Field Evaluation
Plume Labs Flow 2
Background

- From 04/17/2020 to 06/25/2020, 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: NO₂ (ppb), PM₁₀, PM₂.₅ and PM₁₀ (μg/m³);
  - 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 PM₂.₅); cost: $25,000 and up
  - Time resolution: 1-min
  - Teledyne API T640 (FEM PM₂.₅); cost: $21,000
  - Time resolution: 1-min
  - NOₓ instrument (FRM NO₂); cost: ~$11,000
  - Time resolution: 1-min

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

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 NO₂ measurements.

Flow 2; Intra-model variability

- Absolute intra-model variability was ~ 1.4 ppb for NO₂ measurements. (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 8.6% for NO₂ 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.
The Flow 2 sensors showed no to very weak correlations with the corresponding FRM NO\textsubscript{2} data (0.03 < R\textsuperscript{2} < 0.14).

Overall, the Flow 2 sensors overestimated the NO\textsubscript{2} concentrations as measured by the FRM NO\textsubscript{2} instrument.

The Flow 2 sensors did not seem to track the diurnal NO\textsubscript{2} variations as recorded by the FRM NO\textsubscript{2} instrument.

Note: FRM NO\textsubscript{2} (calculated as the difference between NO\textsubscript{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.
• 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$_2$ 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 ($R^2 \approx 0.77$)
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 ($R^2 \sim 0.85$)
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.
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.
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.
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.
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.
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.
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.
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.
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.
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