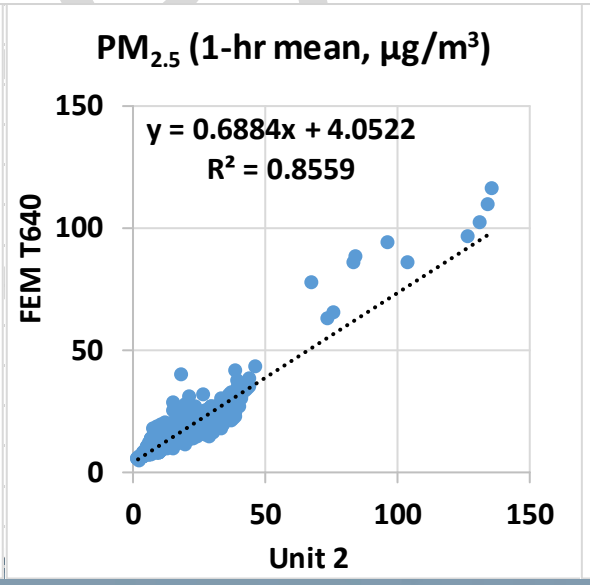


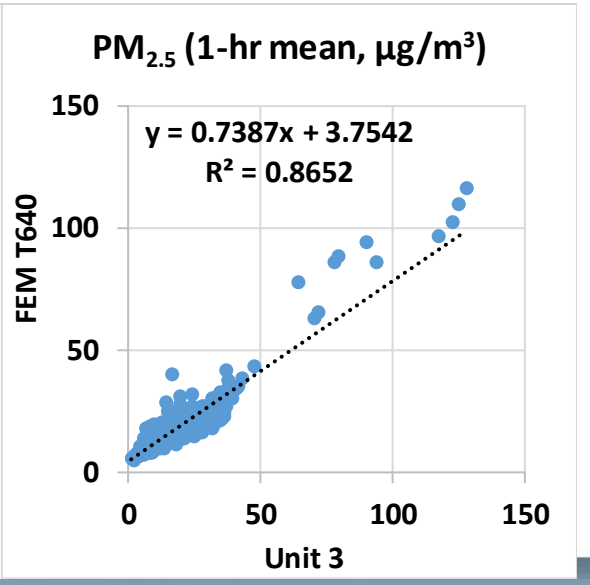
Canary-S vs FEM T640 ($PM_{2.5}$; 1-hr mean)



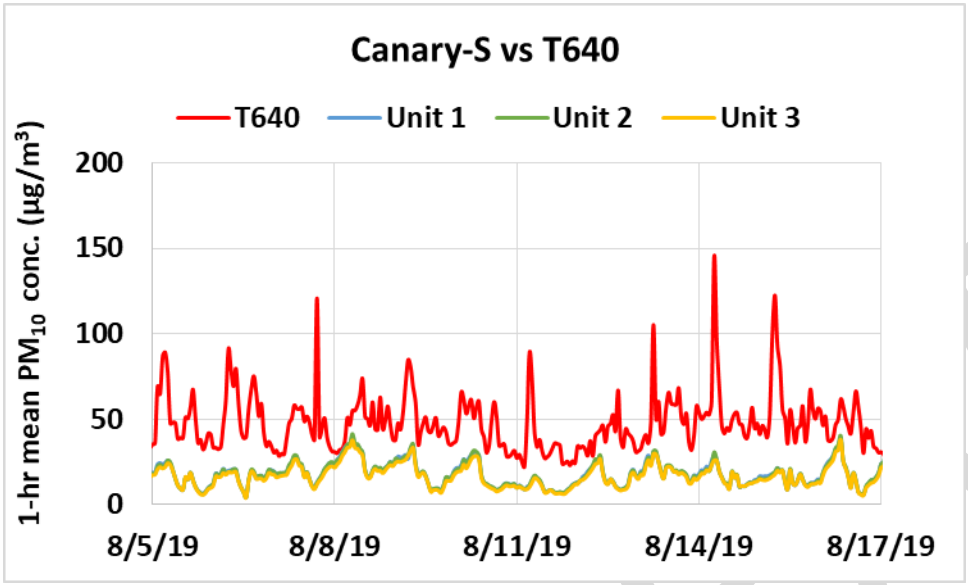
- Canary-S sensors showed strong correlations with the corresponding FEM T640 data (R^2 ~ 0.86)
- Overall, the Canary-S sensors overestimated the $PM_{2.5}$ mass concentrations measured by FEM T640
- The Canary-S sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



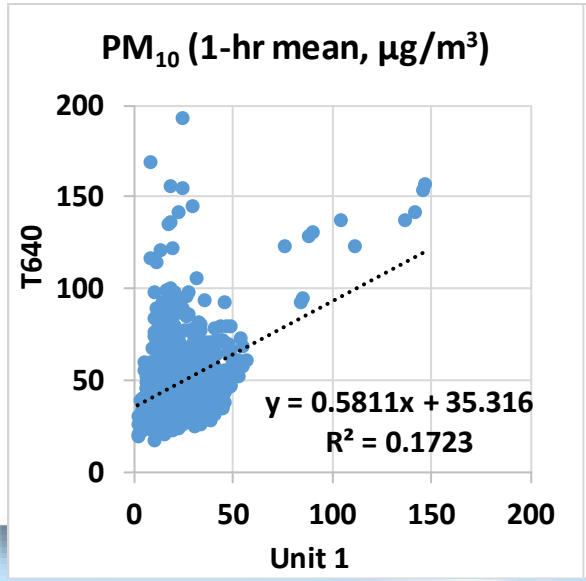


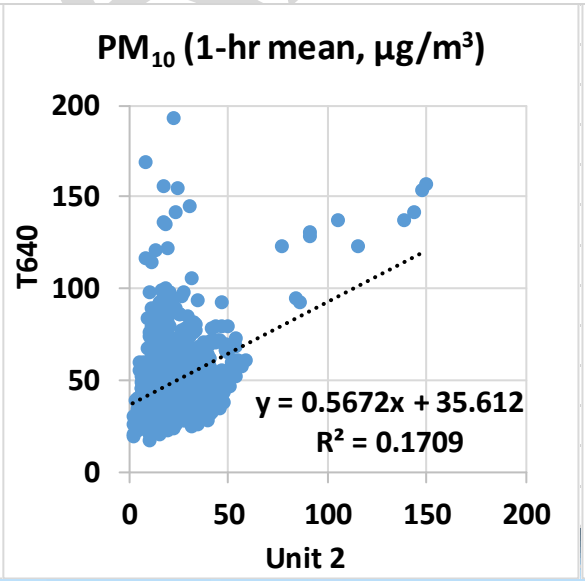


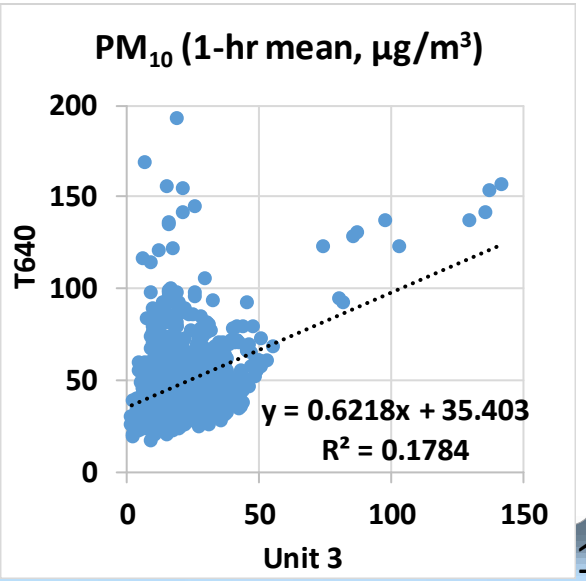
Canary-S vs T640 (PM_{10}; 1-hr mean)



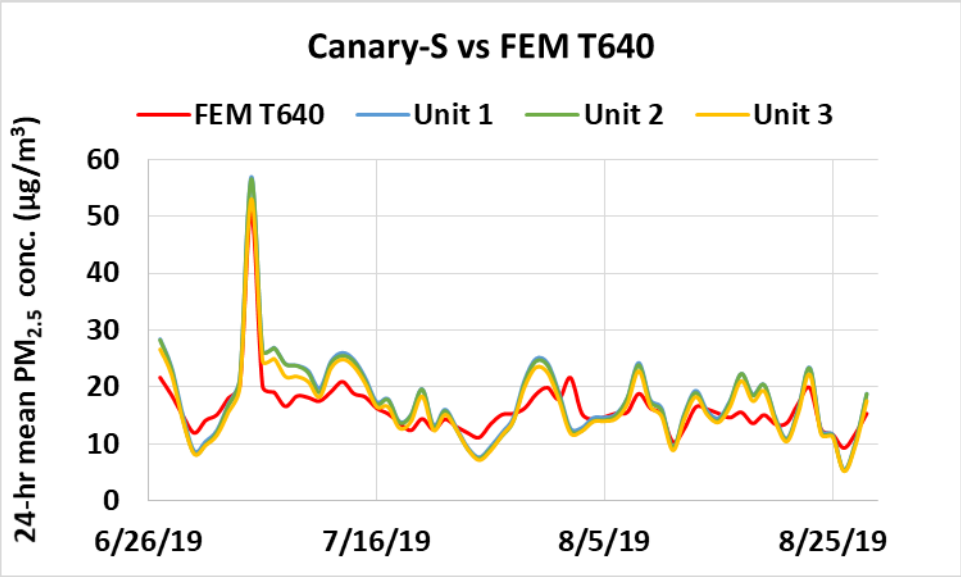
- Canary-S sensors showed very weak correlations with the corresponding T640 data (R^2 ~ 0.17)
- Overall, the Canary-S sensors underestimated the PM_{10} mass concentrations measured by T640
- The Canary-S sensors did not seem to track the PM_{10} diurnal variations as recorded by T640



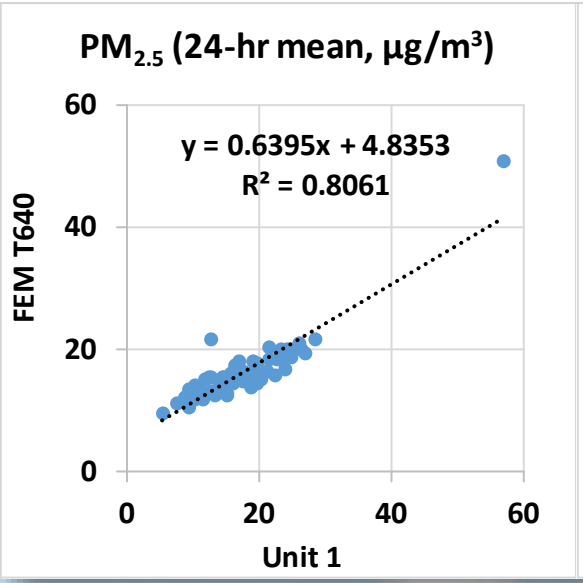


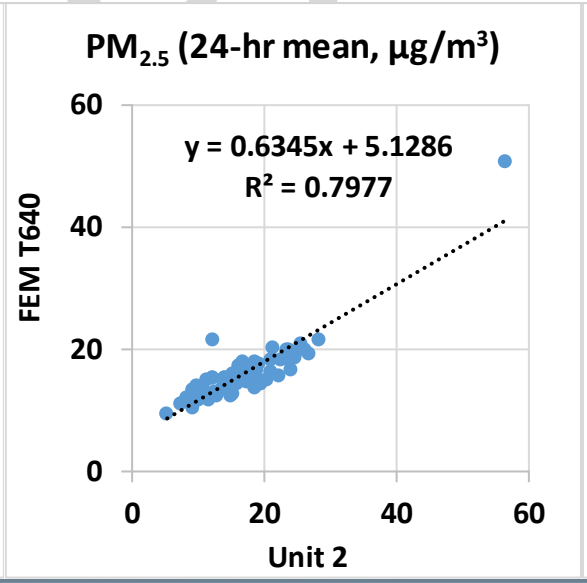


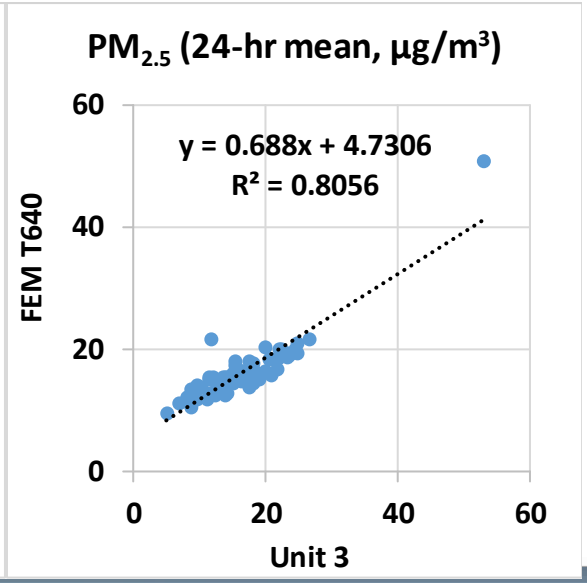
Canary-S vs FEM T640 ($PM_{2.5}$; 24-hr mean)



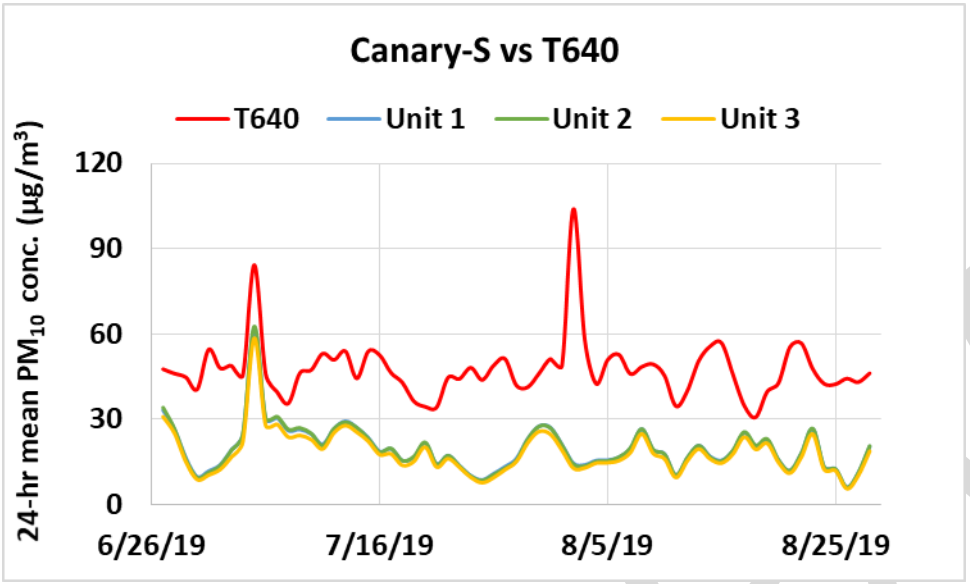
- Canary-S sensors showed strong correlations with the corresponding FEM T640 data (R^2 ~ 0.80)
- Overall, the Canary-S sensors overestimated the $PM_{2.5}$ mass concentrations measured by FEM T640
- The Canary-S sensors seemed to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640



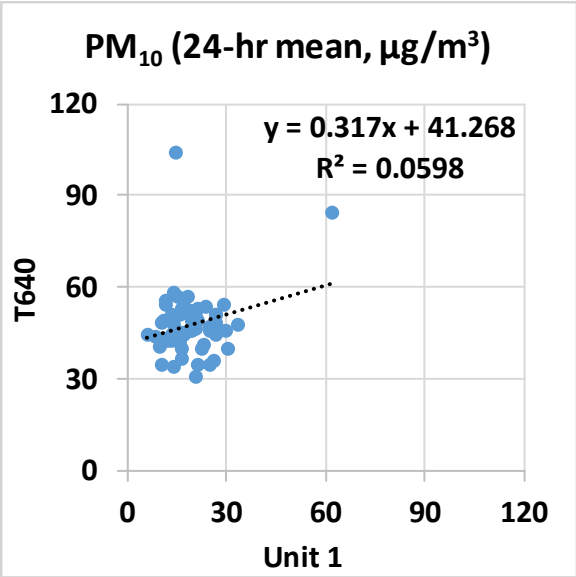


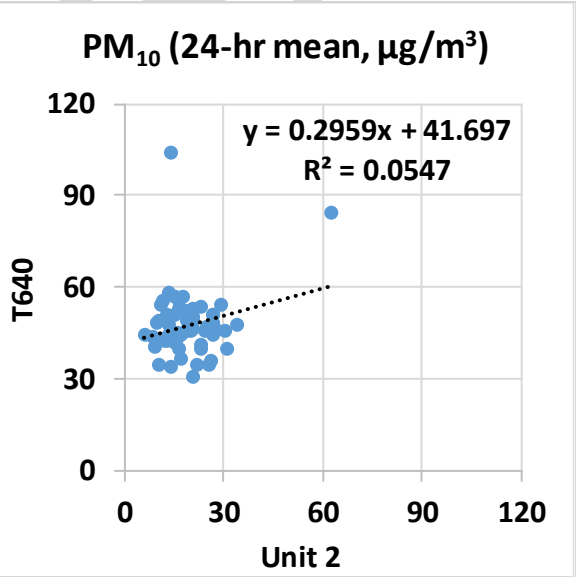


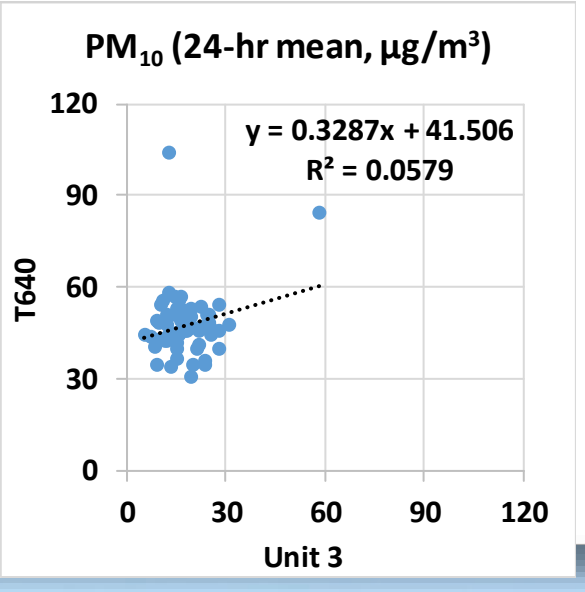
Canary-S vs T640 (PM_{10}; 24-hr mean)



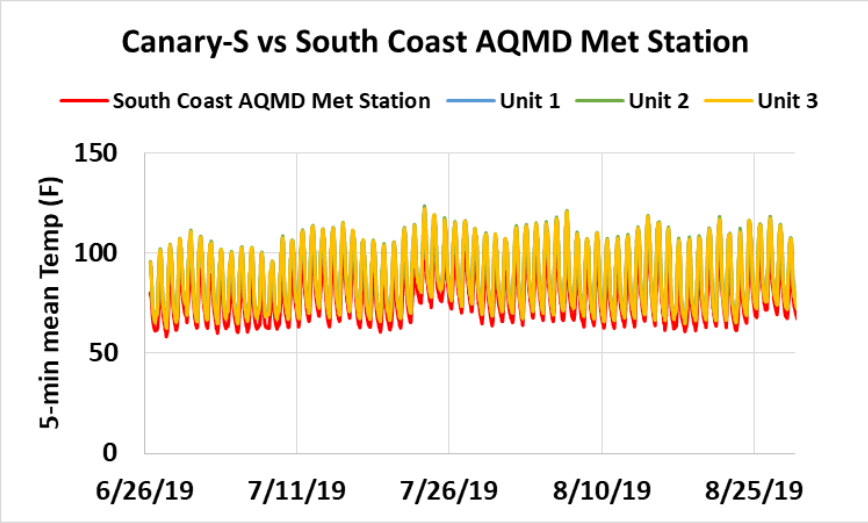
- Canary-S sensors did not correlate with the corresponding T640 data (R^2 ~ 0.057)
- Overall, the Canary-S sensors underestimated the PM_{10} mass concentrations measured by T640
- The Canary-S sensors did not seem to track the PM_{10} diurnal variations as recorded by T640





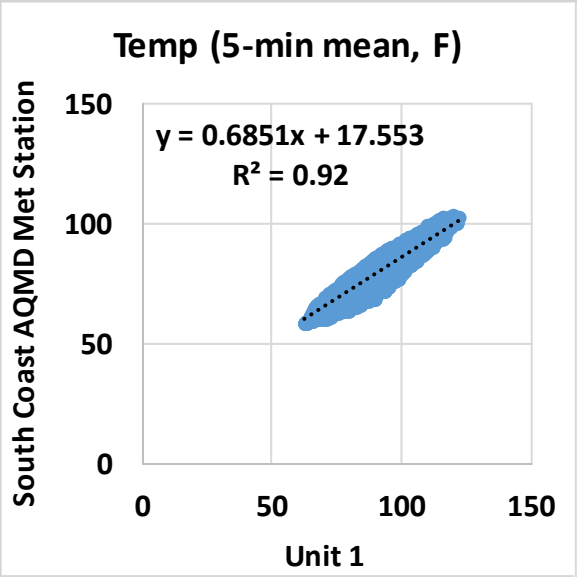


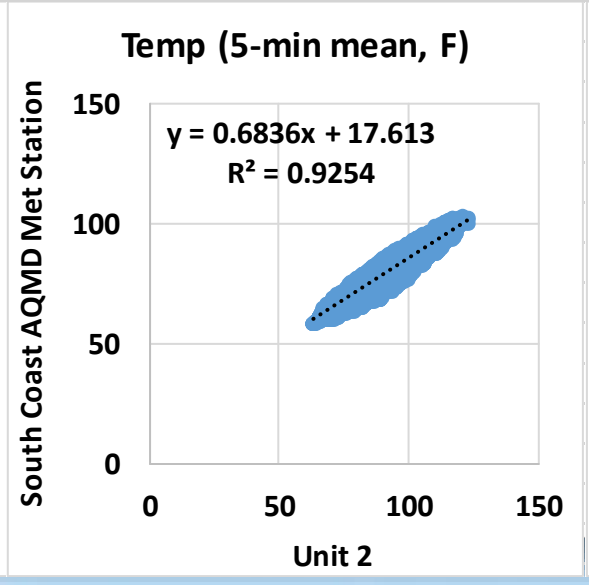
Canary-S vs South Coast AQMD Met Station (Temp; 5-min mean)

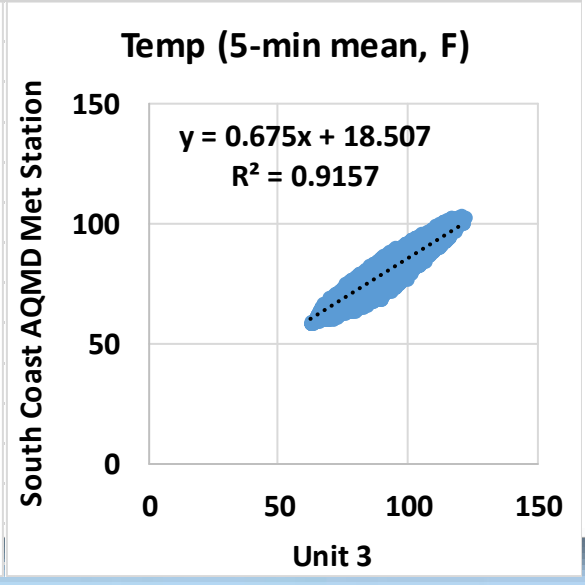


- Canary-S temperature measurements showed very strong correlations with the corresponding South Coast AQMD Met Station data (R^2 ~ 0.92)
- Overall, the Canary-S temperature measurements overestimated the corresponding South Coast AQMD Met Station data
- The Canary-S sensors seemed to track well the temperature diurnal variations as recorded by South Coast AQMD Met Station

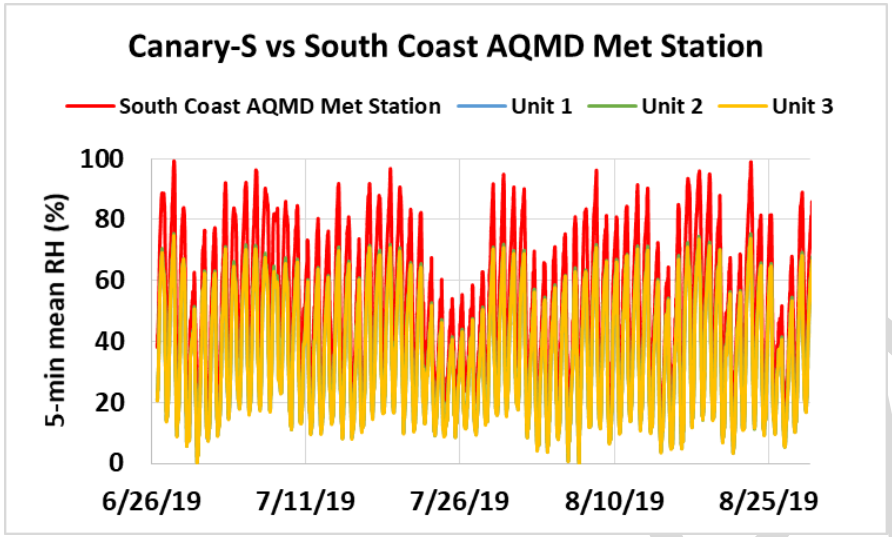
Note: The Canary-S sensors measure internal temperature.





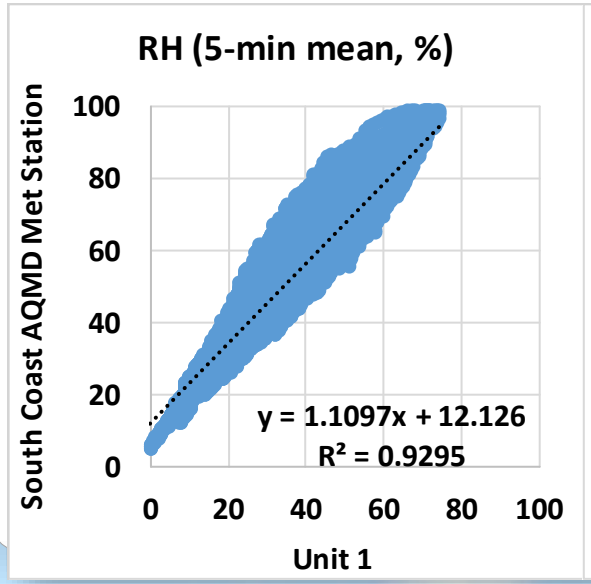


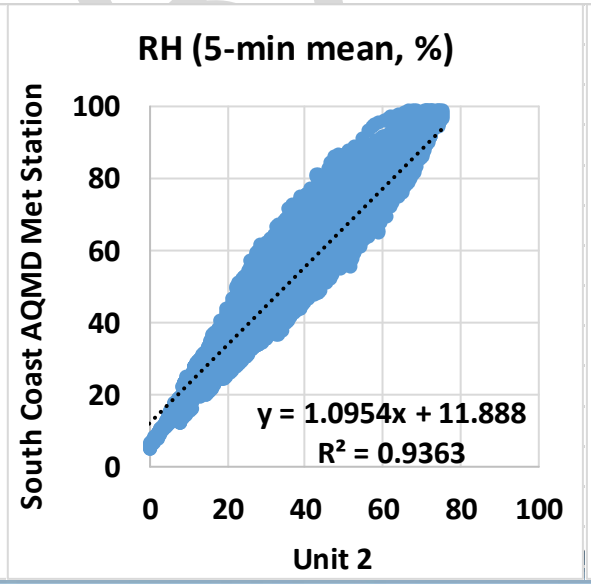
Canary-S vs South Coast AQMD Met Station (RH; 5-min mean)

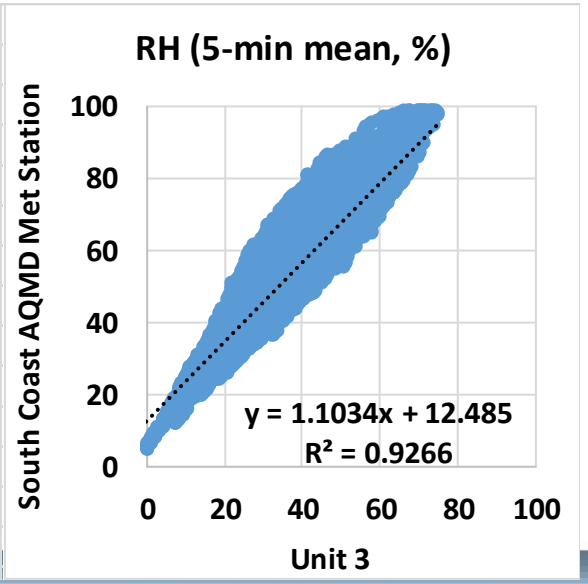


- Canary-S RH measurements showed very strong correlations with the corresponding South Coast AQMD Met Station data (R^2 ~ 0.93)
- Overall, the Canary-S RH measurements underestimated the corresponding South Coast AQMD Met Station data
- The Canary-S sensors seemed to track well the RH diurnal variations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

Note: The Canary-S sensors measure internal RH.







Discussion

- The three **Canary-S** sensors' data recovery from all units was ~ 100% for all PM measurements
- The absolute intra-model variability was ~ 0.57 and 0.82 µg/m^3 for $PM_{2.5}$ and $PM_{10,}$ respectively
- The reference instruments (BAM and T640) showed strong correlations with each other for both $PM_{2.5}$ (R^2 ~ 0.90) and PM_{10} (R^2 ~ 0.87) mass concentration measurements (1-hr mean)
- $PM_{2.5}$ mass concentration measurements measured by Canary-S sensors showed strong correlations with the corresponding FEM BAM and FEM T640 data (R^2 ~ 0.72 and 0.86, respectively, 1-hr mean). The sensors overestimated $PM_{2.5}$ mass concentrations measured by FEM BAM and FEM T640
- PM_{10} mass concentration measurements measured by Canary-S sensors showed no to very weak correlations with the corresponding FEM BAM and T640 data (R^2 ~ 0.09 and 0.17, respectively; 1-hr mean) and underestimated PM_{10} mass concentrations measured by FEM BAM and T640
- 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