Field Evaluation
Davis Instruments - Airlink
Background

- From 04/02/2021 to 06/01/2021, three **Davis Instruments Airlink** (hereinafter Airlink) 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.

- **Airlink (3 units tested):**
  - Particle sensor: optical; non-FEM (PMSA003, Plantower)
  - Each unit reports: PM$_{1.0}$, PM$_{2.5}$ and PM$_{10}$ (μg/m$^3$), Temperature (°F), RH (%)
  - Unit cost: $179
  - Time resolution: 1-min
  - Units IDs: 023B, 023F, 0206

- **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$_{1.0}$, PM$_{2.5}$ and PM$_{10}$ (μg/m$^3$)
  - 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 all units was ~ 100% for all PM measurements

Airlink; intra-model variability

• Absolute intra-model variability was ~ 0.35, 0.37 and 0.75 µg/m³ for PM$_{1.0}$, PM$_{2.5}$ and PM$_{10}$, respectively (calculated as the standard deviation of the three sensor means)

• Relative intra-model variability was ~ 3.4%, 2.5% and 3.8% for PM$_{1.0}$, 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$_{1.0}$
GRIMM and T640

- Data recovery for PM$_{1.0}$ from GRIMM and T640 was ~ 100%.
- Strong correlations between the reference instruments for PM$_{1.0}$ measurements ($R^2 \sim 0.90$) were observed.

![Graph showing 1-hour mean PM$_{1.0}$ concentration from GRIMM and T640](image)

![Scatter plot with linear regression line](image)
• Data recovery for PM$_{2.5}$ from FEM GRIMM and FEM T640 was ~ 100%.
• Very strong correlations between the reference instruments for PM$_{2.5}$ measurements (R$^2$ ~ 0.91) were observed.
Reference Instruments: PM$_{10}$
GRIMM and T640

- Data recovery for PM$_{10}$ from GRIMM and T640 was ~ 100%.
- Strong correlations between the reference instruments for PM$_{10}$ measurements ($R^2$ ~ 0.89) were observed.
The Airlink sensors showed strong correlations with the corresponding GRIMM data ($0.87 < R^2 < 0.89$).

Overall, the Airlink sensors underestimated the PM$_{1.0}$ mass concentrations as measured by GRIMM.

The Airlink sensors seemed to track the PM$_{1.0}$ diurnal variations as recorded by GRIMM.
The Airlink sensors showed strong correlations with the corresponding FEM GRIMM data (0.79 < $R^2$ < 0.81).

Overall, the Airlink sensors overestimated the PM$_{2.5}$ mass concentrations as measured by FEM GRIMM.

The Airlink sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM GRIMM.
The Airlink sensors showed very weak correlations with the corresponding GRIMM data (0.24 < $R^2$ < 0.28).

Overall, the Airlink sensors underestimated the PM$_{10}$ mass concentrations as measured by GRIMM.

The Airlink sensors did not seem to track the PM$_{10}$ diurnal variations as recorded by GRIMM.
Airlink vs GRIMM (PM$_{1.0}$; 1-hr mean)

- The Airlink sensors showed strong correlations with the corresponding GRIMM data ($0.88 < R^2 < 0.90$)
- Overall, the Airlink sensors underestimated the PM$_{1.0}$ mass concentrations as measured by GRIMM
- The Airlink sensors seemed to track the PM$_{1.0}$ diurnal variations as recorded by GRIMM
Airlink vs FEM GRIMM (PM$_{2.5}$; 1-hr mean)

- The Airlink sensors showed strong correlations with the corresponding FEM GRIMM data ($0.80 < R^2 < 0.82$)
- Overall, the Airlink sensors overestimated the PM$_{2.5}$ mass concentrations as measured by FEM GRIMM
- The Airlink sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM GRIMM
The Airlink sensors showed very weak correlations with the corresponding GRIMM data ($0.26 < R^2 < 0.29$).

Overall, the Airlink sensors underestimated the PM$_{10}$ mass concentrations as measured by GRIMM.

The Airlink sensors did not seem to track the PM$_{10}$ diurnal variations as recorded by GRIMM.
The Airlink sensors showed very strong correlations with the corresponding GRIMM data ($0.91 < R^2 < 0.93$).

Overall, the Airlink sensors underestimated the PM$_{1.0}$ mass concentrations as measured by GRIMM.

The Airlink sensors seemed to track the PM$_{1.0}$ diurnal variations as recorded by GRIMM.
The Airlink sensors showed strong correlations with the corresponding FEM GRIMM data (0.79 < $R^2$ < 0.82).

Overall, the Airlink sensors overestimated the PM$_{2.5}$ mass concentrations as measured by FEM GRIMM.

The Airlink sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM GRIMM.
Airlink vs GRIMM (PM\textsubscript{10}; 24-hr mean)

- The Airlink sensors showed very weak correlations with the corresponding GRIMM data (0.22 < R\textsuperscript{2} < 0.26)
- Overall, the Airlink sensors underestimated the PM\textsubscript{10} mass concentrations as measured by GRIMM
- The Airlink sensors did not seem to track the PM\textsubscript{10} diurnal variations as recorded by GRIMM
The Airlink sensors showed strong correlations with the corresponding T640 data ($0.85 < R^2 < 0.87$).

Overall, the Airlink sensors underestimated the PM$_{1.0}$ mass concentrations as measured by T640.

The Airlink sensors seemed to track the PM$_{1.0}$ diurnal variations as recorded by T640.
The Airlink sensors showed strong correlations with the corresponding FEM T640 data ($0.73 < R^2 < 0.76$).

Overall, the Airlink sensors underestimated the PM$_{2.5}$ mass concentrations as measured by FEM T640.

The Airlink sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM T640.
Airlink vs T640 (PM$_{10}$; 5-min mean)

- Airlink sensors showed very weak to weak correlations with the corresponding T640 data ($0.28 < R^2 < 0.31$)
- Overall, the Airlink sensors underestimated the PM$_{10}$ mass concentrations as measured by T640
- The Airlink sensors did not seem to track the PM$_{10}$ diurnal variations as recorded by T640
• The Airlink sensors showed strong correlations with the corresponding T640 data (0.88 < $R^2$ < 0.90)

• Overall, the Airlink sensors underestimated the PM$_{1.0}$ mass concentrations as measured by T640

• The Airlink sensors seemed to track the PM$_{1.0}$ diurnal variations as recorded by T640
Airlink vs FEM T640 (PM$_{2.5}$; 1-hr mean)

- The Airlink sensors showed strong correlations with the corresponding FEM T640 data ($0.76 < R^2 < 0.78$)
- Overall, the Airlink sensors underestimated the PM$_{2.5}$ mass concentrations as measured by FEM T640
- The Airlink sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM T640
The Airlink sensors showed very weak to weak correlations with the corresponding T640 data ($0.29 < R^2 < 0.33$).

Overall, the Airlink sensors underestimated the PM$_{10}$ mass concentrations as measured by T640.

The Airlink sensors did not seem to track the PM$_{10}$ diurnal variations as recorded by T640.
The Airlink sensors showed very strong correlations with the corresponding T640 data ($0.92 < R^2 < 0.94$).

Overall, the Airlink sensors underestimated the PM$_{1.0}$ mass concentrations as measured by T640.

The Airlink sensors seemed to track the PM$_{1.0}$ diurnal variations as recorded by T640.
Airlink vs FEM T640 (PM$_{2.5}$; 24-hr mean)

- The Airlink sensors showed strong correlations with the corresponding FEM T640 data (0.73 < $R^2$ < 0.75)
- Overall, the Airlink sensors underestimated the PM$_{2.5}$ mass concentrations as measured by FEM T640
- The Airlink sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM T640
The Airlink sensors showed weak correlations with the corresponding T640 data ($0.30 < R^2 < 0.33$).

Overall, the Airlink sensors underestimated the PM$_{10}$ mass concentrations as measured by T640.

The Airlink sensors did not seem to track the PM$_{10}$ diurnal variations as recorded by T640.
**Summary**

<table>
<thead>
<tr>
<th>Average of 3 Sensors, PM$_{1.0}$</th>
<th>Airlink vs GRIMM &amp; T640, PM$_{1.0}$</th>
<th>GRIMM &amp; T640 (PM$_{1.0}$, µg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (µg/m$^3$)</td>
<td>SD (µg/m$^3$)</td>
<td>R$^2$</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>5-min</td>
<td>10.3</td>
<td>7.3</td>
</tr>
<tr>
<td>1-hr</td>
<td>10.3</td>
<td>7.2</td>
</tr>
<tr>
<td>24-hr</td>
<td>10.1</td>
<td>5.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average of 3 Sensors, PM$_{2.5}$</th>
<th>Airlink vs FEM GRIMM &amp; FEM T640, PM$_{2.5}$</th>
<th>FEM GRIMM &amp; FEM T640 (PM$_{2.5}$, µg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (µg/m$^3$)</td>
<td>SD (µg/m$^3$)</td>
<td>R$^2$</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>5-min</td>
<td>14.8</td>
<td>11.5</td>
</tr>
<tr>
<td>1-hr</td>
<td>14.8</td>
<td>11.3</td>
</tr>
<tr>
<td>24-hr</td>
<td>14.5</td>
<td>8.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average of 3 Sensors, PM$_{10}$</th>
<th>Airlink vs GRIMM &amp; T640, PM$_{10}$</th>
<th>GRIMM and T640 (PM$_{10}$, µg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (µg/m$^3$)</td>
<td>SD (µg/m$^3$)</td>
<td>R$^2$</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>5-min</td>
<td>19.5</td>
<td>14.2</td>
</tr>
<tr>
<td>1-hr</td>
<td>19.5</td>
<td>13.8</td>
</tr>
<tr>
<td>24-hr</td>
<td>19.2</td>
<td>10.0</td>
</tr>
</tbody>
</table>

1 Mean Bias Error (MBE): the difference between the sensors and the reference instruments. MBE indicates the tendency of the sensors to underestimate (negative MBE values) or overestimate (positive MBE values).
2 Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.
3 Root Mean Square Error (RMSE): another metric to calculate measurement errors.
• The Airlink sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($0.92 < R^2 < 0.93$)

• Overall, the Airlink sensors overestimated the temperature measurement as recorded by South Coast AQMD Met Station

• The Airlink sensors seemed to track the diurnal temperature variations as recorded by South Coast AQMD Met Station
The Airlink sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.94$).

Overall, the Airlink sensors overestimated the RH measurement as recorded by South Coast AQMD Met Station.

The Airlink sensors seemed to track the diurnal RH variations as recorded by South Coast AQMD Met Station.

### Graphs

- **Unit 023B**
  - Equation: $y = 0.8599x + 6.1476$
  - $R^2 = 0.9437$

- **Unit 023F**
  - Equation: $y = 0.866x + 5.7068$
  - $R^2 = 0.9439$

- **Unit 0206**
  - Equation: $y = 0.869x + 5.8789$
  - $R^2 = 0.9457$
Discussion

- The three **Airlink** sensors’ data recovery from all units was ~ 100% for all PM measurements
- The absolute intra-model variability was ~ 0.35, 0.37 and 0.75 µg/m³ for PM₁₀, PM₂₅ and PM₁₀, respectively
- Strong correlations between GRIMM and T640 for PM₁₀ (R² ~ 0.90, 1-hr mean); very strong correlations between FEM GRIMM and FEM T640 for PM₂₅ (R² ~ 0.91, 1-hr mean) and strong correlations between GRIMM and T640 for PM₁₀ (R² ~ 0.89, 1-hr mean) mass concentration measurements
- PM₁₀ mass concentrations measured by the Airlink sensors showed strong correlations with the corresponding GRIMM and T640 data (0.88 < R² < 0.90, 1-hr mean). The sensors underestimated PM₁₀ mass concentrations as measured by GRIMM and T640
- PM₂₅ mass concentrations measured by the Airlink sensors showed strong correlations with the corresponding FEM GRIMM and FEM T640 data (0.76 < R² < 0.82, 1-hr mean). The sensors overestimated PM₂₅ mass concentrations as measured by FEM GRIMM and underestimated PM₂₅ mass concentrations as measured by FEM T640
- PM₁₀ mass concentrations measured by the Airlink sensors showed very weak to weak correlations with the corresponding GRIMM and T640 data (0.26 < R² < 0.33; 1-hr mean). The sensors underestimated PM₁₀ mass concentrations as measured by GRIMM 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