Field Evaluation
Plume Labs Flow 2

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 04/17/2020 to 06/25/2020[1], three **Plume Labs Flow 2** (**hereinafter Flow 2**) multi-sensor units were deployed at the South Coast AQMD stationary ambient monitoring site in Rubidoux and were run side-by-side with Federal Equivalent Method (FEM) and Federal Reference Method (FRM) instruments measuring the same pollutants

- Flow 2 (*3 units tested*):
  - Gas Sensors: Heated Metal Oxide (non-FEM/non-FRM);
  - PM Sensors – Laser Particle Counter (non-FEM)
  - Each unit reports: NO_2 (ppb), $PM_{1.0}$, $PM_{2.5}$ and PM_{10} ($\mu g/m^3$)
  - Unit also measures: VOC (ppb)
  - Unit cost: $199
  - Time resolution: 1-min
  - [2]Units IDs: 2baf, 2b23, 2c18, 367b

- South Coast AQMD Reference instruments:
  - GRIMM (FEM $PM_{2.5}$); cost: $25,000 and up
    - Time resolution: 1-min
  - Teledyne API T640 (FEM $PM_{2.5}$); cost: $21,000
    - Time resolution: 1-min
  - NO_X instrument (FRM NO_2); cost: ~$11,000
    - Time resolution: 1-min

[1]*Note: sensor data were not available between 6/2/2020 and 6/11/2020 due to preventive maintenance activities at the monitoring site*

[2]*Note: the internal fan in Unit 2b23 was not functioning, therefore, the PM data were invalidated. The replacement Unit 367b was deployed on 5/27/2020*

Nitrogen Dioxide (NO_2) in Plume Labs Flow 2

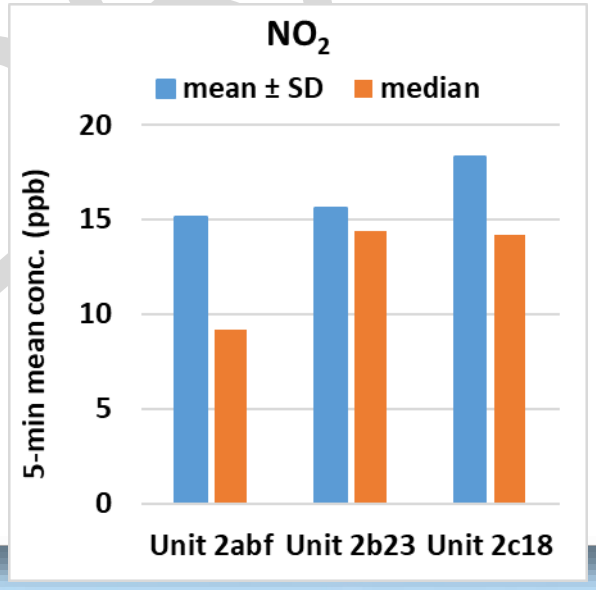
Data validation & recovery

- 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 Unit 2abf, Unit 2b23, Unit 2c18 and Unit 367b was ~ 71%, 55%, 66% and 49%, respectively, for NO_2 measurements.

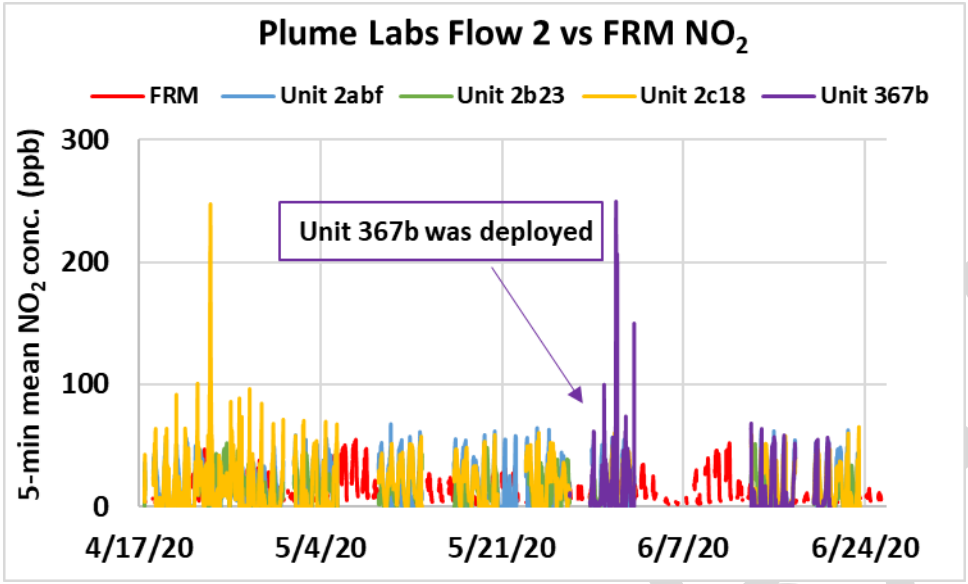
Flow 2; Intra-model variability

- Absolute intra-model variability was ~ 1.4 ppb for NO_2 measurements.
  (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 8.6% for NO_2 measurements.
  (calculated as the absolute intra-model variability relative to the mean of the three sensor means)

Note: Intra-model variability was calculated using Unit 2abf, Unit 2b23 and Unit 2c18. Unit 367b was not included because it was a replacement unit and was deployed towards the end of the field evaluation.

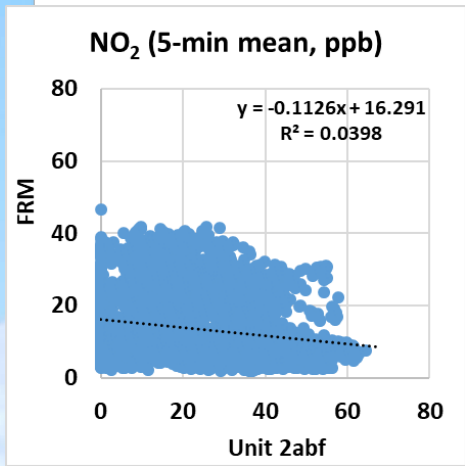


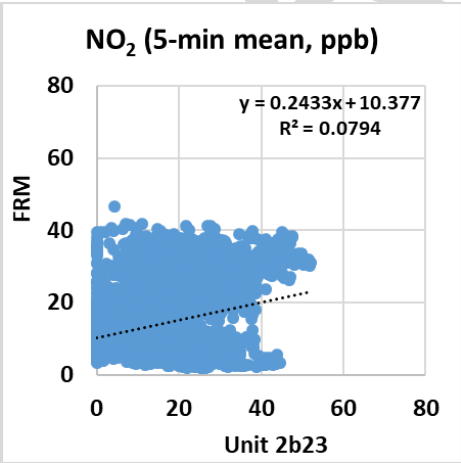
Flow 2 vs FRM (NO_2; 5-min mean)

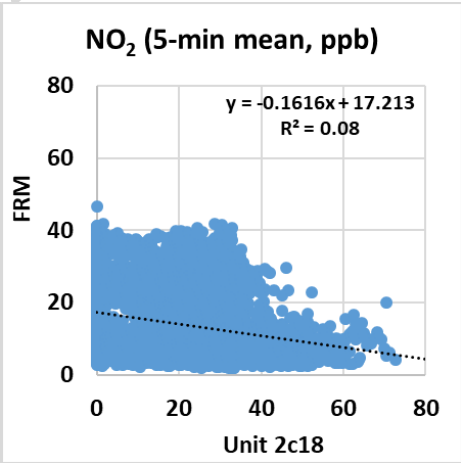


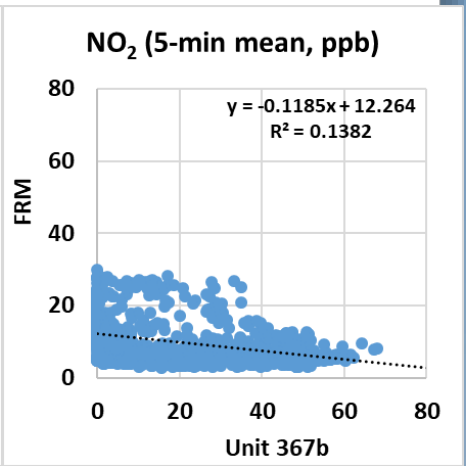
- The Flow 2 sensors showed no to very weak correlations with the corresponding FRM NO_2 data ($0.03 < R^2 < 0.14$)
- Overall, the Flow 2 sensors overestimated the NO_2 concentrations as measured by the FRM NO_2 instrument
- The Flow 2 sensors did not seem to track the diurnal NO_2 variations as recorded by the FRM NO_2 instrument

Note: FRM NO_2 (calculated as the difference between NO_x and NO) data were removed if the corresponding NO values were negative. 24-hr data were not shown due to the lack of data.

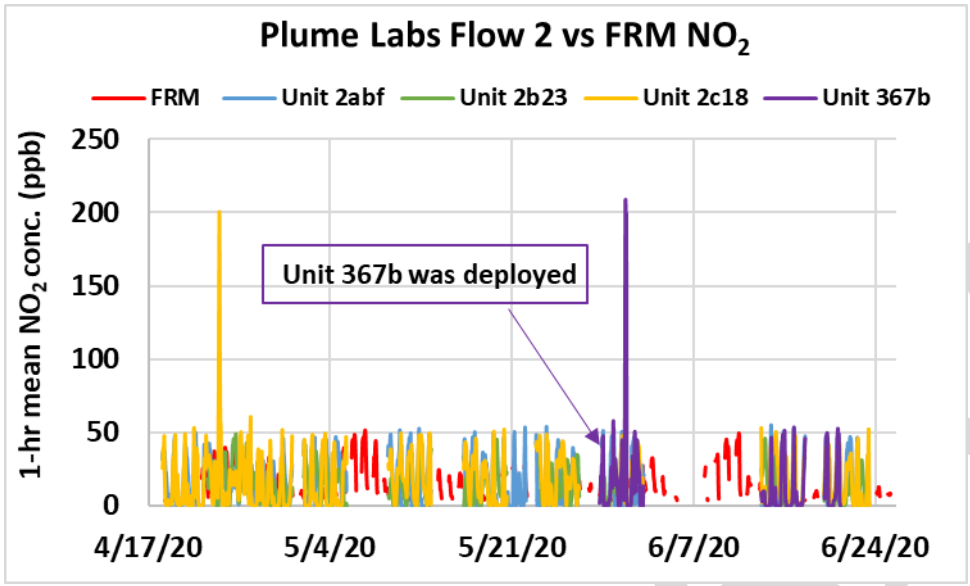






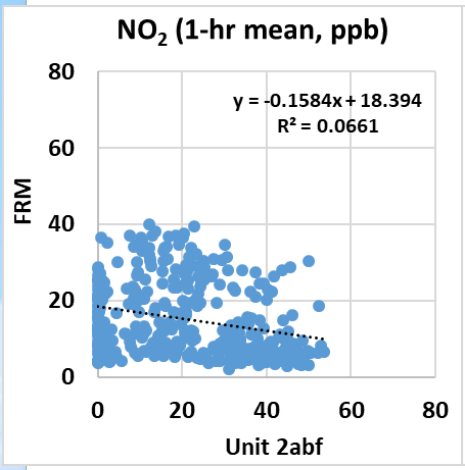


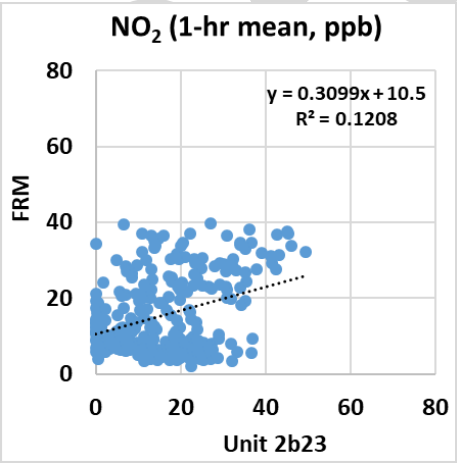
Flow 2 vs FRM (NO_2; 1-hr mean)

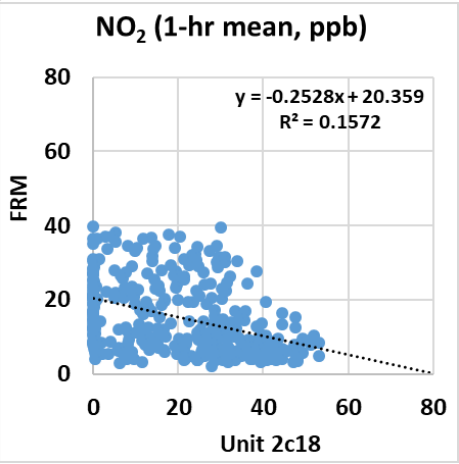


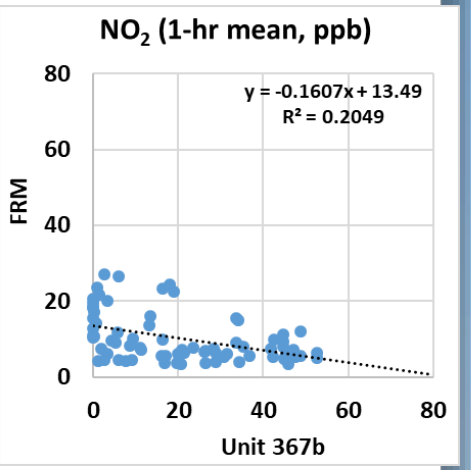
- The Flow 2 sensors showed no to very weak correlations with the corresponding FRM NO_2 data ($0.06 < R^2 < 0.21$)
- Overall, the Flow 2 sensors overestimated the NO_2 concentrations as measured by the FRM NO_2 instrument
- The Flow 2 sensors did not seem to track the diurnal NO_2 variations as recorded by the FRM NO_2 instrument

Note: FRM NO_2 (calculated as the difference between NO_x and NO) data were removed if the corresponding NO values were negative. 24-hr data were not shown due to the lack of data.









Particulate Matter (PM) in Plume Labs Flow 2

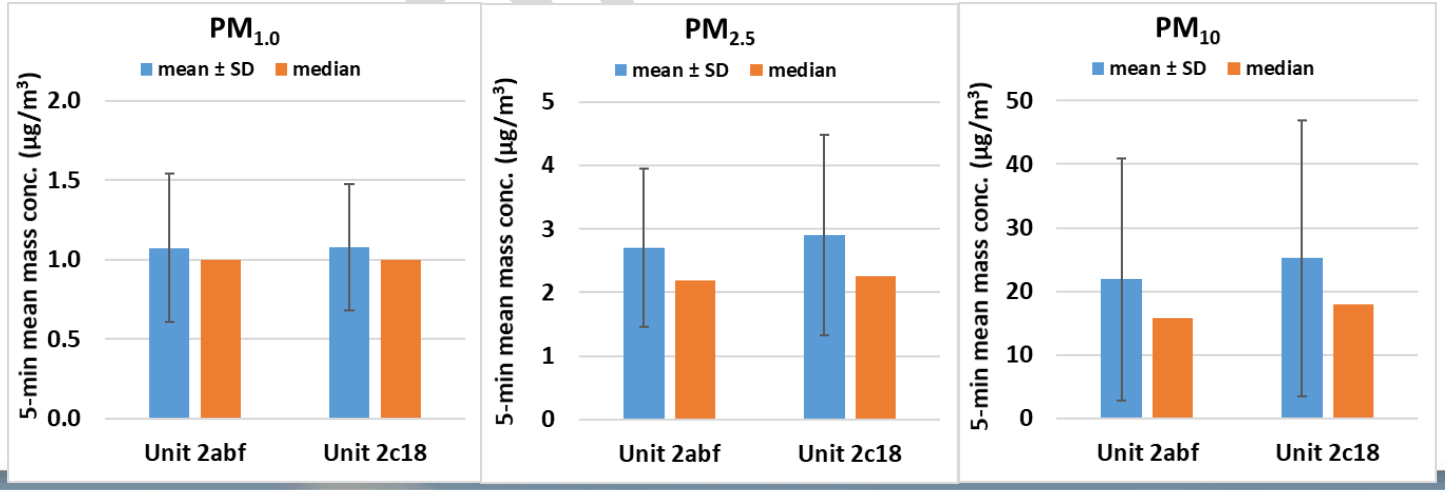
Data validation & recovery

- 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 Unit 2abf, Unit 2c18 and Unit 367b was 71%, 66% and 49%, respectively, for $PM_{1.0}$, $PM_{2.5}$ and PM_{10} mass concentration measurements.

Flow 2; Intra-model variability

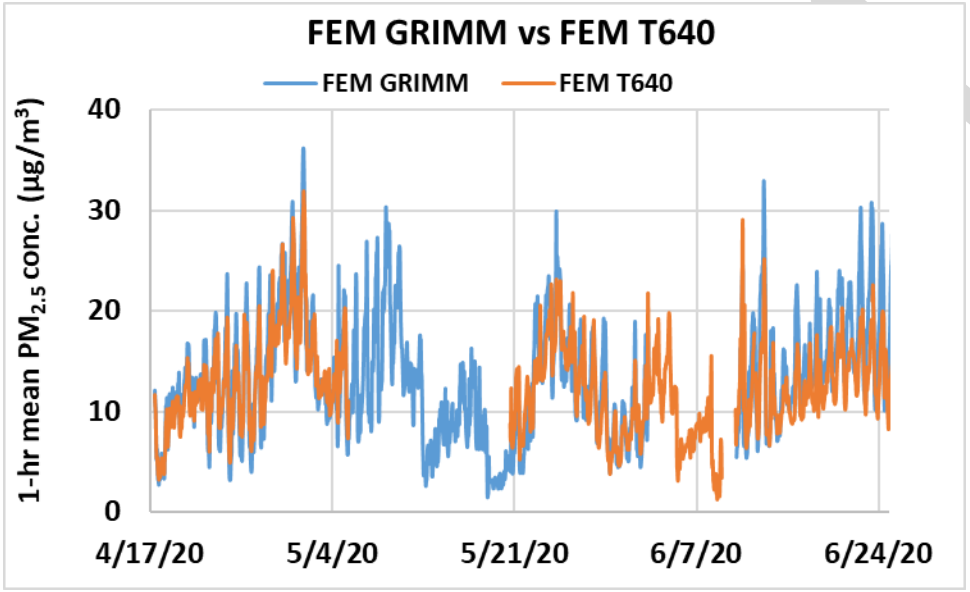
- Absolute intra-model variability was ~ 0.001, 0.1 and 1.7 µg/m^3 for the $PM_{1.0}$, $PM_{2.5}$ and PM_{10} measurements, respectively. (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 0.1, 3.6 and 7.1% for the $PM_{1.0}$, $PM_{2.5}$ and PM_{10} measurements, respectively. (calculated as the absolute intra-model variability relative to the mean of the three sensor means)

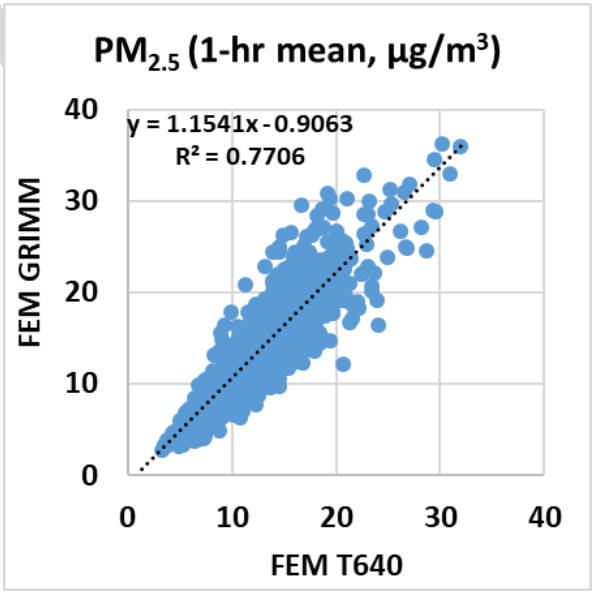
Note: Intra-model variability was calculated using Unit 2abf and Unit 2c18. Unit 367b was not included because it was a replacement unit and was deployed towards the end of the field evaluation.



Reference Instruments: $PM_{2.5}$ FEM GRIMM & FEM T640

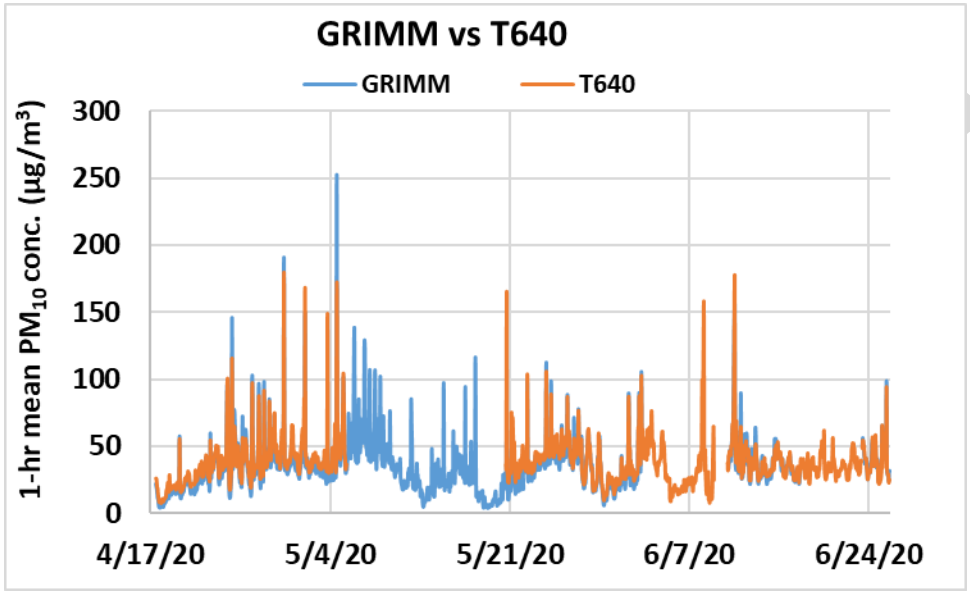
- Basic QA/QC procedures were used to validate the collected data (i.e. obvious outliers, negative values and invalid data-points were eliminated from the data-set)
- Data recovery for $PM_{2.5}$ from FEM GRIMM and FEM T640 is ~88% and 76%, respectively.
- Strong correlations between FEM GRIMM and FEM T640 for $PM_{2.5}$ measurements (R^2 ~ 0.77)

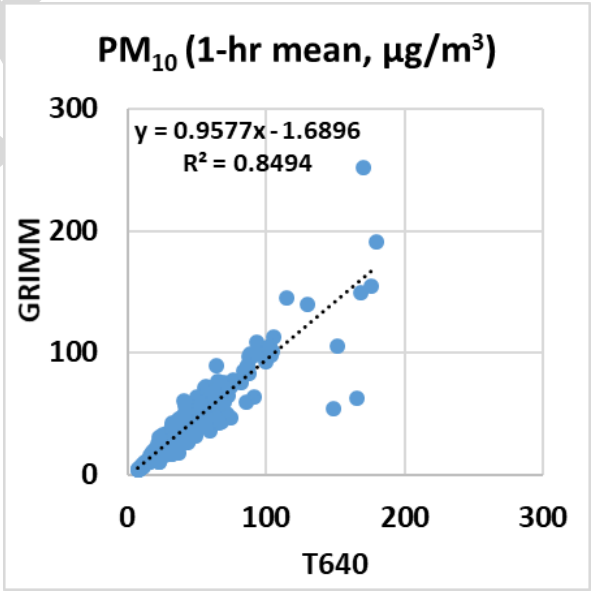




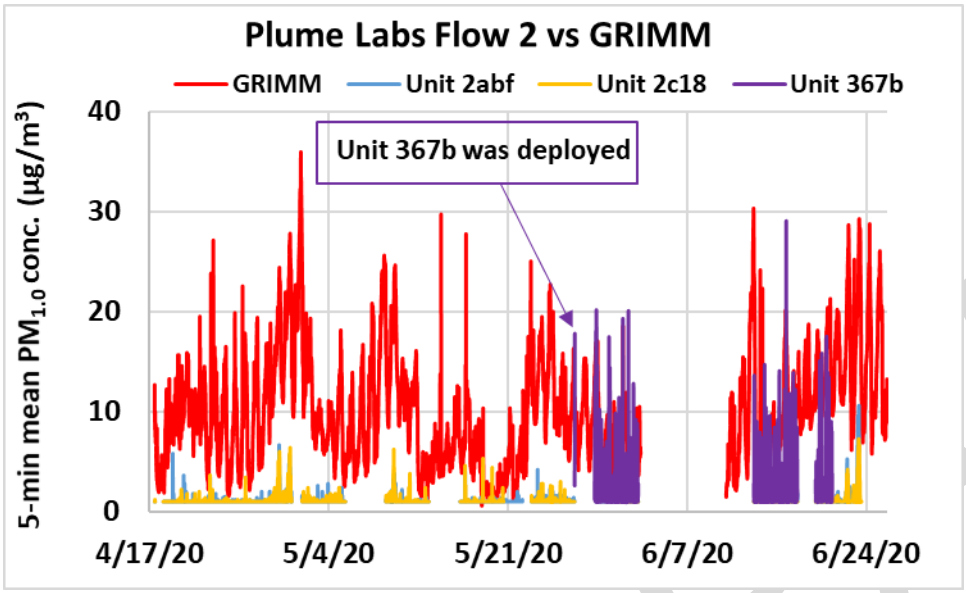
Reference Instruments: PM_{10} GRIMM & T640

- Basic QA/QC procedures were used to validate the collected data (i.e. obvious outliers, negative values and invalid data-points were eliminated from the data-set)
- Data recovery for PM_{10} from GRIMM and T640 is ~88% and 76%, respectively.
- Strong correlations between GRIMM and T640 for PM_{10} measurements (R^2 ~ 0.85)



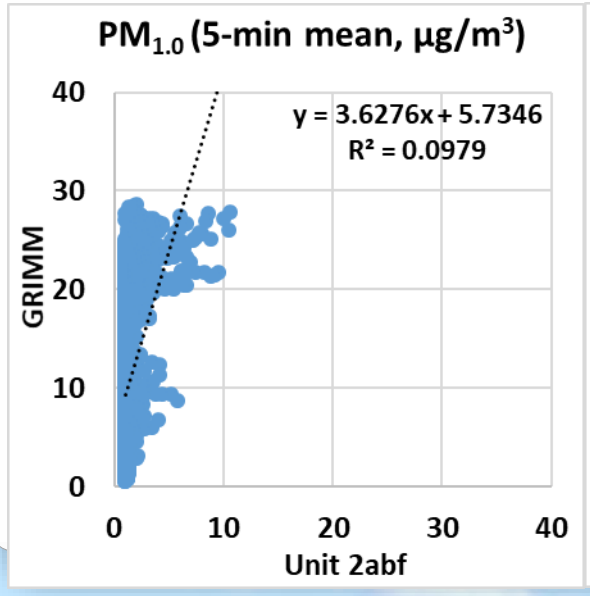


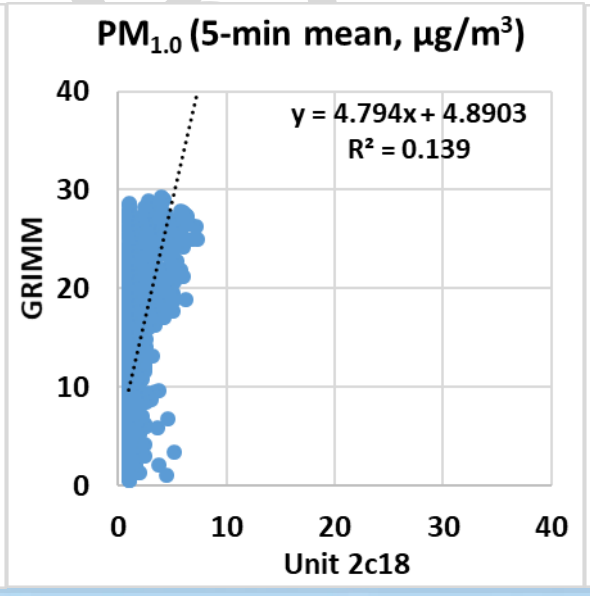
Flow 2 vs GRIMM ($PM_{1.0}$; 5-min mean)

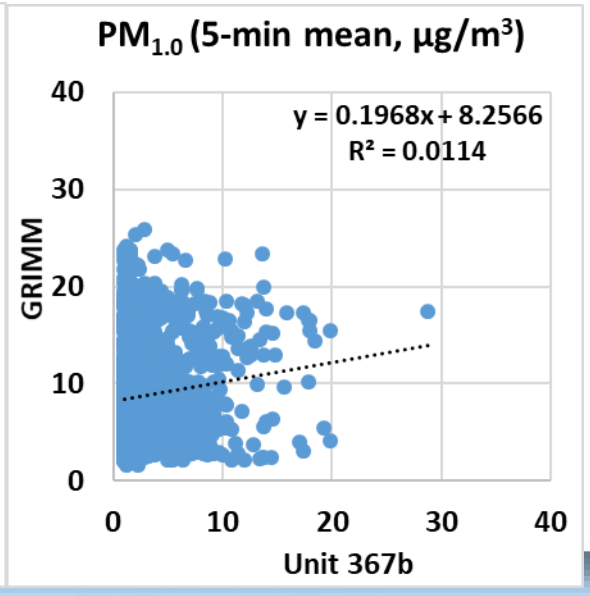


- The Flow 2 sensors showed no to very weak correlations with the corresponding GRIMM data ($0.01 < R^2 < 0.14$)
- Overall, the Flow 2 sensors underestimated the $PM_{1.0}$ mass concentrations as measured by the GRIMM
- The Flow 2 sensors did not seem to track the diurnal $PM_{1.0}$ variations as recorded by the GRIMM

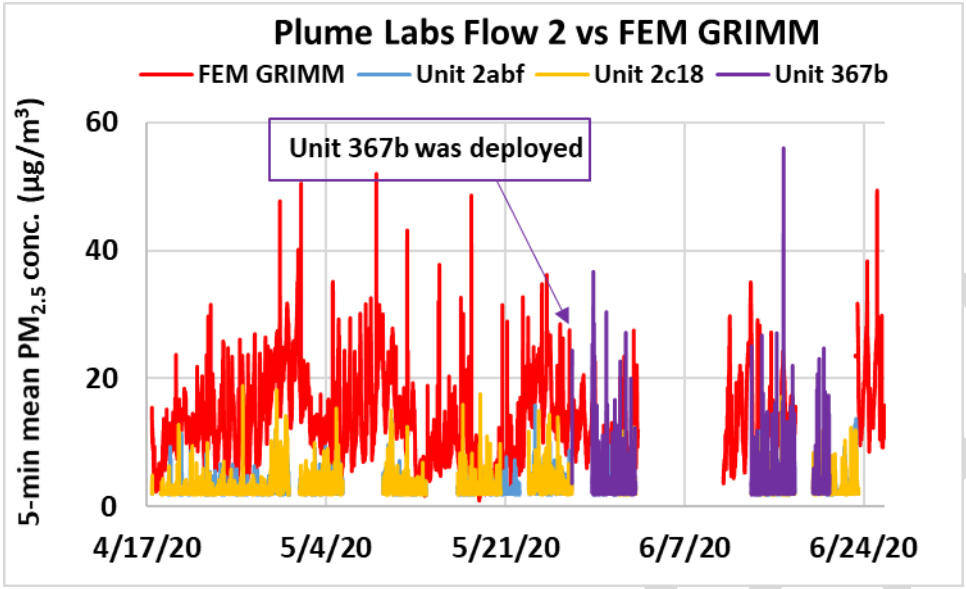
Note: PM data from Unit 2b23 were invalidated because its internal fan was not functioning.





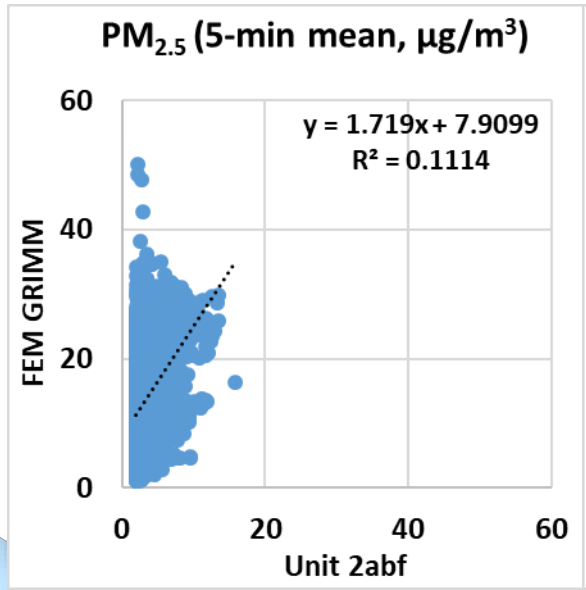


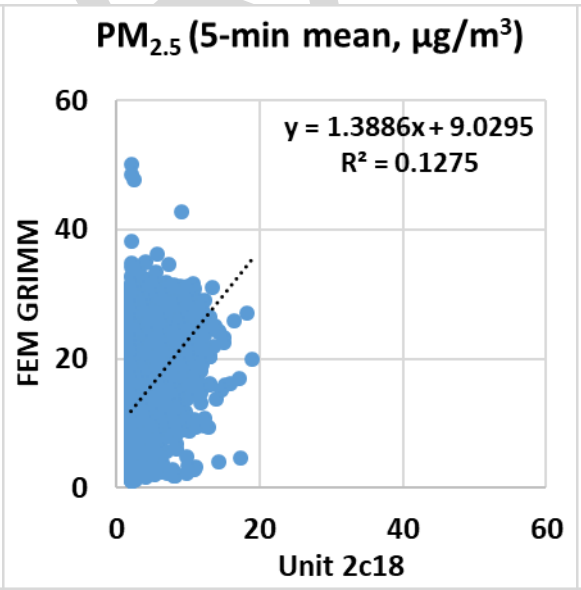
Flow 2 vs FEM GRIMM ($PM_{2.5}$; 5-min mean)

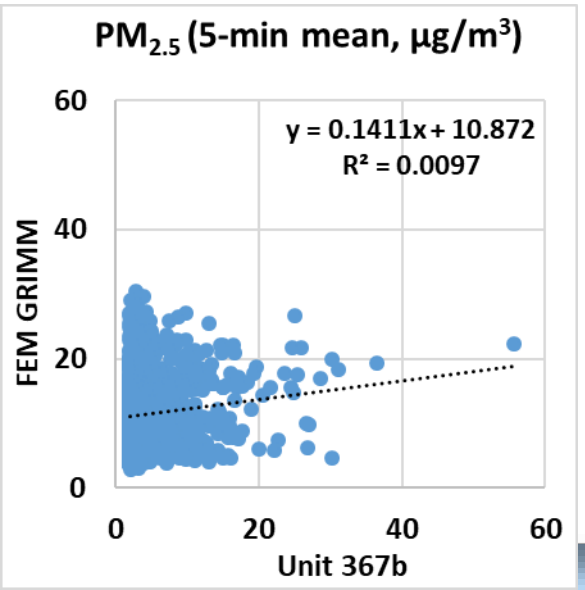


- The Flow 2 sensors showed no to very weak correlations with the corresponding FEM GRIMM data ($0.009 < R^2 < 0.13$)
- Overall, the Flow 2 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by the FEM GRIMM
- The Flow 2 sensors did not seem to track the diurnal $PM_{2.5}$ variations as recorded by the FEM GRIMM

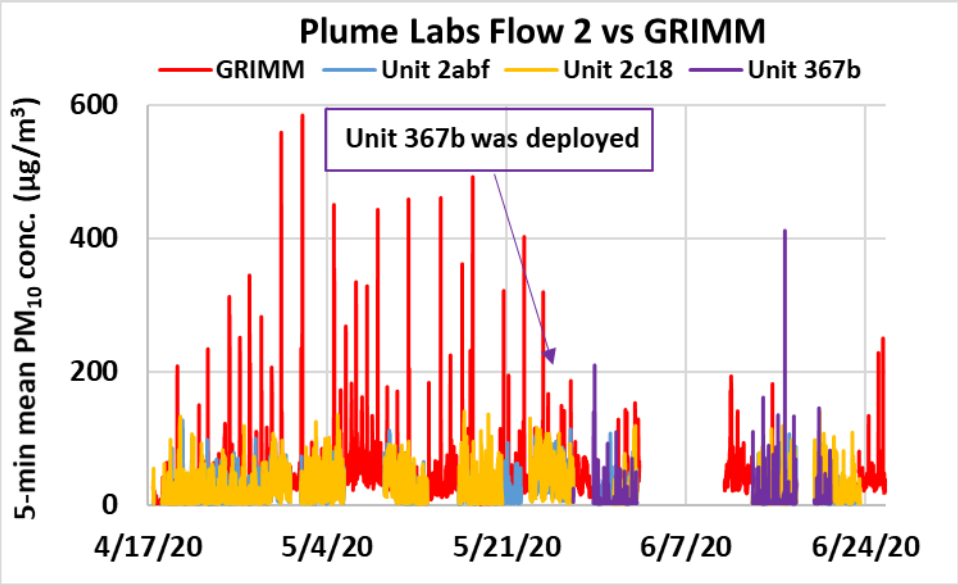
Note: PM data from Unit 2b23 were invalidated because its internal fan was not functioning.





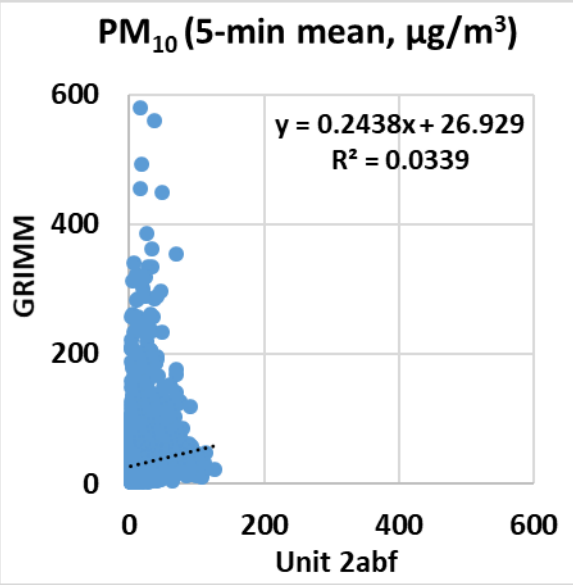


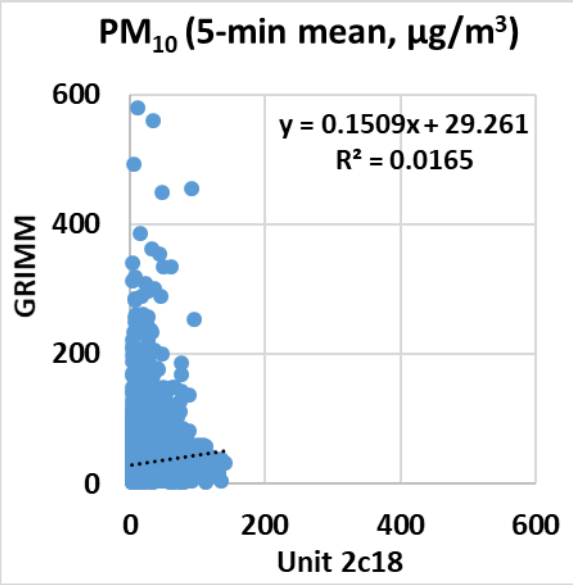
Flow 2 vs GRIMM (PM_{10}; 5-min mean)

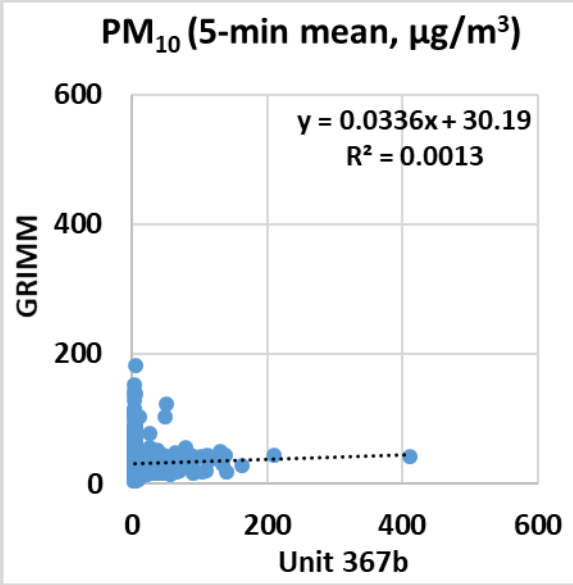


- The Flow 2 sensors did not correlate with the corresponding GRIMM data ($R^2 < 0.04$)
- Overall, the Flow 2 sensors underestimated the PM_{10} mass concentrations as measured by the GRIMM
- The Flow 2 sensors did not seem to track the diurnal PM_{10} variations as recorded by the GRIMM

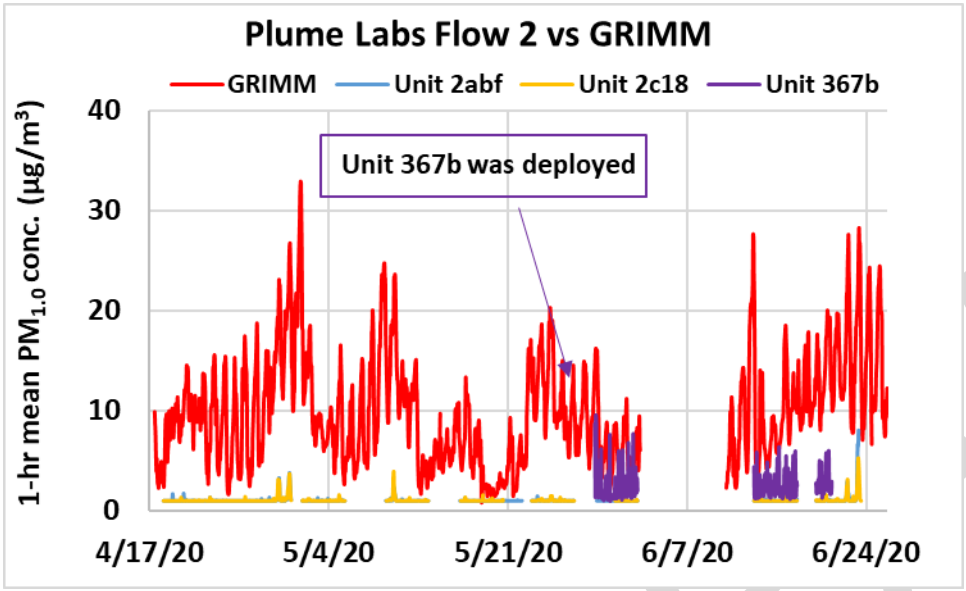
Note: PM data from Unit 2b23 were invalidated because its internal fan was not functioning.





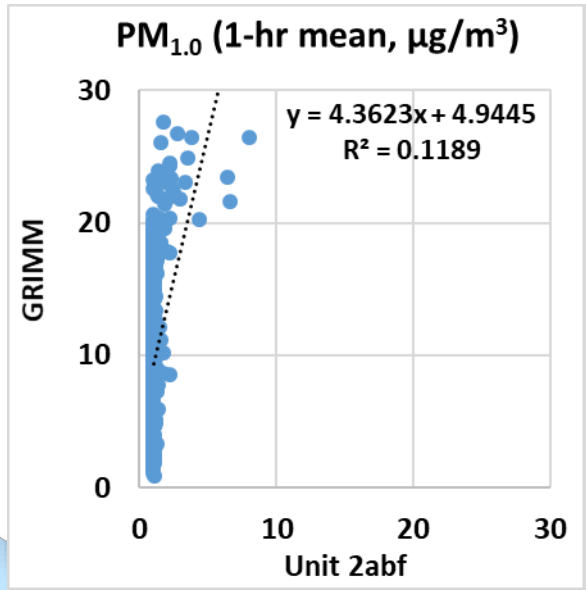


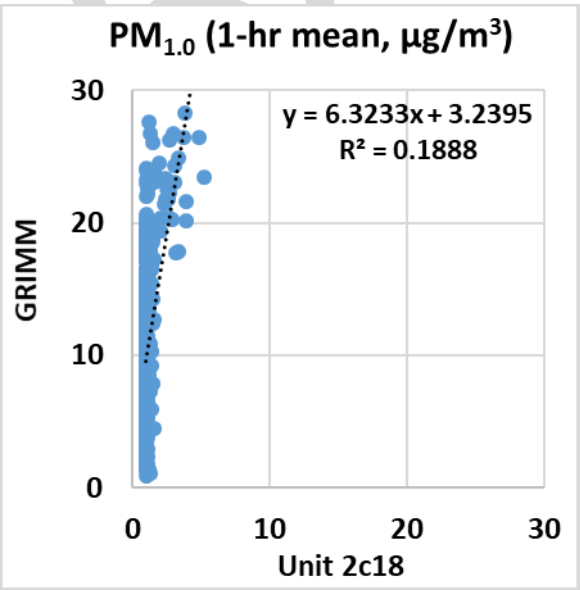
Flow 2 vs GRIMM ($PM_{1.0}$; 1-hr mean)

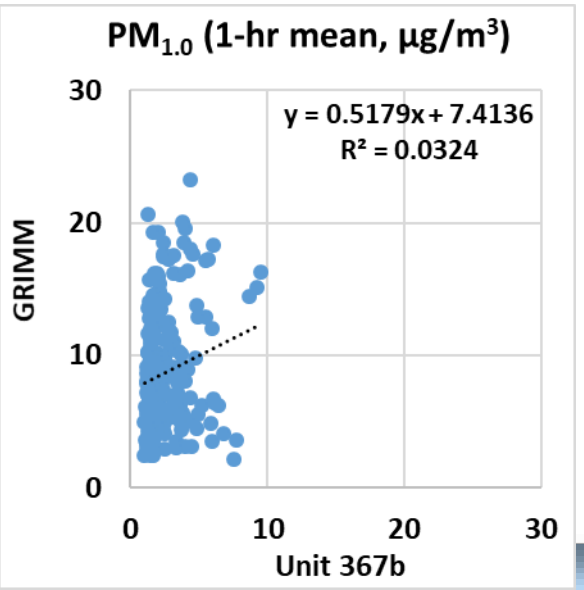


- The Flow 2 sensors showed no to very weak correlations with the corresponding GRIMM data ($0.03 < R^2 < 0.19$)
- Overall, the Flow 2 sensors underestimated the $PM_{1.0}$ mass concentrations as measured by the GRIMM
- The Flow 2 sensors did not seem to track the diurnal $PM_{1.0}$ variations as recorded by the GRIMM

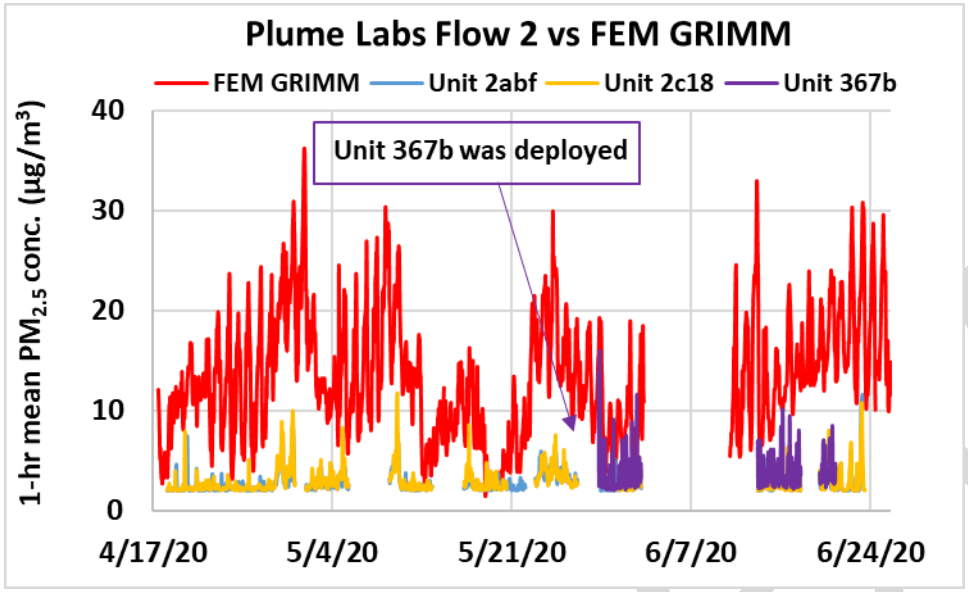
Note: PM data from Unit 2b23 were invalidated because its internal fan was not functioning.





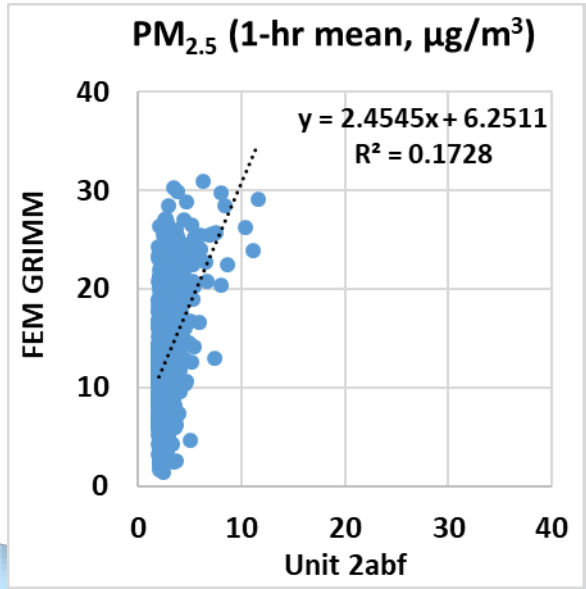


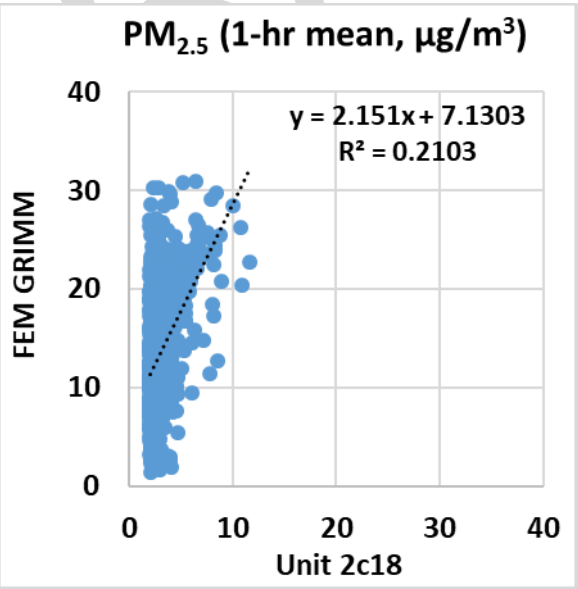
Flow 2 vs FEM GRIMM ($PM_{2.5}$; 1-hr mean)

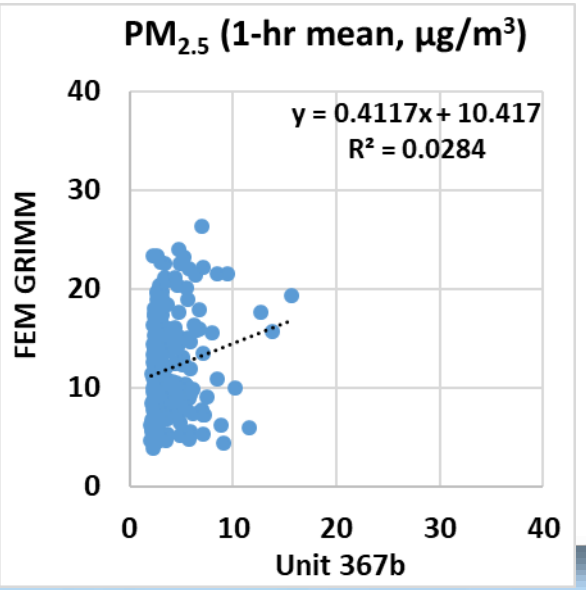


- The Flow 2 sensors showed no to very weak correlations with the corresponding FEM GRIMM data ($0.02 < R^2 < 0.22$)
- Overall, the Flow 2 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by the FEM GRIMM
- The Flow 2 sensors did not seem to track the diurnal $PM_{2.5}$ variations as recorded by the FEM GRIMM

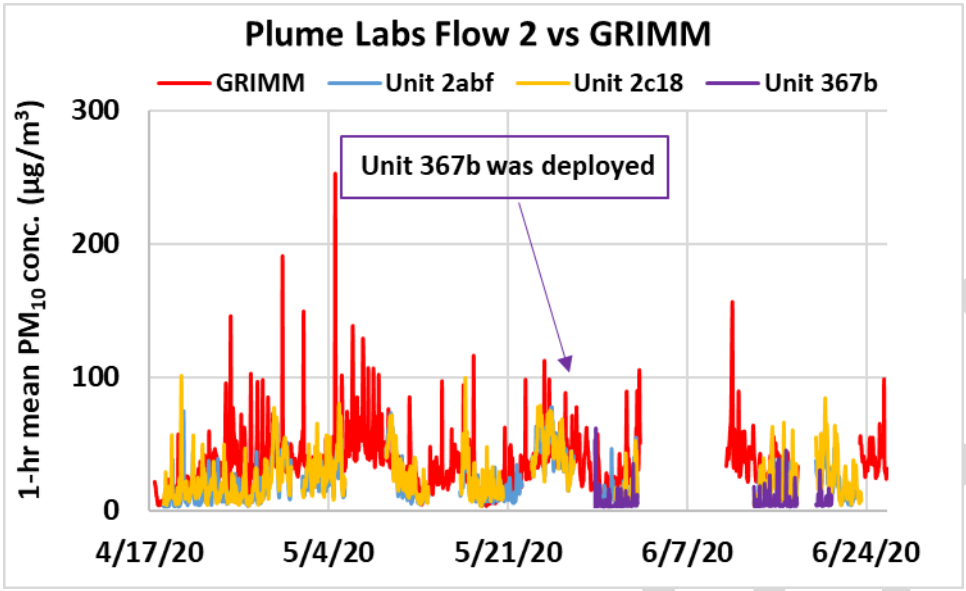
Note: PM data from Unit 2b23 were invalidated because its internal fan was not functioning.





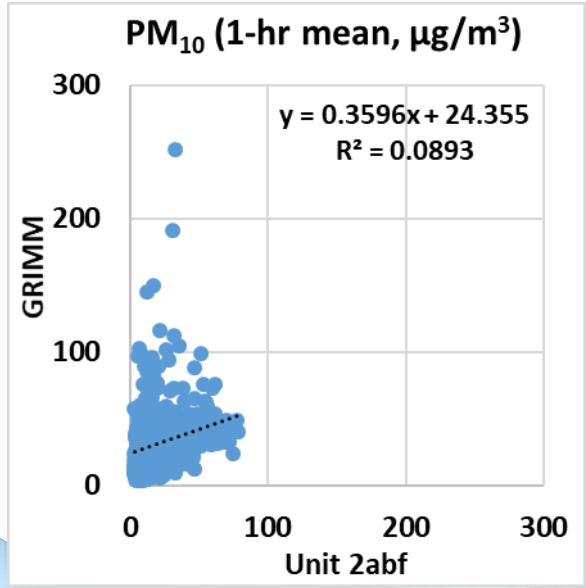


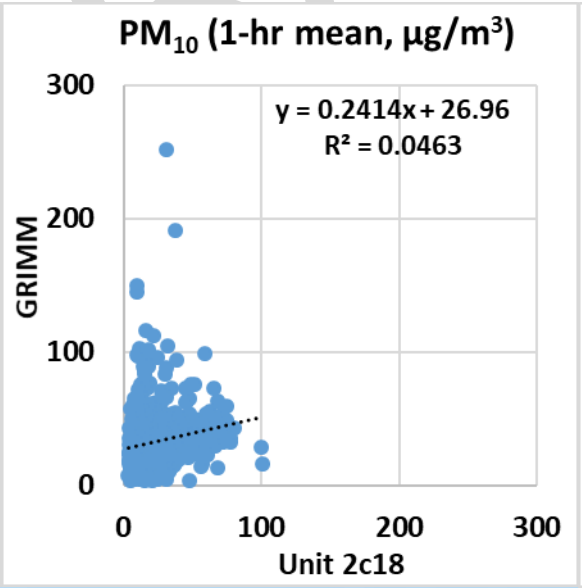
Flow 2 vs GRIMM (PM_{10}; 1-hr mean)

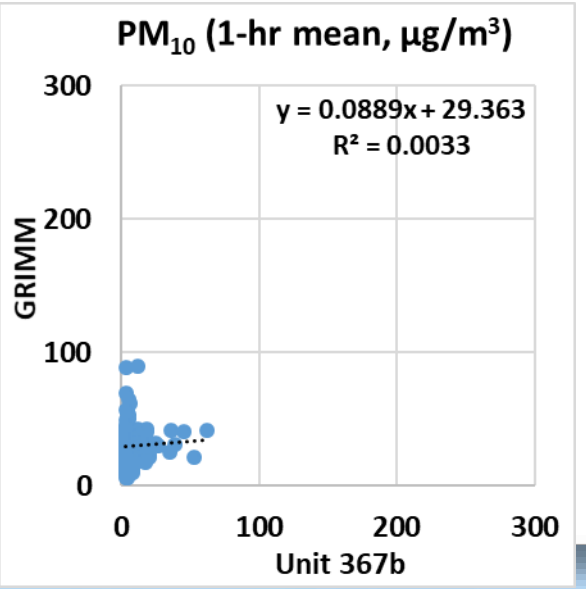


- The Flow 2 sensors did not correlate with the corresponding GRIMM data ($R^2 < 0.09$)
- Overall, the Flow 2 sensors underestimated the PM_{10} mass concentrations as measured by the GRIMM
- The Flow 2 sensors did not seem to track the diurnal PM_{10} variations as recorded by the GRIMM

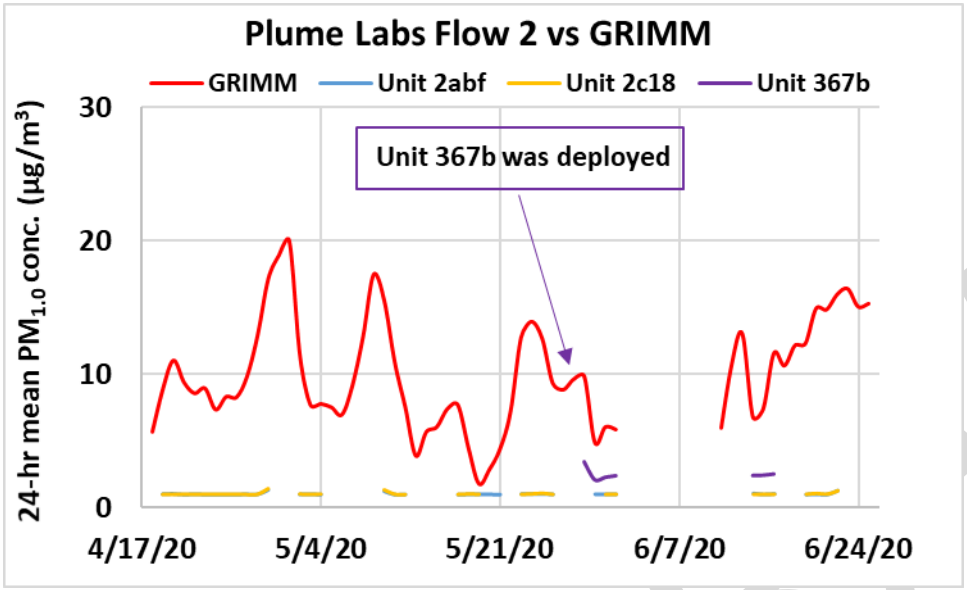
Note: PM data from Unit 2b23 were invalidated because its internal fan was not functioning.





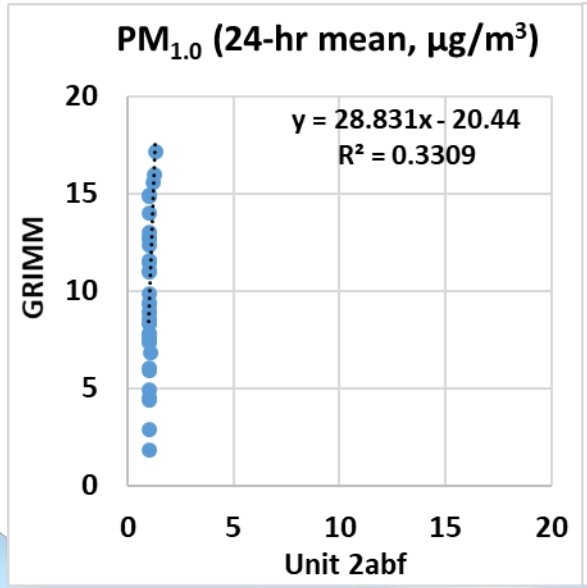


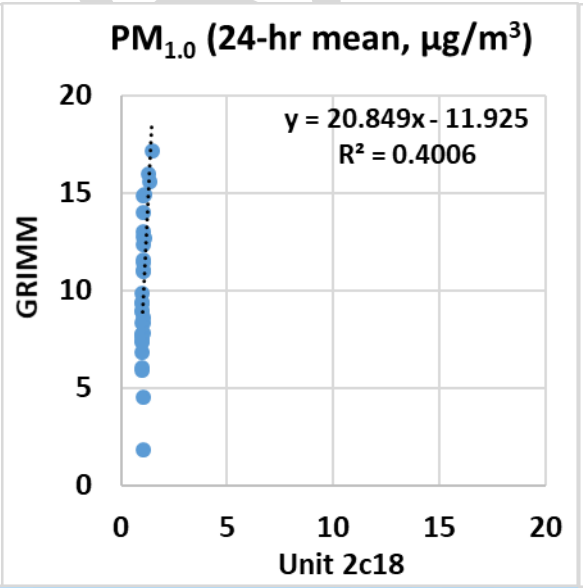
Flow 2 vs GRIMM ($PM_{1.0}$; 24-hr mean)

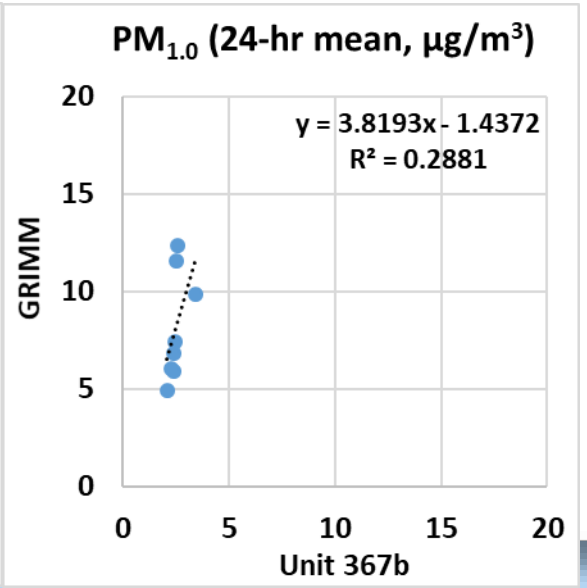


- The Flow 2 sensors showed very weak to weak correlations with the corresponding GRIMM data ($0.28 < R^2 < 0.41$)
- Overall, the Flow 2 sensors underestimated the $PM_{1.0}$ mass concentrations as measured by the GRIMM
- The Flow 2 sensors did not seem to track the diurnal $PM_{1.0}$ variations as recorded by the GRIMM

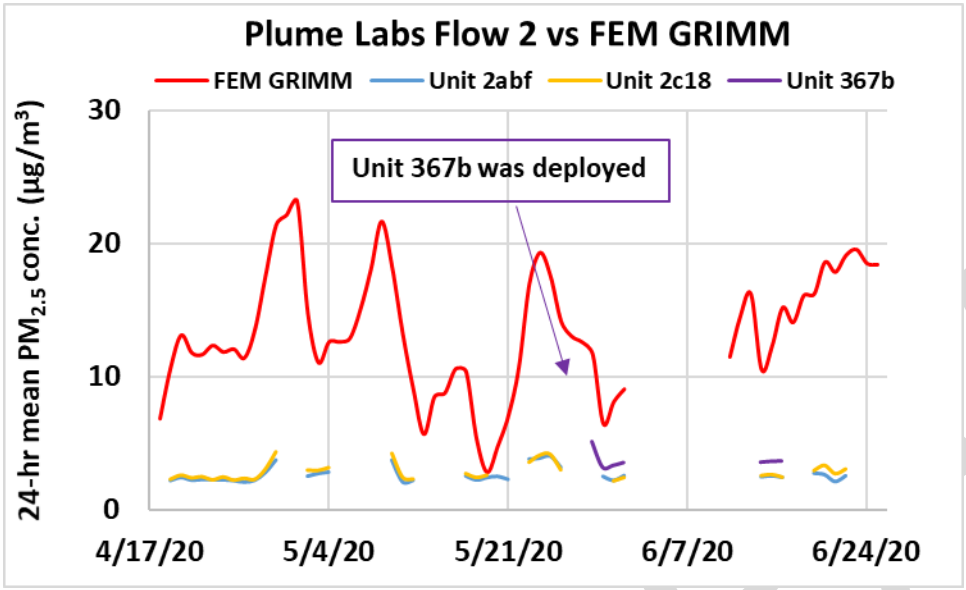
Note: PM data from Unit 2b23 were invalidated because its internal fan was not functioning.





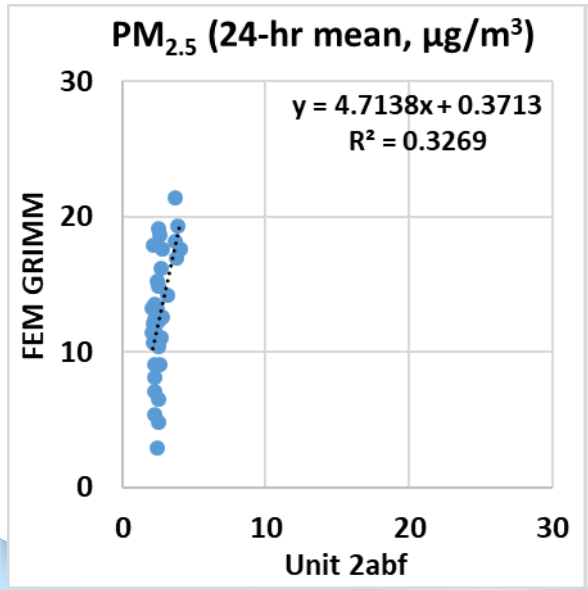


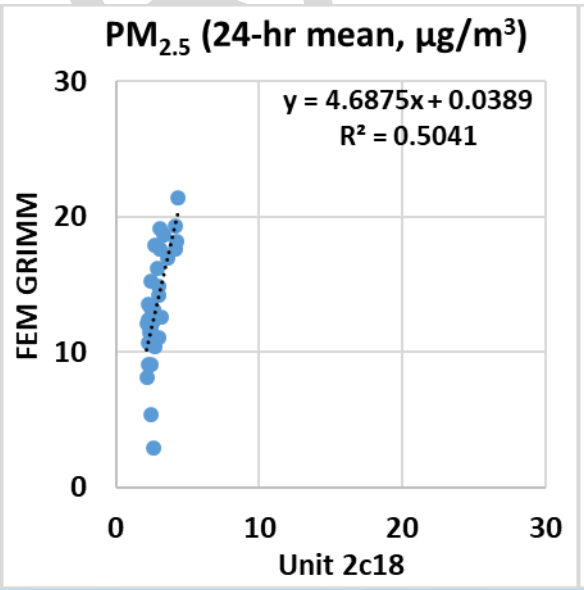
Flow 2 vs FEM GRIMM ($PM_{2.5}$; 24-hr mean)

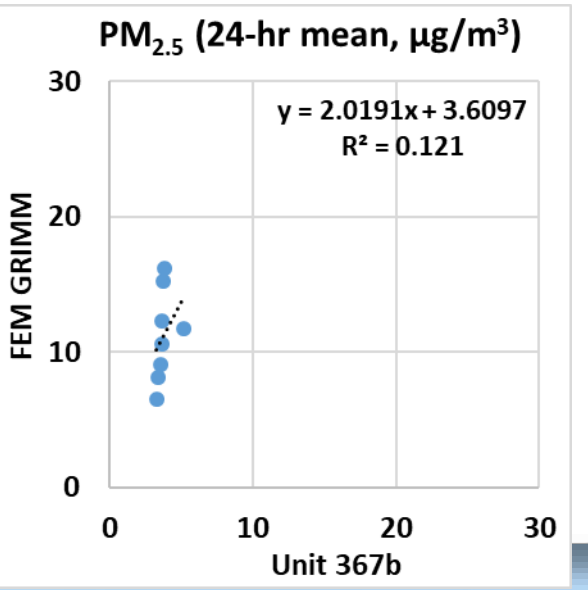


- The Flow 2 sensors showed very weak to moderate correlations with the corresponding FEM GRIMM data ($0.12 < R^2 < 0.51$)
- Overall, the Flow 2 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by the FEM GRIMM
- The Flow 2 sensors did not seem to track the diurnal $PM_{2.5}$ variations as recorded by the FEM GRIMM

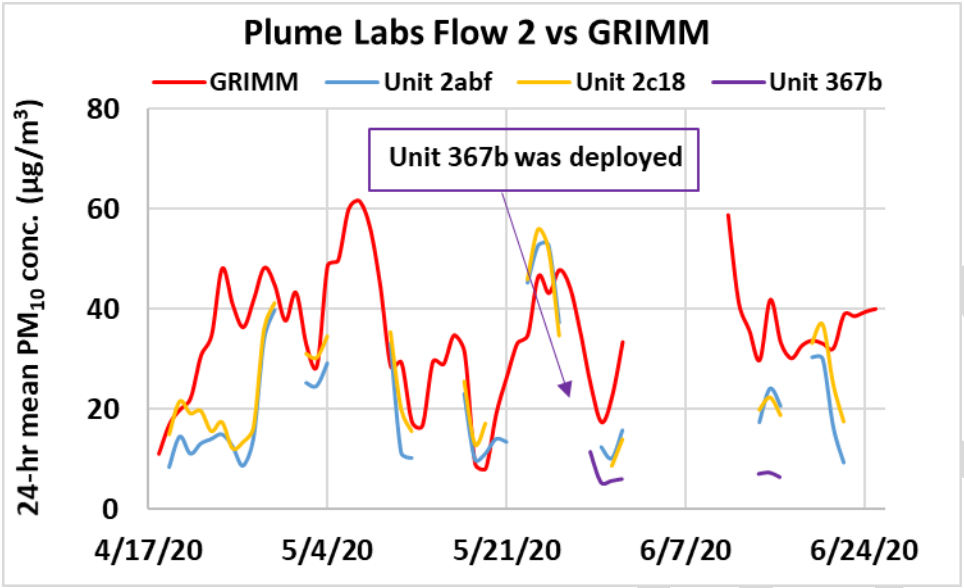
Note: PM data from Unit 2b23 were invalidated because its internal fan was not functioning.





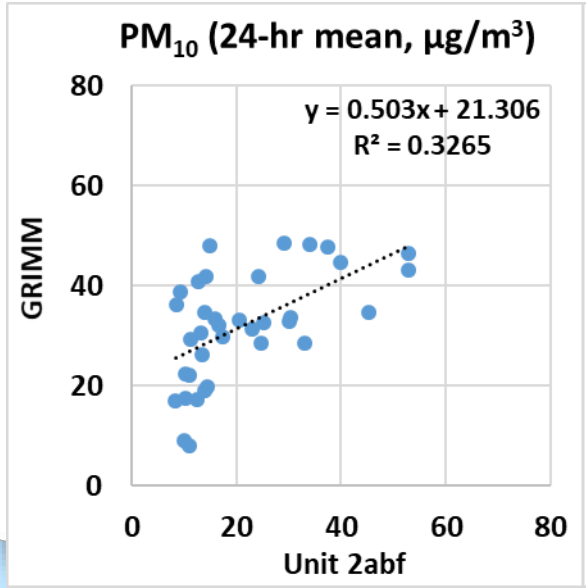


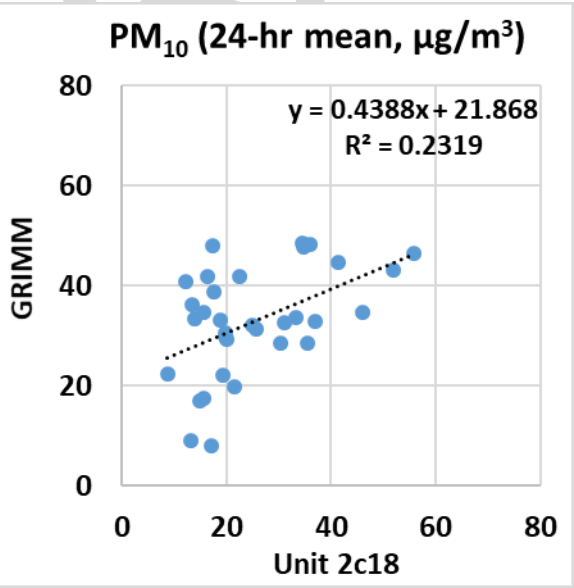
Flow 2 vs GRIMM (PM_{10}; 24-hr mean)

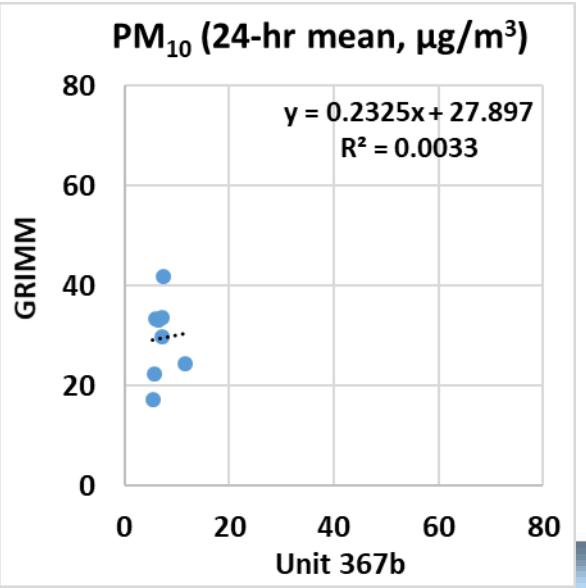


- The Flow 2 sensors showed no to weak correlations with the corresponding GRIMM data ($0.003 < R^2 < 0.33$)
- Overall, the Flow 2 sensors underestimated the PM_{10} mass concentrations as measured by the GRIMM
- The Flow 2 sensors did not seem to track the diurnal PM_{10} variations as recorded by the GRIMM

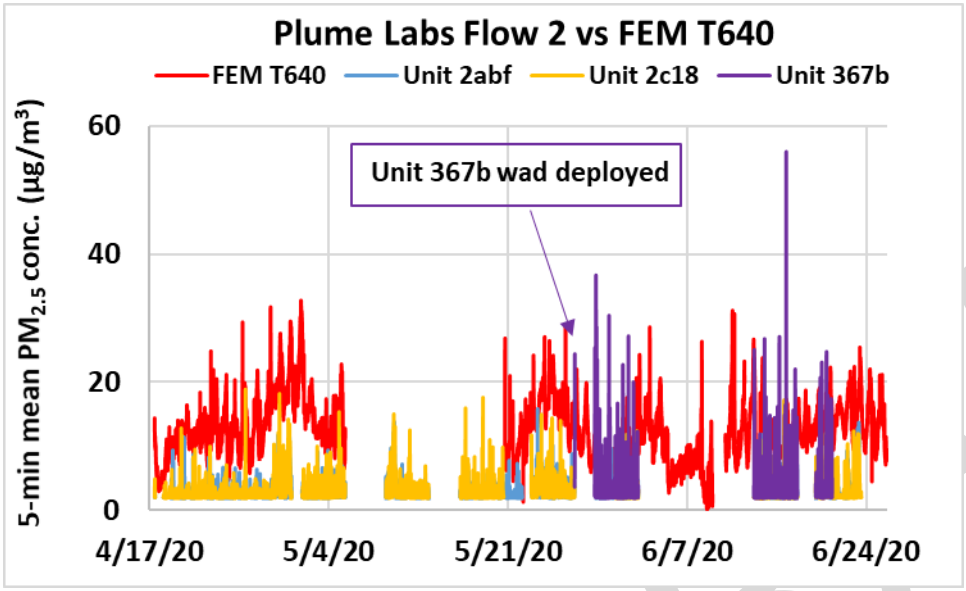
Note: PM data from Unit 2b23 were invalidated because its internal fan was not functioning.





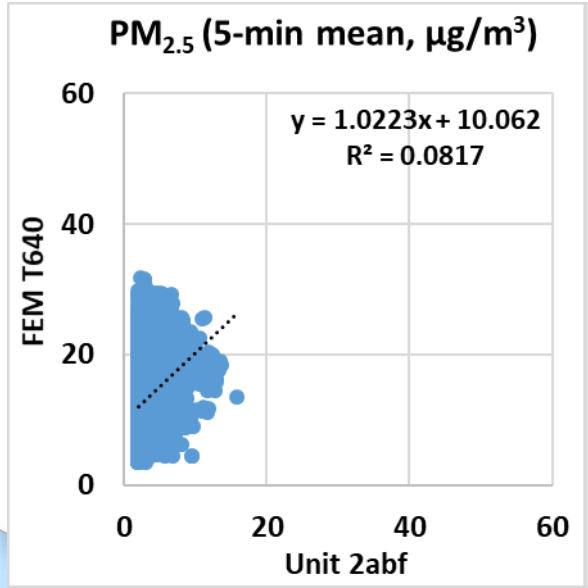


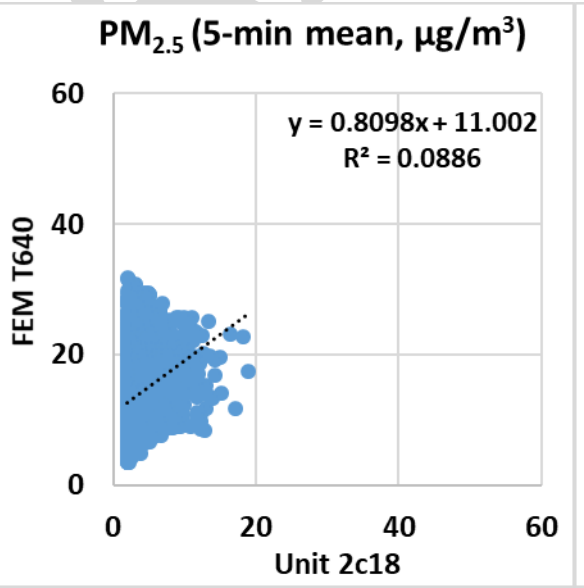
Flow 2 vs FEM T640 ($PM_{2.5}$; 5-min mean)

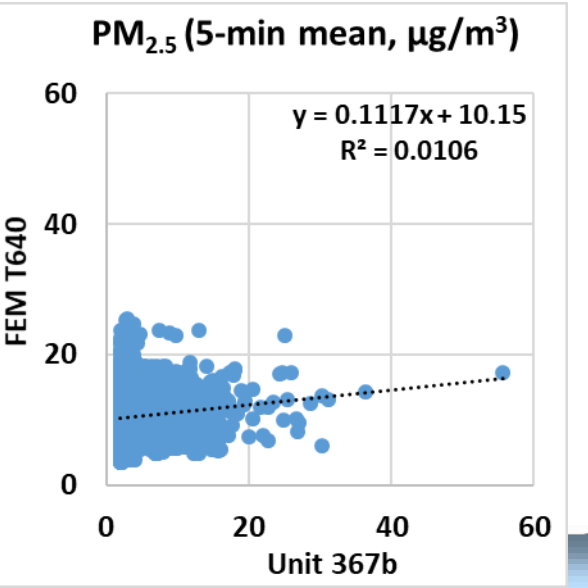


- The Flow 2 sensors did not correlate with the corresponding FEM T640 data (R^2 < 0.09)
- Overall, the Flow 2 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by the FEM T640
- The Flow 2 sensors did not seem to track the diurnal $PM_{2.5}$ variations as recorded by the FEM T640

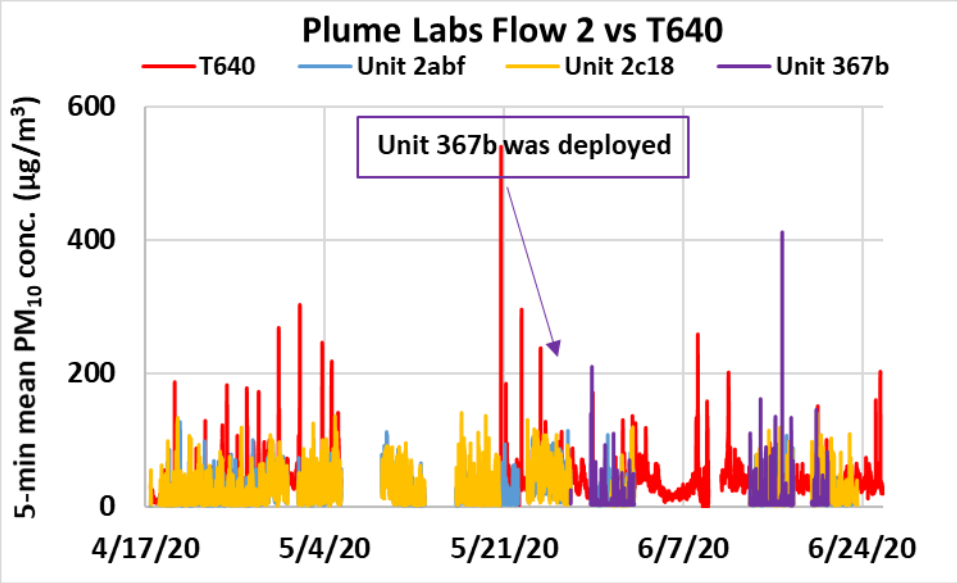
Note: PM data from Unit 2b23 were invalidated because its internal fan was not functioning.





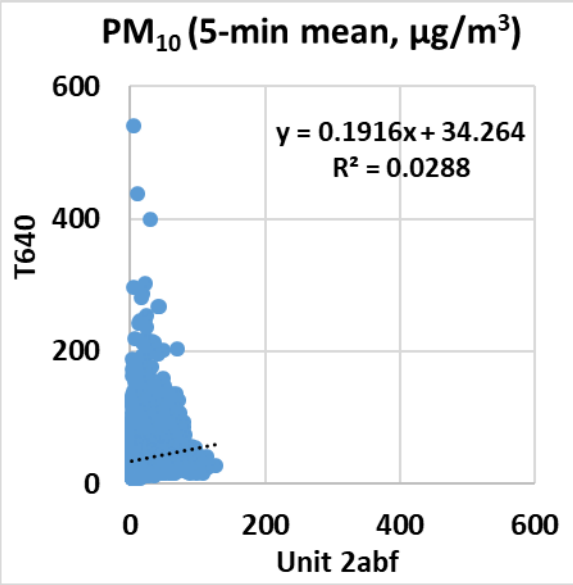


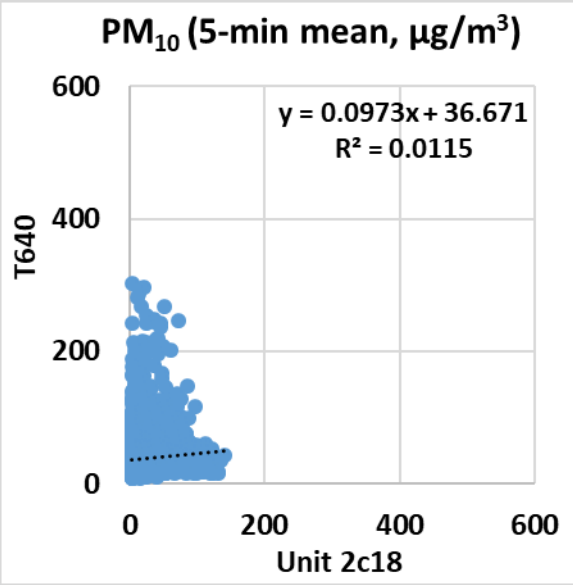
Flow 2 vs T640 (PM_{10}; 5-min mean)

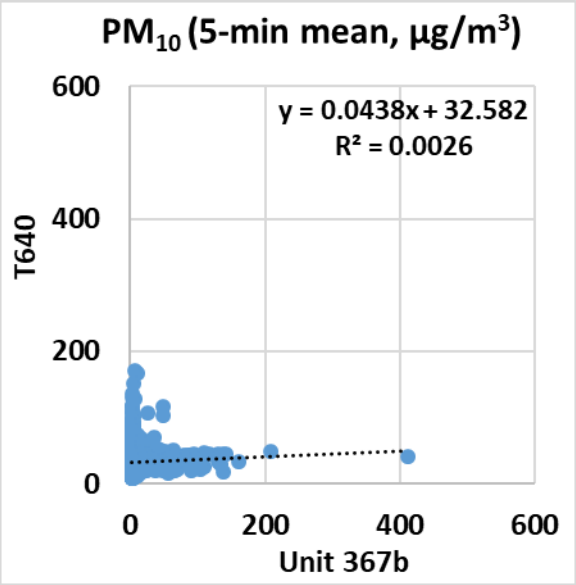


- The Flow 2 sensors did not correlate with the corresponding T640 data ($R^2 < 0.03$)
- Overall, the Flow 2 sensors underestimated the PM_{10} mass concentrations as measured by the T640
- The Flow 2 sensors did not seem to track the diurnal PM_{10} variations as recorded by the T640

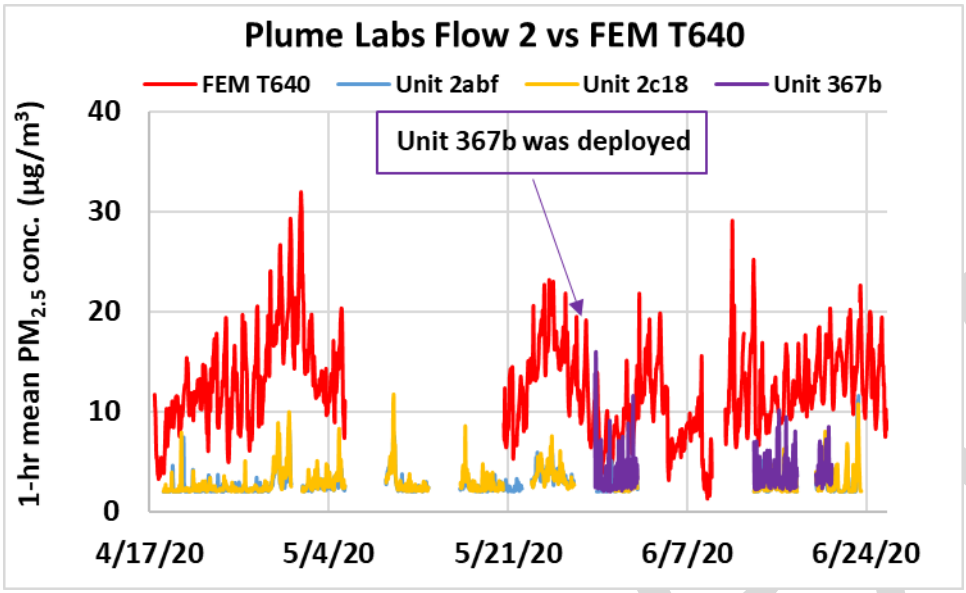
Note: PM data from Unit 2b23 were invalidated because its internal fan was not functioning.





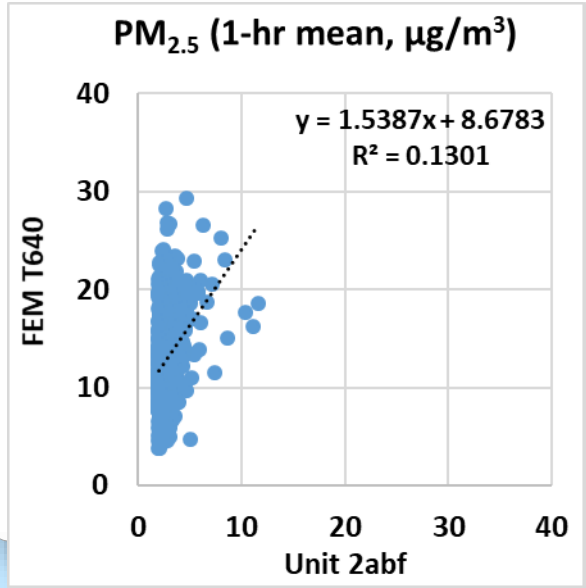


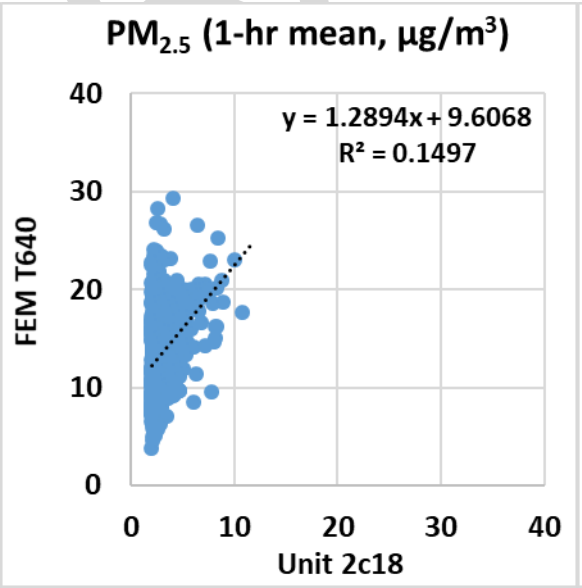
Flow 2 vs FEM T640 ($PM_{2.5}$; 1-hr mean)

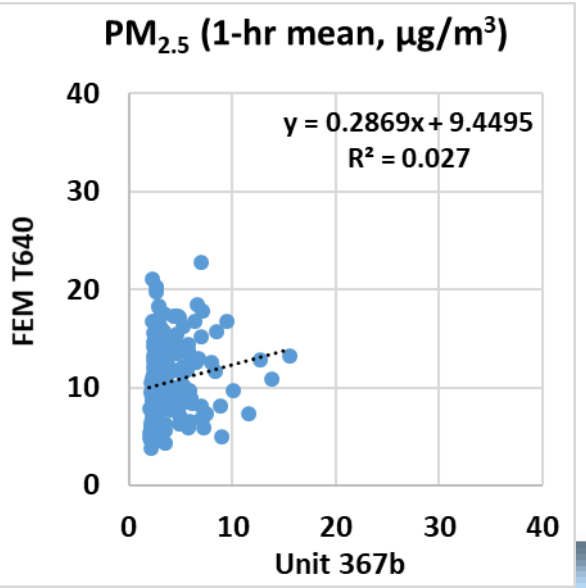


- The Flow 2 sensors showed no to very weak correlations with the corresponding FEM T640 data ($0.02 < R^2 < 0.15$)
- Overall, the Flow 2 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by the FEM T640
- The Flow 2 sensors did not seem to track the diurnal $PM_{2.5}$ variations as recorded by the FEM T640

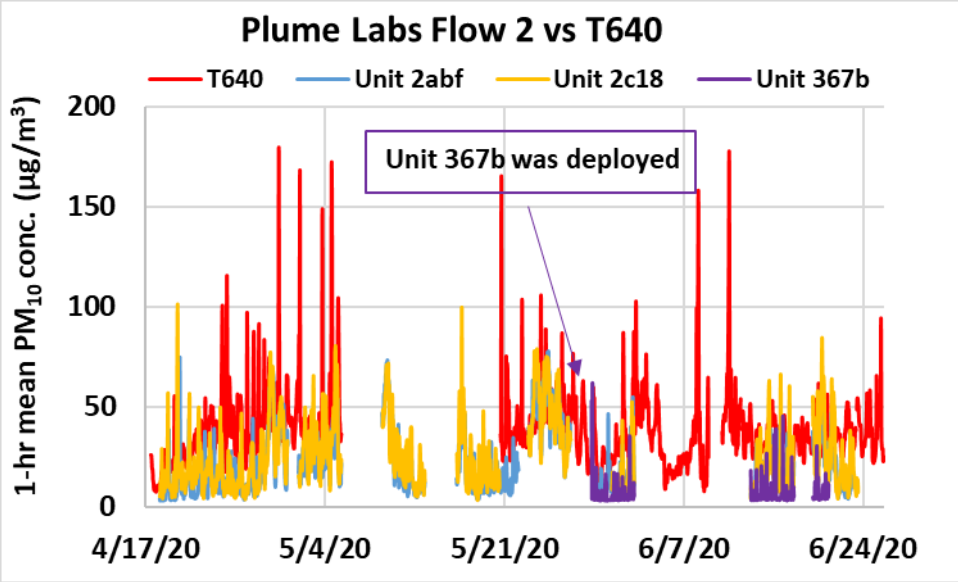
Note: PM data from Unit 2b23 were invalidated because its internal fan was not functioning.





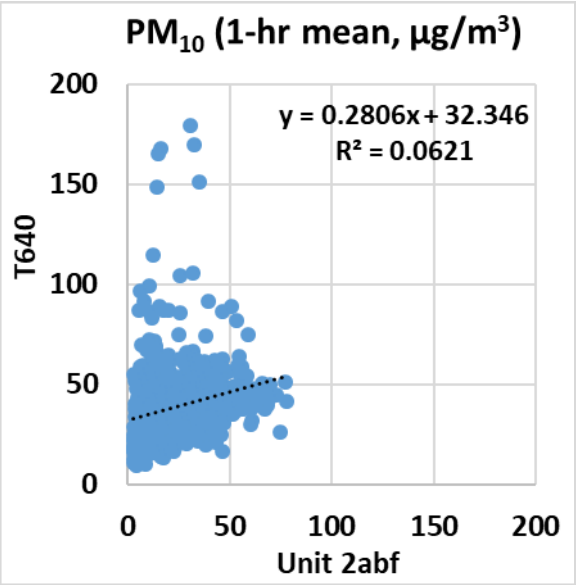


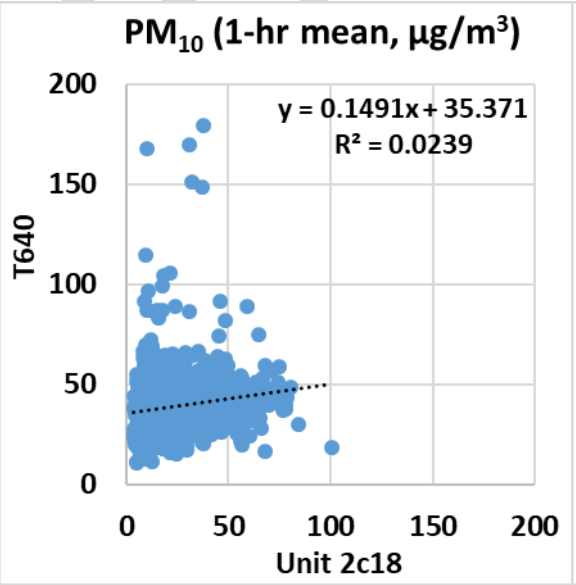
Flow 2 vs T640 (PM_{10}; 1-hr mean)

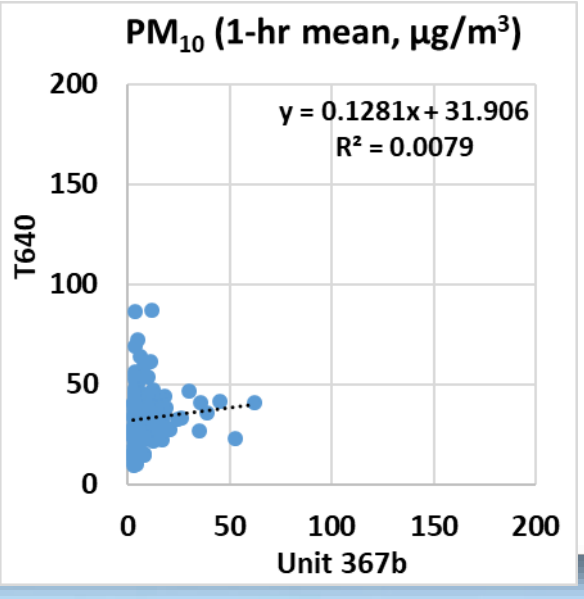


- The Flow 2 sensors did not correlate with the corresponding T640 data ($R^2 < 0.07$)
- Overall, the Flow 2 sensors underestimated the PM_{10} mass concentrations as measured by the T640
- The Flow 2 sensors did not seem to track the diurnal PM_{10} variations as recorded by the T640

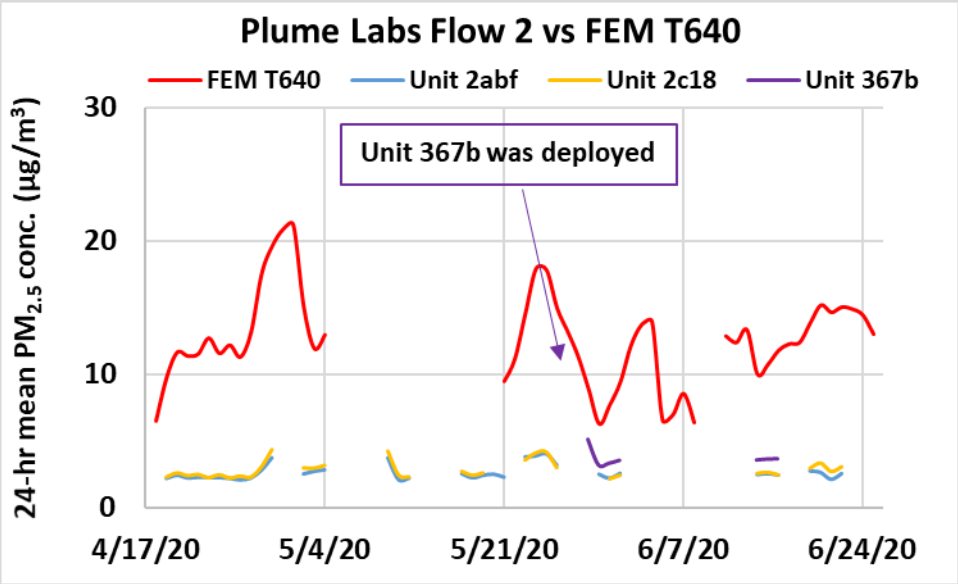
Note: PM data from Unit 2b23 were invalidated because its internal fan was not functioning.





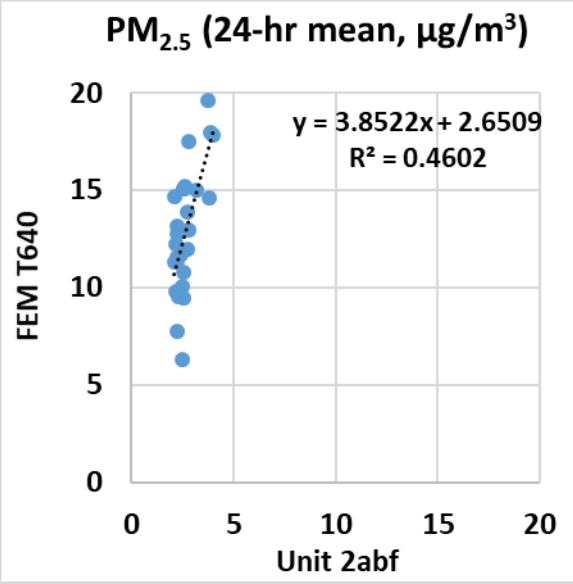


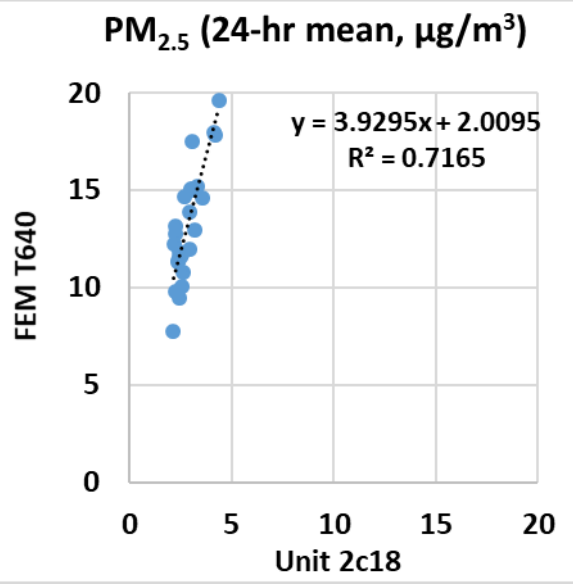
Flow 2 vs FEM T640 ($PM_{2.5}$; 24-hr mean)

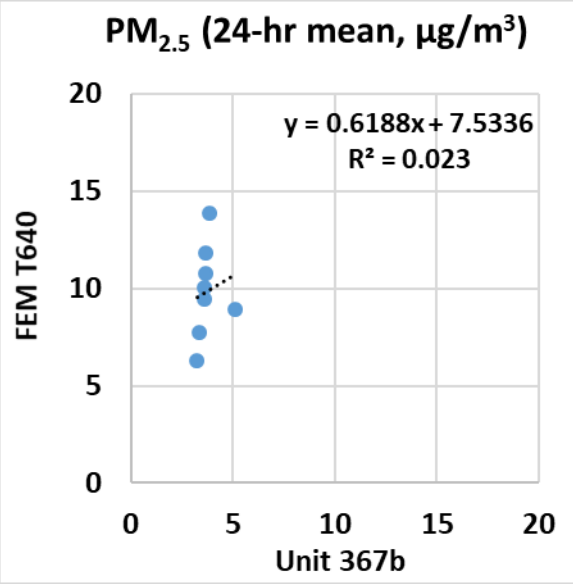


- The Flow 2 sensors showed no to strong correlations with the corresponding FEM T640 data ($0.02 < R^2 < 0.72$)
- Overall, the Flow 2 sensors underestimated the $PM_{2.5}$ mass concentrations as measured by the FEM T640
- The Flow 2 sensors did not seem to track the diurnal $PM_{2.5}$ variations as recorded by the FEM T640

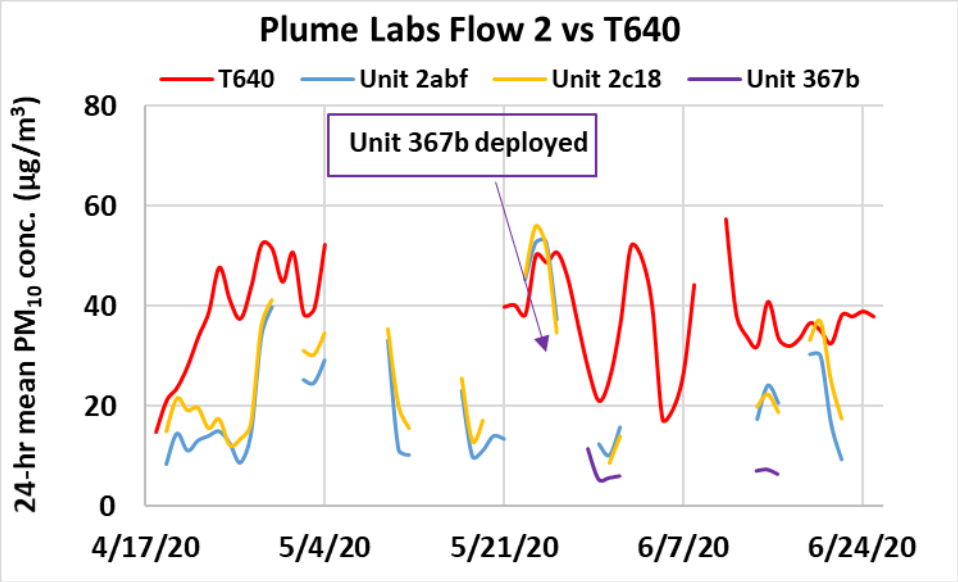
Note: PM data from Unit 2b23 were invalidated because its internal fan was not functioning.





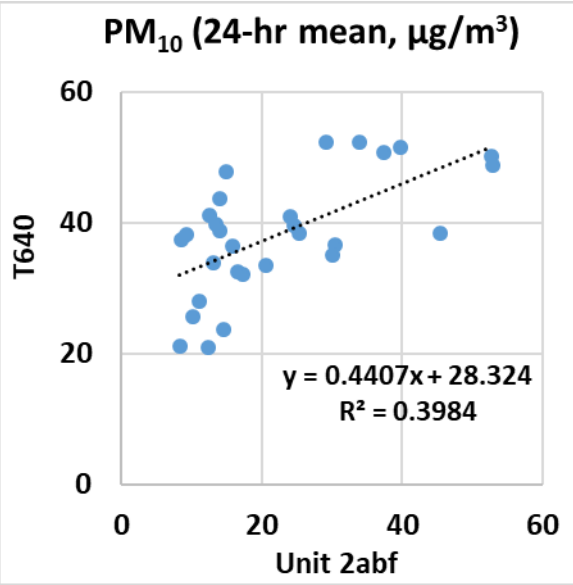


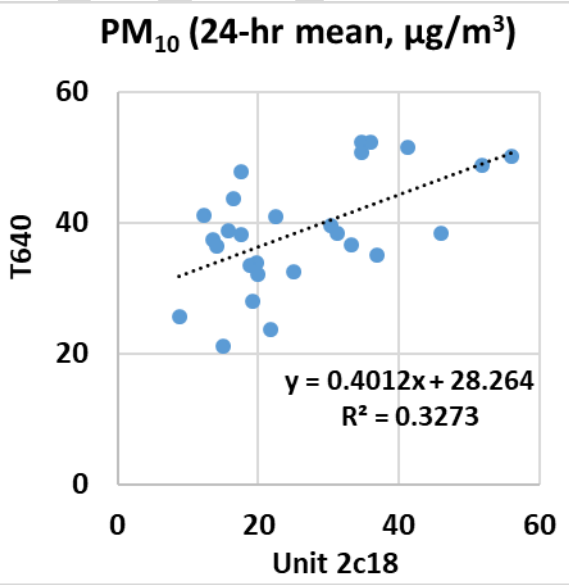
Flow 2 vs T640 (PM_{10}; 24-hr mean)

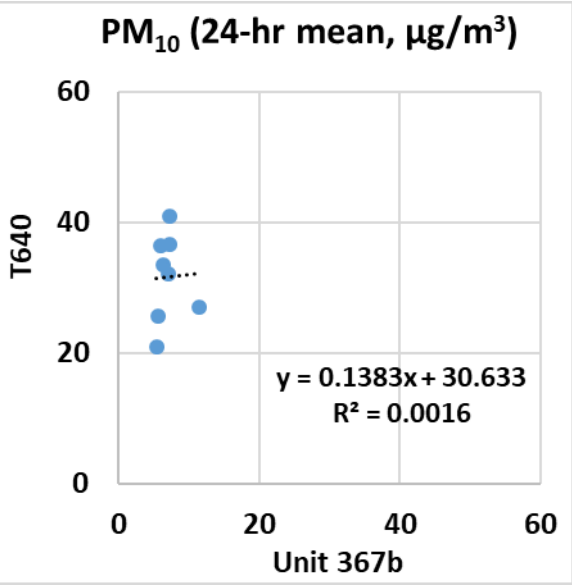


- The Flow 2 sensors showed no to weak correlations with the corresponding T640 data ($0.001 < R^2 < 0.40$)
- Overall, the Flow 2 sensors underestimated the PM_{10} mass concentrations as measured by the T640
- The Flow 2 sensors did not seem to track the diurnal PM_{10} variations as recorded by the T640

Note: PM data from Unit 2b23 were invalidated because its internal fan was not functioning.







Discussion

- The **Flow 2** sensors' data recovery Unit 2abf, Unit 2b23, Unit 2c18 and Unit 367b was ~ 71%, 55%, 66% and 49%, respectively, for NO_2 measurements. Data recovery from Unit 2abf, Unit 2c18 and Unit 367b was 71%, 66% and 49%, respectively, for $PM_{1.0}$, $PM_{2.5}$ and PM_{10} mass concentration measurements.
- The absolute intra-model variability was ~ 1.4 ppb for NO_2 measurements and ~ 0.001, 0.1 and 1.7 µg/m^3 for the $PM_{1.0}$, $PM_{2.5}$ and PM_{10} measurements, respectively.
- NO_2 concentrations measured by the Flow 2 sensors showed no to very weak correlations with the corresponding FRM NO_2 data ($0.03 < R^2 < 0.14$, 5-min mean). The sensors overestimated the NO_2 concentrations as measured by the FRM NO_2 instrument.
- The reference instruments (GRIMM and T640) show strong correlations with each other for $PM_{2.5}$ mass concentration measurements (R^2 ~ 0.77, 1-hr mean) and PM_{10} mass concentration measurements (R^2 ~ 0.85, 1-hr mean).
- $PM_{1.0}$ mass concentrations measured by the Flow 2 sensors showed no to very weak correlations with the corresponding GRIMM data ($0.03 < R^2 < 0.19$, 1-hr mean). The sensors underestimated $PM_{1.0}$ mass concentrations as measured by GRIMM.
- $PM_{2.5}$ mass concentrations measured by the Flow 2 sensor showed no to very weak correlations with the corresponding FEM GRIMM and FEM T640 data ($0.02 < R^2 < 0.22$, $0.02 < R^2 < 0.15$, respectively; 1-hr mean). The sensors underestimated $PM_{2.5}$ mass concentrations as measured by FEM GRIMM and FEM T640.
- PM_{10} mass concentrations measured by the Flow 2 sensors did not correlate with the GRIMM and T640 data ($R^2 < 0.09$ and < 0.07, respectively; 1-hr mean). The sensors underestimated PM_{10} mass concentrations measured by GRIMM and T640.
- No sensor calibration was performed by AQ-SPEC prior to the beginning of this field testing.
- Laboratory chamber testing is necessary to fully evaluate the performance of these sensors under controlled T and RH conditions, and known target and interferent pollutants concentrations.
- These results are still preliminary